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# Conservation Agriculture Adoption and Its Impact: Evidence from Shiga Prefecture, Japan

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## Abstract

The adoption and diffusion of conservation agriculture, which is as one of the agri-environmental policy measures for addressing regional environmental issues, has become important and widespread worldwide. However, there is little evidence on the determinants of conservation agriculture adoption and diffusion in Japan. This article investigates the farmers' determinants of conservation agriculture adoption in Shiga Prefecture, Japan, and the impacts of conservation agriculture adoption were analyzed using propensity score matching. Our results found neighborhood effects in the diffusion process of conservation agriculture. In addition, farmers' attitudes, risk preference and farm size were correlated to the likelihood of conservation agriculture adoption. Our analysis further shows that adopting conservation agriculture significantly induces farmers to raise the willingness to expand their farm size, increase the number of market channels and implement direct marketing. This confirms the potential role of conservation agriculture adoption in improving the efficiency and structure of agriculture.

***Keywords***: Conservation agriculture, Propensity score matching, Japan, Lake Biwa

***JEL classification***: O33, Q12, Q16

## 1. Introduction

Agri-environmental policy aimed at promoting conservation practices in the agricultural sector is widespread worldwide. For instance, the conservation reserve program (CRP) and the best management practices (BMPs) in the United States and agri-environmental payment scheme in the EU countries are well known as typical measures of promoting conservation practices in agri-environmental policy.[1] As the synthesis review articles of Knowler and Bradshaw (2007) and Prokopy *et al*. (2008) show, much previous literature exists on CRP participation, BMPs adoption and scheme participation.[2] Despite conservation agriculture or the measures of agri-environmental policy have been widely adopted, few studies have investigated the determinants of farm-level decisions to adopt conservation agriculture in Japan. Most of the literature regarding conservation agriculture in Japan treats several farm households qualitatively as a case study.[3] Moreover, very few studies have quantitatively examined the effects of conservation agriculture adoption on farming outcomes such as the securement of farm successors and the implementation of direct marketing.

[1] For the institutional framework of agri-environmental policy in developed countries, see Shobayashi *et al*. (2012).

[2] Kawasaki (2014) also provides an insightful review of the previous literature on CRP.

[3] As an exception, Hu (2007) provides both of the quantitative analysis and case study on the conservation agriculture in Japan.

The main goal of agri-environmental policy and conservation agriculture diffusion in Japan is to reduce environmental load from agricultural sector or improve water quality in watershed area. In particular, Shiga Prefecture, which is one of the prefectures of Japan, is home to Lake Biwa, which has experienced serious water pollution. This serious water pollution was associated primarily with agricultural practices and other industrial activities that discharge organic, nitrogen, and phosphorous runoff into the lake. Lake Biwa thus became one of symbols of non-point source pollution in Japan. Shiga Prefecture has therefore established various regional environmental policies, such as the Lake Biwa ordinance (Shiga Prefecture ordinance pertinent to the eutrophication in Lake Biwa), and has played a leading role as a regional environmental policy maker.[4] This article focuses on regional agri-environmental policy, especially for the diffusion of conservation agriculture in Shiga Prefecture.

The aim of this article is to contribute to the literature on conservation agriculture adoption in Japan by analyzing the factors that have affected conservation agriculture adoption in Shiga Prefecture. Furthermore, using propensity score matching, this article aims to identify how conservation agriculture adoption affects the farming outcomes of farm households. The results could help to improve understanding of the farmers' adoption behavior of conservation agriculture and develop agri-environmental policy measures to promote conservation agriculture adoption.

The remainder of this article is structured as follows. Section 2 describes conservation agriculture in Shiga Prefecture, and Section 3 outlines the data and farmers' attitudes toward conservation agriculture. Section 4 presents our empirical approach and the estimation results of the adoption model. Section 5 presents the results of the impacts of conservation agriculture adoption on farming outcomes using propensity score matching. The final section is dedicated to concluding remarks.

## 2. Environmental Conservation Agriculture in Shiga Prefecture

### *2.1. Water Pollution in Lake Biwa and Agri-Environmental Policy in Shiga Prefecture*

Our study area is Shiga Prefecture, one of the prefectures of Japan. Shiga Prefecture is home to Lake Biwa, which is Japan's largest lake and covers one-sixth of the prefecture. Lake Biwa was seriously polluted during the period of rapid economic growth and became one of symbols of non-point source pollution in Japan. The extensive use of pesticides and chemical fertilizers in the agricultural sector was one cause of the water pollution in Lake Biwa. Thus public and citizen initiatives have sought to improve the water quality in Lake Biwa since the 1970s.[5] According to Nishizawa (2014), Shiga Prefecture has played a leading role in agri-environmental policy in Japan, and the implementation of its regional agri-environmental policy is regarded as a successful case. Many environmental conservation measures have been adopted in the Lake Biwa watershed area.

