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**JICA-RI Working Paper**

An Empirical Analysis of Expanding Rice Production in Sub-Sahara Africa

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**Yoko Kijima**

No. 161

February 2018

JICA Research Institute



JICA Research Institute

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JICA Research Institute  
10-5 Ichigaya Honmura-cho  
Shinjuku-ku  
Tokyo 162-8433 JAPAN  
TEL: +81-3-3269-3374  
FAX: +81-3-3269-2054

# Long-term and Spillover Effects of Rice Production Training in Uganda

Yoko Kijima\*

## Abstract

Using panel data from 2009, 2011, and 2015, this study estimates the impact of rice production training conducted in Uganda on the adoption of improved cultivation practices and productivities. Since participants were encouraged to share information with fellow farmers, the average effects on training participants and non-participants in training villages (spillover effects) are separately estimated by selecting comparable households from villages without training projects. Because of the non-random assignment of project villages and training participation, a difference-in-differences model with household fixed effects is combined with propensity score weighting for mitigating biases. We find that training increases adoption rates for improved cultivation practices among training participants, both in the short and long term, and the long-term impact of training on rice yield is 0.47 tons per hectare. Although non-participants in training villages increased the adoption of transplanting in the long term, no improvements in non-participants' knowledge on rice cultivation nor in rice productivity were detected. The results of the heterogeneous impacts on non-participants' adoption show non-participants who visited the demonstration plot increased the adoption of transplanting, but those who talked with training participants about rice cultivation did not increase the adoption rate more than those who did not.

**Keywords:** Agricultural training project, Impact evaluation, Sub-Saharan Africa

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\* National Graduate Institute for Policy Studies (GRIPS), 7-22-1 Roppongi, Minato-ku, Tokyo, 106-8677, Japan, kijima@grips.ac.jp; Phone:+81-3-6439-6188

This paper was prepared as part of a research project “An Empirical Analysis of Expanding Rice Production in Sub-Sahara Africa” of the Japan International Cooperation Agency Research Institute (JICA-RI). I would like to thank Kazushi Takahashi, Yukichi Mano, Keijiro Otsuka, Jun Goto, Yuko Nakano, Kei Kajisa, and Kisho Miyamoto for their valuable comments.

## 1. Introduction

Agricultural productivity in Sub-Saharan African (SSA) countries has been stagnant for a long period (FAOSTAT 2017). Since improved agricultural technologies are the basis for enhancing productivity, enhancing their adoption rate has become an important research question for solving the problem of low agricultural productivity in SSA countries.<sup>1</sup> Although agricultural technologies developed by scientists are delivered by agricultural extension workers to farmers through public extension systems in numerous SSA countries, public extension systems have not been functioning optimally.<sup>2</sup> As such, the issue is how to improve public extension systems for enhancing technology adoption, a subject that has not been studied in detail to date.

For improving rice productivity by strengthening extension systems, the Japan International Cooperation Agency (JICA) proposed a lowland rice farming training project, namely a project on sustainable irrigated agricultural development (SIAD) to Eastern Uganda. Before this project started, there were few experts on rice cultivation in Uganda, and most extension workers were not trained to advise farmers. After this project provided intensive training to the extension workers with the National Crops Resources Research Institute (NaCRRI), a national agricultural research organization in Uganda, the trained extension workers undertook field training for groups of farmers in demonstration plots set within project villages. The project can enhance technology adoption, because training participants acquire new useful information and group training is likely to increase peer learning. Since training participants were encouraged to share the information learnt in training with fellow farmers, the

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<sup>1</sup> Factors identified as major determinants of adoption are related with access to input and output markets, attitudes towards risk, characteristics of technologies, and information failure, among others (Feder, Just, and Zilberman 1985; Jack 2013; Bandiera and Rasul 2006; Conley and Udry 2010; Munshi 2004; Krishnan and Patnam 2014).

<sup>2</sup> Some of these reasons are high cost of delivering information due to lack of transportation infrastructure in remote rural areas and insufficient travel allowances given to extension agents; lack of monitoring and enforcing mechanism for extension workers to deliver services; unsuitability and out-of-date delivered information for the local context due to lack of training opportunities and

project may also increase technology adoption among non-participants through farmer-to-farmer social networks.

