Observed and predicted adoption of eco-friendly rice

Note: The numbers in rectangles indicate number of farmers

→ indicates correct predictions  --- indicates incorrect predictions

The calculations in rectangles are based on the highest probabilities among categories

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Modelling the factors affecting the adoption of eco-friendly rice production in the Vietnamese Mekong Delta

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Abstract: While the introduction of agro-chemicals has had positive effects on rice productivity, its application has also caused environmental pollution and biodiversity losses. To reduce the pollution, the Vietnamese government has implemented several programs to encourage eco-friendly cultivation practices to discourage the overuse of agro-chemicals. However, farmers in the Vietnamese Mekong Delta have resisted the adoption of these eco-friendly practices. The current study aimed at investigating the factors affecting the adoption of eco-friendly rice production practices. We conducted structured interviews with 202 rice farmers. Analysis using generalized ordered logit regression produced evidence that membership in agricultural cooperatives or clubs, perception of biodiversity losses, perceived ease of use, farmer experience, and the perceived difference in selling price all had positive effects on adoption, while risk perception and the number of paddy plots negatively affected the adoption. We also found that the single eco practice (adoption of one eco-friendly practice in rice farming) had the highest economic achievement. One more interesting finding is that a large proportion of farmers who use conventional...
methods shared similar characteristics with eco rice farmers. Based on the results, to promote the adoption of eco practices, it is necessary to create an incentive mechanism to encourage farmers to join farmer organizations. In addition, policy makers should focus on informing farmers about mitigating risks such as adverse climatic impacts, polluted water, and other environmental threats. Technical training courses and other information-sharing meetings should also be required to introduce to farmers about the benefits of eco practices.

**Subjects:** Development Studies, Environment, Social Work, Urban Studies; Social Sciences; Behavioral Sciences; Economics, Finance, Business & Industry

**Keywords:** adoption; eco-friendly rice production; generalized ordered logit regression; Vietnamese Mekong Delta

### 1. Introduction

The Mekong Delta (VMD) produces most of Vietnam’s rice, contributing significantly to the food security of the nation. According to the General Statistics Office of Vietnam (GSO), the region produced more than 25 million tons of rice in 2015, more than 50% of the nation's total volume (GSO, 2015). The region also contributes to more than 90% of Vietnam's total annual rice export volume.

However, this productivity has come with challenges that threaten the region’s environment and agricultural sustainability because of the inappropriate application of agrochemicals (Bosma, Nhan, Udo, & Kaymak, 2012; Dung & Dung, 1999; Heong, Escalada, & Mai, 1994; Heong & Hardy, 2009; Tu, Yabe, Trang, & Khoi, 2015). The “Green Revolution” of the 1960s and 1970s prompted Vietnam, along with other Asian countries, to introduce agrochemicals into rice paddy fields (Bag, 2000; Barker, Herdt, & Rose, 1985; Thi Ut & Kajisa, 2006). While this has had positive effects on yield, these chemicals are also the source of environmental pollution (Farvar, Thomas, Boksenbaum, & Soule, 1971; Xuan, 1975; Xuan & Matsui, 1998). There are also severe human health and environmental consequences from exposure to high levels of the chemicals (Dasgupta, Meisner, Wheeler, Xuyen, & Lam, 2007; Dung & Dung, 1999; Phung, Connell, Miller, Rutherford, & Chu, 2012; Stadlinger, Berg, Van den Brink, Tam, & Gunnarsson, 2016).

Several previous studies have provided evidence that Vietnamese rice farmers overuse pesticide and fertilizer inputs (Dung & Dung, 1999; Heong et al., 1994; Heong & Hardy, 2009; Meisner, 2005; Tu et al., 2015). The imported volume of nitrogen, potassium, and phosphate fertilizers in 1960 was 130,750 metric tons; this reached 372,183 metric tons in 1973 and 4,675,000 metric tons in 2013, an annual growth rate of 7% for the period 1960–2013 (Barker et al., 1985; Xuan, 1975). The imported volume of pesticide also increased significantly from 294 tons in 1965 to 3,238 tons in 1973 to 162 million tons in 2015, an annual increase of nearly 30% (Turner, Aoike, & Tauji, 1973; Xuan, 1975). In contrast, the average rice yield increased from 1.9 tons/ha in 1965 to 5.7 tons/ha in 2013, an annual growth rate of only 2.3%, which includes a large increase after the implementation of doi moi (economic reform) policies in the 1990s (Hai & Talbot, 2014; Justin et al., 2016; Minot & Goletti, 2000). The growth rate of agrochemical usage has far exceeded the improvement of rice productivity in the same period.

To manage overuse of agrochemicals and the consequential detrimental impacts, the Vietnamese government has implemented several environmentally friendly (hereafter, “eco”) technological and farming programs. These have included integrated pest management (IPM), “One Must and Five Reductions,” “3 Reductions, 3 Gains,” ecological engineering, “Good Agricultural Practices” certification (VietGAP, GlobalGAP), “small farmers, large field” production, and other campaigns. Farmers have also been encouraged to conserve traditional floating rice cultivation, which uses no pesticides and only small amounts of fertilizer. All of these rice farming approaches have the common
purposes of reducing the use of agro-chemicals, protecting both the environment and public health, and conserving biodiversity in the paddy fields.

However, farmers’ acceptance of eco rice production has been limited in the VMD, even though these farming methods constitute important components of a comprehensive sustainable agriculture program (Demont & Rutsaert, 2017). For example, seven years after the introduction of VietGAP methods, the total verified area of rice production using those methods was only about 840 hectares out of the 7.5 million hectares that produce rice in the VMD. In addition, out of 1,663 organizations (clubs and cooperatives) for farmers who satisfied VietGAP requirements, only 22 (1.3%) were rice farmers. In 1974, the total area of floating rice was about 0.5 million ha, in which An Giang province made up about 50% (250,000 ha) (Xuan & Matsui, 1998). By 2015, acreage devoted to floating rice production in An Giang decreased to only 50 ha, as farmers made the transition to high-yielding rice varieties. Thus, even with government efforts to promote eco-friendly cultivation practices, farmers have resisted the conversion.

Rice is one of the staple products consumed daily in Vietnam and many other countries. As economic conditions improve, Vietnamese consumers are likely to choose healthier food options (Mishra & Ray, 2009; Truong, Yap, & Ineson, 2012; Vuong, Gallegos, & Ramsey, 2015). Rice export is also a key component of the country’s broader economic development strategy (Ha, Nguyen, Kompas, Che, & Trinh, 2015). Thus, demand for “safe” rice products will require an increase in current production, yet farmers seem reluctant to embrace these methods of production. Within this context, the purpose of the present research is to investigate the factors that lead farmers to adopt eco-friendly rice production methods.

1.2. Literature review: Factors in farmer adoption of new technologies

Previous studies have examined a variety of factors related to the adoption of new technologies. The most well recognized factors that influence technology acceptance are the perceived ease of use and perceived benefits or economic value (Davis, 1989). This basic technology acceptance model is considered robust, such that it may be applied across contexts and may thus include context-specific variables.