In 2001, the certification system of environmental conservation agricultural products was established. This system certifies agricultural products as conservation agricultural products when they are grown according to the following cultivation basis, consisting of four items: (i) Defined plots with conservation agriculture that are clearly segmented; (ii) Prohibition of the use of genetically modified seeds and seedlings; (iii) Cultivation methods that: a) reduce the use of chemical fertilizers and agricultural chemicals to less than 50% of those used in regular cultivation; b) appropriately use compost and other organic inputs in soil preparation; c) adopt conservation

[4] Sato (2014) shows the transition of environmental conservation measures in the Lake Biwa watershed area.

[5] Tomioka (2005) summarizes the development of agri-environmental policy in Shiga Prefecture before the establishment of the certification system of environmental conservation agricultural products. For the practices of water quality conservation in Lake Biwa, see Ohashi (2003). For background to the establishment of the agri-environmental direct payment scheme, see Akiyama (2004).

agricultural technology such as the prevention of agricultural drainage discharge; (iv) Compliance with the “norm of agricultural activities” (Shiga Prefecture 2013). Conservation agriculture based on this cultivation basis is known as *Kankyo Kodawari Nogyo* (Environmental Conservation Agriculture), which for simplicity we describe as conservation agriculture (CA) in this article.

### *2.2. Diffusion Process of CA in Shiga Prefecture*

CA was introduced in the early 2000s to improve the water quality of Lake Biwa and reduce the environmental load in Shiga Prefecture.

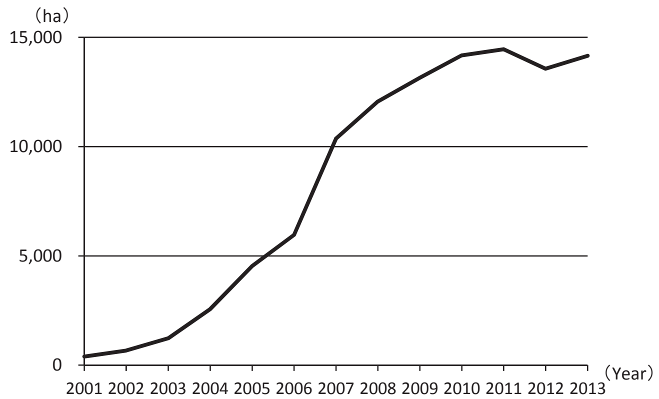


**Figure 1: Diffusion of Conservation Agriculture in Shiga Prefecture**

Figure 1 shows the area under CA cultivation in Shiga Prefecture. After implementing the certification system in 2001, CA diffused slowly until 2003, but accelerated thereafter. This is because the ordinance promoting environmental conservation agriculture was introduced in 2003, and in 2004 the agri-environmental direct payment scheme for CA was introduced to compensate for the additional costs of practicing CA. The technical manuals for practicing CA were also distributed after the introduction of this scheme and farmers thus could learn to utilize standardized technical information to adopt CA. In addition, intensive extension activities for farmers’ organizations or group farming contributed to rapid diffusion of CA (Morino 2008). Next, the area under CA cultivation increased rapidly between 2006 and 2007 as a result of implementing the measures to conserve and improve land, water, and environment in 2007. In contrast, the diffusion speed of CA slowed after 2007. These dynamics of CA diffusion in Shiga Prefecture suggest that the characteristics of adopters might differ at each stage of CA diffusion.

## 3. Sampling and Data Description

### *3.1. Data and Descriptive Statistics*

We derived the data used in this article from a mail survey of farm households in Shiga Prefecture, randomly selected based on certain conditions. The survey was conducted in June and July 2013 to clarify the factors that affect CA adoption and its impact on household farming outcomes. The sample covered 252 farm households that were selected by a multistage sampling procedure. First, based on the ratio of farm households in each agricultural classification zone, postal codes (PCs) were selected by stratified random sampling, and 30 PCs were selected. Next, the farming communities where the ratio of farm households to the total number of households exceeded 20%

were selected from each PC[6] and the questionnaire was sent to all of the households in each PC.[7] A total of 406 farm households returned questionnaires, and we excluded those with missing or incomplete data from the analysis, yielding a final dataset of 252 observations.

