Yield and Income Effects of Ecologically-based Rodent Management in Mekong River Delta, Vietnam

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ABSTRACT

Regression-based strategies along with propensity score matching (PSM) were used to assess the farm-level economic impact of community action (CA) strategies associated with ecologically-based rodent management (EBRM). The paddy yield and real net income of rice farmer-beneficiaries of the EBRM approach in An Giang Province, Mekong River Delta, Vietnam, were analyzed using panel data from 151 rice farmers. PSM along with the difference-in-difference framework using the fixed-effect approach were found to be the most appropriate methods to evaluate the farm-level economic impact of the adoption of the CA strategies. The EBRM through CA did not replace what the farmers were doing, but rather built on their practices and incorporated a scientific basis by encouraging farmers to work together at key times of a cropping season. In terms of labor use for rodent control, CA only entailed an additional 0.3 man-days/ha for every CA. Normally, for a 40-hectare (ha) rice field, around 30 persons participated in each CA including men, women, and children. With two to three times done in a season, a total of 1 man-day/ha is as an additional labor for the whole season. The adoption of the EBRM through CA had a significant and positive impact on paddy yield and real net income of rice farmers. The mean paddy yield increased by 0.43-0.45 ton per ha and real net income of the beneficiaries increased by VND1.16–1.19 million/ha (approximately USD65-67/ha). These findings imply that the adoption of the CA strategies in rodent pest management as part of EBRM may not only have partly contributed to food security and increased household income of the rice farmer-beneficiaries but also to environmental improvement in these communities.

Keywords: Impact evaluation, EBRM, rice farmers, difference-in-difference, PSM
JEL Classification: Q1

INTRODUCTION

Rodents are significant pests of lowland irrigated rice crops throughout Southeast Asia, both in pre-and post-harvest operations (Singleton et al. 2010). In Vietnam where rice is an important commodity, crop damage is approximately 10 percent each year (Singleton 2003). Rodent infestation is considered one of three most important problems faced by the agricultural sector in Vietnam (Huynh 1987). In some years and locations, rodent damage can be up to 100 percent of total production (Tuan et al. 2003). As in other areas of Asia, the rodent problem in Vietnam has increased since the 1970s in rice-based farming systems (Singleton 2003), possibly due to increases in area and intensity of rice production, and asynchronous planting of crops (Singleton and Petch 1994; and Singleton 2003).

Farmers often use inappropriate methods to reduce the impacts of crop damage caused by rodents, and rely heavily on chemicals, causing risks to non-target species and to the environment, and generally providing poor return on investment (Singleton 2003). Rodenticides are likely to remain the central management tool for controlling rodent damage in tropical agriculture once rodent populations are high (Buckle 1999; Wood and Fee 2003). Early community action (CA) involves non-chemical approaches such as locally made kill traps, a plastic barrier around their fields to exclude rodents, digging up burrows using dogs to locate active burrows, hunting rats at night with a spotlight, and flooding burrows with water (Tuan et al. 2003). The rodent management undertaken by farmers however, is generally conducted individually, in an uncoordinated manner, or is only carried out when rodent damage has occurred already (Brown et al. 2006).

In the past, farmers have tended to respond only when outbreaks happen rather than proactively prevent chronic losses; they also generally rely on chemical and physical methods applied after the rodents have already damaged the crop (Palis et al 2007). During the early 1990s, farmers took a reactive response because they lacked knowledge on the ecology of rodent pest species, the relationship between cropping systems and rodent population dynamics, and awareness on rodent management at the community level (community-based approach) (Brown et al. 2011). Reactive methods are generally ineffective in controlling rodents in the field. Thus, beginning 1996, a concerted effort to develop ecologically-based rodent management (EBRM) in Vietnam was started. EBRM was introduced to farmers and led to increased capacity of farmers to manage rodent populations and to reduce yield loss (Brown et al. 2006).

EBRM relies on an understanding of the ecology of rats, which then governs better integrated CA (synchronized cropping, field and village hygiene, rat hunts at key times) and the community trap barrier systems (CTBS, a plastic fence set with rat traps enclosing a small area of early-planted rice). These approaches need community cooperation. However, CTBS is only occasionally adopted since rice farmers are constrained by: (1) the high costs of CTBS materials, (2) high labor requirements, and (3) it is difficult to forecast the rodent population for the succeeding rice crop before planting (Palis et al. 2004; and Brown et al. 2010). In contrast, integrated CA are easy for farmers to practice and adopt for managing rodent populations effectively in the rice fields.

In effect, the EBRM through CA did not replace what the farmers were doing, but rather built on their practices and incorporated a scientific basis by encouraging farmers to work together at key times of a cropping season, that is, early on every season (before rodent breeding), particularly at the tillering stage or two weeks after planting, using various physical and cultural methods. The timing of actions was based on the population dynamics, habitat use, and breeding ecology of the rodents (Brown et al. 2006). Thus, the common practices of digging and hunting, either as a small group or individually, at arbitrary times was consequently transformed to the community working together at key times before rodent damage occurred in their crops.

In terms of labor use for rodent control, CA only entailed an additional 0.3 man-days/hectare (ha) for every CA. About one person per hectare participates in CA. For example, for a 40 hectare rice field, around 30 persons are involved in CA to control rodents, including men, women, and children. With two to three times done in a season, a total of 1 man-day/ha is as an additional labor for the whole season. This rodent CA also served as an avenue for strengthening community camaraderie since rodents caught can be brought home as food for lunch, and for drinking activity among men.

The implementation of EBRM in the Red River delta from 2006 to 2010 produced positive results; rodenticide use was reduced by 75 percent, rice yields were increased, the benefit–cost ratio was up to 17:1, and there was a marked change in attitude and practices of farmers towards rodent management (Brown et al. 2006; Palis et al. 2011). By comparison, in the Mekong River Delta there is little information on the economic benefits or otherwise of adopting the EBRM technology. Hence, there is a need to conduct an empirical study on the economic impact of CA under the EBRM platform on rice production in the Mekong River Delta in Vietnam.