Research that has examined decision-making within the specific context of agriculture has analyzed the roles of farmers’ attitudes, evaluations, and perceptions (Mwangi & Kariuki, 2015; Tey et al., 2014). Attitudes toward risk may shape farmers’ participation in new programs (Barreiro-Hurlé, Espinosa-Goded, & Dupraz, 2010). Perceptions or awareness of the environment and attitudes toward the eco-farming approaches’ characteristics may also influence the adoption of an agricultural program (Adesina & Zinnah, 1993; Negatu & Parikh, 1999; Sidibé, 2005; Wang, Gao, Wang, & Li, 2016). Other studies have considered extrinsic factors, farm biophysical characteristics, regulations from government, availability of funds and financial characteristics (Knowler & Bradshaw, 2007; Lee, 2005; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015; Wang et al., 2016).

However, these earlier studies did not consider how perceptions of risk that farmers may associate with the new farming practices or how farmers’ perceptions of biodiversity loss may influence the implementation of the new methods. The results from earlier studies have been quite mixed, depending on each specific type of conservation practice and geographic region.

Studies that have directly examined eco practice adoption the Vietnam Mekong Delta (Berg, Söderholm, Söderström, & Tam, 2017; Bosma et al., 2012; Dang & Duong, 2002; Da, Phuoc, Duc, Troell, & Berg, 2015) have dealt with the narrow contexts of integrated rice-fish farming systems and mono-rice cultivation. These previous studies were limited to specific geographic regions, such that the policy implications they derived may not be applicable to other regions even within Vietnam. To foster the expansion of eco rice production so as to meet the increasing demands for both agricultural sustainability and production of healthy food, the research question to be addressed in this study is: which factors influence the adoption of such rice farming programs? Results from this
research can help to devise and promote specific policy interventions and to identify specific groups of farmers who would benefit from these programs.

The following section presents the conceptual and analytical frameworks that we used to investigate the determinants of the adoption of eco rice. These determinants are identified using ordered logistic regression/generalized ordered logistic regression. The third section of the paper describes the process of data collection and analysis. The final sections present results of the analysis, followed by discussion and conclusions.

2. Materials and methods

2.1. Conceptual framework

The theoretical framework for the current study is derived from two models. First, the technology characteristics-user's context model (Negatu & Parikh, 1999) assumes that a farmer’s perceptions of the characteristics of a technology are fundamental determinants of that farmer’s adoption of the technology, hence the diffusion of the technology. Second, the utility maximization model (Rahm & Huffman, 1984; Sidibé, 2005) posits that farmers are more likely to adopt new agricultural technologies, innovations, or conservation practices if the utility derived from them is greater than that of the old ones. This would include both observable and unobservable variables such as perceptions of risks, perceptions about the environment and conservation, agro-ecological characteristics, institutional effects, and socio-economic and demographic conditions. The conceptual model describing the adoption of eco-friendly practices is shown in Figure 1.

Using the technology characteristics-user’s context and utility maximization models, the factors affecting the adoption of eco rice in this study can be classified into eight subgroups: (1) socio-demographic characteristics (age, education, experience, labor and female laborers), (2) perceptions of risk, (3) perceived usefulness (output, selling price, benefit), (4) perceptions about the environment (pollution and biodiversity), (5) perceived ease of use (technical aspect); (6) farm physical characteristics (farm size and plots), (7) social network (membership in organizations) and (8) financial characteristics (perception of outside support and access to credit) (Adesina & Zinnah, 1993; Barreiro-Hurlé
The detailed description of how each of the individual independent variables were operationalized is provided in Tables 1 and 2.

2.2. Analytical framework

The utilities considered in this study include both tangible and intangible benefits gained from the new practices. In the context of eco rice production methods, the former explicitly indicates the profits while the latter represents the environmental values that new practice adopters would like to conserve. Therefore, the utility function \( (U_j) \) or the \( i \)th farmer to adopt a new practice or an alternative is given as follows:

\[
U_j = \beta_j X_i + e_j
\]

where \( X_i \) a vector of variables affecting the adoption; \( \beta_j \) is a vector of parameters to be estimated; \( j \) indicates the adopted alternative; \( i \) indexes farmers \( (i = 1, 2, 3, \ldots N) \), and \( e_j \) presents the random and error term. Therefore, the utility of adopting a new technology (under the premise that there are only two option) is greater than the utility of the old one can be expressed as

\[
U_j > U_{(j-1)}
\]

\[
\beta_j X_i + e_j > \beta_1 X_i + e_{(j-1)}
\]

\[
e_j - e_{(j-1)} > \beta_1 X_i - \beta_j X_i
\]

### Table 1. Definition of variables used in ordered logit model

| Variables                              | Notation | Description                                                                 |
|----------------------------------------|----------|-----------------------------------------------------------------------------|
| Dependent variable                     | ADOPTION | Adoption of eco rice 0 = conventional rice; 1 = single eco practice and 2 = combined eco practices |
| Independent variables                  |          |                                                                             |
| Age of the family head                 | AGE      | Continuous variable, years                                                 |
| Education of the family head           | EDUCATION| Continuous variable, schooling years                                       |
| Number of family labors                | LABOR    | Continuous variable, members                                                |
| Rice experiences of the family head    | EXPERIENCE| Continuous variable, years                                                 |
| Numbers of female labors cultivating rice | FEMALE | Continuous variable, members                                                |
| Risk perception                        | RISK\*   | Continuous variable, in range [16–80]                                       |
| Perceived benefits of the eco practices | BENEFIT† | Continuous variable, in range [4–20]                                       |
| Perceived selling price of output      | PRICE    | Five-point scale, 1 = low to 5 = high                                       |
| Perceived output level                 | OUTPUT   | Five-point scale, 1 = low to 5 = high                                       |
| Perception towards biodiversity        | BIODIVERSITY| Dummy, 1 if reduction, 0 otherwise                                        |
| Perception towards water pollution     | POLLUTION| Dummy, 1 if pollution, 0 otherwise                                          |
| Perceived ease of use                  | USE      | Five-point scale, 1 = low to 5 = high                                       |
| Total area of farm land                | AREA     | Continuous variable, hectare                                               |
| Numbers of paddy plots                 | PLOT     | Continuous variable, number of plot                                        |
| Membership in cooperatives             | ORGANIZATION| Dummy, 1 if participate, 0 otherwise                                     |
| Perceived receipt of outside supports  | SUPPORT | Dummy, 1 if yes, 0 otherwise                                                |
| Accessing credit                       | CREDIT   | Dummy, 1 if yes, 0 otherwise                                                |

Source: Own estimates; data appendix available from authors.

\*Risk perceptions were calculated as the sum of 16 five-point scaled indicators, including weather variability, dam construction, market volatility, rice diseases, management and technology expertise, etc.