The structured questionnaire consisted of detailed items about 1) farm characteristics, such as farm size, farm income and the securement of farm successor; 2) farmer attributes, such as age, risk attitude and education; 3) adoption time of CA and area under CA cultivation, if applicable; 4) environmental awareness toward Lake Biwa, such as farmers' attitudes toward water quality and agricultural drainage; 5) response to hypothetical policy change, such as changes in payment scheme; 6) social network capital, such as participation in community meetings, confidence in extension services or community, and the existence of a farming mentor; 7) adoption of specific conservation practices, such as the preservation of indigenous fish in Lake Biwa.

### *3.2. Farmers' Attitudes toward CA*

Farmers' attitudes toward CA and products are summarized into factors using principal component analysis (PCA). Table 1 presents the results of the PCA application on farmers' attitudes and opinions toward CA and products. PCA was applied to the variables that measure farmers' attitudes toward CA and agricultural products. We obtained two factors as the PCA application results to measure farmers' attitudes. The resulting relevant factors are: "environmental/product quality improvement" and "economic profitability" (Table 1). We included these principal component scores as independent variables in the adoption model.

Additionally, some literature indicates that farmers' risk preference and objectives are related to the likelihood of adopting sustainable agricultural practices. For instance, Gardebroek (2006)

**Table 1: Results from Principal Component Analysis on Farmers' Attitudes toward Conservation Agriculture and Products**

| Variables | Principal component 1 (PC1) Environmental/product quality improvement | Principal component 2 (PC2) Economic profitability |
|---|---|---|
| Conservation agricultural products are healthier than regular products | ***0.515*** | -0.014 |
| Adoption of conservation agriculture leads to the alleviation of farmers' health damage | ***0.511*** | -0.056 |
| Adoption of conservation agriculture leads to improvements in the quality of soil and water | ***0.507*** | -0.005 |
| The quality of conservation agricultural products is higher than that of regular products | ***0.466*** | 0.087 |
| The price of conservation agricultural products ensures economic feasibility | -0.013 | ***0.710*** |
| Conservation agriculture contributes to the vitalization of the rural economy | 0.010 | ***0.697*** |
| Total explained variance (%) | 48.7 | 78.1 |
| Rotation method: Varimax | | |
| Cronbach's α | 0.857 | |
| Kaiser-Meyer-Olkin test | 0.777 | |

The principal component is classified with reference to principal component loading (≥0.4).

[6] The farm household ratio was set at 20% to avoid a low recovery rate.

[7] Due to the act on the protection of personal information, we could not identify whether surveyed households were farm or non-farm households. We thus sent our questionnaire to the total of 3,807 households in the 30 PCs.

indicates that organic farmers are significantly less risk averse than their non-organic farmers. Kallas *et al*. (2010) suggest that the importance of environmental over economic considerations is one of factors in adopting organic farming. We therefore included the farmers' awareness toward the risk of CA adoption and their farming objectives as independent variables in the adoption model.

### *3.3. Independent Variable and Household and Farm Characteristics*

The dependent variable considered is the adoption of CA. In this article, CA is part of a sustainable agricultural system and entails reduced (or no) use of pesticides and chemical fertilizer, and the control of agricultural drainage.

The adoption model includes several independent variables based on previous literature on the adoption of CA or agricultural technology (e.g., Case 1992; Wozniak 1993; Rogers 1995; Abdulai and Huffman 2005; Gardebroek 2006; Genius *et al*., 2006; Knowler and Bradshaw, 2007; Prokopy *et al*., 2008; Marshall 2009; Fujie *et al*., 2010; Kallas *et al*., 2010; Giovanopoulou *et al*., 2011; Tamini 2011; Jara-Rojas *et al*., 2013).

Table 2 shows the descriptive statistics for the dependent and independent variables used in the adoption model. Based on the definition of CA used in this article, 42% of farmers had adopted it in our study area.

Many previous studies have indicated that farm size, farm income and human capital are correlated to the decision to adopt CA (e.g., Knowler and Bradshaw, 2007; Prokopy *et al*., 2008). Therefore, we controlled for socio-demographic characteristics relevant to the adoption decision, such as farm size, farm income, age, and education of the farmers.[8] Some literature on conservation agriculture in Japan also argues that farm size has a positive association with adoption (e.g., Noguchi, 2002; Fujie, 2003; Hu, 2007; Kinoshita, 2008; Ando, 2013). The size variable in this article represents small-scale farming, which is categorized into the bottom 20% of the sample households to capture the effects of small-scale farming on CA adoption. The average farm size of the whole sample is 3.6 hectares while the size of the farming households categorized in this variable is 1.1 hectares. 26% of the sample households have no farm income, and the ratio of elderly farmers (over 80 years old) is 6%, which is consistent with the widely held view in Japan that some farmers grow crops only for home consumption and receive no income from their farming activities, and that young people tend to choose non-farm labor opportunities.

