"One Must Do, Five Reductions" Technical Practice and the Economic Performance of Rice Smallholders in the Vietnamese Mekong Delta

by Le Canh Bich Tho, Le Canh Dung, and Chieko Umetsu

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Abstract

The "One Must Do, Five Reductions" (1M5R) program was certified in 2013, by Vietnam Ministry of Agriculture and Rural Development, as a national approach to promoting the best management practices in lowland rice cultivation. The main idea behind 1M5R is the use of good-quality/certified seeds (the One Must Do) as well as the reduction of seed rates, pesticide use, fertilizer inputs, water use, and postharvest losses (Five Reductions). However, the impact of these farming practices is not well understood. This study employs the propensity score matching (PSM) approach to investigate the factors that affect the adoption of the 1M5R practice and to estimate this technique's impact on the economic performance of rice cultivation. Primary data were collected through a household survey of 380 rice farms in four provinces in the Mekong Delta (MKD), Vietnam. The findings indicate that adopting the 1M5R technique is significantly correlated with the educational level of household heads, their memberships in paddy cooperatives, and their attendance to previous training classes. Additionally, the results of the PSM indicate that applying the 1M5R technical package helps farmers to reduce their production cost by 10%, increase a paddy's selling price by 4.5% per kg, and obtain 10% more profit, compared to traditional farming households. The return on investment for adopters increased by 22%. However, while the findings indicates that a sustainable farming technique is advantageous to local farmers, they fail to indicate any paddy yield increase in treatment fields, because most input items are reduced. Therefore, farmers who are well-educated in paddy households should be targeted for 1M5R training classes and cooperatives memberships to expand this eco-friendly model and enhance the economic benefits to rice smallholders in MKD.

Keywords: Mekong Delta, 1 Must Five Reductions, economic performance, rice smallholders, propensity score matching

1. Introduction

The Mekong Delta (MKD), the world's third largest delta, comprises 54% of Vietnam's rice production areas and produces 55% of Vietnam's total rice output (GSO, 2018). Since the late 1990s, rice production in MKD has intensified rapidly, resulting in an overreliance on agrochemicals to achieve higher yields as well as rising production costs and environmental unsustainability (Tu, 2015; Tong, 2017). Compared to other agricultural countries in the region, Vietnam ranked second (430 kg/ha) after China (503 kg/ha), in terms of fertilizer consumption, while other countries, such as India (166 kg/ha), Thailand (162 kg/ha), and the Philippines (157 kg/ha), consume relatively low amounts of fertilizers per hectare of arable land (FAO, 2016). Each year, over 10 million tons of fertilizers are consumed in Vietnam, of which 80% are supplied by domestic factories. Approximately 60.6% of this amount is used to cultivate rice, and the rest is used to cultivate maize, coffee, sugarcane, fruits, and vegetables (IFA, 2017). Fertilizer is also the costliest item, compared to other crop production costs. In the period 2014–2015, Vietnam consumed 2.6 million tons of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O), of which, 60% (1.6 million tons) was N fertilizer used for rice production. According to the Soil and Fertilizers Research Institute, the N use efficiency for rice plants in Vietnam is still low, at only 35–40%, and fertilization is imbalanced. Specifically, too much N is used, compared to P_2O_5 and K_2O. The calculated data across 5 years (2008–2012) indicate that the ratio of applied nutrients N: P_2O_5: K_2O is 3.3:1.5:1.[1] Thus, the excessive use of N not only generates waste and pollutes the environment, but it also creates a suitable environment for pests and diseases to develop (SFRI, 2016). This poses both economic and environmental risks and challenges in achieving sustainable agricultural development in the nation.

The Vietnamese agricultural sector also uses large amounts of pesticides, despite many integrated pest management programs having been implemented for many years. A recent report by the Vietnam Environment Administration (Ministry of Natural Resources and Environment) states that, on average, Vietnam uses 15,000–25,000 tons of pesticides each year. There is also proof that farmers and communities that use water sources with pesticide residues, in Vietnam and along the MKD, face serious health risks. The study by Dasgupta (2007) showed that 35% of the MKD farmers who were medically tested showed signs of contamination by the organic phosphorus and carbamates in pesticides, of whom, 21% had symptoms of chronic poisoning. The household survey by Toan et al. (2013) found that household-level pesticide management remains suboptimal in the MKD, and a wide range of pesticide residues was found in the water, soil, and

[1] Recommended fertilizer amounts, each season, for rice varieties with growth time between 85 and 100 days (kg/ha) are (i) Alluvial soil: winter–spring season (90–100 kg N; 30–40 kg P2O5; 30–40 kg K2O); summer–autumn season (75–90 kg N; 30–40 kg P2O5; 30–40 kg K2O). (ii) Light acid sulfate soil: winter–spring season (80–100 kg N; 40–50 kg P2O5; 25–30 kg K2O); summer–autumn season (70–80 kg N; 40–50 kg P2O5; 25–30 kg K2O) (Phung et al., 2014).

sediments throughout the monitoring period. Further, the human and environmental health awareness is limited, as evidenced by improper pesticide storage and waste disposal during pesticide handling and application (Chau et al., 2015). Owing to pesticide pollution, the authors failed to identify a clean water source in the MKD.