†Benefit is measured as the sum of 4 five-point scaled indicators, including lower production cost, biodiversity improvement, high quality product and ease of selling.
Let $Y_j$ denote the adoption decision with $j = 0, 1, 2$

As mentioned earlier, there are several eco rice farming methods available to VMD farmers. The alternative is conventional rice production. Because conventional rice farmers were considered non-adopters of eco practices, they were coded as zero ($Y_0 = 0$). With regards to eco rice farmers (hereafter referred as adopters), those who have adopted a single eco practice were indexed with 1 ($Y_1 = 1$) and those who employed or integrated two eco rice practices were coded as 2 ($Y_2 = 2$). With these as dependent variables, we can use generalized ordered logit or ordered logit model to investigate the factors that influence farmers’ adoption decisions.

The ordered logit model is a special case of generalized ordered logit model. The results estimated from ordered logistic regression will be straightforward if the model does not violate the parallel-lines assumption by using the Brant test (Williams, 2006). If the parallel-lines assumption is violated, the alternative is to use the generalized ordered logit model (Cornwell, Laumann, & Schumm, 2008; Do & Farooqui, 2011; Kleinjans, 2009). The main difference between ordered logit and generalized ordered logit is that the ordered logit model requires the $\beta_j$’s to be the same for each value of $j$, while the generalized ordered logit model relaxes all or some of the $\beta_j$’s variance across values of $j$. Thus, analysis will focus on presenting the methodology of the generalized ordered logit model, which will reduce to an ordered logit model if the assumption of $\beta_j = \beta$ for all alternatives is satisfied. However, a key problem with the parallel-lines model (ordered logit model) is that its assumptions are often violated (Williams, 2006); it is common for one or more $\beta_j$’s to differ across values of $j$. The partial proportional odds model (through which some of the $\beta$ coefficients can be the same for all values of $j$, while others can differ) can be expressed as:

$$P(Y > j) = \frac{\exp(\alpha_j X_1 \beta_1 + X_2 \beta_2 + \cdots + X_{m-1} \beta_{m-1})}{1 + \left[ \exp(\alpha_j X_1 \beta_1 + X_2 \beta_2 + \cdots + X_{m-1} \beta_{m-1}) \right]}$$

Table 2. Descriptive statistics and hypotheses of the variables used in the model

| Categories                        | Variables   | Mean  | Std. Dev. | Hypothesis |
|-----------------------------------|-------------|-------|-----------|------------|
| Adoption decision                 | ADOPTION    |       |           |            |
| Socio-demographic characteristics | AGE         | 48.18 | 12.04     | Negative   |
|                                  | EDUCATION   | 7.54  | 3.02      | Positive   |
|                                  | LABOR       | 2.38  | 1.26      | Positive   |
|                                  | EXPERIENCE  | 24.09 | 11.44     | Negative   |
|                                  | FEMALE      | 0.67  | 0.73      | Positive   |
| Perception of risk               | RISK        | 41.08 | 8.36      | Negative   |
| Perceived usefulness             | BENEFIT     | 15.35 | 3.37      | Positive   |
|                                  | PRICE       | 4.02  | 1.26      | Positive   |
|                                  | OUTPUT      | 3.23  | 1.32      | Positive   |
| Perception towards environment   | BIODIVERSITY| 0.83  | 0.38      | Positive   |
|                                  | POLLUTION   | 0.62  | 0.49      | Positive   |
| Perceived ease of use            | USE         | 4.05  | 1.21      | Positive   |
| Farm physical characteristics    | AREA        | 2.69  | 2.32      | Positive   |
|                                  | PLOT        | 1.63  | 1.01      | Negative   |
| Social network                   | ORGANIZATION| 0.36  | 0.48      | Positive   |
| Financial characteristics        | SUPPORT     | 2.88  | 1.38      | Positive   |
|                                  | CREDIT      | 0.30  | 0.46      | Negative   |

Source: Own estimates from the collected data in 2016, $n = 202$. Data appendix available from authors.
From Equation (3), in order to predict the probabilities of different alternatives for a given farmer, we need to model a function that presents the relationship between dependent variable \(Y_{ik}\) and the explanatory variables \(X_{ik}\). The empirical model presenting the relationship is given by

\[
Y_{ik} = a_0 + a_1 \text{AGE} + a_2 \text{EDUCATION} + a_3 \text{LABOR} + a_4 \text{EXPERIENCE} + a_5 \text{FEMALE} \\
+ a_6 \text{RISK} + a_7 \text{BENEFIT} + a_8 \text{PRICE} + a_9 \text{OUTPUT} + a_{10} \text{BIODIVERSITY} + a_{11} \text{POLLUTION} \\
+ a_{12} \text{USE} + a_{13} \text{AREA} + a_{14} \text{PLOT} + a_{15} \text{ORGANIZATION} + a_{16} \text{SUPPORT} + a_{17} \text{CREDIT}
\]

(4)

2.3. Data collection and analysis

For this study, eco rice practices included floating rice, large-field rice, VietGAP rice, GlobalGAP rice and ecologically engineered rice. To gather data for the study, we conducted structured interviews with 202 farmers. One hundred forty-three of the farmers had adopted one or more of the eco rice production methods. As discussed earlier, the intention of each of these all rice farming approaches is to decrease or forgo the use of agro-chemicals. Fifty-nine farmers produced rice using conventional methods. These were considered non-adopters who did not apply any of the above-mentioned eco friendly practices. Because a small number of farmers in the Mekong Delta use eco rice methods, the observations represented nearly the entire population of eco methods farming for each of the geographic target locations.

The process of conducting interviews with the eco rice farmers is as follows. First, we contacted with extension workers at provincial level to discuss and select the districts that had the largest number of eco rice farmers. Second, we worked with extension workers at district levels to get the list of eco rice farmers. Based on the list, we conducted face-to-face interviews with all eco rice farmers.

The most important criterion for selecting non-adopting/conventional farmers was geographic proximity to adopters/eco rice farmers. We assumed, based on local knowledge, that non-adopters were well aware of eco practices but they had refused these practices. This selection also ensured homogeneity in terms of natural conditions (soil, water, rain, etc.) as well as cultural characteristics for both adopters and non-adopters. Thus, survey responses from conventional (non-adopting) rice farmers were gathered as a convenience sample, but represented each target location. The data were collected in April 2016 in the districts of Tri Ton, Chau Thanh, Thoai Son and Cho Moi in An Giang province and Vinh Thanh district of Can Tho city. These two study areas are the major rice zones in the VMD, with the former producing more than 4 million tons and the latter supplying 1.3 million tons in 2016 (see Figure 2 for more details of the study sites).

As mentioned, the dependent variable (adoption) was coded as follows: 0 = conventional rice; 1 = single eco practice; and 2 = combined eco practices. In terms of environmental and economic values, the utility derived from the alternative 1 will be better than that of the alternative 0 and that of the alternative 2 will be the greatest. The classification for each alternative is that if those who were cultivating conventional rice (without any eco practices) are indexed as 0, those who were applying one eco practice (VietGAP, GlobalGAP, large-field, floating rice or ecologically engineered rice, etc.) are coded as 1 and those with two eco practices are numbered 2.

