

ECONOMIC IMPACT OF TECHNOLOGY ADOPTION IN RICE FARMING: THE CASE OF “ONE MUST DO, FIVE REDUCTIONS” IN VIETNAM

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ABSTRACT

Technology adoption helps farmers gain more benefits in comparison to conventional practices. “One Must Do, Five Reductions” (1M5R) has been introduced in the Vietnamese Mekong Delta Region for nearly a decade, integrated into agricultural extension programs, and recent concerns have arisen, including farmers’ low benefits and socio-economic barriers to adoption. Using survey data from 455 smallholder rice farmers, including both adopters and non-adopters, in Hau Giang province in the Winter-Spring crop 2020-2021 and Summer-Autumn crop 2021, the study confirmed the economic advantage of the adoption of 1M5R through the lower costs of production inputs and higher revenues. 1M5R adoption helped the farmers reduce 31.1-39.2% seed quantity, 10.6-16.4% nitrogen, 9.8-20.9% phosphate, 16.4-23.1% potassium in purities, and 1.67-1.84 times of pesticide spraying and significantly contributed to successfully applying AWD on rice farms, leading to an increasing net benefit of 3-5 million VND per ha. The benefit-cost ratios were estimated to increase by 35.4% and 41.4% in the Winter-Spring and Summer-Autumn rice crops, respectively. The findings of the study suggest 1M5R is a good practice in rice farming for the agricultural sector to disseminate across the Mekong Delta Region as well as to test this model in different agroecological regions through the national agricultural extension programs.

Keywords: 1M5R, economic impact, Mekong Delta Region, One Must Do Five Reductions, technology adoption.

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1. INTRODUCTION

Rice is a staple grain that feeds the most population of the world. Rice production worldwide has reached 787.3 million tons and a harvested area of 165.3 million ha, of which the Asian region is the largest rice producer, accounting for 89.9% of the total quantity and 86.6% of the harvested area [1]. In Vietnam, the Mekong River Delta Region (MRD) accounts for 53.9% of the total harvested area, 55.5% of the total production [2], and contributes about 90% of rice export [3]. Vietnam has made great efforts in farm system reforms, hybrid rice adoption, and irrigation investment [4], and recently supported a transformation to sustainable rice production known as the “One Must Do, Five Reductions” program in

the eight MRD provinces with the involvement of 104,448 smallholder rice farmers and the adopted rice area of 113,870 ha [5].

“One Must Do, Five Reductions”, hereafter 1M5R, helps the MRD to improve the sustainability of rice production by reducing major inputs such as chemical fertilizers and pesticides and then reducing negative impacts on the environment [6]. From an economic perspective, 1M5R helps smallholder farmers increase their profits in comparison to conventional rice farming [5]-[7]. The increase in rice-farming profitability relies on increased rice yield through the intensive use of production inputs such as seeds, fertilizers, pesticides, and labor. However, overuse of production inputs, at some point, has been reduced profits and caused serious consequences for health, the environment, and sustainable agriculture. Some challenges in reducing chemical fertilizers, irrigated water, and seed as well as low income in rice farming reported recently in some MRD provinces, alert the maintenance of 1M5R in the region [8], [9]. Therefore, the objective

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of this study is to revisit the economic impact of 1M5R with the hypothesis that 1M5R adoption helps farmers gain more benefits compared to conventional rice farming. The relevant environmental issues have also been discussed in the following.

2. RESEARCH METHODS

2.1. 1M5R definition

In 2012, the Department of Crop Production, the Ministry of Agriculture and Rural Development of Vietnam (MARD) recognized 1M5R as an advanced technical package in rice farming by Decision No. 532-QD-TT-CLT dated on November 7, 2012. Historically, 1M5R has been developed through longitudinal technical support from the International Rice Research Institute (IRRI) and a national expert panel

based at the Plant Protection Department (PPD) of An Giang province through some technology transfer projects [10]. 1M5R in nature requires simultaneous activities in rice farming. Specifically, “One Must Do” requests the usage of seeds certified by the authorized organizations meanwhile requests reduction in seed rate, use of fertilizers and pesticides, irrigation cost, and post-harvest losses, farmland management following the Alternate Wetting and Drying technique (AWD) as well as using combine harvesters. In our study, a farmer is defined as an adopter if he or she meets all criteria of 1M5R below. If at least one criterion unqualifies, the farmer is defined as a non-adopter [11]. The criteria for the 1M5R assessment are presented in table 1.