This study assesses the impact of the SIAD project on the adoption of technologies and on agricultural productivities to determine whether extension worker training followed by group field training for farmers is an effective extension system. Since the effectiveness of the extension system depends on how much technology adoption is enhanced among training participants and non-participants, we estimate the effects on directly trained farmers and non-participants in the project villages, respectively. Because of the non-random assignment of project villages and training participation, a difference-in-differences (DID) model with household fixed effects is combined with propensity score weighting for mitigating biases. By estimating the impact of the actual implemented project in improving the extension system in Uganda, not only on technology adoption and agricultural productivities of training participants, but also on those of the non-participants in project villages, this study contributes to a recently growing literature on the modalities of agricultural extension systems in SSA countries (Kondylis, Muller, and Zhu 2017; Beaman et al. 2015; BenYishay and Mobarak 2015; Pamuk, Bulte, and Adekunle 2014).<sup>3</sup>

The second contribution of this study is estimating the short- and long-term effects of the project on technology adoption and agricultural productivity. Although a long-term impact evaluation is critical for assessing project sustainability, existing studies are few due to the data limitations. On one hand, training participants may adopt the technologies immediately after training, but they may dis-adopt them when support from the project ends. If so, even when the

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recruitment of extension workers (Anderson and Feder 2007).

<sup>3</sup> Beaman et al. (2015) and BenYishay and Mobarak (2015) examined how the selection of contact farmers affects the diffusion of agricultural technologies through public extension systems and found that selecting contact farmers socially connected to others and selecting multiple contact farmers with different backgrounds enhanced the diffusion of the technology more. Kondylis, Mueller, and Zhu (2017) studied the effect of the provision of direct training to contact farmers for technology adoption, so that contact farmers receive the same materials provided to agricultural extension workers, and found that directly trained contact farmers increased their adoption rate, but that of other farmers did not

impact of the project on technology adoption is positive in the short term, it can disappear over the long term.<sup>4</sup> On the other hand, when the diffusion process is lengthier, the spillover effects of the project may not be identified in the short term, but only in the long term. Therefore, it is unclear whether the long-term effect of the project is more important than the short-term one.

We find training increases the adoption rates of improved cultivation practices among training participants both in the short and long terms, and the long-term impact of training on rice yield is 0.47 tons per hectare. Although non-participants in the training villages increased the adoption rate of the transplanting method in the long term, there was improvement neither in non-participants' knowledge on rice cultivation nor in rice productivity. The results of the heterogeneous impacts on non-participants' adoption show non-participants who visited the demonstration plots increased their adoption of transplanting, but those who talked with training participants about rice cultivation did not increase the adoption rate more than those who did not.

The remainder of the article is structured as follows. Sections 2 and 3 describe JICA's project, the data, and rice cultivation practices adopted by the training participants and non-participants. The empirical framework is explained in Section 4 and the results are shown in Section 5. The last section concludes the article.

## **2. JICA Projects (SIAD)**

In Uganda, the public agricultural extension system has been under reform since 1997. The first reform was the decentralization of responsibilities to district local governments for implementing agricultural extension services from the Ministry of Agriculture, Animal Industry,

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increase.

<sup>4</sup> By applying propensity score matching with cross-section data collected just after the program, Godtland et al. (2004) found that the Farmer Field School model (FFS) in Peru enhanced potato farmers' knowledge of integrated pest management practices. By contrast, Feder, Murugai, and Quizon (2004) did not find significant effects of FFS on productivity and pesticide use in rice production in Indonesia by using a DID approach with panel data for 1991 and 1999.

and Fisheries (MAAIF) (Bashasha, Mangheni, and Nkonya 2011). For modernizing the agricultural sector, the government introduced the National Agricultural Advisory Services (NAADS), which are supposed to be a “demand-driven” approach because the farmers are the ones who decide on target enterprises (specific crops, livestock rearing, fish cultivation, etc.) and types of supports required (training, information, grants, etc.) (Benin et al. 2011). Under the NAADS Act, the public extension system was phased out and replaced by a contracted privatized system implemented by NAADS, which is a semi-autonomous body under the MAAIF (Bashasha, Mangheni, and Nkonya 2011).