The map of the study sites is presented in Figure 2.

The dependent and independent variables used in the ordered logit analysis are described in Table 1.

2.4. Hypotheses

In terms of individual farmer demographics, several previous studies (Lee, 2005; Sidibé, 2005; Soule, Tegene, & Wiebe, 2000) have provided evidence that the farmer’s age (AGE) and experience (EXPERIENCE) are negatively related to ADOPTION, since older or more experienced farmers may be less willing to make changes in their production practices. Education levels of farmers are expected to be positively associated with ADOPTION (Lee, 2005; Sidibé, 2005; Wang et al., 2016).
With respect to human capital, because farming is labor intensive, the available number of family laborers (LABOR) is expected to be positively related to ADOPTION. The number of female laborers participating in rice cultivation (FEMALE) is expected to be positively related to ADOPTION because women are in a better position at a very local level to note environmental changes and hazards (e.g. lack of drinking water) (Carvajal-Escobar, Quintero-Angel, & García-Vargas, 2008) and may also be more responsive to some environmental issues (Turner et al., 1973).

Perceptions of risk would decrease the attractiveness of new practices and overemphasize a higher likelihood of failure, such that RISK is expected to be negatively related to ADOPTION (Lee, 2005). Perceived usefulness derived from new practices (BENEFIT, PRICE and OUTPUT) will be associated with higher adoption rate (Lee, 2005; Shiferaw & Holden, 1998; Wang et al., 2016). Our assumption is that farmers who recognized reductions in biodiversity and increases in water pollution will be more likely to adopt eco-friendly practices. Perceived ease of use is expected to have a positive relationship with ADOPTION, as rice farmers ordinarily have lower educational level, are relatively conservative, and are averse to risks (Davis, 1989).

The impact of farm size on eco friendly adoption has very important policy implications in Vietnam and the VMD region, as the government has invested considerable efforts to establish cooperative-based farming. Farm size is hypothesized to affect ADOPTION positively, while number of plots is expected to have a negative effect. The number of plots leads to both physical constraints and difficulties in management. Membership in cooperative organizations is anticipated to be positively related to ADOPTION (Soule et al., 2000; Wang et al., 2016). With regard to financial characteristics, SUPPORT is assumed to have a positive relationship with ADOPTION, while CREDIT is predicted to be negatively associated with ADOPTION.
Descriptive statistics and summaries of the hypotheses for each explanatory variable used in the ordered logit model are shown in Table 2.

The average age for farmers interviewed for this study was 48 years. This is relatively higher than that of the national population (GSO, 2015), suggesting that fewer younger people participate in farming in this region. The average number of years of education for farmers was 7.5 years, slightly higher than that measured by Berg (2002). On average, more than two members of a family were involved in rice farming, and in over half of the farms, one of these was female. Regardless of their contribution level, this result suggests that female family members play an important role in rice production.

Measurement of rice farmers’ perceptions of risk provided neutral responses, on average (mean = 41.08). A large majority (83%) of the interviewed farmers reported observing biodiversity loss; sixty-two percent detected severe water pollution. Overall, the survey participant farmers expressed favorable perceptions with respect to the “ease of use” of eco production practices (mean = 4.02).

The average size of eco practice farms was quite large compared to the national agricultural area per household (2.69 ha compared to 0.42 ha) (GSO, 2015). The average number of separate paddy plots per farmer was 1.63. The greater the number of plots, the more management difficulties rice farmers would have to face, which is one reason that the Vietnamese government has encouraged farmers to aggregate agricultural land for producing large-field rice (known locally as Canh Dong Mau Lon). This farming method is intended to reduce per-unit production costs and enhance scale economies.

The following section describes and discusses further analysis of the data, including the cost-benefit analysis, the predicted probabilities of eco rice production methods, and the ordered logit regression used to identify factors that are related to the adoption of eco methods. The study employed Stata® software version 12 to perform the ordered logistic regression.

3. Results and discussion

3.1. Cost-benefit analysis and comparison of rice farming approaches

Table 3 provides the results of a cost-benefit analysis for different rice farming approaches. As shown in Table 3, the implementation of a single eco method consumed the least of the three environmentally detrimental inputs (fertilizer, pesticide and fuel) among all rice farming approaches. The average fertilizer cost for single eco practice was significantly lower than that for any of the combined eco practices. In terms of consumption of environmentally detrimental inputs, these results suggest that the single eco practice was more environmentally friendly. At the same time, the selling price of rice produced by the average single eco method farm was significantly higher than that produced through the other options. One explanation for this outcome is that nearly all floating rice farmers, and the majority of VietGAP and GlobalGAP farmers, had contracts with distribution companies, which then offer a higher selling price. It is also likely that companies and consumers may have recognized floating rice as a more environmentally friendly product (almost no use of agro-chemicals), and were willing to pay a higher price. The selling price of combined eco practices was not significantly different from that for conventional rice production methods.

With respect to output level, the single eco method farmers had the lowest yield per hectare, significantly lower than that of conventional rice but insignificantly different from combined eco practices. Agro-chemical usage was positively related to production output, and single eco method farmers consume the least of the agro chemicals. Table 3 also shows that the net benefit, benefit-cost ratio (BCR) and benefit-revenue ratio (BRR) from the use of a single eco rice method was significantly higher than those same indices for the other concerned rice farming approaches; the single eco method resulted in the lowest cost but the highest selling price.
One of the most important determinants of the adoption and continued use of environmentally friendly rice production methods, especially in developing countries, is economic achievement, that is, whether the practices allow the farmer a profit. Thus, based on this cost-benefit analysis, the use of the single eco rice method showed the highest economic potential among the rice production farming approaches. This result suggests that the single eco practice is a feasible alternative for farmers in the study sites. The next section presents the analysis of factors that affect the farmer’s adoption decisions for rice production.

3.2. Factors affecting the adoption decisions for eco-friendly rice methods

The results of the generalized ordered logit model are presented in Table 4 and identify the factors affecting the adoption of eco rice. As mentioned, the ordered logit regression requires a test of the parallel-lines assumption. The Brant test showed that the assumptions of the parallel-line model were violated, since $P_{value} > \chi^2_{critical} = 0.001$. Thus, we used the alternative generalized ordered logit model.

The likelihood ratio value is 12.78, which is smaller than $\chi^2_{10,0.01} = 23.21$, suggesting that we accept the null hypothesis or the restricted model as appropriate. The Wald test produced $\chi^2 = 58.03$, which is greater than $\chi^2_{10,0.01} = 23.21$, indicating that the model fit is acceptable for prediction.