To reduce the excessive use of chemical fertilizers and pesticides, the Vietnam Ministry of Agricultural and Rural Development (MARD) has encouraged farmers to apply a farming technology known as climate smart agriculture (CSA),[2] which is aimed at promoting sustainability in rice cultivation. First, following the framework of a crop management technology designed by the International Rice Research Institute (IRRI), the "Three Reductions, Three Gains" (3R3G)[3] program was developed to reduce production costs, improve farmers' health, and protect the environment when rice-production areas in the MKD are irrigated. The campaign was piloted in Can Tho, Tien Giang, and Vinh Long provinces in 2003. Built on the success of the 3R3G campaign, the eco-friendly farming technique "One Must Do, Five Reductions" (1M5R) is a technological package that was developed during Phase IV of the IRRI's Consortium and promoted by the World Bank's Agricultural Competitiveness Project. More specifically, farmers who apply this technique are promoted to use certified seeds (1 must) and reduce the seed rate, use of fertilizers and pesticides, irrigation cost, and post-harvest losses (Five Reductions). In particular, this advanced technology is expected to be the best practice for intensive rice production in the MKD, and includes benefits, such as reducing production costs, increasing paddy yield, improving rice grain quality, enhancing farm profit, saving water and natural resources, reducing greenhouse gas emissions, and protecting the community's health (Phung et al., 2014). 1M5R has been recognized by the Department of Crop Production as technical progress, according to Decision No. 532/QD-TT-CLT, dated November 7, 2012. This recognition caused the wide deployment of 1M5R rice production areas in the MKD. Therefore, MKD's agriculture sector urgently requires a formal assessment of the benefits of 1M5R application for rice producers. The most recent study by Connor et al. (2020) explores the factors that influence farmers' decision to apply the 1M5R package in two MKD provinces: An Giang and Can Tho. It concluded that, while all farmers meticulously met the requirements for certified seeds, pesticides, and post-harvest loss reduction, they still had difficulties reducing their fertilizer use, water use, and seed rate. Other studies have measured the difference between farmers applying 1M5R and other groups of conventional farmers (Chi et al., 2013; Son et al., 2013; Tin et al., 2015). These studies compared descriptive statistics to draw conclusions regarding the higher profitability for households participating in

[2] The most commonly-used definition of CSA is that provided by FAO (2010), which defines CSA as a form of agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gases (GHGs) (mitigation) where possible, and enhances achievement of national food security and development goals.
[3] The three reductions reflects the reduction of seed rate, fertilizer use and insecticide spraying. The three gains are an increase in net-farm profit, better health for farmers and an improved environment (Huan et. al, 2005).

1M5R, compared to traditional households. However, making conclusions on the differences in potential outcomes, without considering the observed sociological factors of the two household groups, may lead to self-selection bias. Therefore, using the propensity score matching (PSM) method, this study aims to i) identify the factors that influence farmers' decision to join 1M5R and ii) assess the impact of the 1M5R technique on the economic performance of rice smallholders in the Vietnamese MKD. The empirical results of this study have implications for policymakers and local authorities, regarding the causal effects of such an important rice farming technique. Some potential suggestions to improve the economic benefits of 1M5R for rice smallholders and, simultaneously, protect the surrounding natural environment in the region are suggested.

The remainder of this paper proceeds as follows. Section 2 introduces the methodology and data used in this study. Section 3 presents the results and discussions. The last section concludes the study and presents policy recommendations for enhancing the economic welfare of 1M5R rice farming in MKD.

2. Methodology and Data

2.1. Methodology

To date, many studies have used PSM to eliminate non-randomization bias and, simultaneously, calculate the causal effects of a program or project on smallholders in the agricultural sector. Recently, PSM was used to calculate the impact of CSA and climate change adaptation on smallholder rice farmers' technical efficiency (TE) (Ho and Shimada, 2019). The results indicate that both climate change adaptation and CSA application affect the rice growers' TE score. More specifically, climate change adaptation and CSA help households increases the TE scores by 13–14% and 5–6%, respectively compared to households that do not apply it. Duong and Thanh (2019) use the PSM–DID approach to examine the economic impact of the adopting modern rice varieties in Vietnam, using a dataset derived from the Vietnam Access to Resources Household Survey in 2012 and 2014. The empirical results reveal that only large farms can improve their productivity by adopting modern varieties, and that the impact of the adoption on the value-added, in terms of profit and based on different farm sizes, is insignificant. Concerning the Pakistan agricultural sector, Ali et al. (2014) used PSM to establish the impact of a direct sowing technology on rice production. This technique saves a considerable amount of irrigation water, compared to the traditional transplanting method, thereby helping adopters to reduce production and labor costs, and simultaneously increase rice and corn yields in the same cultivated area, compared with conventional households. Wu et al. (2010) also used PSM to conclude that adopting the improved upland rice technology has had a significant positive effect on farmers' well-being in rural China, which is measured by increased household income and reduced poverty incidences. The incomes for households that apply science and technology to production are expected to be approximately 1.53, 1.32, and 1.26 times higher in 2000, 2002, and 2004, respectively, compared to those of households that do not apply science and technology. With increased income and reduced poverty incidences considered as possible outcomes, PSM was used effectively by Mendola (2006) to estimate the impact of adopting agricultural technology on households in rural Bangladesh. Adopting a high-yielding variety (HYV) was found to have a robust and positive impact on household income, which in turn contributes to poverty alleviation in rural Bangladesh.

PSM was first defined by Rosenbaum and Rubin (1983) and supplemented by Khandker et al., in 2010. PSM constructs a statistical comparison group, which is based on a model of the probability of participating in treatment T and is conditional on observed characteristics X or the propensity score, $P(X) = Pr(T = 1|X)$. Two important assumptions need to be followed to estimate the causal effects of a program. These include (i) the conditional independence assumption (CIA) and (ii) the presence of common support or overlap condition. Under these two assumptions, matching on $P(X)$ is as good as matching on X, according to Rosenbaum and Rubin (1983).