Table 1. Description of 1M5R criteria

Criteria	Non-adoption	Adoption
Seed standard	Uncertified	Certified
Seed rate (kg ha ⁻¹)	>120	80 -120
Nitrogen (kg ha ⁻¹)		
<i>Winter - Spring crop</i>	> 100	≤ 100
<i>Summer - Autumn crop</i>	> 80	≤ 80
Pesticides (times per crop)	>5	≤5
AWD application	No	Yes
Combine harvester application	No	Yes

2.2. Data collection and processing

A total of 455 rice farmers, including farmers who adopted 1M5R and farmers who did not adopt 1M5R, participated in the survey. The selected areas represent the different soil conditions, a critical regulation in Decision No. 532-QD-TT-CLT [10], in Hau Giang province (Table 2). The study used a structured questionnaire asking about the household farmers' characteristics and their rice farming practices in the Winter-Spring rice crop in 2020-2021 (W-S) and the Summer-Autumn rice crop in 2021 (S-A). The missing data was fulfilled by the responsible interviewees, who are the district and communal

agricultural extension staff belonging to the Department of Agriculture and Rural Development (DARD) of Hau Giang province and had previously been trained for data collection.

The surveyed information was transformed into an Excel sheet, and some calculation steps were conducted to convert the input information; for example, compound fertilizers and single-element fertilizers need to be transformed into pure nitrogen, phosphate, and potassium. Next, the data processing, including calculation and testing, was performed by Stata software, Version 17.

Table 2. The surveyed area for 1M5R data collection

District	Commune	Number of households	Soil condition
Vi Thuy	Vi Thang	93	Alluvial
Vi Thanh	Vi Tan	116	Acid
Long My	Xa Phien	103	Saline
	Thuan Hung	113	Saline
Long My town	Long Tri	30	Saline
Total		455	

2.3. Economic analysis

The economic variables include the costs of the production inputs, which are seeds, fertilizers, pesticides, pumping, labor, and harvesting; and the other costs, which include public irrigation fees and property depreciation; and the outcomes, which include rice revenue and other revenue. Net benefit (π) is calculated as total revenue (TR) minus total costs (TC). The benefit - cost ratio (BCR) is the ratio between the net benefit (π) and the total costs (TC). Equations (1) and (2) illustrate their calculations, respectively.

$$\pi = TR - TC \quad (1)$$

$$BCR = \frac{\pi}{TC} \quad (2)$$

All the currency indicators are calculated in thousand Vietnamese Dong. For testing, the two-

sample t-test was used to determine whether the means of two groups are equal or not.

3. RESULTS AND DISCUSSION

3.1. Rice production in Hau Giang province

Hau Giang province is located at the center of the MRD and administratively formed of 1 city, 2 towns, and 5 districts. The natural land covers 162.2 thousand ha, of which agricultural land is approximately 134 thousand ha and ranked ninth amongst MRD provinces [12]. The rice farming system covers 2 rice crops, some areas produce 3 rice crops or rice-fish rotation. In recent years, the total annual rice area of Hau Giang has fluctuated around 190,000 ha, with the average production and productivity at 1,250,000 tons and 6.4 tons ha⁻¹, respectively (Figure 1) [2].