Under the NAADS approach, most counties do not readily access extension services because districts are unable to cover operational expenses, except in areas where non-governmental organizations (NGOs) supplemented the efforts of local governments.<sup>5</sup> Since rice cultivation became popular only after the mid-2000s, there were few extension workers with sufficient knowledge on rice cultivation in Uganda when JICA implemented its training project in 2008. To strengthen extension services on rice production, JICA offered training to extension workers so that they acquire sufficient knowledge to support rice farmers. As part of the training, extension workers undertook field training for farmers under the supervision of JICA experts.<sup>6</sup>

Before the project started, JICA experts identified a low adoption of the sustainable rice cultivation practices widely adopted in Asia as one of the problems of rice cultivation in Uganda. Since not only cultivation practices, but also chemical fertilizers and high-yield rice variety (HYV) are critical for higher productivity, productivity effectiveness is believed to be limited without applying these cultivation practices. Additionally, since it is uncommon for farmers to

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<sup>5</sup> After decentralization, the number of extension officers decreased by about half, and the shortage of qualified agricultural extension officers became problematic for effective service delivery (Bashasha, Mangheni, and Nkonya 2011).

<sup>6</sup> The JICA project focuses only on training and provides neither credit nor grants (including chemical fertilizers, other chemicals, and construction materials), unlike NAADS.

apply chemical fertilizers to any crops in Eastern Uganda and HYV rice was not officially released in Uganda when the project started, promoting the adoption of chemical fertilizers and HYV rice was not realistic. This is why JICA's project focused on training for cultivation practices that would increase rice production and productivity in Uganda.<sup>7</sup>

The project covers all 22 districts of Eastern Uganda. The field training was done in phases as follows: the first cropping season of 2009 (called Group A in 10 districts),<sup>8</sup> the second cropping season of 2009 (Group B in six districts), and the first cropping season of 2010 (Group C in six districts). A baseline survey was conducted from September to October 2009, and information on rice cultivation covering the first cropping season of 2009 and second cropping season of 2008 was collected.

One project site (lowland area) was selected in each district by JICA experts. The selection of these sites was purposive, since lowland rice cannot be grown in upland areas. Indeed, all project sites were endowed with wetlands with seasonal or year-round springs or streams. Therefore, farmers from the project sites had relatively more favorable access to water than the average Ugandan farmer with access to only upland areas. The sites selected by JICA were more or less similar in terms of the environment for rice cultivation.<sup>9</sup>

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<sup>7</sup> Kijima, Ito, and Otsuka (2012) estimated the impact of similar training programs on productivity and technology adoption, but since the data were collected only after the program, the results were based on strong assumptions. Nakano et al. (2018) analyzed the effect of a farmer-to-farmer agricultural training scheme on technology adoption and productivity in one irrigation scheme in Tanzania, and found that proximity to trained farmers increases the adoption of better cultivation practices. Kijima (2015) examined the impact of distributing rice cultivation guidebooks randomly on rice productivity and adoption of cultivation practices and did not find any significant effects.

<sup>8</sup> Among Group A, five districts have been carrying out similar projects since 2005. To assess the mid-term impact of the training project, two sites from Group A (i.e., Bugiri and Mayuge, where the water source consists of seasonal streams) were also sampled in the 2009 survey, although similar training had been provided in these districts before the survey. Kijima, Ito, and Otsuka (2012) estimated the impact of this training program implemented before SIAD by matching training participants in Group A districts with non-participants in Group A and households in Group B.

<sup>9</sup> The size of wetland is around 20–30 hectares, and the number of rice growers using wetland is 90 to 150, residing in 7–11 LC1s (lowest administrative unit, with 2–3 villages in one LC1). The percentage of households growing lowland rice is relatively low (30–40%). Most rice growers started cultivating rice in the late 1990s or early 2000s.



In addition to this geographical condition, the rice farmers from selected sites were asked to form an association to make it easier for project coordinators to pass information and implement training.<sup>10</sup> Therefore, training participants were not selected by JICA experts but by the association. Often, group chairpersons for receiving JICA training were asked to inform the dates of training to group members and those interested in training. Therefore, training participants can be more motivated towards rice farming than non-participants.