The CIA posits that given a set of observable covariates X, which are not affected by treatment, potential outcomes Y are independent of treatment assignment T (Khandker et al., 2010). Hence, in the first PSM step, a probit model is used to identify the determinants of farmers' decisions to participate in the 1M5R package (T) and to calculate the propensity scores, using a set of covariates (X_i). The main purpose of the propensity score estimation is not to predict selection into treatment but to balance all covariates (Caliendo and Kopeinig, 2008). The probit model is specified as

$$y\,(0,1) = \beta_0 + \beta_1 X_1 + \ldots + \beta_{11} X_{11} \qquad (1)$$

where $y\,(0,1)$ is the status of farmers' participation in 1M5R ($y = 1$ participating in 1M5R; $y = 0$ not participating in 1M5R/conventional farmers), and β_0 to β_9 are the regression coefficients. The covariates are chosen following the assumption that only variables that are unaffected by participation (or related anticipation) should be included in the model. If these variables are measured before participation, it must be guaranteed that they are not influenced by the anticipation of participation (Caliendo and Kopeinig, 2008). The data for participants and non-participants should also be obtained from the same sources (same questionnaires). As such, the independent variables in equation (1) are as follows: X_1 is the age of household head, X_2 is the gender, X_3 is education level, X_4 is the years of experience, and X_5 is the family members. Further, X_6 is the paddy land size, X_7 is the number of land plots, X_8 is the credit status of households, X_9 is the prior participation in training classes, X_{10} is the off-farm (non-agricultural activities), X_{11} is the cooperative membership, and X_{12} is the membership of Farmers' Association. The details for these covariates are described in detail in Section 2.4 (Table 1).

Subsequently, the common support region, where the propensity score distributions for the treatment and comparison groups overlap, $0 < P(T_i = 1|X_i) < 1$, need to be defined. Therefore, treatment units have to be similar to non-treatment units, in terms of observed characteristics that are unaffected by participation. The common support region was assessed by examining a graph of propensity scores across the treatment and comparison groups. Some of the non-participant observations, which fall outside the common support region, are excluded at this stage. In addition to overlapping, there should be a similar distribution ("balance") in the treatment and comparison groups within each of the five quintiles to ensure that the mean propensity score is equivalent (Imbens, 2004). Therefore, a balancing test should be performed on individual covariates (Dehejia and Wahba, 2002), to check if $\hat{P}(X \mid T=1) = \hat{P}(X \mid T=0)$ (Khandker et al., 2010). No rule states the extent to which imbalance is acceptable in a propensity score, and the proposed maximum standardized differences for specific covariates range from 10% to 25% (Stuart et al., 2013; Garrido et al., 2014).

Because of the overlap of propensity scores between treatment and comparison groups, due to CIA, the average treatment effect on the treated (ATT) can be written as

$$ATT_{PSM} = E_{P(X)|T=1}\{E[Y_1 \mid T=1, P(X)] - E[Y_0 \mid T=0, P(X)]\} \quad (2)$$

where T refers to the treatment and is equal to 1 if the farmer is a 1M5R participant, Y_1 is the participant's outcome, Y_0 is the non-participants' outcome, and X is a vector of the control variables. The ATT in this study represents the average difference between the observed outcomes of the two groups of farmers: participants and non-participants, in the 1M5R technical package. The outcome variables used in this study are paddy yield, output price, production cost, gross income, and return on investment (ROI) ratio.

After the propensity scores were generated, and the balancing test passed, participants and non-participants with similar propensity scores were matched using different matching algorithms, including nearest neighbor, caliper or radius, stratification or interval, kernel matching, and local linear matching. Without a clearly superior propensity score weighting or matching method (Garrido et al., 2014), we used two extensively applied methods: nearest neighbor matching (NNM) and kernel matching (KM).

2.2. Study site

This study uses data of the household survey in Can Tho, An Giang, Dong Thap, and Bac Lieu provinces, from the "Market Oriented Smallholder Value Chains" (MSVC) project conducted in the period from September to December, 2018. The MSVC project is a public–private partnership (PPP) between the Federal Ministry for Economic Cooperation and Development (BMZ) through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Olam International Limited. The study site chosen by stratification sampling technique represents four out of six agro-ecological sub-regions of the MKD, including An Giang province (Long Xuyen Quadrangle), Dong Thap province (Dong Thap Muoi area), Can Tho city (the riverside of Tien and Hau rivers), and Bac Lieu province (coastal area) (Figure 1). The paddy area and production for these four provinces accounted for 38.11% and 39.98% of the entire MKD region and production in 2018, respectively.