In addition to the conventional household characteristics, the survey also collected variables related to social networks that can influence the CA adoption decision. For instance, Case (1992) indicates that neighborhood externality affects the likelihood of technology adoption. Abdulai and Huffman (2005) and Fujie *et al*. (2010) also show that communication with neighboring previous adopters and their geographical proximity is related to agricultural technology adoption and that positive externalities exist in the diffusion process of agricultural technology.[9] We thus employed the number of neighborhood adopters as a proxy of a social network variable. Since previous literature also suggested that voluntary activities or local group involvement such as participation in community activities positively affects CA adoption (e.g., Marshall 2009; Kallas *et al*., 2010; Jara-Rojas *et al*., 2013), we treat the variables on farm and social activity as a voluntary activity or a local group involvement variable. Tamini (2011) investigated the impact of agri-environmental extension activities on best management practices (BMPs) and found that these activities are valid for some BMPs. Thus we also included a variable on participation in extension workshops on CA in the adoption model.

[8] For seminal reviews of technology adoption, see Feder *et al*. (1985) and Foster and Rosenzweig (2010).

[9] Rogers (1995) also emphasizes the importance of social learning through communication with previous adopters in the diffusion process of technology.

**Table 2: Variable Defenitions and Summary Statistics**

| Variables | Definition | Mean | Standard deviation |
|---|---|---|---|
| *Dependent Variable* | | | |
| Adoption | 1 if the farmer adopts the conservation agriculture, 0 otherwise | 0.42 | 0.49 |
| *Household and Farmers' Characteristics* | | | |
| Size | 1 if the farm size is categorized into the bottom 20% of sample households, 0 otherwise | 0.20 | 0.40 |
| No farm income | 1 if the farmer has no farm income, 0 otherwise | 0.26 | 0.44 |
| Soil inspection | 1 if the farmer inspects soil, 0 otherwise | 0.33 | 0.47 |
| Elder farmer | 1 if age of household head is above 80 years old, 0 otherwise | 0.06 | 0.24 |
| Education | 1 if the farmer graduated college or university, 0 otherwise | 0.18 | 0.38 |
| *Farmers' Attitudes, Awareness and Objective* | | | |
| PC1 [enviromental/product quality improvement] | principal component 1 (PC1) presented in Table 1 | 7.33 | 1.75 |
| PC2 [economic profitability] | principal component 2 (PC2) presented in Table 1 | 3.84 | 1.39 |
| Awareness [risk] | higher value = higher level of awareness toward the risk of conservation agriculture adoption ("strongly agree" = 5 to "strongly disagree" = 1) | 3.48 | 0.90 |
| Objective [environmental or ecological conservation] | 1 if the farmer's main objective in farming is environmental or ecological conservation, 0 otherwise | 0.21 | 0.41 |
| *Social Network* | | | |
| Number of neighborhood adopters | higher value = higher number of previous adopters of conservation agriculture in the neighborhood ("above ten adopters" = 5 to "one to two adopters" = 1) | 3.57 | 1.82 |
| Farm activity | total number of farm activities that the farmer engages in (farm activity = "direct marketing", "processing farm products", "information exchange and communication with consumers", "farm restaurant" and "others") | 0.28 | 0.58 |
| No social activity | 1 if the farmer does not participate in social activity, 0 otherwise | 0.06 | 0.23 |
| Participation in workshop | 1 if the farmer participates in workshop on conservation agriculture, 0 otherwise | 0.43 | 0.50 |
| *Crop Dummy* | | | |
| Rice | 1 if the farmer cultivates rice, 0 otherwise | 0.86 | 0.35 |
| Wheat and soybean | 1 if the farmer cultivates wheat or soybean, 0 otherwise | 0.20 | 0.40 |
| Out-door vegetables | 1 if the farmer cultivates out-door vegetable, 0 otherwise | 0.39 | 0.49 |
| Greenhouse vegetables | 1 if the farmer cultivates greenhouse vegetable, 0 otherwise | 0.04 | 0.20 |
| Flowers | 1 if the farmer cultivates flower, 0 otherwise | 0.05 | 0.22 |
| Fruit | 1 if the farmer cultivates fruit, 0 otherwise | 0.08 | 0.28 |
| Tea | 1 if the farmer cultivates tea, 0 otherwise | 0.06 | 0.24 |
| Forage | 1 if the farmer cultivates forage, 0 otherwise | 0.02 | 0.15 |
| Other crop | 1 if the farmer cultivates other crops, 0 otherwise | 0.02 | 0.14 |
| *Area Dummy* | | | |
| Plain area | 1 if the farmer is located in plain area, 0 otherwise | 0.56 | 0.50 |
| Hilly area | 1 if the farmer is located in hilly area, 0 otherwise | 0.36 | 0.48 |
| Mountainous area | 1 if the farmer is located in mountainous area, 0 otherwise | 0.07 | 0.26 |