Previous studies that investigated EBRM in Southeast Asia failed to explicitly examine the farm-level economic impact of the EBRM technology, especially the CA strategies in the context of rice production (e.g., Brown et al. 2006; Singleton et al. 2005). Furthermore, most of the EBRM yield and net income studies cited above were based on controlled field experiments that used simple "with EBRM or without EBRM" comparisons without controlling for selection biases on observable and unobservable characteristics. The difference-in-difference (DID) framework along with propensity score matching (PSM) methods could provide empirical approaches that control for selection biases on both observable-time varying factors and time-invariant characteristics in the impact analysis of the EBRM technology. EBRM has now been adopted widely around the globe (John 2016); yet this is the first time such an economic analysis has been conducted on EBRM.

The objective of this paper is to evaluate the mean impact of CA strategies (EBRM technology) on the paddy yield of farmer-beneficiaries and real net farm income from rice production in An Giang province in the Mekong River Delta. A different method was used in previous studies on EBRM: the balanced panel farm survey (baseline survey data prior to, and post-survey data after EBRM implementation). Further supporting the balanced panel data, the study's analysis also relied on a combined panel approach using a DID framework along with PSM techniques to deal with selection issues present in impact analysis.

METHODOLOGY

Survey Design and Data Description

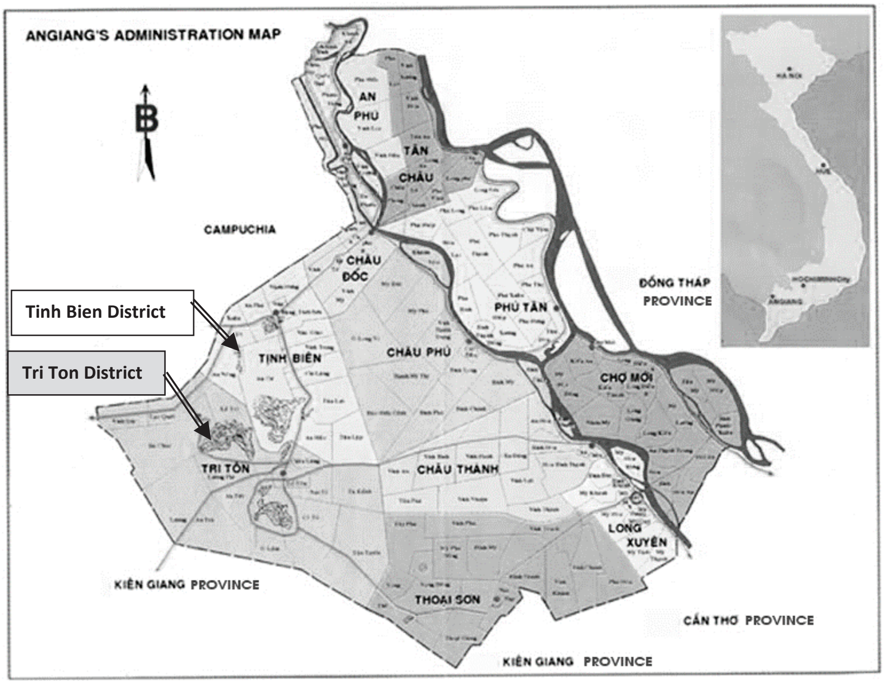
The panel data used in this study of EBRM were obtained from the knowledge, attitudes and practices, and socio-economic (KAP & SE) survey (for more details, see Brown et al. 2010). The EBRM Project was implemented in two key lowland irrigated rice production areas (Mekong River Delta in Southern Vietnam and Red River Delta in Northern Vietnam) from 2006 to 2010. These regions are large low-lying areas with good soil and water resources and provide a majority of the rice grown in Vietnam for domestic consumption and export. The current analyses focuses on data from Mekong River Delta in An Giang Province (10°22’N, 105°26’E) where three rice crops are grown each year.

In 2006, the baseline KAP & SE survey was conducted before the implementation of the EBRM Project, capturing data from the 2005 summer-autumn crop. In 2009, a post-baseline KAP & SE survey was implemented with the same respondents capturing data from the 2008 summer-autumn crop.

Two different treatments in a quasi-experimental design were used: (1) CA, which consisted of rice farmers who participated in CA based on recommendations from EBRM on where and when to conduct rodent control, and also included planting of their rice crops within two weeks of each other (synchronous planting); and (2) Control group, which included rice farmers who did not participate in CA but used their own experiences and practices on rodent management in rice production (Figure 1).

The selected sample districts of An Giang Province in Mekong River Delta were Tinh Bien (10°61’N, 104°96’E) and Tri Ton (10°42’N, 105°00’E). These two districts historically had high and chronic rodent problems. Within each district, two communes located far from each other were selected as the treatment and control sites[a]. Vinh Gia Commune in Tri Ton District

Figure 1. The EBRM project sites and study area in the Mekong River Delta, Vietnam



a As recorded by the Plant Protection Sub-division in An Giang Province, the rodent infestation on rice production in the selected communes and districts was similar prior to the implementation of the EBRM Project (2006).

and Nhon Hung Commune in Tinh Bien District were selected as the control sites; Lac Quoi Commune in Tri Ton District and An Nong Commune in Tinh Bien District were selected as the treatment sites. The selection of the treatment and control sites within a district was designed to reduce selection bias due to differences in socio-economic characteristics between the CA participants and non-participants. The distance from the treatment communes to the control communes was at least 7 km, which could restrict the spillover effects of the CA strategies (EBRM technology) from the treatment sites to the control sites.