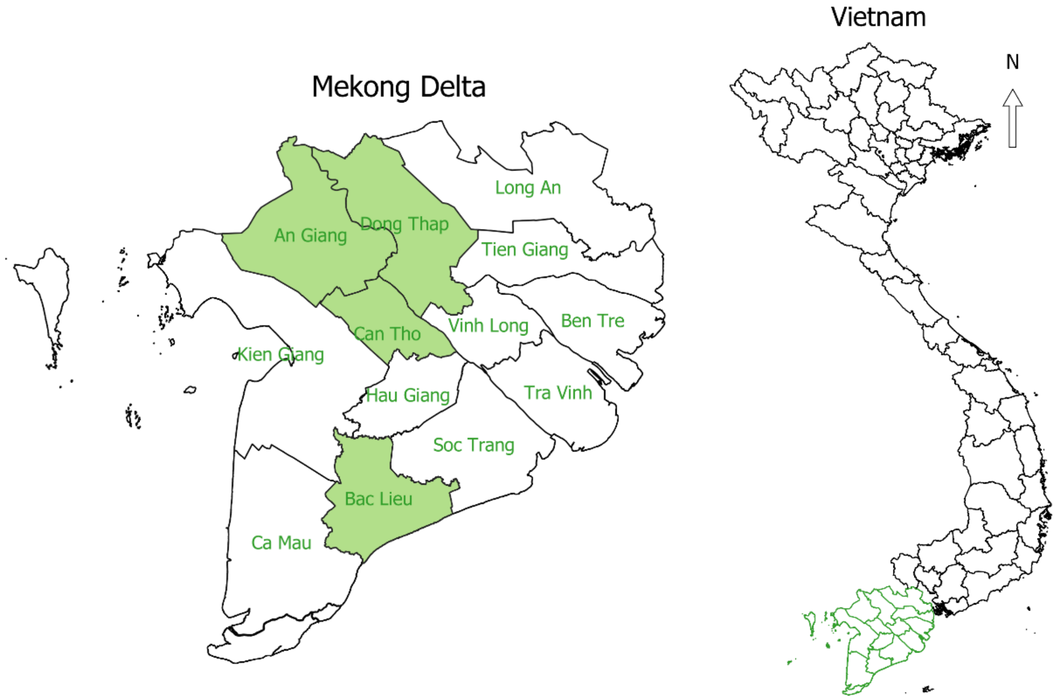

Figure 1. Map of Mekong Delta and study site

Source: Authors' compilation, using GIS mapping

2.3. Data collection

After the study site was identified, primary data were collected using the convenience sampling method in the two seasons Summer-Autumn and Autumn-Winter in the crop year 2018. Each province has 100 paddy producers, who were interviewed on the following: households demographic information (age, gender, farming experience, family members, number of family labour, cultivated land size, number of plots, credit status, training class attendance, memberships of cooperatives and farmer associations); information regarding production activities (production cost items, paddy yield, selling price, gross income, and profit); the experience and application of smart rice cultivation techniques (1M5R, 3R3G, integrated pest management – IPM, alternative wet and drying – AWD). Specifically, households who practice 1M5R must follow the six elements of the technical package. These elements include: households must use certified seeds,[4]

[4] Certified seed varieties are defined according to the national technical standards on the quality of rice seeds QCVN 01-54: 2011/BNNPTNT, issued by the Ministry of Agriculture and Rural Development. The following is observed: (i) The seeds must be bright with little or no streaks, few discolored and deformed grains, homogeneous in size; (ii)

reduce the seed sown density to the range 80–100 kg/ha, reduce the amount of nitrogen fertilizer applied to less than 130 kg/ha, reduce the amount and frequency of pesticide use, reduce the amount of irrigation water, and finally reduce the post-harvest loss by using combine harvesting machines. To meet the study objectives, the authors conducted PMS analysis on extracted data from the 380 households, which included 140 1M5R adopters and 240 non-adopters/individual rice producers. These two groups of farmers have similar farming areas, weather conditions, and climate conditions for comparison.

2.4. Explanation of variables used in the model

The treatment variable represents participation of households in the 1M5R farming technique for the four provinces. The treated group (adopters/participants) comprises farmers who practiced 1M5R for at least three seasons on their farms. The untreated group (non-adopters, non-participants, and control group) include those who use their own traditional techniques to cultivate paddies (conventional farmers).

The independent variables used in the probit model to compute trend scores are shown in Table 1. The most recent study on the determinants of 1M5R adoption in the MKD indicates that all six elements of the package are adopted owing to the ease of implementation, education, satisfaction, and non-rice income (Connor et al., 2020). In existing studies, household demographic factors, such as gender, age (Tran et al., 2020), education level (Dung, 2020; Abegunde et al., 2020), farming experience (Abegunde et al., 2020), cultivated area (Abegunde et al., 2020; Ho and Shimada, 2019; Dung, 2020), formal credit access (Mwungu, 2018; Dung, 2020); technologies and the cost of implementation (Khatri-Chhetri et al., 2017), and memberships in agricultural organization (Tran et al., 2020; Abegunde et al., 2020) were found to have significant impacts on farmers' decision to join climate smart agriculture (CSA) in developing countries and Vietnam. Based on previous studies, the authors included variables, such as participation in agricultural training and membership of local Farmer's Associations (FAs). Among these variables, farmer characteristics, such as education level, production experience, membership of cooperatives or FAs, and training participation are expected to have positive impacts on the decision to adopt the 1M5R package. Farmers with higher education levels and much more experience could achieve better understanding when trained on, or consulted about, the technical requirements. FA membership and production groups could also help farmers obtain incentives for input materials and agricultural mechanization to apply modern farming technology. The statistical information and mean difference of these covariates between adopters and non-adopters are presented in Table 2, Section 3.1.

The seeds origins must be pure (not mixed with other varieties), have low impurity and the germination rate > 80%; (iii) The seeds must be free from insects, sclerotia, or dangerous pathogens.