Two of the variables in Table 4, PRICE and USE, are relaxed for the parallel-lines assumption in the generalized ordered logit model. The interpretation of the relationships between the dependent variables and these unconstrained variables are not straightforward as compared to the other constrained variables that have the same coefficients between panels. For PRICE, the perceived difference in selling prices had a positive, significant relationship in the first panel but a negative

### Table 3. Cost-Benefit analysis of different rice farming approaches

| Indicators          | Conventional | Single eco | Combined eco |
|---------------------|--------------|------------|--------------|
| 1 Fertilizer cost   | 13,537.98    | 9,863.48   | 19,983.30    |
| 2 Pesticide cost    | 4,894.52     | 2,873.80   | 3,736.79     |
| 3 Fuel cost         | 518.17       | 379.01     | 867.70       |
| 4 Seed cost         | 1,926.52     | 1,971.68   | 1,518.98     |
| 5 Machinery cost    | 4,064.44     | 3,440.13   | 3,602.78     |
| 6 Total cost $\Sigma$ | 24,941.62   | 18,528.09  | 29,689.55    |
| 7 Selling price (kg$^{-1}$) | 5.18  | 8.07      | 5.40         |
| 8 Output (kg)       | 8,595.08     | 7,207.00   | 8,143.33     |
| 9 Revenue (7) × (8) | 44,502.84    | 58,187.54  | 44,006.57    |
| 10 Benefit (9) – (6) | 19,561.22   | 39,659.45  | 14,317.03    |
| 11 BCR (10)/(6)     | 0.78         | 2.14       | 0.48         |
| 12 BRR (10)/(9)     | 0.44         | 0.68       | 0.33         |

Note: The same superscripted letters (a, b and c) in one row indicate that the mean values are insignificantly different by using Duncan test; Cost-Benefit analysis was measured in thousand VND for one ha; BCR and BRR stand for Benefit-Cost Ratio and Benefit-Revenue Ratio, respectively.

Source: Own estimates from the collected data in 2016, n = 202. Data appendix available from authors.
relationship in the second panel, indicating that farmers were likely to adopt conventional rice and single eco practice rather than combined eco practices. This may be because more labor and other inputs are required for combined eco practices, although market prices are not significantly different between the two outputs. For the perceived ease of use variable (USE), the positive coefficient in the first panel (conventional rice versus single eco practice/combined eco practices) indicates that farmers preferred single and combined eco practices to conventional rice methods.

With regard to the constrained variables, EXPERIENCE, RISK, BIODIVERSITY, PLOT and ORGANIZATION had significant effects on ADOPTION, although not all in the predicted directions. The effect of farm size (PLOT) on the adoption was in the predicted direction but was not significant (2 value = 1.58 and P value = 0.11); so we cannot say conclusively that farmers with larger farm size were more likely to adopt combined eco practices. Our expectation was larger-sized paddy fields could create more advantages for the management and application of new technologies. However, consistent with our expectation, farmers with more paddy plots (PLOT) were less likely to adopt eco practices. An increasing number of paddy plots creates more difficulties and constraints for management of the rice farm.

| Variables | Unrestricted model | Restricted model |
|-----------|--------------------|------------------|
|           | 0--1&2 | 0&1--2 | 0--1&2 | 0&1--2 |
| AGE       | α  | s.e  | α  | s.e  | α  | s.e  | α  | s.e  |
| EDUCATION | 0.037 | 0.059 | 0.037 | 0.059 |
| LABOR     | −0.087 | 0.165 | −0.087 | 0.165 |
| EXPERIENCE| 0.042* | 0.021 | 0.042* | 0.021 | 0.028* | 0.015 | 0.029* | 0.015 |
| FEMALE    | 0.242 | 0.278 | 0.242 | 0.278 |
| RISK      | −0.099*** | 0.024 | −0.099*** | 0.024 | −0.107*** | 0.022 | −0.107*** | 0.022 |
| BENEFIT   | 0.108 | 0.086 | 0.108 | 0.086 |
| PRICE†    | 0.130 | 0.225 | −0.951*** | 0.279 | 0.338*** | 0.155 | −0.624*** | 0.218 |
| OUTPUT    | 0.069 | 0.166 | 0.069 | 0.166 |
| BIODIVERSITY | 1.095* | 0.573 | 1.095* | 0.573 | 1.034*** | 0.527 | 1.034*** | 0.527 |
| POLLUTION | 0.432 | 0.378 | 0.432 | 0.378 |
| USE†      | 0.428*** | 0.163 | −0.477*** | 0.305 | 0.395*** | 0.153 | −0.318 | 0.291 |
| AREA†     | 0.027 | 0.110 | 0.328** | 0.134 | 0.139 | 0.087 | 0.139 | 0.087 |
| PLOT†     | −0.357 | 0.207 | −0.357 | 0.207 | −0.387** | 0.199 | −0.387** | 0.199 |
| ORGANIZATION | 2.464*** | 0.509 | 2.464*** | 0.509 | 2.501*** | 0.481 | 2.501*** | 0.481 |
| SUPPORT   | 0.136 | 0.154 | 0.136 | 0.154 |
| CREDIT    | −0.498 | 0.403 | −0.498 | 0.403 |
| Intercept | −0.615 | 1.915 | 1.126 | 2.330 | 0.684 | 1.461 | 2.389 | 1.957 |

Source: Own estimates; data appendix available from authors.
*Indicates the significant level p < 0.1.
**Indicates the significant level p < 0.05.
***Indicates the significant level p < 0.01.
†Indicates the unconstrained variables.
We also predicted that farmer experience (EXPERIENCE) would be negatively related to ADOPTION. However, the estimated result indicates that experience was significantly and positively associated with ADOPTION. Farmers with more experience may be more aware of the benefits of agricultural programs, including those that are environmentally friendly. It is also possible that farmers with more experience have succeeded because they are innovative and more open to new farming practices (Willock et al., 1999).

Risk perceptions (RISK) were negatively related to ADOPTION; farmers who perceived higher risk were less likely to adopt eco practices. This result is consistent with previous studies (Ghadim, Pannell, & Burton, 2005; Jerneck & Olsson, 2013) and our expectation. Farmers who had perceived biodiversity losses (BIODIVERSITY) were more likely to take environmentally friendly action. In fact, this was the second-largest coefficient among all variables that predicted adoption. Again, this result was consistent with previous research (Herzon & Mikk, 2007) and our hypothesis.

The results also show that membership in a farmer-based organization (ORGANIZATION) had the largest positive effect on the adoption decision of eco rice. Those farmers who participated in agricultural cooperatives or clubs had more access to information about the effectiveness and other benefits of the new technologies.

For a clearer picture of the effects of individual predictors on the adoption probability, Table 5 illustrates the probabilities for each adoption decision at different values of independent variables.

The probability of a farmer’s adoption of a single eco practice was the highest at 78.4% as compared to 18.95% for conventional rice and only 2.65% for combined eco practices. This suggests that the single eco practice was preferred among those farmers in the sample.