Before field training of farmers, a three-day intensive training on rice cultivation and small irrigation management practices was provided for the district agricultural officers (DAO) and extension workers at the NaCRRI. Then, the JICA experts and trained extension workers provided field training to farmers at demonstration plots on each project site, with the plots ranging from 0.2 to 0.4 hectares. The field training consisted of four parts: (1) establishing a demonstration plot and constructing irrigation canals in the surrounding area for three days; (2) preparing nursery beds and seedlings, constructing bunds,<sup>11</sup> and leveling the main field for half a day; (3) transplanting<sup>12</sup> and weeding for half a day; and (4) harvesting and threshing for half a day. On each day, extension workers first explained the cultivation practices by using flip charts, and then asked all participants to implement them on the demonstration plot to make sure

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<sup>10</sup> According to the explanation by the JICA expert in charge of selecting the project site, selection was done by location, not by farmers' characteristics. As we will see in the next section, there are no differences in the pre-project characteristics of farmers between training participants and non-participants. The more detailed procedure for the expert to select the project site is as follows. He/she finds a suitable location for lowland rice cultivation with a reliable water source, and then talks to some rice growers in that location to find out whether they are interested in the training program. If yes, then he/she asks to form a group and prepare a rice plot to be used as a demonstration plot until the next visit. If they have not prepared it, they are eliminated from the candidate list.

<sup>11</sup> Constructing bunds allows the field to hold water and is an important practice in areas where the water supply is not reliable.

<sup>12</sup> In sample areas, all rice cultivation practices are done manually. No machinery for planting and harvesting is available. There are three methods of planting rice in sample areas: broadcasting, transplanting in row, and transplanting not in row. Transplanting requires growing seedlings in nursery beds for 2–3 weeks, and then planting them onto the main rice field. Transplanting can be done by planting in line or not in line. In sample areas, transplanting is commonly implemented, but not in line. In the broadcasting method, seeds are spread into the field directly. In terms of the labor requirement of planting, broadcasting is the most labor-saving method, while transplanting in row takes more time. However, transplanting in row is best for plant growth (and higher production) due to easiness of weeding and proper spacing between plants.

that they can implement them on their own fields. Once all participants understood the purpose and methods of cultivation practices, the training participants were asked to implement what they learnt on the demonstration plot, together with the extension workers. After the actual field training, there was a brief wrap-up session for extension workers to give feedback and answer questions from the participants.

The project implementers were responsible for setting up the demonstration plots and building the water canals that connected the demonstration plots with a source of water identified by JICA experts. The farmers were required to construct their water canals with guidance and help from JICA experts by digging ditches using hand hoes, so that rice plots were irrigated before transplanting seedlings. This small irrigation scheme did not require the establishment of systematic water distribution facilities. Normally, water canals are not maintained communally. The farmers only clean the canals adjacent to their own plots, and there are no devices for metering the intake of water on individual fields.

Although the name of the project includes the term “irrigation,” it does not involve the construction of modern irrigation facilities. This is because JICA experts believe that, even if modern irrigation systems are constructed, there is no guarantee the productivity of rice cultivation can be significantly enhanced if proper cultivation practices and water control are not applied. Therefore, simple irrigation facilities were promoted in this project.

Although this training project covered the entire agricultural season, it was less intensive and less complicated than the Farmer Field School (FFS) model. Since FFS was developed as an alternative to the top-down extension method and meant for farmers to solve complex problems by themselves, it is time consuming (weekly meetings over the entire cropping season) and expensive (Anderson and Feder 2007). The topics covered in the JICA training are only rice cultivation practices, with only three to four training sessions in each agricultural season, where a few rice cultivation practices are learnt at each session and farmers implement what they learn from extension workers on demonstration plots. The similarity with

FFS is that trained farmers are expected to become farmer-trainers and disseminate the acquired knowledge to other farmers. This farmer-to-farmer knowledge diffusion is considered a cost-effective model because public extension systems tend to have a financial sustainability issue (Nakano et al. 2018).

### **3. Data**

The survey was conducted in villages with and without JICA projects to collect information on rice cultivation for 2009. For JICA project villages, two districts were selected out of Group B districts, whose project sites had been selected before the baseline survey, but the field training was not yet implemented at the time of data collection. Therefore, the adoption of cultivation practices of these two districts in the baseline survey was not affected by JICA training. In the JICA project villages, 75 households in each district were selected based on the distance from the demonstration plot to the rice plot of each household in the baseline survey to capture the diffusion process beginning from the demonstration plot (150 households in total).<sup>13</sup> Because of this sampling design, all sampled households were assumed to be rice growers at the time of data collection. However, there are six households in the sample who did not grow rice in 2009 and five households with incomplete information. The sample size in JICA villages for the baseline survey is 139.