The rice farmer-respondents were chosen using simple random sampling. The number of rice farmer-respondents in each study site depended on the total number of rice farm households in that area (1,109 households) and the desired marginal error (6%). However, due to data constraints (i.e., change of residence and migration, and missing quantitative information), only data from 151 farmer-respondents were analyzed. The respondents were distributed by treatment with 63 CA farmers (23% of the total rice farming households involved in the CA treatment) and 88 control farmers (13% of the non-treated rice farming households) in each time period (Table 1).

Table 1. Number of sample rice farmer-respondents by study area, An Giang Province, Mekong River Delta, Vietnam, 2006 and 2009

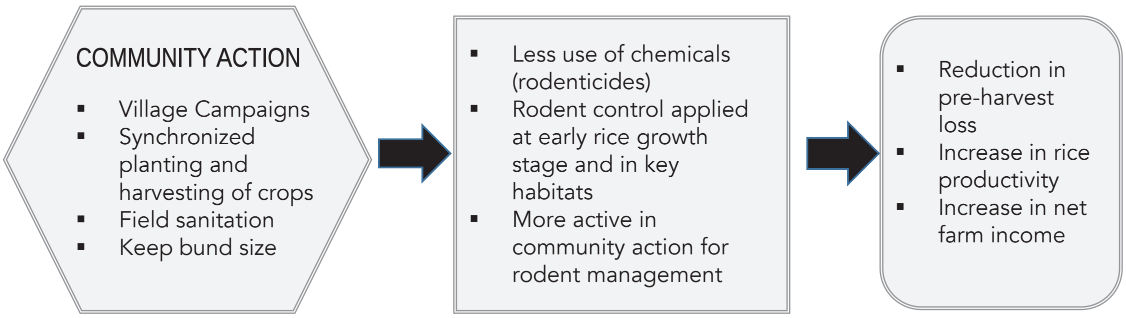
Study Area	2006 (Before)		2009 (After)		Total
	CA Farmers	Control Farmers	CA Farmers	Control Farmers	
Tri Ton District	35	50	35	50	170
• Vinh Gia	-	50	-	50	100
• Lac Quoi	35	-	35	-	70
Tinh Bien District	28	38	28	38	132
• Nhon Hung	-	38	-	38	76
• An Nong	28	-	28	-	56
TOTAL	63	88	63	88	302

Focus group discussion (FGD) and key informant interviews (KII) were conducted at the end of August 2012 to complement the surveys and to validate the research findings for the economic impact assessment of CA strategies. Participants included rice farmers in both the treatment and control groups, key personnel from the Sub-Plant Protection Division (Sub-PPD) in An Giang, the Plant Protection Stations (PPS) in the two districts, and the People's Committee, and extension workers at the village level.

Conceptual Framework

The principles of EBRM are based on a solid understanding of the biology of the main rodent pest species, *R. argentiventer*. CA is outlined in Figure 2 and is further described in Singleton (2003) and Brown et al. (2010). CA is a combination of a number of activities that farming communities were encouraged to work together to implement: (1) village campaigns in the fields and villages early in the rice crop growth stages (before maximum tillering stage) to kill rats before they start breeding and to work together to control rats together over a large area and minimize reinvasion, (2) synchronized planting and harvesting of crops to keep the breeding season of rats short, (3) field sanitation to keep fields clean of weeds and piles of straw that provide good habitat and food resources for rodents, and (4) keep bund size small between paddy fields to stop rats from building burrows in the fields. These new rodent management practices will teach the participants' (including farmers and other organizations) to reduce the use of chemicals, make them more active in CA in rodent management, and urge them to apply more rodent control during the early stage of rice growth. These changes lead to reduction in pre-harvest loss in rice production, increase in rice productivity, and increase in net income. Hence, if EBRM strategies are widely disseminated and applied by rice farmers, it was hypothesized that there will be a positive effect in rice productivity and real net income (see Figure 2).

Figure 2. Conceptual framework for yield and income effects of the EBRM in Mekong River Delta, Vietnam



Estimation Methods

To obtain an accurate assessment of the CA effect, empirical methods which control for selection bias (due to observable and unobservable characteristics) were used. More formally, let Yi be an outcome variable for rice farmer i in a sample size n. The outcomes of interest in this study are paddy yield and real net farm income from rice of the irrigated rice farmers. Some rice producers participated in the CA treatment and some did not. Thus, let CA_i be a dummy variable representing CA participation. $CA_i = 1$ if a rice producer participated in the CA treatment, and zero otherwise. Given the missing counterfactual, this study was restricted to estimating only the outcomes difference between the CA participants and non-participants. Thus, in applied work, economists use data on the participant and non-participant groups to estimate a regression of outcomes (Y_i) on participation dummy (CA_i) and a vector of control covariates (X_i) as shown in the regression equation (Equation 1):

$$Y_i = \alpha + \mu X_i + \beta CA_i + \varepsilon_i \quad \text{for } {}_i = 1,\ldots, n$$

where β is simply the estimate of the CA impact.

The estimator β is unbiased only if the observed mean counterfactual (i.e., the observed outcome from the non-participant group) is truly equal to the unobserved mean counterfactual (i.e., the outcome for the participant group had they not participated). This condition means that the observed non-participant group is, on average, a good surrogate for the unobserved counterfactual outcome. This condition can only be met if the assignment of participant and non-participant groups in the sample is truly exogenous. Specifically, there is no selection bias where the selection of the participant and non-participant groups is invariant to the outcome of interest.