We also found that the farmers who did not observe biodiversity losses were more likely to adopt conventional rice production (35.47%) than those who perceived biodiversity losses (16.35%). With respect to the adoption of single eco practice, the probability of farmers who witnessed biodiversity losses was higher (i.e. 80.5% > 63.39) that of those who did not. This result suggests that one means by which to stimulate the adoption of eco practice would be to improve farmers’ awareness and understanding of the benefits of biodiversity.

Additionally, the results offer that those farmers who participated in organizations were more likely to adopt single eco practice (83.63%) than those who did not (62.32%). As mentioned earlier, this is an indication that participation in agricultural cooperatives and clubs facilitate shared information and practice.

Table 5. Predicted probabilities by the adoption decisions

| Variables    | Conditions | P(Y = 0|X) | P(Y = 1|X) | P(Y = 2|X) |
|--------------|------------|------|--------|--------|
| All predictors| At means   | 0.1895 | 0.7840 |        |
| BIODIVERSITY | = 0        | 0.3547 | 0.6339 | 0.0114 |
| BIODIVERSITY | = 1        | 0.1635 | 0.8050 | 0.0315 |
| ORGANIZATION | = 0        | 0.3659 | 0.6232 | 0.0109 |
| ORGANIZATION | = 1        | 0.0452 | 0.8363 | 0.1185 |
| USE          | = 3        | 0.2617 | 0.7016 | 0.0367 |
| USE          | = 4        | 0.1928 | 0.7802 | 0.0270 |
| AREA         | mean + 1   | 1,691 | 0.8006 | 0.0303 |
| PLOT         | mean + 1   | 2,560 | 0.7258 | 0.0182 |
| EXPERIENCE   | mean + 1   | 1,851 | 0.7876 | 0.0273 |
| RISK         | mean + 1   | 2,064 | 0.7697 | 0.0239 |

Note: As one variable is fixed at a certain value, the remaining variables are at means.
Source: Own estimates; data appendix available from authors.
The perceived ease of use (USE) was also significant in predicting the probability of adopting single eco practice. When farmers perceived the technology to be easier to implement by one additional unit, the probability of selecting single eco practice increases about 8%.

Farmers with more paddy plots were less likely to adopt single eco methods. Again, multiple plots are more difficult to manage and require more capital and human resources. When farmers had one more plot, the probability of adopting single eco practice declined about 6%.

One further finding of the generalized ordinal logit analysis is that conventional rice farmers may share characteristics of eco friendly rice farmers. That is, the analysis provides an estimation of membership in a specific rice cultivation category, and those conventional rice farmers who are similar to eco rice farmers represent a target group for transition to eco-friendly methods. These values (probabilities) are important for policy implications to encourage and maintain farmers' adoption. The predicted probabilities are illustrated in Figure 3.

Figure 3 shows that 39 of 59 observed conventional rice farmers were correctly predicted. This implies that, based on the characteristics that we measured, only 66.1% of them were expected to use conventional methods based on their associated characteristics. The remaining farmers (approximately 34%) were predicted to belong to single eco practice.

Regarding single eco practice, the estimated result shows that 85.2% (i.e. 109/128) of single eco rice farmers were correctly predicted. The remaining farmers 14.8% (i.e. 19/128) were predicted to belong to conventional rice (12.5%) and combined eco practices (2.3%). For farmers who were applying combined eco practices, only 1 out of 15 farmers (6.7%) were predicted to belong to the current practice. The remaining 14 farmers were expected to belong to the group of single eco practice (12 farmers) and the group of conventional rice (2 farmers).

The results from the cost-benefit analysis and the generalized ordered logit suggest that the single eco practice is the most feasible farming approach to promote to farmers in these geographic areas.

4. Conclusions
The findings of this study are consistent with those from other studies that have considered the adoption of environmentally sustainable agricultural practices in developing countries (Ma, Abdulai, & Goetz, 2016; Onob). More importantly, the results contribute to the limited body of research on agricultural intensification and sustainability benefits of the various rice production methods in Vietnam, specifically the Mekong Delta. As mentioned earlier, these results may be location-specific but help to identify factors that influence adoption (or rejection) of environmentally friendly farming methods.
In particular, and again consistent with other studies (Cai, Ma, & Su, 2016; Ma et al., 2016; Onubogu, Esiobu, Nwosu, & Okereke, 2014; Tey et al., 2014b), the results here suggest that membership in agricultural cooperatives or clubs is important for increases in farm productivity as well as for expansion of eco friendly methods of rice farming. These organizations serve as important sources of information for farmers, and can serve to disseminate the benefits and efficiencies of eco methods. Technical training courses and information sharing meetings can introduce farmers to the eco practices and illustrate the benefits (ease of use, biodiversity conservation, etc.). In addition, policy makers should focus on mitigating risks from production stage (technical aspects and adverse climatic impacts) to market (differentiation in selling price of eco rice versus conventional rice). Further research may address more specific questions as to how farmer-oriented organizations influence technology adoption decisions.

The study results also identify farmers with larger farms, but fewer plots, as the most feasible group to adopt eco practices. However, farmers with more paddy plots were less likely to adopt eco practices. To promote eco practices in a new area, farmers with larger farm size but fewer plots are a good target group for demonstrations and training in the application of these techniques.

With respect to characteristics of individual farmers, again the results from the study provide some useful guidance. Farmers’ perceptions of biodiversity losses were an important influence of adoption decisions. This is a vital starting point for collaborative policy that encourages technological innovations in environmentally friendly production methods. Perceptions about the ease of use of the technology positively influenced adoption, suggesting that farmers preferred eco practices. The perceived differences in selling prices suggest that farmers were likely to adopt conventional rice and single eco practice rather than combined eco practices. Farmers who perceived higher risk were unlikely to adopt eco practices. Farmer experience was positively associated with the adoption. All of these indicate a need for education, but also persuasive efforts to overcome the negative perceptions.

Additionally, when the characteristics of individual farmers were used as independent variables to predict rice production method in the logit analysis, a large proportion of farmers who use conventional methods shared similar characteristics with eco rice farmers. This indicates a favorable group to encourage the conversion to eco friendly methods. Policy makers may provide financial or other incentives to facilitate the transition.

Based on the cost-benefit analysis, the single eco practice had the highest economic achievement when compared to the conventional rice and the combined eco practices, suggesting that the single eco practice is the most feasible to introduce to farmers in the study sites. The eco friendly practices identified here can reduce the costs while also increasing the prices that farmers receive. Additionally, finding and/or establishing a good market that allows for the differentiation between selling prices for eco rice and conventional rice is essential.

To promote the adoption of eco practices, policy makers should create an incentive mechanism to encourage farmers to join farmer organizations. In addition, policy makers should focus on informing farmers about mitigating risks such as adverse climatic impacts, polluted water, and other environmental threats. Technical training courses and other information-sharing meetings should also be required to introduce to farmers about the benefits of eco practices.