Table 1. Covariates used in the probit model to generate the propensity scores

Variable	Description	Mean	S.D
T: 1M5R participation	Treatment-Dummy, receives 1 value if households practice 1M5R package on their farms, 0 otherwise.	0.37	0.48
Age	Age of the household heads (year)	49.46	10.64
Gender	Dummy, receives 1 value if household heads are male, 0 otherwise.	0.94	0.23
Educational level	Number of years in school of the household heads	6.97	3.53
Farming experience	Number of years of rice farming experience	26.17	19.14
Household size	Number of family members	4.46	1.43
Rice land	Total area of rice farmland, measured in hectare	2.77	3.35
No. of rice plots	Number of plots in that rice farmland	2.10	1.80
Credit	Dummy, receives 1 value if households had a loan for agricultural production from banks, 0 otherwise.	0.19	0.40
Training	Dummy, receives 1 value if households did participate in training classes for 1M5R, 0 otherwise	0.71	0.46
Off-farm	Dummy, receives 1 value if households have non-agricultural job that can create income, 0 otherwise	0.14	0.35
Cooperative membership	Dummy, receives 1 value if household heads are rice cooperative members, 0 otherwise	0.69	0.46
Farmer's Association	Dummy, receives 1 value if household heads are members of farmer associations, 0 otherwise	0.26	0.44

Source: Authors' calculation based on household survey

Regarding the outcome variables, some studies have used economic indicators to estimate the causal effect of a program or agricultural technology on smallholders. Bidzakin et al. (2019) used yield and gross margins as outcomes to investigate the importance of contract farming in rice production. Ma and Abdulai (2017) examined the impact of agricultural cooperative membership on output price, gross income, farm profit, and ROI. Ali et al. (2015) estimated the impact of direct seeding, using the rice sowing technology, on rice and wheat crop yields and farmers' incomes. Wu et al. (2010) utilized households' incomes and poverty gap as outcome variables to assess the impact of improved upland rice technology on farmers' well-being. Based on the advantages of adopting the 1M5R package, indicated in the guidebook of MARD (Phung et al., 2014), this study uses production cost, rice yield, output price (per kg), farm's income, and the ROI ratio as the outcome variables for comparison. The input data mentioned in this study is the average values of the two seasons. Farm's net profit was calculated by deducting total production cost from the gross income. The gross income was computed by fresh paddy yield multiplying with farm-gate selling price reported by each household. Total production cost included all the costs for seeds, fertilizers, pesticides, herbicides, fungicides, hired labor and machinery for all steps including land preparation, irrigation, seeding, fertilizing, pesticides spraying and harvesting. The return on investment ROI was calculated by (Returns – Investment/Investment). Using ROI as an indicator to measure farm performance is preferred because it not only introduces the farm's income from rice production, but it also considers the profitability of agricultural investments (Ma and Abdulai, 2017; Böhme, 2015; Kleemann et al., 2014).

3. Results and discussion

3.1. Descriptive statistics

General information regarding the two groups of rice farmers is presented in Table 2. Compared to conventional farmers, farmers who participate in 1M5R comprise younger and more educated heads of households. Specifically, there is a significant difference between the heads of households in the treated and control farms, in terms of their participation in previous agricultural technical training and their agricultural cooperatives' memberships. In addition, farmers who choose to apply the 1M5R technique also have more experience in paddy cultivation; however, this difference is not statistically significant. The difference in other characteristics, such as household size, rice land area, number of plots, credit status, and non-agricultural activities, is not significant. This indicates similarities in the sociological characteristics of the interviewees.

Regarding the inputs required for the cultivation steps, Table 3 shows the difference in physical materials used by the two groups of rice households. It is clear that households who practice 1M5R use fewer seeds, which are sown at 121 kg/ha, compared to households who do not practice 1M5R. While this amount is still high, compared to the technical recommendation (seed density should be 80–100 kg/ha) (Phung et al., 2014), it still indicates the farmers' effort in seed reduction compliance. Seed rate reduction is the first important step in the 1M5R technical package. Reducing the amount of seeds to 80–100 kg/ha reduces the pest infestation, compared to a strong seeding density. For this reason, farmers can reduce the amount of pesticides and nitrogen fertilizers and save irrigation water. As described in Figure 3, households participating in 1M5R used nitrogenous fertilizers N, P_2O_5, and K_2O at 95, 64, and 50 kg/ha, respectively, while ordinary households with larger amounts of seeds used more fertilizer at 117, 79, and 58 kg/ha, respectively.

Table 2. Main characteristics of rice farms by 1M5R participation status

Characteristics	Adopters (1) (140)	Non-adopters (2) (240)	Diff. (1)–(2)
Age	49.40	49.50	0.10
Gender	0.94	0.94	0.00
Educational level	7.73	6.51	1.22 ***
Farming experience	28.22	24.96	3.26
Household size	4.55	4.41	0.14
Rice farmland	2.94	2.68	0.26
Rice plots	2.07	2.11	– 0.04
Credit	0.21	0.18	0.03
Training	0.87	0.60	0.27 ***
Off-farm activities	0.14	0.13	0.01
Cooperative membership	0.85	0.60	0.25 ***
Farmer's association	0.23	0.27	– 0.04

Source: Authors' calculations, based on household surveys. *** *indicates 1% significant level.*

A significant difference is noted in almost all types of costs between 1M5R participants and non-participants. Following the instructions of the technical package, participants can reduce their seed cost by an average of 549,000 VND/ha. Consequently, this group could also reduce their fertilizer and pesticide expenses by 885,000 and 720,000 VND/ha, respectively. Using tractors combined with laser technology for land leveling,[5] before each season, not only helps farmers to reduce the amount of seeds but also to reduce the water pumping cost[6] (Phung et al., 2014; Aryal et al., 2015). Moreover, applying the AWD technique mentioned in the guidebook can effectively help 1M5R adopters to reduce irrigation costs by 150,000 VND/ha. Regarding the harvesting step, the 1M5R group was promoted to harvest paddy using a combined harvesting machine. This sharing activity in renting machinery helps 1M5R farmers to lower their harvesting costs by 134,000 VND/ha, compared to individuals who hire labor to complete their harvests. The data also show that the total production cost and the cost per kg of 1M5R fields are lower by 2,575,000 VND/ha and 261 VND/kg, respectively, compared to those of ordinary households. Except for

[5] Laser land leveling (LLL) is a laser-guided technology used to level fields by removing soil from their high points and depositing it in their low points. LLL reduces greenhouse gas emissions by saving on energy, reducing cultivation time, and improving input-use efficiency. In a level field, water is distributed evenly, thus, reducing the amount of time and volume of water needed for irrigation (Mitigation technologies, IRRI).