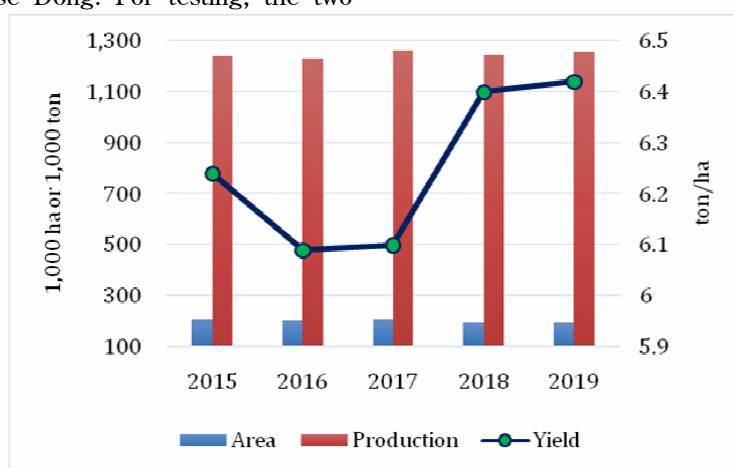


Figure 1. Rice production of Hau Giang province from 2015 - 2019

3.2. Characteristics of the participants

In our study, 68-69% of the farmers adopted 1M5R, a far more impressive proportion than a prior estimate of 40% in the other MRD province [13]. Almost the adopters (97-99%) participated in agriculture cooperatives, while only 34-38% of non-adopters were the cooperative members. Besides, 71-73% of the adopters were male farmers because men often manage agriculture farms as well as the targets of extension programs [14], [15]. For the non-adopter group, only 49-53% were male farmers. The average age of the adopters was 50-year-old, significantly 3-year-old younger than the non-adopters. This result is consistent with many other findings that young farmers are more likely to adopt new technologies [16]–[18]. For education attainment, the education level of the two farmer

groups did not significantly differ in our study. The adopters and non-adopters attended on average 6.55-6.72 and 6.03-6.38 years, respectively, in the 12-year schooling system in Vietnam. Education attainment is a controversial factor in technology adoption literature. Well-educated farmers tend to actively adopt agricultural technologies [19], [20] but in some cases, the education level of farmers does not determine their adoption behavior [21], [22]. Most of the adopters (93%) and non-adopters (88 - 89%) were Kinh, the majority ethnic group in Vietnam, and the rest were Khmer. There was no significant difference in the proportion of Kinh group between the adopters and non-adopters in S-A although it was significantly different in W-S and Kinh is reported a higher probability of technology adoption [23].

Table 3. Characteristics of the participants

Variables	W-S			S-A		
	Adopters n = 312	Non- adopters n = 143	Mean difference	Adopters n = 309	Non- adopters n = 146	Mean difference
1M5R adoption	0.69	0.31	-	0.68	0.32	-
Cooperative member	0.99 (0.11)	0.34 (0.48)	0.65***	0.97 (0.16)	0.38 (0.49)	0.59***
Gender	0.73 (0.44)	0.49 (0.50)	0.24***	0.71 (0.45)	0.53 (0.50)	0.18***
Age	49.62 (12.22)	52.79 (11.13)	-3.17***	49.68 (12.27)	52.61 (11.09)	-2.93***
Education	6.55 (2.79)	6.38 (2.77)	0.17 ^{ns}	6.72 (2.70)	6.03 (2.89)	0.69***
Ethnicity	0.93 (0.26)	0.88 (0.32)	0.05***	0.93 (0.26)	0.89 (0.31)	0.04 ^{ns}

Note: Standard deviation in parenthesis; Significance level: *** = 1%, ** = 5%, * = 10%, No significance = ns; Unit of variables: 1M5R adoption: 1 = adopted, 0 = otherwise; Cooperative member: 1 = yes, 0 = otherwise; Gender: 1 = Male, 0 = Female; Age: The age of household header; Education: The education level of household header; Ethnicity: 1 = Kinh, 0 = otherwise

3.3. Rice farming characteristics and environmental impacts

The adopters cultivated an average of 0.90-0.94 ha rice farmland, while the non-adopter farmed on an area of 0.79 - 0.85 ha. These farm sizes are impressive in comparison to half of the MRD households cultivating less than 0.5 ha [24]. No difference was reported in the rice area between the adopters and non-adopters in W-S, but the adopters cultivated on a significantly 0.15 ha higher area than the non-adopters in S-A.