For non-project villages, we selected five lowland rice cultivating districts to cover different rice cultivation experiences and agro-ecological conditions. In each district, two sub-counties with active rice production and access to wetlands were purposively selected. From these sub-counties, 60 LC1s (lowest administrative unit in Uganda) were randomly drawn

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<sup>13</sup> The sample lowland areas are oval-shaped. Across the short diameter there are 6–10 plots. One plot was selected randomly at approximately 25-meter intervals from the demonstration plot in two directions along the long diameter.

as sample communities. In each LC1, 10 households were randomly sampled, thus the number of sampled households in non-project villages reaching 600. In non-JICA project villages, not all sample households grow lowland rice. In the baseline survey, 396 households cultivated rice.<sup>14</sup>

Among the 60 non-project LC1s, most households in 12 of them have access to modern irrigation facilities. We dropped these LC1s from our analysis, since they are not comparable to project villages. Additionally, 25 households located in one village of the project districts were dropped from the sample, since none of them harvested rice due to serious drought in 2009. The effective sample sizes for project and non-project villages in 2009 are 114 (139 minus 25) and 280 (396 minus 116), respectively.

The first follow-up survey was conducted in 2011–2012 covering rice production in 2010–2011. The second follow-up survey was conducted in 2015–2016, covering rice production in 2014–2015 (Figure 1). Attrition in JICA project villages was minor in both the first and second follow-up surveys: only three households in the first follow-up survey could not be interviewed, since they were not available during the survey, while two households in the second follow-up survey were not interviewed since they migrated to different districts. For non-project villages, the attrition rate for the follow-up survey was 6% (564 and 560 households were re-interviewed in the first and second follow-up surveys, respectively). From the sample, five households in the project villages and 48 households in non-project villages grew rice in neither 2011 nor 2015, resulting in 109 and 232 households in project and non-project villages, respectively, to be used in our analyses on rice-growing panel households.<sup>15</sup>

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<sup>14</sup> Households in sample areas grow many types of crops, such as maize, beans, cassava, and ground nuts. In the baseline survey, the rice planted area was around 35–40% of the cultivated area. The rice price received by farmers is 1.5–2 times higher than that of maize. Therefore, it is considered a cash crop rather than a food crop locally. Although there is no evidence, the consumption of rice has been increasing even in rural areas, as rice production increased over time.

<sup>15</sup> As shown in Appendix Tables 1 and 2, the baseline characteristics and performance of rice cultivation are not different statistically, except for a few variables, between panel rice-growing households and households who did not grow rice in the follow-up surveys, separately by treatment

Table 1 shows pre-treatment household characteristics separately for training participants, non-participants in the project villages, and households in non-project villages. The means of all the variables are not statistically different between participants and non-participants in project villages, except for one variable (see column c). The only difference is that participants' rice plots are closer to the demonstration plot than non-participants'. There are few baseline characteristics that are different between households in project and non-project villages (see columns a and b). Households in non-project villages are less likely to be members of local groups than those in the project villages<sup>16</sup>. Although the training project was not randomly assigned, this table suggests households in project villages are neither more educated/experienced in rice cultivation nor more endowed with land and family labor than those in non-project villages.

Table 2 shows adopted rice cultivation practices and rice production information (yield, total production, revenue per adult equivalent, and income per hectare) separately for the treatment status and survey years.<sup>17</sup> Cultivation practices to be analyzed are improved methods of transplanting in rows and constructing bunds, which are the main practices taught in the training and easily observed when implemented. Although the use of chemical fertilizers was not taught during training, we also examine its adoption, since it can increase rice production.

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status. As explained later, we estimate the impact of the training by incorporating attrition weights to adjust for the oversampling of certain types of households in the baseline and selective attrition of the other types of households.

<sup>16</sup> For identifying the membership of local group, we excluded the group that was formed just for receiving the training in the project villages.