[6] The empirical results from the study by Aryal (2015) indicated that laser leveling in rice fields reduced irrigation time by 47–69 h/ha/season and improved yield by approximately 7 %, compared with traditionally leveled fields.

spraying pesticides, fertilizing, and hired labor costs, all 1M5R fields' cost items are significantly lower than those for traditional fields are. Due to the reduction of inputs, paddy yield of the treated fields (5.90 ton/ha) was lower than that of the control fields (6.24 ton/ha) by 340 kg/ha. However, with a significantly higher output price, at 5,759 VND/kg, 1M5R households achieve much better profitability at 19,791,000 VND/ha. Therefore, the calculated profitability ROI ratio of participants in CSA was 31% higher than that of regular households in MKD provinces. Generally, it is shown that the values of the four, out of five, outcome variables are higher for 1M5R adopters than they are for non-adopters, and the mean differences are statistically significant at the 1% level. However, this comparison, based on the t-test, is only descriptive; to obtain the true effects of the 1M5R technical package on farms' economic outcomes, a potential selection bias needs to be considered.

Table 3. Mean difference in rice production cost and outcome variables between 1M5R participants and non-participants in MKD

	Adopters (1)	Non-adopters (2)	Diff. (1)–(2)
Inputs quantity (kg/ha)			
Seeds	121 (25.86)	187 (34.40)	– 66***
N	95 (30.27)	117 (46.16)	– 22***
P_2O_5	64 (30.67)	79 (38.63)	– 15***
K_2O	50 (32.80)	58 (37.01)	– 8*
Cost items (thousand VND/ha)			
Seeds	1,621	2,170	– 549***
Fertilizer	3,905	4,790	– 885***
Pesticide, herbicides, insecticides	3,543	4,263	– 720***
Land preparation	1,353	1,681	– 328***
Irrigation	862	1,012	– 150**
Fertilizing, spraying	1,566	1,330	236
Harvesting	1,863	1,997	– 134***
Others	82	122	– 40*
Total cost	16,011	18,586	– 2,575***
Cost per kg (VND/kg)	2,748	3,009	– 261***
Outcome variables			
Rice output (ton/ha)	5.90	6.24	– 0.34***
Output price (VND/kg)	5,759	5,506	253***
Revenue (thousand VND/ha)	35,802	35,999	– 197
Profit (thousand VND/ha)	19,791	17,412	2,379***
ROI	1.32	1.01	0.31***

***, **, and * significant at 1, 5, and 10% probability level, respectively
Source: Authors' calculation based on household survey;
Standard deviation in parentheses

3.2. Estimating the effect of 1M5R technical package on economics performance of rice smallholders in the MKD

The result of the probit model, presented in Table 4, indicates the correlation between participation in 1M5R and households' demographic characteristics. More specifically, the decision to adopt this CSA is positively correlated with the education of household heads, their 1M5R training class attendance, and cooperative memberships. Household heads with higher education are more likely to participate in the 1M5R. It is understandable that farmers with better education will understand cultivation techniques, and they can benefit in their production and natural environments if the amount of seeds and chemical fertilizer are reduced. This result supports the findings of previous studies on households' decisions to engage in CSA (Dung, 2020; Connor et al., 2019; Abegunde et al., 2020). Farmers who had previously participated in 1M5R technical training prefer to join 1M5R, as they were officially and technically aware of the importance of this farming technique and its benefits to production and to the environment. Finally, for cooperatives memberships, the institutional factor has a significantly positive impact on the implementation of the 1M5R technique, at the 1% significance level. Similar conclusions are also indicated by Abegunde et al. (2020) and Tran et al. (2020). These results emphasize the importance of information distribution to farmers through training classes and the support of cooperatives/farming groups in providing seed supply, fertilizer, agricultural machinery, and irrigation systems during dry seasons.

The propensity score distributions of the two groups are shown in Figure 2. The estimated propensity scores for the entire sample range between 0.035 and 0.999, with a mean score of 0.374 (SD = 0.178). The propensity scores for members vary between 0.058 and 0.999 and have a mean score of 0.462 (SD = 0.150). The propensity scores for non-members vary between 0.035 and 0.717, with a mean score of 0.321 (SD = 0.171). Thus, the common support region for the distribution of the estimated propensity scores of members and non-members would range between 0.058 and 0.717. Those households whose propensity scores lie outside this range are excluded from the sample. The final number of households in the common support region is 364, including 136 participants and 228 non-participants in the 1M5R package.

The next important step is checking for selection bias and the quality of the matching algorithm used in this study. The results of the balancing test for all covariates between the 1M5R participants and non-participants are presented in Table 5. Before matching, the mean standardized bias for all variables used in the probit model was 17.8%. After matching, using NNM (n = 5) and kernel algorithms, the mean bias between these covariates was significantly reduced to 4.3% and 2.2%, respectively. Before matching, the large bias values of educational level and training activity between the two groups were greatly reduced to values smaller than 10%. The balancing test's result, through KM and NNM, presents a good matching quality, which can be used to draw conclusion regarding the treatment effect and to provide further implications of the 1M5R package.