As regards the main production inputs, including seeds, fertilizers, and pesticides, the non-adopters invested a more significant amount than the adopters in the two rice crops. The non-adopters used an extra 30-39 kg ha⁻¹ seeds than the adopters, equivalent to 31.1-39.2% higher in comparison to the adopters' usage. Regarding fertilizers, the problem of excessive usage is reported to negatively impact on pests, diseases, and underground water. In our study, the non-adopters used an extra 10.61-13.08 kg ha⁻¹ nitrogen than the adopters did. In other words, the non-adopters overused 10.6-16.4% nitrogen in W-S and S-A, respectively. Similarly, the non-adopters used an extra 5.23-11.57 kg ha⁻¹ phosphate, equivalent to 9.8% and 20.9%, and 6.34-7.65 kg ha⁻¹ potassium, equivalent to 16.4% and 23.1%, compared

to the adopters' usage. Although the 1M5R assessment does not include phosphate and potassium thresholds, but the increase in nitrogen will lead to an increase in the usage of phosphate and potassium on rice farms. As a result, overuse of all fertilizers and more diseases occur on the rice farms. Indeed, the non-adopters sprayed pesticides during both rice crops on rice farms more than the adopters 1.67-1.84 times. This might lead to intensive labor and chemicals utilized, that we examine in the next section.

As regards the rice yield, in general, the adopters achieved 7.84 tons ha⁻¹ in W-S and 5.65 tons ha⁻¹ in S-A meanwhile the non-adopters achieved 7.63 tons ha⁻¹ and 5.58 tons ha⁻¹, respectively. The farmers in our study achieved a higher yield in comparison to the average rice productivity in MRD, which yielded only 6.83 tons ha⁻¹ in W-S and 5.56 tons ha⁻¹ in S-A [2]. Our study found that in W-S, the adopters yielded 0.21 tons ha⁻¹, equivalent to 2.8%, significantly higher than the non-adopters while utilizing lower main production inputs. This result shares the common finding with some corresponding research [6], [7], [25] and affirms the overuse of production inputs in the MRD. In S-A, the non-adopters were reported to yield 0.2 tons ha⁻¹, equivalent to 3.5%, significantly higher than the

adopters. The S-A in the MRD region is well known for the influence of harsher natural conditions such as high temperature and heavy rainfall, so production inputs might play a decisive role in rice yield.

The literature often discusses the environmental advantages associated with technology adoption as a bonus of the adoption behavior rather than environmental outcomes as well as human health alone. Therefore, these issues are not given sufficient discussion in rice farming. In MRD, the farmers often use knapsack sprayers to spray pesticides in the absence of appropriate protection equipment such as masks, gloves, and protective clothing [26].

When 1M5R is adopted, the reduction in pesticides directly affects, in a positive manner, to the health of farmers when spraying these toxic chemicals on rice fields. The reduction in fertilizers such as nitrogen (10.61-13.08 kg ha⁻¹), phosphate (5.23-11.57 kg ha⁻¹), and potassium (6.34-7.65 kg ha⁻¹) creates a large spillover effect when 1M5R has been disseminated across the MRD provinces, promising a reduction in water underground pollution at the regional level. In Vietnam, the agricultural sector emitted 104.5 Mt CO₂eq, of which rice production accounted for 41.9 Mt CO₂eq, equivalent to 40% [27], and 1M5R adoption helped reduce GHG emissions by 26.6% and 29.9% in W-S and S-A, respectively [28].

Table 4. Characteristics of rice farming

Variables	W-S			S-A		
	Adopters n = 312	Non-adopters n = 143	Mean difference	Adopters n = 309	Non-adopters n = 146	Mean difference
Area	0.90 (0.72)	0.85 (0.60)	0.05 ^{ns}	0.94 (0.73)	0.79 (0.56)	0.15***
Seed rate	96.57 (7.10)	126.61 (27.97)	-30.04***	98.76 (3.29)	137.45 (32.59)	-38.69***
Nitrogen rate	79.33 (10.93)	89.94 (21.01)	-10.61***	80.74 (11.41)	93.82 (27.39)	-13.08***
Phosphate rate	55.37 (13.26)	66.94 (17.77)	-11.57***	53.17 (10.39)	58.40 (22.37)	-5.23***
Potassium rate	33.11 (11.01)	45.77 (29.16)	-7.65***	38.69 (9.52)	45.03 (32.63)	-6.34***
Spraying	5.90 (1.31)	7.75 (2.58)	-1.84***	6.05 (1.25)	7.72 (2.04)	-1.67***
Yield	7.84 (0.44)	7.63 (0.40)	0.21***	5.65 (0.49)	5.85 (0.42)	-0.20***