The regression in equation (Equation 1) implicitly assumes a single cross-sectional data set where the impact measure is essentially a "single-difference" calculation. Availability of a two-period panel data set as in this study allows the calculation of a "double difference" or "difference-in-difference" (DID) estimator of the CA impact (Wooldridge 2002; Ravallion 2005). In essence, the DID approach compares the difference between the outcomes of the participant and non-participant groups during a pre-intervention baseline period (i.e., "before" implementation) versus the difference in the outcomes "after" program implementation. The regression equation is:

$$Y_{it} = \mu X_{it} + \beta CA_{it} + \varepsilon_{it} \quad \text{for } {}_i = 1,\ldots, n; {}_t = 1, 2$$

where ε_{it} is defined as having both a time-invariant component (α_i) and time-varying component (v_{it}) such that $\varepsilon_{it} = \alpha_i + v_{it}$.

In this specification, the vector of control covariates Xs also includes a "before and after implementation" dummy variable.

If unobservable characteristics that cause selection bias are time-invariant, then the first-differencing or a fixed-effect transformation of the variables in equation (Eq.2) can resolve this problem:

$$\Delta Y_i = \mu \Delta X_i + \beta CA_i + \Delta v_i \quad \text{for } {}_i = 1,\ldots, n$$

where the deltas (Δ) represent either: (a) differencing out the first time period value from the second period value (if we use a first-differencing transformation) or (b) a time-demeaning or mean-differencing transformation where each value is subtracted by the mean value (over time) for each cross-sectional unit (if we use a fixed-effects transformation) (Wooldridge 2002). In this study, the fixed-effects approach was used to estimate the impact of CA adoption on the rice farmer adopters.

In addition, there still may be a selection problem due to the difference in observable time-varying characteristics prior to the implementation of EBRM project between the treated and the control groups. This bias is likely to arise in this study's context because the selection criteria for the initial dissemination of this technology in the region (i.e., areas with a history of chronic rodent damage, good extension network and linkages) can also be expected to affect outcome variables directly (yield and net income) even in the absence of the program. To address the observable time-varying characteristics that cause initial heterogeneity in the sample, the PSM techniques (Rosanbaum and Rubin 1983) were applied. The basic idea behind the PSM method is to find control observations (i.e., control farmers) having observable characteristics as similar as possible to the treatment group, to serve as valid surrogates for the missing counterfactuals.

In this study, the common practice in the PSM by using a parametric binary response model (a probit model) to estimate the propensity score for each observation in the recipient and control groups (Sianesi 2001; Baker and Ichino 2002; Smith and Todd 2005) was followed. A rich set of observable covariates was used to estimate the propensity scores, with special focus on the observable variables used as the criteria for the initial dissemination of the EBRM technology in the area and the factors used in previous literature that studied the adoption of EBRM and other technologies. The "balancing property" of the observables used in the probit specification was then tested to ensure that observations with similar propensity scores have the same distribution of observable characteristics independently of whether or not CA was adopted. Using the calculated propensity scores from the probit model that satisfy the balancing property, the sample was then matched whereby the EBRM recipients and non-recipients shared sufficiently similar values of their observed characteristics. Following standard practice in PSM literature, the 1-to-1 nearest neighbor matching approach (without replacement) and the Epanechnikov kernel matching approach to identify the non-program recipients who matched the program recipients (Sianesi 2001; Baker and Ichino 2002) were used. Using both approaches enabled the study to determine whether the results are robust to changes in the matching criteria (Rodriguez et al. 2007). A "common support" constraint was also imposed, where program recipients to be matched were dropped from the sample when their estimated propensity score was either above the maximum or below the minimum propensity score for the comparison (non-participant) group. A standard t-test was then used on pre-intervention observed characteristics to verify that these were not statistically different between the eventual program participants and non-participants. This allows the conclusion that there was a matched sample that provides a reasonable surrogate for the unobserved counterfactual from which an accurate program impact can be estimated (Rodriguez et al. 2007).

The PSM method was combined with the DID model to improve matching control and treatment units on preprogram characteristics (Khandker et al. 2010). The combination of both methods in estimating the mean impact of the CA strategies is more accurate because it controls for selection bias caused by time-invariant factors (regardless of observable or unobservable) and observable time-varying factors.

Model Specification: Probit Model and Impact Model

The probit equation with independent variables that affect whether or not a farmer participates in the CA treatment was specified. The following variables were included in the probit specification: (1) knowledge index on rodent pest management (KI)[b], (2) total land devoted to rice cultivation (AREA), (3) educational attainment of a farmer in years (EDU), (4) household size (HHSIZE), (5) number of years of farming experiences (EXP), (6) membership in a farmer association (ASSN), (7) a location dummy variable (LOCA)[c], (8) age of head of the household (AGE), and (9) distance from the farmer's house to the farm (DISTANCE). The "balancing property" of the probit specification was tested to ensure that the sample of program participants and the sample of non-participants have similar mean propensity scores and observables at various levels of the propensity scores.

In the impact analysis of CA adoption strategies in rodent pest management on paddy yield, the following control variables (Xit) were included: (1) total land in rice production (AREA), (2) nitrogen (N) fertilizer, (3) phosphorus (P) fertilizer, (4) potassium (K) fertilizer, (5) seed use (SEED), (6) total hired and family labor use (LABOR), (7) pesticide use which includes herbicides, insecticides, rodenticides and fungicides (PEST), (8) variety dummy (VART), (9) farmer educational attainment (EDU), (10) village location dummy (LOCA), (11) knowledge index about rodent management (KI), (12) cropping intensity dummy (CROP), (13) farming experience (EXP), and (14) membership in a farmer association (ASSN) (Table 2). A "before and after" project implementation dummy variable (CA) was included in the model as a control variable.

To evaluate the impact of the adoption of the CA strategies on real net income from rice production, the following covariates (Xit) were included: (1) total land under rice production (AREA), (2) total hired and family labor use (LABOR), (3) material expenses in rice production (MATEXP), (4) a rice variety dummy (VART), (5) farmer educational attainment (EDU), (6) knowledge index about rodent pest management (KI), (7) farming experiences (EXP), (8) village location dummy (LOCA), (9) cropping intensity dummy (CROP), and (10) membership in a farmer association (ASSN). A "before and after" project implementation dummy variable (CA) was included in this model as a control variable.