Table 4. Determinants of farmers' participation in 1M5R package

	Coef.	Std. error
Age	– 0.013	0.010
Gender	0.286	0.314
Educational level	0.036 *	0.022
Farming experience	0.011	0.010
Household size	0.041	0.052
Rice land	0.022	0.022
No. of rice plots	– 0.010	0.043
Credit	0.127	0.182
Training	0.768 ***	0.177
Off-farm	0.091	0.213
Coop. membership	0.532 ***	0.171
Farmers Assoc.	– 0.148	0.165
_cons.	– 1.692	0.608
Number of observations		364
Log-likelihood		– 212.724
Prob > chi^2		0.000
Pseudo R^2		0.116

****, **, and * significant at 1, 5, and 10% probability level, respectively*

Source: Authors' calculation based on household survey

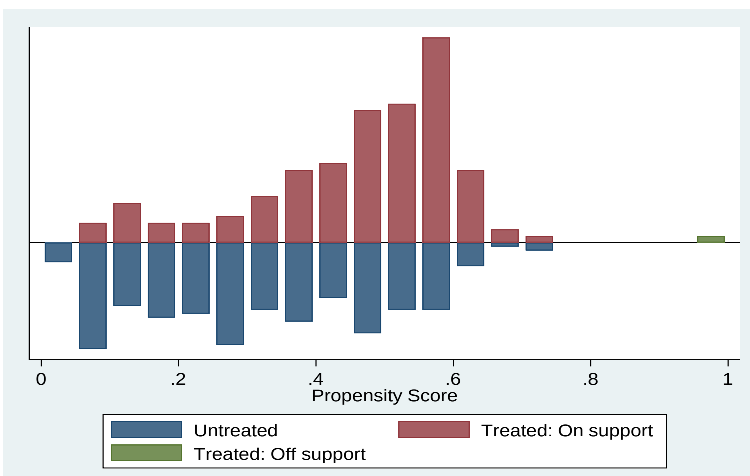

Figure 2. Distribution of the propensity score for 1M5R participants (treated group) and non-participants (untreated group)

Table 5. Balancing test with unmatched and matched samples

Variable	Unmatched				NNM (n = 5)				Kernel			
	Treated	Control	% bias	T	Treated	Control	% bias	T	Treated	Control	% bias	T
Age	49.40	49.45	– 3.9	– 0.36	48.99	48.41	5.4	0.46	48.99	48.83	1.5	0.13
Gender	0.95	0.94	2.4	0.22	0.96	0.96	0	0	0.96	0.95	1.6	0.14
Educational level	7.63	6.52	33.1***	3.01	7.61	7.35	7.8	0.67	7.61	7.43	5.5	0.47
Farming experience	28.22	25.10	14.6	1.50	25.99	26.08	– 0.5	– 0.08	25.99	26.35	– 1.7	– 0.28
Household size	4.56	4.44	8.2	0.75	4.57	4.69	– 8.5	– 0.72	4.57	4.57	– 0.1	– 0.01
Rice land	2.95	2.61	9.9	0.96	2.96	2.68	8	0.7	2.96	2.77	5.5	0.46
No. of rice plots	2.09	2.12	– 1.7	– 0.15	2.09	2.19	– 5.8	– 0.54	2.09	2.16	– 3.7	– 0.34
Credit	0.21	0.18	7.7	0.72	0.21	0.18	6.4	0.52	0.21	0.19	3.4	0.28
Training	0.85	0.62	52***	5.77	0.87	0.88	– 1.4	– 0.15	0.84	0.84	0	0.02
Off-farm	0.88	0.60	65.4	0.34	0.14	0.13	2.6	0.21	0.87	0.87	0.2	– 0.13
Cooperative memberships	0.14	0.13	3.7***	4.63	0.84	0.84	1	0.1	0.14	0.15	– 1.6	0
Farmers Assoc.	0.24	0.29	– 11.3	– 1.04	0.24	0.22	4.7	0.41	0.24	0.24	– 1.8	– 0.15
Mean standardized bias (%)			17.8				4.3				2.2	

*Note: *** significant at the 1% probability level*; *NNM = nearest neighbor matching.*

Finally, the economic impact of 1M5R on household performance is presented in Table 6. Overall, applying 1M5R can help reduce the total production cost by more than 1.8 million VND/ha. For adopters, the cost per kg is lower by 172 VND/kg through kernel matching, compared to that for ordinary farmers, which is still a very modest figure. Regarding the outcome variables, households following 1M5R package have lower rice yields, compared to households using normal amount of inputs, which are equivalent to 0.37 tons/ha and 0.28 tons/ha with NNM and Kernel matching, respectively. Paddy yield was not maintained or slightly increased as mentioned in previous studies when Vietnamese farmers practiced the reductions in seeds, fertilizers and pesticides application (Huan et. al, 2005; Tin et. al, 2008). In the framework of this survey, this may be caused by the reduction in seed density and fertilizer use of adopters. Paddy products from 1M5R households are purchased by traders at a higher average price of 246 and 230 VND/kg, respectively, thanks to the operation of cooperatives as agencies in selling products and making contracts with traders[7]. The total revenue of the 1M5R household group decreases slightly due to lower paddy output; however, owing to the relative cost reduction, the gross margin is higher by 1,450 VND/ha and 1,808 VND/ha with NNM and KM, respectively. This result is in line with the findings from other studies (Alexander et. al, 2018; Tin et. al, 2008; Huan et. al, 2005) that the improved farming technique (mainly cutting down excessive input items activities) significantly helped applicants to reduce production cost and increase their net income. Finally, the technical package 1M5R proves to be effective in helping participants improve economic performance when their ROI is higher by 0.24, which is statistically significant at the 1% level. In conclusion, the technical package 1M5R does not ensure paddy yield, but achieves its primary objective of reducing the production costs and improving households' earnings in treatment fields. Hence, the advantageous ROI ratio not only presents the 1M5R adopters' benefits from rice production but also introduces their effective investments into agricultural activity. The practical results of this study could encourage farmers in other areas to join in and be convinced about both the economics and environmental impacts of 1M5R technical package to paddy smallholders. Through the benefits brought to rural life, scaling up the 1M5R in every province of the MKD is very promising.