# 4. Factors Affecting Conservation Agriculture Adoption

## *4.1. Empirical Model*

To examine the possible determinants of various factors, such as farmers' attitudes, household/farm characteristics, and social network on CA adoption, we used a probit model. The empirical model can be written as follows.

$$Adoption_i^* = \beta x_i + \varepsilon_i \qquad \varepsilon_i \sim N(0,1)$$

$$Adoption = 1 \quad \text{if } Adoption_i^* > 0,$$

$$Adoption = 0 \quad \text{if } Adoption_i^* \leq 0$$

$Adoption_i^*$ is the (unobservable) probability that farmer $i$ adopts CA. $\boldsymbol{x}_i$ are independent variables that are assumed to affect the adoption decision. $\boldsymbol{\beta}$ are the parameters to be estimated and $\boldsymbol{\varepsilon}_i$ is the error term. The independent variables were selected based on data availability and previous literature.

### *4.2. Results*

The estimation result of the probit model is presented in Table 3. Since the coefficients of this estimation result cannot be easily interpreted, we also show the marginal effects of independent variables. In the estimation result, most of the parameter estimates are statistically significant. Regarding household and farmers' characteristics, farm size, farm income and age all have a negative and significant effect on the likelihood of adopting CA. In contrast, soil inspection, which captures investment in soil, has a positive and significant influence on adoption.

Regarding farmers' attitudes and awareness, the variable PC1 represents their attitudes toward environmental/product quality improvement. As expected, the coefficient and marginal effect is positive and significant, suggesting that the farmer is likely to adopt CA if he believes that its implementation improves the quality of the soil, the water, and farm products. This finding is

**Table 3: Probit Estimation of Factors Affecting the Adoption of Conservation Agriculture**

| | Coef. | | Robust Std.Err. | z | Marginal Effect |
|---|---|---|---|---|---|
| *Household and Farmers' Characteristics* | | | | | |
| Size | -0.932 | ** | 0.402 | -2.32 | **-0.283** |
| No farm income | -0.794 | *** | 0.301 | -2.63 | **-0.256** |
| Soil inspection | 0.747 | *** | 0.246 | 3.03 | **0.278** |
| Elder farmer | -1.594 | *** | 0.585 | -2.72 | **-0.341** |
| Education | 0.333 | | 0.306 | 1.09 | 0.125 |
| *Farmers' Attitudes, Awareness and Objective* | | | | | |
| PC1 [environmental/product quality improvement] | 0.471 | *** | 0.090 | 5.26 | **0.171** |
| PC2 [economic profitability] | -0.083 | | 0.096 | -0.86 | -0.030 |
| Awareness [risk] | -0.268 | * | 0.138 | -1.94 | **-0.097** |
| Objective [environmental or ecological conservation] | 0.699 | *** | 0.269 | 2.60 | **0.266** |
| *Social Network* | | | | | |
| Number of neighborhood adopters | 0.226 | *** | 0.073 | 3.11 | **0.082** |
| Farm activity | 0.433 | ** | 0.189 | 2.30 | **0.157** |
| No social activity | -1.096 | *** | 0.417 | -2.63 | **-0.284** |
| Participation in workshop | 1.289 | *** | 0.260 | 4.96 | **0.456** |
| Constant | -3.730 | *** | 0.684 | -5.45 | |
| *Crop Dummy* [reference: rice] | Yes | | | | |
| *Area Dummy* [reference: plain] | Yes | | | | |
| Obs. | 254 | | | | |
| Log pseudolikelihood | -79.46 | | | | |
| Wald chi2(23) | 122.42(0.000) | | | | |
| Pseudo R2 | 0.540 | | | | |

Robust standard errors are used to correct for heteroscedasticity. * Significant at 10%. ** Significant at 5%. *** Significant at 1%.

consistent with results reported by Marshall (2009). In contrast, the parameter for PC2, which represents the attitudes toward the profitability of CA adoption, is negative but insignificant. This finding is consistent with our observation that the strongest motivation of CA adoption was the regional environment or ecological preservation and not pursuing farming profitability.