In addition, all variables measured in values for assessing the impact on the real net income of all farmers in 2009 were expressed in real terms using the prevailing Consumer Price Index (CPI). Definitions of the main variables used in this study are presented in Table 2, and the summary statistics for these variables are shown in Table 3 (before and after the implementation of the EBRM Project).

b Knowledge index was calculated by giving an equal weight to all 12 questions included in the questionnaires to check the farmers' knowledge on rodent pest management and practices before and after the implementation of the project. Each correct answer is equivalent to one point. Then, it is the proportion of the true answers following the suggested strategies in the EBRM technology on rodent pest management over the given 12 questions.

c LOCA is a dummy variable: 1 if respondents are residing in Tri Ton District and 0 otherwise

Table 2. Definition of variables

Variable Name	Definition
NI	Real net income from rice production ('000VND/ha)[d]
YIELD	Rice yield (tons/ha)
AREA	Total land under rice production (ha)
N	Nitrogen fertilizer use (kg/ha)
P	Phosphorus fertilizer use (kg/ha)
K	Potassium fertilizer use (kg/ha)
SEED	Seed use (kg/ha)
LABOR	Total hired and family labor use (man-days/ha)
PEST	Pesticide use (kg/ha) which includes herbicides, insecticides, rodenticides, and fungicides
MATEXP	The amount of real material expenses in rice production (e.g., fertilizer, seed, pesticide, irrigation) ('000VND/ha)
VART	Variety dummy: 1 if it is improved variety, and 0 otherwise
EDU	Farmer's educational attainment in number of years
ASSN	Dummy variable: 1 if farmer is a member of a farmers' association and 0 otherwise
HHSIZE	Number of household members
LOCA	Dummy variable: 1 if respondents are residing in Tri Ton District and 0 otherwise
EXP	Farming experience in rice production in years
CROP	Cropping intensity dummy: 1 if the farmer plants three rice crops per year, and 0 if otherwise
KI	Farmer's knowledge index on rodent pest management(proportion of the true answers about the knowledge on rodent pest management)
DISTANCE	Distance from the farm to house (km)
AGE	Age of household head (years)
CA	Dummy variable: 1 if farmer participated in the Community action treatment and 0 if farmer under control group
T	Time dummy, T =1 if 2009, and T=0 if 2006

d Net income from rice production was computed by using the gross revenues less variable production costs (e.g., fertilizer, chemicals, labor, tractor rental, fuel and electricity costs for irrigation, land preparation, harvesting, and other activities). Variable production costs did not include interest costs.

Table 3. Summary statistics of all variables before and after the implementation of the EBRM Project

Variable	CA Farmers (N=63)		Non-CA Farmers (N=88)	
	Before	**After**	**Before**	**After**
YIELD (ton/ha)	5.02	5.84	4.84	5.18
NI (‘000VND/ha)	1,395.02	3,890.84	1,082.79	2,878.83
AREA (ha)	3.00	2.61	2.67	2.45
N (kg/ha)	131.13	122.22	114.25	103.71
P (kg/ha)	29.03	34.55	28.14	26.67
K (kg/ha)	42.83	49.43	43.17	35.61
SEED (kg/ha)	240.96	201.02	231.90	200.42
LABOR (man-days/ha)	49.29	39.02	49.38	39.01
PEST (kg/ha)	5.73	5.00	4.63	4.53
MATEXP (‘000VND/ha)	6,966.50	10,463.15	6,734.90	9,417.00
VART	0.13	0.02	0.34	0.05
CROP	0.44	0.44	0.00	0.00
EXP (years)	18.94	21.94	19.51	22.51
EDUC (years)	6.10	6.10	5.14	5.14
KI	0.69	0.85	0.69	0.79
DISTANCE	0.31	0.31	0.54	0.54
ASSN	0.24	0.24	0.09	0.09
AGE (years)	43.87	46.87	46.63	49.63
LOCA	0.56	0.56	0.57	0.57

Note: All income and expenses variables (in ‘000VND) used in this study are real (rather than nominal) values, with 2006 as the base year.

RESULTS AND DISCUSSION

Propensity Score Matching Results

Membership in farmer associations (e.g., people's committee, Integrated Pest Management club, etc.) and the distance from the farmer houses to farms are important in the CA participation decision. Membership in a farmer organization had a statistically significant positive effect on the decision to be involved in the CA treatment at 5 percent level of significance. However, the distance from the farms to the farmer houses had a negative effect on the decision to be involved in the CA treatment. The significance of these two variables as well as all the probit models suggests that there may be selection bias in the sample of rice farmer-respondents. Hence, the PSM method was applied to reduce selection bias caused by differences in the observed characteristics between the CA beneficiary-farmers and the non-CA farmers.

Propensity scores were computed to match non-CA adopters for the missing counterfactuals. The region of common support for the probit specification was between the interval [0.13, 0.80]. The balancing property was satisfied for the specification (Table 4).

The 1-to-1 nearest neighbor matching procedure demonstrated that all the 63 CA observations were within the acceptable levels. We were able to match with 63 non-CA farmers, for a total of 126 farmers (63 CA and 63 matched non-CA farmers) in the 1-to-1 matched sample, with 252 total observations (126 farmers multiplied by two years of data). For the kernel matching procedure, four non-CA participants who were not within the region of common support were dropped from the matched sample. Thus, the kernel matched sample consisted of 147 farmers (63 CA farmers and 84 matched non-CA farmers) and a total of 294 observations (147 farmers multiplied by two years of data).