*Note: Standard deviation in parenthesis; Significance level: *** = 1%, ** = 5%, * = 10%, No significance = ns; Unit of variables: Area: ha; Seed rate: kg ha⁻¹; Nitrogen rate, Phosphate rate, and Potassium rate: pure kg ha⁻¹; Spraying: times crop-1; Yield: t ha⁻¹*

3.4. Economic analysis of rice farming

Table 5 indicates the cost-benefit analysis and BCR indicator between the two farmer groups. The total cost covers all the component costs incurred during rice farming, including production costs and other costs. In our study, family labor cost was calculated according to the average hired labor in the local area. The other cost might not cover all its components because, in our study, other cost was

calculated based on only the cost of depreciation of irrigation systems and properties. However, we assume the remaining other costs only account for a small proportion. Total revenue equals the revenue from selling rice plus other revenue, which comes from selling by-products such as straw and husk.

As regards the costs, our study shows that the non-adopters paid significantly more than the adopters for all the input costs, except for land

preparation in W-S, and for pumping and hired labor in S-A. Overall, the adopters had to pay approximately 13 million VND in W-S and 13.3 million VND in S-A meanwhile the non-adopters had to pay approximately 15 million VND and 16 million VND in the corresponding rice crops. The total costs the non-adopters paid more than the adopters by approximately 2.0 million VND in W-S and 2.8 million VND in S-A, equivalent to 15.2% and 20.9% of the total production costs, respectively. Figure 3 shows the illustration for the input costs, highlighting the difference in the costs of seeds, fertilizers, and pesticides between the two farmer groups. There is no doubt that the non-adopters used more major inputs than the adopters, and as a result, more cost they had to pay. An interesting point in the input costs is that the adopters paid significantly higher costs for family labor in W-S, for land preparation and family labor in S-A than the non-adopters. It can be explained that the adopters paid more for land

preparation because they might flatten more their rice fields in order to easily apply AWD, a mandatory criterion in 1M5R practice. The adopters paid more for family labor partly because they had to spend more working days visiting the rice farms. More farm visits are popular in other sustainable rice farming practices, for example, Integrated Pest Management (IPM) where the farmers regularly observe the ecosystem during the crop [29]. For other costs, the non-adopters paid 133.40 - 195.79 thousand VND more than the adopters did. In this case, the difference in other costs, on the one hand, was explained that the non-adopters had to pay more on property depreciation because the MRD farmers often calculate this cost based on the amount of seed sown. On the other hand, the cost of irrigation is noted to be equal for each hectare in the same area. These contribute to the difference of other cost of the two farmer groups.

Table 5. Economic indicators of rice farming (1,000 VND)

Variables	W-S			S-A		
	Adopters n = 312	Non-adopters n = 143	Mean difference	Adopters n = 309	Non- adopters n = 146	Mean difference
<i>Costs</i>						
Seed	1,512.50	1,819.08	-306.58***	1,412.91	1,802.87	-389.96***
Land preparation	865.32	837.42	27.90 ^{ns}	1,058.53	1,002.87	55.66***
Fertilizers	3,331.28	3,816.01	-484.73***	3,122.14	3,667.29	-545.15***
Pesticides	2,531.03	3,238.36	-707.33***	2,780.92	4,407.98	-1,627.06***
Pumping	655.88	731.43	-75.55***	638.58	631.91	6.67 ^{ns}
Harvesting	2,052.00	2,190.52	-138.52***	2,046.94	2,171.47	-124.53***
Hired labor	1,028.36	1,213.14	-184.78***	1,208.79	1,281.85	-73.06 ^{ns}
Family labor	146.88	64.34	82.55***	134.63	79.45	55.18***
Other cost	865.97	1,061.76	-195.79***	867.62	1,001.02	-133.40***
Total cost	12,989.22	14,972.06	-1,982.84***	13,271.06	16,046.72	-2,775.67***
<i>Revenues</i>						
Rice revenue	43,574.31	40,464.27	3,110.03***	29,782.56	29,778.77	3.79 ^{ns}
Other revenue	75.72	117.03	-41.31***	360.70	115.76	244.94***
Total revenue	43,650.03	40,581.30	3,068.73***	30,143.26	29,894.53	248.73 ^{ns}
<i>Benefit</i>						
Net benefit	30,660.81	25,609.24	5,051.56***	16,872.21	13,847.81	3,024.40***
<i>Ratio</i>						
BCR	2.45	1.81	0.64***	1.33	0.94	0.39***