[7] The selling price of cooperatives members is significantly higher (5,669 VND/kg) when compared to non-members (5,442 VND/kg) at the 1% level of significance using t-test.

Table 6. Treatment effect of 1M5R on farm's performance with Nearest Neighbor Matching and Kernel algorithms

	Variables	Sample	Adopters	Non-adopters	Diff.		T-stat
NNM (n = 5)	Cost/kg (VND/kg)	Unmatched	2,761.32	2,991.85	-230.54		-3.21
		ATT	2,758.56	2,894.79	-136.22		-1.54
	Total cost (thousand VND/ha)	Unmatched	16,101.28	18,475.61	-2,374.33	***	-5.51
		ATT	16,120.96	18,003.28	-1,882.32	***	-3.63
	Yield (ton/ha)	Unmatched	5.91	6.24	-0.33	***	-3.39
		ATT	5.92	6.29	-0.37	***	-3.11
	Output price/kg (VND/kg)	Unmatched	5,756.18	5,510.35	245.83	***	5.43
		ATT	5,757.33	5,511.60	245.73	***	4.38
	Revenue (thousand VND/ha)	Unmatched	35,802.26	36,021.45	-219.19		-0.35
		ATT	35,880.80	36,312.79	-432.00		-0.56
	Farm's profit (thousand VND/ha)	Unmatched	19,700.98	17,545.84	2,155.14	***	3.37
		ATT	19,759.83	18,309.52	1,450.32	***	1.82
	ROI	Unmatched	1.31	1.03	0.28	***	4.97
		ATT	1.32	1.08	0.24	***	3.48
Kernel	Cost/kg (VND/kg)	Unmatched	2,761.32	2,991.85	-230.54	***	-3.21
		ATT	2,758.56	2,931.13	-172.57	**	-2.09
	Total cost (thousand VND/ha)	Unmatched	16,101.28	18,475.61	-2,374.33	***	-5.51
		ATT	16,120.96	17,986.79	-1,865.83	***	-3.83
	Yield (ton/ha)	Unmatched	5.91	6.24	-0.33	***	-3.39
		ATT	5.92	6.20	-0.28	***	-2.57
	Output price/kg (VND/kg)	Unmatched	5,756.18	5,510.35	245.83	***	5.43
		ATT	5,757.33	5,526.87	230.46	***	4.4
	Revenue (thousand VND/ha)	Unmatched	35,802.26	36,021.45	-219.19		-0.35
		ATT	35,880.80	35,938.81	-58.01		-0.08
	Farm's profit (thousand VND/ha)	Unmatched	19,700.98	17,545.84	2,155.14	***	3.37
		ATT	19,759.83	17,952.02	1,807.81	***	2.45
	ROI	Unmatched	1.31	1.03	0.28	***	4.97
		ATT	1.32	1.08	0.24	***	3.64

****, **, and * significant at 1, 5, and 10% probability level, respectively*
Source: calculated from household survey in 2017

4. Conclusion

The 1M5R package has become one of the most important techniques for paddy producers to adopt in Vietnam and the MKD, since 2011. The empirical results from this study indicate that educational level, training class attendance, and cooperative membership are the key factors driving households' decision to practice the 1M5R technique in their fields. The PSM results are also consistent with the objectives of the 1M5R application, which helps farmers to reduce production costs, have better output prices, and enhance profit per hectare. However, the rice yield was not maintained, but was slightly lower in the treatment fields due to the decrease in seed density and chemical fertilizer usage. PSM is found to be effective in estimating the treatment effects of the important 1M5R technique on the economic performance of smallholders, after eliminating the selection bias problem. With the significant reduction in seed sown density and chemical input, it is possible to conclude that 1M5R is a climate-smart practice that contributes not only to rice producers' economic performance but also to the sustainable environment of the MKD region.

Some policy implications are suggested through the main findings of this study. First, participating in cooperatives and farming groups could provide better access to irrigation, mechanization, and after-harvest storage for farmers because of the available input supply and output contracts associated with rice enterprises. Second, agricultural training courses should emphasize and encourage paddy producers to continue reducing the seeds sown, to meet the recommended amount, which is 80–100 kg/ha. By visiting fields that implement 1M5R in local areas successfully, traditional producers could understand and practice input reduction on their own farms. In addition, the government could encourage rice enterprises to expand their paddy areas, and grant certificates to 1M5R products for both domestic and export demands.

The limitation of this study is the absence of post-harvest loss indicator on fields for comparison. Finally, some suggestions for future research topics include examining the difference in TE between 1M5R adopters and traditional fields and estimating the impact of climate smart technologies, such as Laser land Leveling or AWD, on rice production systems in the MKD.

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