The parameter for risk awareness is negative and significant at the 10% level. This is in line with the findings of Gardebroek (2006) and Giovanopoulou *et al*. (2011) who stated that less risk averse farmers are likely to adopt organic farming or participate in conservation schemes. An attempt is also made to capture the influence of farmers' objectives on the adoption of CA including a variable representing environmental or ecological conservation as farming objectives. The parameter for farmers' objective is significantly positive, indicating that targeting the farmers who prefer environmental or ecological conservation is an effective way to diffuse CA smoothly. This finding is consistent with Flaten *et al*. (2006).

Many previous studies clarified the role of social interaction, such as social learning through communication with neighbor farmers (e.g., Case 1992; Rogers 1995; Fujie *et al*. 2010) and the acquisition of various information channels in the diffusion process of technology (e.g., Wozniak 1993; Genius *et al*. 2006). To account for social networks, the adoption model includes four independent variables that capture communication with neighbor adopters and information acquisition from other farmers or extension services. The parameter for the number of neighborhood adopters is positive and statistically significant, which is in line with Abdulai and Huffman (2005) and Fujie *et al*. (2010). However, this result may entail the endogeneity bias.[10] We thus conducted a Davidson and MacKinnon (1993) endogeneity test. The test result failed to reject the null hypothesis that the number of neighbor previous adopters is exogenous. This result indicates the existence of neighborhood externality in the diffusion process of CA. We also included the variables "farm activity" and "no social activity" that represent the degree of communication with farmers or consumers. As expected, the parameters for the two variables are respectively positive and negative and significant. These results are consistent with previous literature that indicates the positive impact of social interaction or communication on the adoption of CA.

In Shiga Prefecture, agricultural extension offices or cooperatives often hold training workshops to disseminate CA and exchange technical information. The parameter for participation in workshops is significantly positive, which is in line with Tamini (2011). The marginal effect is relatively high and shows that participation in extension workshops increases the likelihood of adoption by 45.6%, suggesting that such participation and the development of extension activities is an effective way to diffuse CA.

## 5. Measuring Impact of Conservation Agriculture Adoption on Farming Outcomes

### *5.1. Estimation Method*

CA diffusion in Shiga Prefecture has received extensive attention as a successful practice of regional agri-environmental policy in Japan. The main goal of CA diffusion is to reduce the environmental load in the agricultural sector, and some literature has examined the effects of CA on the water quality or the pollution level of Lake Biwa (e.g., Tanaka 2014), while there are few studies that have measured the impact of CA adoption on farming outcomes. We therefore measure the impacts of CA adoption on farming outcomes.

However, farmers do not adopt CA randomly; nor are they randomly distributed between

[10] This bias is well known as the "reflection problem" (Manski 1993).

adopters and non-adopters. As Wooldridge (2010) notes, if adopters and non-adopters are systematically different, a simple comparison between the two groups (adopters and non-adopters) captures the biased effects of CA adoption. Thus this simple comparison entails a self-selection bias due to the observed and unobserved farm household characteristics, and the self-selection makes it difficult to assess the impacts of CA adoption. We need to compare the outcomes in households that adopted CA to what those outcomes would have occurred if the same households had not adopted CA to obtain a valid measure of the impact of CA adoption. We therefore use propensity score matching (PSM) to obtain valid measurements of the adoption impact.[11] PSM addresses the self-selection problem, summarizes the pre-treatment characteristics of each subject into a single index variable and uses the propensity score to match similar households (Rosenbaum and Rubin 1983). We would like to construct an estimate of the average impact of CA adoption on those who adopt it. This effect is known as the average treatment effect on the treated (ATT). The ATT is:

$$ATT = E(Y_1 - Y_0|\mathbf{x}, D = 1) = E(Y_1|\mathbf{x}, D = 1) - E(Y_0|\mathbf{x}, D = 1)$$

where $D$ is an indicator variable equal to 1 if the farmer adopts CA and 0 otherwise. $Y_1$ is the adopter's outcome and $Y_0$ is the non-adopter's outcome. $\mathbf{x}$ is a vector of the control variables. When CA is randomly adopted, we can replace $E(Y_0|\mathbf{x}, D = 1)$ with $E(Y_0|\mathbf{x}, D = 0)$. However, as mentioned above, adopters and non-adopters are not randomly distributed, and $E(Y_0|\mathbf{x}, D = 1)$ is unobservable. Therefore we estimate propensity score (P) to construct the counterfactual outcome for adopters. PSM constructs a statistical comparison group by matching observations on adopters to observations on non-adopters with similar value of P. When the two assumptions are satisfied,[12] PSM provides a