Once the 1-to-1 matched sample and the kernel matched sample were delineated, the next step was to confirm if the values of the observable characteristics of the treated and control groups were equal using t-tests with the baseline data. The corresponding p-values of the t-test for both the 1-to-1 and kernel matched samples suggest that the observed characteristics were not significantly different (at 5% level of significance) between the rice farmers-beneficiaries group and the control group (Table 5). Hence, both PSM procedures generated a matched sample that provides a reasonable surrogate for the unobserved counterfactual, allowing for a more accurate estimate of the CA impact.

Estimated Economic Impact of the Adoption of the CA Strategies on the Rice Farmer-Beneficiaries

Without matching, the mean impact of CA strategies in rodent management on paddy yield was about 0.70 ton/ha using ordinary least squares (OLS) regression with cross-section data, while it was about 0.445 ton/ha in the fixed-effect estimation under DID model. Estimates were statistically significant (Table 6). The estimated impact of the CA strategies on paddy yield was much higher in the OLS estimation using cross-section data than that of the DID models using panel data. This may be attributed to the selection problem due to time-invariant factors. Hence, the DID approaches using panel data are more accurate in estimating the mean impact of the adoption of the CA strategies on paddy yield.

In contrast, the mean impact of the CA strategies on paddy yield was lower using the matched samples along with the DID approaches (Tables 6). For example, the mean impact of the CA strategies on paddy yield was approximately 0.43 ton/ha in the fixed-effect estimation under the 1-to-1matched sample, while the impact was 0.445 ton/ha in the fixed-

Table 4. Probit results for participation in the CA treatment, 151 sample rice farmer-respondents, An Giang Province, Mekong River Delta, Vietnam

Variable	Coefficient	Standard Error	*p*-value
EXP	0.005[ns]	0.016	0.730
AREA	0.017 [ns]	0.039	0.664
EDU	0.020 [ns]	0.042	0.627
HHSIZE	-0.096[ns]	0.077	0.213
KI	-0.735[ns]	1.242	0.554
DISTANCE	-0.837***	0.301	0.005
ASSN	0.587**	0.300	0.050
AGE	-0.011[ns]	0.236	0.440
LOCA	-0.031[ns]	0.014	0.895
Constant	1.203[ns]	1.132	0.288
Log-likelihood= -92.049			
LR χ^2 Statistics = -92.049			
Pseudo - R^2= *0.103***		*p*-value=0.012	
Akaike Information Criterion (AIC)= 204.099			
Bayesian Information Criterion (BIC) = 234.271			

Note: *, **, *** indicate significant at 10%, 5%, and 1%, respectively.
ns denotes insignificant at 10% probability level.

effect estimation under the kernel matched sample. Both impact estimates on rice yield of the CA strategies using the matched samples were highly significant at 1 percent probability level. Hence, the adoption of the CA strategies in rodent management in rice fields had a significant impact on increasing rice yield by about 7–8 percent, which could be attributed to the significant reduction in yield losses due to rodent damage.

The highly significant and positive impact of CA strategy adoption in rodent pest management on paddy yield seems to be robust to the matching criteria and the estimation strategies (Table 6). Since the DID parameter estimates of the mean impact of the adoption of the CA strategies on paddy yield using both matched samples (i.e., the 1-to-1 matched and kernel-matched samples) were quite similar.

In the absence of matching, the mean impact of the adoption of the CA strategies in rodent pest management on real net farm income per hectare was about VND 1.88 million based on the cross-section post-survey data estimated with OLS (Table 7). Net return per hectare was about VND 1.23 million (USD 69[e]) with the fixed-effect estimation under DID model.

e At the time of the study (2009), the exchange rate was approximately USD 1 = VND 17,810.

Table 5. Comparison of the means of pre-intervention observable farm characteristics: CA recipients vs. non-CA farmers in the study area

Observable Characteristics	Unmatched Sample			Matched Sample[a] (-1-to-1 Nearest Neighbor Matching)			Matched Sample[b] (Kernel Matching)		
	CA Recipients (N=63)	Non-CA Farmers (N=88)	*p*-value	CA Recipients (N=63)	Non-CA Farmers (N=88)	*p*-value	CA Recipients (N=63)	Non-CA[c] Farmers (N=88)	*p*-value
EXP	18.94	19.51	0.722	18.94	19.87	0.613	18.94	19.09	0.927
AREA	3.00	2.67	0.499	3.00	2.95	0.922	3.00	3.06	0.923
EDU	6.10	5.14	0.049	6.10	5.51	0.280	6.10	6.12	0.967
HHSIZE	4.05	4.50	0.088	4.05	4.38	0.248	4.05	4.04	0.977
KI	0.69	0.69	0.986	0.69	0.68	0.558	0.69	0.70	0.465
DISTANCE	0.31	0.54	0.001	0.31	0.36	0.373	0.31	0.33	0.731
ASSN	0.24	0.09	0.013	0.24	0.13	0.108	0.24	0.27	0.689
AGE	43.87	46.63	0.138	43.87	45.51	0.424	43.87	44.77	0.649
LOCA	0.56	0.57	0.878	0.56	0.56	1.000	0.56	0.51	0.610

Notes:

a In the matched sample from the 1-to-1 Nearest Neighbor Matching without replacement, all 63 observations under the treated group lie within the common support. Hence, there are 63 pairs of matched non-CA farmers and CA recipients used to estimate ATT.

b In the Kernel matched sample, all the 63 observations under the treated group lie within the common support, and only 84 observations of the comparison group were matched with the treated individuals.

c The means of the matched non-CA sample is a weighted-average based on the weights produced in the kernel matching procedure. That is, the weights given to each non-CA observation depends on how “close” its propensity score is to a particular CA beneficiary.