Although the study provides some significant evidences to the limited body of knowledge on the adoption of eco-friendly rice practices at the short term in the Vietnamese Mekong Delta, it did not capture the dynamic adoption patterns of eco-friendly rice in the long term. Therefore, a further research on potential and long-term adoption of eco-friendly rice practices is required.
Author contributions
V.H.T., M.Y., N.D.C and Y.T. conceived and designed the questionnaires; V.H.T. performed data collection; V.H.T., M.Y., N.D.C. and Y.T. analyzed the data; V.H.T. and S.K. wrote the paper.

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The authors declare no competing interest.

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Appendix

Questionnaire used for face-to-face interviews with farmers
(It should be noted that the survey was completed in Vietnamese; the attached questionnaire is an English translation to give an idea of the constructs we measured)

QUESTIONNAIRE

RESEARCH ON ADOPTION OF ECO-FRIENDLY RICE PRACTICES

I. General information

1. Interview date: / / 201

2. Full name of the respondent: ........................................ Phone No.:

3. Address: Hamlet: .................. Commune .................., District:

4. No. of family members: ...... persons, in which: female: ...... persons; Rice labor: ...... persons

5. Household’s head information

   Education of the head: ..................; Experience of rice: ..................years; Age:

   Joining in cooperatives/clubs:  1. Yes  2. No  Year of joining:

6. The role of women in rice production

   No. of female joining rice production?..............persons

   The general percentage that the female join in rice production?..........%  

7. Description of paddy field and irrigation

   (a) Total paddy land area?..............ha: in which how many plots are there?..............................

   (b) Ways of water pumping?

      (1) Collective pumping     (2) Individual pumping     (3) Transit pumping

   (c) No. of rice crops per year: ............... crops/year

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8. General information of Eco-friendly rice production

(a) Are you applying any eco-friendly practices (EFR) as below

(1) Ecological engineering (2) GlobalGAP (3) VietGAP
(4) Large-scale rice (5) Floating rice (6) Others (specify)

(b) Total area applying EFR …………………… ha Year of application: …………………………

(c) Please tell us the reasons that you applied EFR

………………………………………………………………………………………………………………………………………………………………
…………………………………………………………………….

II. Information about rice production

A. General information about the harvest

*If the household has over one plots (both EFR and conventional rice), please choose the biggest plot to ask*

| Plot | (a) Crop | (b) Yield (tons/ha) | (c) Total cost of fertilizers (Million VND) | (d) Total cost of pesticide (Million VND) | (e) Selling price (1,000 VND) | (f) Buyers |
|------|----------|---------------------|------------------------------------------|-----------------------------------------|-------------------------------|-----------|
|      |          | 1. Wet rice         | 1. Wet rice                               |                                        |                               |           |
|      |          | 2. Dried rice       | 2. Dried rice                             |                                        |                               |           |
| Biggest | Winter- | 1.                  | 1.                                        |                                        |                               |           |
|        | Spring   | 2.                  | 2.                                        |                                        |                               |           |
|       | Summer-  | 1.                  | 1.                                        |                                        |                               |           |
|       | Autumn   | 2.                  | 2.                                        |                                        |                               |           |

Note: Part (b) please circle the kind of rice before collecting data about yield

Part (e) Please circle the kind of rice before collecting data about selling price

Part (f) 1 = middle man; 2 = cooperatives; 3 = contracted company; 4 = others (specify)

Please tell me your plans and suggestions in applying the EFR in the future

………………………………………………………………………………………………………………………………………………………………
### B. The tariffs of expenditures

#### 1. Fixed costs

| Properties                                      | Quantity | Buying year | Value (million VND) | Tenure (Years) |
|------------------------------------------------|----------|-------------|---------------------|----------------|
| Water pumping machine                          |          |             |                     |                |
| Sprayers                                       |          |             |                     |                |
| Motobike for rice production                   |          |             |                     |                |
| Boats/ferry for transportation                 |          |             |                     |                |
| Rice containers                                |          |             |                     |                |
| Net and plastics for drying rice               |          |             |                     |                |
| Others (specify)                               |          |             |                     |                |

#### 2. Variable costs

##### a. Cost of seed, fertilizers, pesticide and water

| Indicators                                      | Detail | The biggest plot | Winter–Spring | Summer–Autum |
|------------------------------------------------|--------|------------------|---------------|--------------|
| (1) Seed varieties                             | Name?  |                  |               |              |
| (2) Family produced seed                       | Quantity (kg) |                  |               |              |
| (3) Buying seed                                | Quantity (kg) | Unit price (VND/kg) | From whom?* |              |
| (4) Flower seeds                               | Varieties? |                  |               |              |
|                                               | Total cost (m) |                  |               |              |
|                                               | From whom?*  |                  |               |              |
| (5) Chemical fertilizers                       | Nitrogen | Quantity (kg) | Unit price (VND/kg) |              |
|                                               | NPK (20-20-15) | Quantity (kg) | Unit price (VND/kg) |              |
|                                               | DAP (18-46-0)  | Quantity (kg) | Unit price (VND/kg) |              |
|                                               | Potassium | Quantity (kg) | Unit price (VND/kg) |              |
|                                               | Other ....... | Quantity (kg) | Unit price (VND/kg) |              |
|                                               | ............... | Unit price (VND/kg) |              |              |
|                                               | Buy from | From whom?*  |              |              |
| (6) Organic fertilizers                        | Buying   | Quantity (kg) | Unit price (VND/kg) |              |
|                                               | Self-produced | Quantity (kg) | Total cost (VND) |              |
| (7) Pesticides                                 | All kinds | Total cost (VND) |              |              |
| (8) Gasoline, petroleum for pumping            | Litre gasoline/crop |              |              |
|                                               | Litre petro./crop |              |              |
### Indicators

| (9) Water consumption (pumping) | The biggest plot |
|---------------------------------|------------------|
|                                 | Winter–Spring    | Summer–Autum    |
| Times/crop                      |                  |                 |
| Hour/time (h)                   |                  |                 |
| Capacity                        |                  |                 |
| Performance (%)                 |                  |                 |
| The height of water level       |                  |                 |

Note: Please use local acre unit, one Cong = 1.296 m² in stead of 1.000 m². Please collect information of the biggest plot mentioned in section A.

*1 = Institute/University, 2 = Seed and fertilizer center, 3 = Seed organization, 4 = other farmers, 5 = Cooperatives, 6 = Farmer club, 8 = Others (please specify).

**1 = Agr. materials companies, 2 = Agr. materials branches, 3 = Cooperatives, 4 = Farmer clubs, 6 = others (please specify).