**Table 4: Balancing Test of Control Variables Using the Propensity Score**

| | before matching | | | after matching | | |
|---|---|---|---|---|---|---|
| | average | | t test | average | | t test |
| | Adopter | Non-Adopter | (p value) | Adopter | Non-Adopter | (p value) |
| Size | 0.056 | 0.299 | 0.000 | 0.056 | 0.075 | 0.582 |
| No farm income | 0.140 | 0.340 | 0.000 | 0.140 | 0.187 | 0.358 |
| PC1 [environmental/product quality improvement] | 8.017 | 6.830 | 0.000 | 8.017 | 7.981 | 0.832 |
| PC2 [economic profitability] | 4.020 | 3.713 | 0.082 | 4.020 | 4.294 | 0.155 |
| No social activity | 0.009 | 0.088 | 0.006 | 0.009 | 0.000 | 0.318 |
| Participation in workshop | 0.748 | 0.204 | 0.000 | 0.748 | 0.813 | 0.250 |
| Elder farmer | 0.019 | 0.088 | 0.020 | 0.019 | 0.000 | 0.157 |
| Education | 0.159 | 0.190 | 0.517 | 0.159 | 0.093 | 0.151 |
| Crop (out-door vegetables) | 0.346 | 0.422 | 0.222 | 0.346 | 0.318 | 0.665 |
| Crop (greenhouse vegetables) | 0.037 | 0.048 | 0.694 | 0.037 | 0.019 | 0.410 |
| Crop (flowers) | 0.065 | 0.041 | 0.382 | 0.065 | 0.056 | 0.776 |
| Crop (fruit) | 0.075 | 0.088 | 0.697 | 0.075 | 0.056 | 0.582 |
| Crop (tea) | 0.037 | 0.082 | 0.153 | 0.037 | 0.056 | 0.519 |
| Crop (forage) | 0.028 | 0.020 | 0.694 | 0.028 | 0.037 | 0.702 |
| Crop (other crop) | 0.019 | 0.020 | 0.923 | 0.019 | 0.009 | 0.563 |
| Location (hilly area) | 0.355 | 0.367 | 0.842 | 0.355 | 0.383 | 0.673 |
| Location (mountainous area) | 0.065 | 0.082 | 0.629 | 0.065 | 0.047 | 0.555 |
| Pseudo R2 | | 0.444 | | | 0.043 | |
| Likelihood ratio test (p value) | | 0.000 | | | 0.632 | |

[11] For seminal explanations of PSM, for example, see Rosenbaum and Rubin (1983) and Wooldridge (2010).

[12] These two assumptions are "assumption of conditional mean independence" and "assumption of common support condition." For these assumptions, see Rosenbaum and Rubin (1983).

valid method for estimating $E(Y_0|\mathbf{x}, D = 1)$ and obtaining unbiased estimates of ATT.

$$ATT = E(Y_1|D = 1, \boldsymbol{P}) - E(Y_0|D = 0, \boldsymbol{P})$$

Several matching methods have been employed to match adopters and non-adopters of similar propensity score in previous literature. We employed nearest neighbor matching and kernel matching, both of which are standardized matching methods often employed in the literature.

To examine the success of matching, we checked if the matching procedure can balance the distribution of the covariates in the control (adopter) and treatment (non-adopter) groups. Table 4 presents the result of the balancing test using the propensity score. After matching, the standardized mean difference decreased from 28.6 to 8.4%, and the p value of the likelihood ratio test suggests that there is no systematic difference in the distribution of the covariates between the two groups. We therefore used this PSM result to measure the impacts of CA adoption on farming outcomes.

### *5.2. Average Effect of CA Adoption*

Table 5 presents the estimates of the average treatment adoption effects by nearest neighbor matching and kernel matching. All estimation results are based on the common support condition.

**Table 5: Conservation Agriculture Adoption Average Treatment Effect on Treated (ATT)**

| | nearest neighbor matching | | | kernel matching | | |
|---|---|---|---|---|---|---|
| *Whole sample* | | | | | | |
| Willingness to expand farm size | 0.131 | *** | (0.033) | 0.124 | ** | (0.055) |
| Securement of farm successor | 0.056 | | (0.136) | 0.008 | | (0.115) |
| Number of market channels | 0.495 | *** | (0.192) | 0.440 | ** | (0.186) |
| Implementation of direct marketing | 0.168 | ** | (0.073) | 0.174 | ** | (0.068) |
| *Early adopters* | | | | | | |
| Willingness to expand farm size | 0.200 | *** | (0.064) | 0.148 | ** | (0.077) |
| Securement of farm successor | -0.125 | | (0.183) | -0.133 | | (0.144) |
| Number of market channels | 0.625 | ** | (0.251) | 0.474 | * | (0.268) |
| Implementation of direct marketing | 0.175 | * | (0.104) | 0.164 | * | (0.096) |
| *Late adopters* | | | | | | |
| Willingness to expand farm size | 0.075 | | (0.065) | 0.078 | | (0.051) |
| Securement of farm successor | 0.060 | | (0.157) | -0.005 | | (0.126) |
| Number of market channels | 0.642 | *** | (0.223) | 0.420 | ** | (0.227) |
| Implementation of direct marketing | 0.164 | ** | (0.072) | 0.161 | ** | (0.079) |

* Significant at 10%. ** Significant at 5%. *** Significant at 1%. Figures in parentheses represent standard error.