Table 6. Estimated mean impact of community action (CA) on paddy yield obtained by the farmer-beneficiaries using the unmatched and matched samples, Mekong River Delta, Vietnam

Independent Variable	Unmatched Sample		1-to-1 NN Matched Sample		Kernel Matched Sample	
	Cross-section Data	Panel Data (DID)	Cross-section Data	Panel Data (DID)	Cross-section Data	Panel Data (DID)
	OLS[a] Estimation	Fixed-Effect[b] Estimation	OLS[a] Estimation	Fixed-Effect[b] Estimation	OLS[a] Estimation	Fixed-Effect[b] Estimation
CA	0.69514***	0.44494***	0.70163***	0.42927***	0.69423***	0.44487***
AREA	0.01268**	-0.00837	0.01481***	-0.00834	0.01247**	-0.00819
SEED	0.00133*	-0.00017	0.00109	-0.00059	0.00130*	-0.00015
LABOR	0.00000	0.00358	-0.00056	0.00455	-0.00018	0.00396
N	0.00081	0.00010	0.00108*	0.00002	0.00080	0.00011
P	-0.00166	0.00063	-0.00237**	0.00044	-0.00185	0.00040
K	-0.00023	0.00052	-0.00072	0.00037	-0.00024	0.00050
PEST	-0.00759	-0.00061	-0.00511	-0.00112	-0.00749	-0.00051
LOCA	-0.14195***	-	-0.16130***	-	-0.13970***	-
EDU	0.01345***	-	0.01413***	-	0.01291***	-
EXP	0.00291***	-	0.00383***	-	0.00310***	-
KI	0.41007***	0.41618***	0.44528***	0.43346***	0.42270**	0.40643***
CROP	-0.15031***	-	-0.16532***	-	-0.14701***	-
ASSN	0.01210	-	0.00754	-	0.00345	-
VART	-0.03991	0.00980	-0.04910	-0.00928	-0.03869	0.01166
T	-	0.33343***	-	0.33816***	-	0.34123***
Constant	4.50325***	4.45984***	4.52755***	4.54358***	4.51167***	4.45310***
Observations	151	302	126	252	147	294
R^2	0.902***	0.928***	0.913***	0.936***	0.901***	0.928***

Notes: *, **, *** indicate significant at 10%, 5%, and 1%, respectively.

a OLS estimation using cross-section data after the implementation of the project (2009). Then the time dummy variable (t) was dropped.

b LOCA, EDU, CROP, EXP, and ASSN variables are time-invariant in the sample. Then they were dropped in the fixed-effect estimation.

Table 7. Estimated mean impact of community action (CA) on real net farm income of rice farmers using the unmatched and matched samples, Mekong River Delta, Vietnam

Independent Variable	Unmatched Sample		1-to-1 NN Matched Sample		Kernel Matched Sample	
	Cross-section Data	Panel Data (DID)	Cross-section Data	Panel Data (DID)	Cross-section Data	Panel Data (DID)
	OLS[a] Estimation	Fixed-Effect[b] Estimation	OLS[a] Estimation	Fixed-Effect[b] Estimation	OLS[a] Estimation	Fixed-Effect[b] Estimation
CA	1,875.34***	1,226.08***	1,827.83***	1,156.75***	1,869.72***	1,188.16***
AREA	60.90**	25.68	58.05**	27.30	57.91**	25.23
LABOR	-34.76**	-28.62**	-34.67**	-26.43*	-36.66***	-31.56**
MATEXP	-0.88***	-0.78***	-0.90***	-0.80***	-0.89***	-0.78***
VART	231.36	235.89*	217.63	218.56	224.27	259.79**
LOCA	-617.85***	-	-655.92***	-	-607.50***	-
EDU	36.73**	-	41.35**	-	37.49**	-
EXP	8.05	-	10.00*	-	8.37	-
KI	1,612.16**	1,135.83**	2,059.55***	1,134.30**	1,653.50**	1,197.22**
CROP	-211.88	-	-254.41	-	-201.44	-
ASSN	56.69	-	31.45	-	53.27	-
T	-	3,445.75***	-	3,730.61***	-	3,540.87***
Constant	11,061.66***	7,019.47***	10,898.16***	7,131.90***	11,178.64***	7,106.90***
Observations	151	302	126	252	147	294
R^2	0.737***	0.921***	0.747***	0.926***	0.901***	0.922***

Notes: *, **, *** indicate significant at 10%, 5%, and 1%, respectively.
a OLS estimation using cross-section data after the implementation of the project (2009). Then the time dummy variable (t) was dropped.
b LOCA, EDU, CROP, EXP, and ASSN variables are time-invariant in the sample. Then they were dropped in the fixed-effect estimation.

The mean impact of the CA strategies on real net farm income per hectare using the 1-to-1 nearest neighbor matched sample was lower compared to that of using the unmatched sample (Table 7). For example, the mean impact of the CA strategies on real net farm income per hectare was approximately VND 1.83 million (USD 103) under the OLS estimation using cross-section data, while the impact was VND 1.16 million (USD 65) in the fixed-effect estimation under the DID approaches using panel data. Both impact estimates of the CA strategies on farmer-beneficiary real net farm income per hectare from rice production using the 1-to-1 nearest neighbor matched sample were significant at the 1 percent probability level.

Similar to using the kernel matched sample, the mean impact of the adoption of the CA strategies in rodent pest management on real net farm income per hectare was slightly lower compared to that of using the unmatched sample (Table 7). For example, the mean impact of the adoption of the CA strategies on real net farm income was approximately VND 1.87 million (USD 105) under the OLS estimation using cross-section data, while it was VND 1.19 million (USD 67) in the fixed-effect estimation under the DID approaches using panel data. Both impact estimates of the adoption of CA strategies on the farmer-beneficiary real net farm income from rice production using the kernel matched sample were highly significant at the 1 percent probability level. The positive and significant mean impact of the adoption of the CA strategies on real net farm income from rice production could be attributed to the increase in paddy yield due to reduction in yield losses caused by rodent damage. Hence, the adoption of the CA strategies in rodent pest management by rice farmers had a significant impact on increasing real net farm income from rice production.