Note: Significance level: *** = 1%, ** = 5%, * = 10%, No significance = ns.

As regards the revenues, in general, the adopters achieved approximately 43.7 million VND in W-S and 30.1 million VND in S-A meanwhile the non-adopters achieved 40.6 million VND and 29.9 million VND, respectively. Our study found that in W-S, a significant difference of approximately 3.1 million VND in total revenues between the adopters and the non-adopters was recorded. The reason behind this is the majority contribution of significant difference in rice revenue. However, the total revenue in S-A was estimated to be equivalent between the two farmer groups. Compared to the non-adopters, the adopters obtained the same rice revenue and approximately 0.24 million VND higher in other revenue. Nevertheless, the higher difference in other revenue was not enough to make the total revenue different. It is worth noting that, on average, the total revenue in W-S varied from 40.6-43.7 million VND ha⁻¹, approximately 1.4-1.5 times higher than the total revenue in S-A, which varied from 29.9-30.1 million VND ha⁻¹. In other words, W-S generated a higher economic benefit for MRD farmers than S-A did, thanks to its higher total revenue (Figure 2).

As regards the net benefit, the adopters achieved the net benefits of approximately 30.7 million VND ha⁻¹ in S-W and 16.9 million VND ha⁻¹ in S-A meanwhile the non-adopters achieved approximately 25.6 million VND ha⁻¹ and 13.8 million VND ha⁻¹, respectively. Our study found the adopters achieved significantly more net benefit than the non-adopters approximately 5 million VND in W-S and 3 million VND in S-A. Compared to the non-adopters, the higher net benefit of the adopters stemmed from the lower total cost and higher total revenue in W-S, and the lower total costs in S-A. This result is consistent with a study in Thailand where the farmers obtain higher profits by saving the total cost of fewer production inputs [25].

In our study, we employed a very simple form of benefit-cost ratio because the main purpose of the study is to compare the farming practices between the two groups of farmers within the same crop. Benefit-cost ratios explain economic efficiency in economic activities, and our estimated BCRs particularly reflect the superiority of the net benefit against the total cost (see Equation 2). Our study found significant differences in BCR between adopters and non-adopters in both two crops. In W-S,

the BCR of the adopters was 2.45, significantly higher than that of the non-adopters at 1.81. Similarly, in S-A, the BCR of the adopters was 1.33, significantly higher than the non-adopters' BCR of 0.94. In other words, 1M5R adoption increased BCRs by 35.4% and 41.4% in W-S and S-A, respectively and both were higher than 28%, as reported in Can Tho city in 2015 [6]. The BCRs in our study confirmed the economic advantage of 1M5R compared to conventional rice farming, and the higher differences in BCRs between two crops, W-S and S-A, indicated the importance of W-S in the MRD rice farming system.