We used four farming outcome variables: willingness to expand farm size, securement of farm successor, number of market channels, and implementation of direct marketing. The willingness to expand farm size is a binary variable that takes a value of 1 if the farmer intends to expand his farm size or 0 otherwise. The securement of farm successor is also a binary variable that takes a value of 1 if the farmer has secured a farm successor or 0 otherwise. The number of market channels takes the value of the sale destinations of the farmer. The implementation of direct marketing is a binary variable that takes a value of 1 if the farmer implements direct marketing or 0 otherwise. The result indicates that the adoption of CA has a positive and significant effect on the willingness to expand farm size, the number of market channels, the implementation of direct marketing, and insignificantly impacts the securement of farm successor.

The increase in the percentage of having willingness to expand farm size ranges from 12 to 20 percentage points using both matching methods. This is the average percentage difference in having willingness to expand the farm size for similar pairs of households that belong to different adoption status (that is, adopters and non-adopters). The adoption of CA could lead to change the agricultural structure in Shiga Prefecture and improve its efficiency via motivating the willingness to expand farm size. The estimated impact of CA adoption on farm activity as measured by the number of market channels is estimated to range from 42 to 64 percentage points, and regarding the implementation of direct marketing, it is estimated to range from 16 to 17 percentage points (Table 5). These results suggest that the adoption of CA might have the effect of encouraging the development of farm business.

To gain further understanding of the impact of CA adoption on different groups of adopters, we also examined the differential impacts of adoption by dividing the whole household samples into early and late adopters. Some literature indicates that adopters differ across the diffusion process of CA (e.g., Flaten *et al*. 2006; Läpple and van Rensburg 2011). As mentioned above, the diffusion process of CA in Shiga Prefecture is classified into two primal stages, that is early and late stage. We thus divided the farm households into two groups that represent the year CA was adopted: (1) farm households that adopted CA by 2006 or earlier (early adopters); (2) farm households that adopted CA in 2007 or later (late adopters).

As observed in Table 5, the impact on the willingness to expand farm size differs by adopter group. The gain in the willingness to expand farm size is significantly positive in the early adopters, while the relationship between the adoption and the willingness of size expansion does not exist in the late adopters. These results suggest that CA adoption might affect only the early adopters for improving the efficiency of their farm business, and that duration effects might exist in CA adoption. While there are few differences in the ATT regarding the number of market channels and the implementation of direct marketing between adopter groups, no duration effect exists in farming outcomes regarding the development of farm business.

## 6. Conclusions

This article investigated the factors affecting farmers' conservation agriculture adoption and the impact of their adoption on farming outcomes. Data were collected from farmers in Shiga Prefecture through a random sampled mail survey from June to July 2013.

Three main conclusions can be drawn from the results of this article. First, farmers' attitudes toward conservation agriculture are mainly grouped into "environmental/product quality improvement" and "economic profitability." Second, the probit estimation for conservation agriculture adoption reveals that participation in extension activities and the existence of neighborhood adopters and farm activities positively correlate with the likelihood of conservation agriculture adoption; age, small/self-sufficient farming, and risk averse preference negatively correlate with the likelihood of conservation agriculture adoption. Third, propensity score matching results suggest that the adopters of conservation agriculture are more significantly motivated to expand their farm size than non-adopters even after controlling for confounding factors. The same results also show that adoption of conservation agriculture significantly enhances the number of market channels and the likelihood of implementing direct marketing.

The results presented in this article suggest the significance of improving the measures for diffusing conservation agriculture. One possibility is targeting objectives for extension activities, with a particular focus on forming groups or communities of adopters via cultivating leading farmers, since the adoption of conservation agriculture has external or neighborhood effects, and younger farmers and medium- or large-scale farmers are desirable as the targeted objectives. Our findings also indicate that conservation agriculture adoption has indirect impacts on raising the willingness to expand farm size and to develop sales routes and marketing methods. These findings suggest that the diffusion of conservation agriculture could lead to improvements in the efficiency of farming and the structure of agriculture.

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