The significant and positive mean impact of the adoption of the CA strategies on real net farm income from rice production seems to be robust to the matching criteria. Since the DID parameter estimates of the mean impact of the CA strategies on real net farm income per hectare using both matched samples (i.e., the 1-to-1 matched and the kernel matched samples) were similar (Table 7).

The estimated mean impact of the CA strategies on rice yield and real net farm income was much higher in the OLS estimation using cross-section data than that of the DID approaches using panel data (Tables 6 and 7). This could be attributed to the selection problem due to time-invariant factors; the mean impact of the adoption of the CA strategies on rice yield and real net farm income tended to be overestimated when panel data with DID approaches were not used. Moreover, the results also could be overestimated if PSM procedures were not applied. These findings suggested that controlling some of the selection problems (due to time-invariant- and observable time-varying factors) had a significant effect on the accuracy of the estimated mean impact of the CA strategies. Hence, the DID approaches using panel data with PSM approaches were more accurate in estimating the mean impact of the adoption of the CA strategies on rice yield and real net farm income of farmer-beneficiaries. Overall, the adoption of the CA strategies for rodent pest management significantly increased the paddy yield and real net farm income of the rice farmer-beneficiaries in the study area.

Moreover, in the DID results, the control covariates that had a significant positive effect on paddy yield and real net farm income were educational level (EDU) and the knowledge index about rodent pest management (KI) of rice farmer-respondents. These results are consistent with the study's theoretical expectation of their effects. Farmers with higher educational levels may better understand and practice rodent control methods following the EBRM strategies from the training lessons conducted by project staff. Thus, farmers were able to reduce losses due to rodent damage and production costs in term of less rodenticide use and other toxic chemicals leading to higher rice yield. Unlike other impact assessment studies, this study used farmer knowledge index about rodent pest management as an independent variable in all models instead of using a training dummy variable, because the training lessons on rodent management following the EBRM strategies were jointly conducted with other training programs such as IPM training. Thus, using the knowledge index on rodent pest management as an explanatory variable to estimate the mean impact of the CA strategies adoption is more relevant in this case.

The time dummy variable (T) also had a positive and significant mean effect on rice yield and real net farm income at one percent probability level. The positive sign of the time dummy variable reflects the general increase in mean rice yield and real net income observed for the entire sample rice farmer-respondents after the implementation of the EBRM Project. As discussed in Wooldridge (2002), this variable also controls for secular trends in the outcome variable.

On the other hand, the location dummy variable (LOCA) had negative and significant average mean impact on paddy yield and real net farm income in all models, and the cropping intensity (CROP) variable also had negative and significant mean impact on paddy yield in all models at the 1 percent probability level. These results are consistent with the study's theoretical expectation of their effects. Farmers who produce three rice crops per year typically use short-maturing varieties, which are normally less suitable to dramatic changes in weather conditions and are more prone to insect and pest (including rats) damage leading to high yield losses. In addition, producing three rice crops per year would lead to a high potential for rodent damage in the second (summer-autumn) and third rice crops each year due to the build-up of rodent population density. Furthermore, increases in pesticide and insecticide costs result in a reduction in real net farm income from rice. Moreover, the location dummy variable (LOCA) had a negative and significant correlation with productivity and real net income due to lower soil quality in the Tri Ton District compared to the Tinh Bien District. In addition, all rice farmer-respondents in communes closer to the border of Cambodia may be more affected by rodent damage due to the difference in the cropping calendar between Cambodia and Vietnam. Since Tri Ton District is closer to the border of Cambodia than Tinh Bien District then rodents could move easily from Cambodia to this area to make more damage to the rice field (Singleton et al. 2003).

CONCLUSIONS

Overall, the results suggest that the adoption of the CA strategies in rodent pest management had a statistically significant and positive impact on paddy yield and real net income from rice production. The impact of the CA strategies adoption on paddy yield and real net farm income from rice production could be attributed to the reduction in yield losses caused by rodent damage. This finding was robust to the matching techniques as well as the estimation strategies undertaken. Hence, the CA strategies following the EBRM technology is a good tool for rice farmers in terms of enhancing their household income and food security.

Moreover, farmers in this area should be encouraged to produce only one to two rice crops per year instead of growing three rice crops per year in order to improve rice yield and net farm income. This finding is important for policy makers to adjust their strategies in developing rice sector for enhancing household income and food security in this region. Furthermore, this policy of growing two rice crops per year would not only address pest build-up such as rodents and insect pests (as in the brown planthopper outbreak), but also on soil depletion due to intensive cropping which is further exacerbated by the impact of drought.

Based on these results, insights from studies about the costs and benefits as well as the flexible implementation of CA strategies need to be effectively disseminated to rice producers through extension and outreach programs. These findings support those reported in the Red River Delta (Brown et al. 2006: Palis et al. 2011) and in West Java in Indonesia (Singleton et al. 2005). As shown in the probit model above, farmer association membership has strong positive impact on the likelihood of the adoption of CA strategies. Moreover, knowledge on rodent pest management and the educational attainment of the household head also have positive and significant impact on the interest outcomes. Extension programs through the farmer associations at the village level should not only focus on the technical aspects of the EBRM technology but also on the provision of information to rice farmers on its economic and social benefits, which can potentially encourage further adoption of this natural resource management technology.

ACKNOWLEDGMENTS

This study was jointly funded by the Irrigated Rice Research Consortium (IRRC) of the International Rice Research Institute (IRRI) through funding from the Swiss Agency for Development and Cooperation (SDC), the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), and the World Bank and Vietnam Ministry of Education and Training.

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