### Labor

#### (a) Activities

| Theo vụ | (b) Family labours (days/crop) | (c) Hired labours (days/crop) | (d) Total expense of hired labour (thousand VND) |
|---------|--------------------------------|-----------------------------|-----------------------------------------------|
|         | Winter–Spring                  | Sum.–Aut.                   | Winter–Spring                  | Sum.–Aut. |
| 1       | Land preparation for rice      |                             |                                |           |
| 2       | Sowing/transplantation          |                             |                                |           |
| 3       | Flower planting & caring       |                             |                                |           |
| 4       | Broadcasting fertilizer        |                             |                                |           |
| 5       | Spraying pesticides           |                             |                                |           |
| 6       | Harvesting                    |                             |                                |           |
| 7       | Caring paddy field            |                             |                                |           |

### Other cost

| Renting machinery/ facilities | Winter–Spring | Summer–Autumn |
|------------------------------|---------------|---------------|
| Tractor                      | Total cost (VND/Cong/crop) |             |
| Pumping machine              | Total cost (VND/Cong/crop) |             |
| Combine harvester             | Total cost (VND/Cong/crop) |             |
| Drying machine               | Total cost (VND/Cong/crop) |             |
| Others                       | Total cost (VND/Cong/crop) |             |
d. Credit access

Did you access credit from banks or your relatives/friends?

1. = yes, 2. = No  If yes, when ..............  How much:.............. million VND

How about interest rate for: formal loan:..............%/year informal loan: ..............%/month

C. Perception of farmers about the EFR

| No | Indicators | Level | Detail explanation |
|----|------------|-------|--------------------|
| 1  | The EFR is easy to cultivate and does not have many constraints | 1 2 3 4 5 |                                   |
| 2  | The EFR rice has lower production cost | 1 2 3 4 5 |                                   |
| 3  | The EFR rice uses lower chemical fertilizers | 1 2 3 4 5 |                                   |
| 4  | The EFR rice uses lower pesticides | 1 2 3 4 5 |                                   |
| 5  | The EFR contributes to reduce water pollution | 1 2 3 4 5 |                                   |
| 6  | The EFR contributes to protect farmers' health | 1 2 3 4 5 |                                   |
| 7  | The EFR contributes to protect consumers' health | 1 2 3 4 5 |                                   |
| 8  | The EFR contributes to improve biodiversity (fish, birds,....) | 1 2 3 4 5 |                                   |
| 9  | The EFR has higher output quantity | 1 2 3 4 5 |                                   |
| 10 | The EFR rice has better quality | 1 2 3 4 5 |                                   |
| 11 | The EFR rice has higher selling price | 1 2 3 4 5 |                                   |
| 12 | The EFR rice is easily to be sold out | 1 2 3 4 5 |                                   |
| 13 | The demand on the EFR rice will increase sharply in the future | 1 2 3 4 5 |                                   |
| 14 | The EFR can receive more supports from the government | 1 2 3 4 5 |                                   |
| 15 | The EFR is the place for research and projects | 1 2 3 4 5 |                                   |
| 16 | The EFR rice is the compulsory option in the future | 1 2 3 4 5 |                                   |

D. Perception of farmers about water use and water resource

1. Overall evaluation of irrigation water?

About the quantity  1. Increase  2. Unchange  3. Reduce
About the quality  1. Improve  2. Unchange  3. Worsen

2. Perception of farmers about water use in agriculture

2.1. Do you carefully consider the water quantity when pumping?  1. Yes  2. No
2.2. Do you know about water use conflicts between upstream and downstream?  1. Yes  2. No
2.3. Are you willing to use lower amount of water to reduce water use conflicts?  1. Yes  2. No
2.4. How do you recognize that your paddy needs to be pumped?
1. Observation  
2. The period ........days  
3. Others ..................

2.5. How do you know that the paddy fields are pumped sufficiently when pumping?

3. Perception about water use conflict

| No. | Indicators                                                                 | Level |
|-----|-----------------------------------------------------------------------------|-------|
|     |                                                                             | 1 2 3 4 5 |
| 1   | Water shortage in downstream is caused by dam construction in upstream      | 1 2 3 4 5 |
| 2   | Water shortage in downstream is caused by overuse of water in upstream      | 1 2 3 4 5 |
| 3   | Water use conflict will be more serious                                    | 1 2 3 4 5 |
| 4   | Climate change (droughts, low rain) is one of the causes of the conflict    | 1 2 3 4 5 |
| 5   | Intensification in agriculture is causing the water use conflict           | 1 2 3 4 5 |
| 6   | Overuse of agro-chemicals increases water use conflicts                     | 1 2 3 4 5 |
| 7   | Flood-protected dykes has changed water flow and caused the conflicts       | 1 2 3 4 5 |
| 8   | Irrigation system is not good and not enough to deliver water              | 1 2 3 4 5 |
| 9   | To cope and adopt, it needs to build reservoirs to store water for dry season | 1 2 3 4 5 |
| 10  | It needs to develop the pumping plans for each area                        | 1 2 3 4 5 |
| 11  | Research on new varieties that are able to tolerate in saline water        | 1 2 3 4 5 |
| 12  | Changing the seasonal calendar to use rain water                           | 1 2 3 4 5 |
| 13  | Changing agricultural systems to adopt                                     | 1 2 3 4 5 |

Note: from 1= strongly disagree to 5= strongly agree.

E. Perception about biodiversity conservation

1. How do you think about the biodiversity now compared to before?

1. No change  
2. Reduced  
3. Increased

2. If reduced, please tell us the reasons?

1. Agrochemicals  
2. Polluted water  
3. Electric catching  
4. Other..................

3. How did you practice to mitigate the damages caused by these reasons

4. How do you think about the importance of biodiversity in the paddy fields?
### F. Perception of risks

| Risks                                                                 | Very low | Low  | Medium | High  | Very high |
|----------------------------------------------------------------------|----------|------|--------|--------|-----------|
| 1. Reduced rain volume                                              | 1        | 2    | 3      | 4      | 5         |
| 2. Changed rain pattern (season)                                     | 1        | 2    | 3      | 4      | 5         |
| 3. Dam construction in upstream                                      | 1        | 2    | 3      | 4      | 5         |
| 4. Disasters (floods, storms,...)                                    | 1        | 2    | 3      | 4      | 5         |
| 5. Polluted water                                                    | 1        | 2    | 3      | 4      | 5         |
| 6. Unstable market                                                   | 1        | 2    | 3      | 4      | 5         |
| 7. Policy and institutions                                           | 1        | 2    | 3      | 4      | 5         |
| 8. Logistics (post-harvest losses,...)                               | 1        | 2    | 3      | 4      | 5         |
| 9. Management skills                                                | 1        | 2    | 3      | 4      | 5         |
| 10. High input prices                                                | 1        | 2    | 3      | 4      | 5         |
| 11. Diseases                                                        | 1        | 2    | 3      | 4      | 5         |
| 12. Producers’ health                                                | 1        | 2    | 3      | 4      | 5         |
| 13. Production technologies                                          | 1        | 2    | 3      | 4      | 5         |
| 14. Production capital                                               | 1        | 2    | 3      | 4      | 5         |
| 15. Fulfillment of the requirements of export                        | 1        | 2    | 3      | 4      | 5         |
| 16. The linkage between production and market                        | 1        | 2    | 3      | 4      | 5         |

Note: 1 = very low risk to 5 = very high risk.