4. CONCLUSION

Rice farming plays a crucial role in the MRD, contributing to Vietnam's food security and exports. Technology adoption in rice farming generally provides higher yields at farm scale but does not automatically generate maximum net benefits for smallholder farmers. The existing literature has identified 1M5R as a profitable model that meets the requirement to shift MRD agriculture from intensive-input production to rice economics. Recent reported challenges in reducing inputs and farming practices prevent MRD agriculture from disseminating of 1M5R across the region. In this study, we used the survey data collected in Hau Giang province to examine the economic perspective of 1M5R adoption at the smallholder farmer scale. The result of the economic analysis confirmed that 1M5R adopters achieved greater significant profitability than the non-adopters, thanks to not only lower expenses for some major production inputs, including seeds, fertilizers, and pesticides, but also higher total revenue. Our study estimated that 1M5R adoption helped the farmers reduce 31.1-39.2% seed quantity, 10.6-16.4% nitrogen, 9.8-20.9% phosphate, 16.4-23.1% potassium in purities, and 1.67-1.84 times of pesticide spraying and successfully applied AWD on rice farms, leading to a higher net benefit from 3-5 million VND ha⁻¹ than non-adoption. The adoption therefore increased BCRs by 35.4% and 41.4% in W-S and S-A, respectively. Our findings suggest the agricultural sector should continue the dissemination of 1M5R across the MRD provinces as well as test this model in different agroecological regions through the national agricultural extension programs.

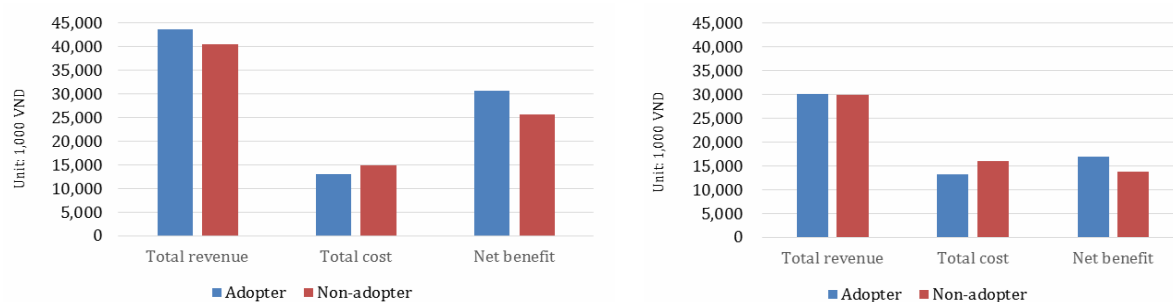


Figure 2. Cost-Benefit analysis (CBA) between the two farmer groups

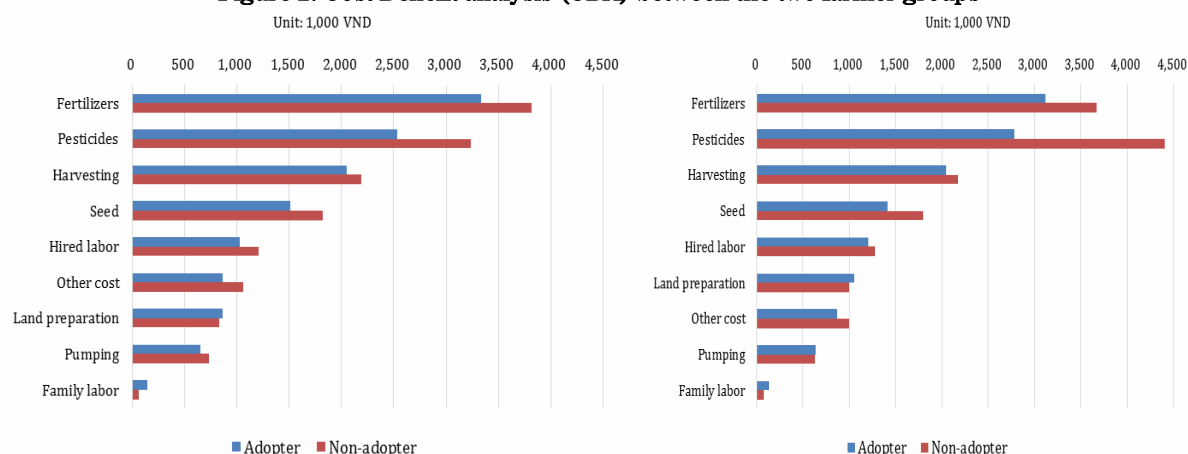


Figure 3. The costs of rice farming between the two farmer groups

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AUTHORS' CONTRIBUTION

N.T.D contributed to the design, analysis, and implementation. V.T.M.H contributed to the design and analysis. H.J.S. contributed to the design. All the authors jointly participated in the manuscript writing.

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