<sup>17</sup> Cultivation practices and rice production measures are calculated at household level. This is because the main objective of this study is to measure the long-term impact of training. Constructing plot-level panel data over the long term is not possible and suffered from selection bias, because around 40% of rice plots were rented, and land rental arrangements are seasonal or on an annual basis. More than 80% of sample households planted rice on one plot per season and two-thirds of households grew rice once a year. Regarding the adoption of cultivation practices, we calculate the share of plot size where a cultivation practice is applied over the total rice area in that year. Even when we conduct same analyses at plot level, rather than household level, the results do not change. The household-level total rice yield is calculated by dividing total rice production in a year by the total area size under rice production in that year. Income and revenue are at 2009 price levels, adjusted by food price index (Uganda Bureau of Statistics). There are separate indexes for several cities in Uganda, and those in Jinja and Mbale are used in this study because of the proximity to the sample households.

As productivity measures for rice production, rice yield (rice harvest per hectare) and income per hectare are examined. Since the project aims to increase total rice production and income of rice-growing households in Uganda, total harvests and rice revenue (per adult equivalent)<sup>18</sup> are also examined.

In terms of the adoption rates of cultivation practices before training, there are no differences between training participants and non-participants. After training, the proportion of training participants who planted rice by the broadcasting method<sup>19</sup> declined from 33% to 21% in the first follow-up survey, and then to 8% in the second. By contrast, while 34% of non-participants broadcasted seeds in the first follow-up survey, their proportion decreased rapidly afterwards, reaching 23% in the second follow-up survey. Therefore, the planting method has changed from broadcasting to transplanting not only among participants, but also among non-participants in project villages. However, in non-project villages, the proportion of households using broadcasting had not changed significantly (45–53%) even during the second follow-up survey.

Among those who implemented transplanting, most households did not transplant in row in the baseline survey, but 21% of the training participants and 10% of non-participants in the JICA training villages adopted transplanting in row in the first follow-up survey. Subsequently, the adoption rate did not increase among both participants and non-participants. Transplanting in row, at least for farmers in sample villages, takes significantly more time compared with transplanting randomly, which may explain the slow diffusion of the former method.

The proportion of households constructing or maintaining bunds increased among the training participants in the first follow-up survey (from 51 to 90%), but did not increase further

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<sup>18</sup> Adult equivalent is calculated with the weight of 1 for an adult aged 15–64 and 0.5 for the other age group.

<sup>19</sup> Explanation on the broadcasting method is given in endnote 12.

after that. This rapid enhancement of the bunds construction rate by training participants seems due to the training, since it did not increase significantly among both non-participants in project villages and in non-project villages.

In Uganda, there is no lowland rice variety officially recommended by the government. Therefore, improved variety seeds were not provided during the training.<sup>20</sup> Since the application of chemical fertilizers was not a part of the training, such fertilizers were not provided during training.<sup>21</sup> Even so, the adoption rate of chemical fertilizers increased for both participants and non-participants over the six analyzed years, and a similar increasing trend is found even in non-project villages.

The rice yield before training was lower in training villages (1.2 tons for participants and 1.4 for non-participants) than that in non-project villages (1.6 tons). In the two years after training, the yield increased significantly to 1.9 tons for participants, the difference between participants and households in non-project villages disappearing, while the yield did not increase significantly among non-participants. However, from 2011 to 2015, non-participants have caught up with the participants in terms of rice yield, resulting in yields of 2 tons in 2015. This change in yield is contrasting with that in non-project villages, where the change in average yield was moderate over time. Overall, there are similar trends in total rice production, revenue per adult equivalent, and rice income per hectare.

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<sup>20</sup> Lowland rice seeds tend to be recycled (reused) and traded locally among farmers. There are two popular lowland varieties: one is the modern rice variety crossed with local varieties and a popular variety called “K5,” “K85,” or “Kaiso” developed initially for the Kibimba irrigation scheme, and the other is a local variety called “Supar” (meaning rice), which has been widely adopted in the lowland areas of Eastern Uganda, as well as in Tanzania. While the origin of K5 is one of the early Asian modern varieties, the origin of Supar is less clear. It takes more time for Supar to be harvested than the K-series (six months and four months). Supar has an aroma valued more in Uganda and its price is higher than that of the K-series. Since many farmers do not know the variety, this study does not examine the adoption of HYV.

<sup>21</sup> The chemical fertilizer (powdered form) applied is DAP (Di-ammonium Phosphate) or urea, while the liquid type known as booster is becoming popular. During the study period, there was no government fertilizer subsidy program to farmers. Additionally, none of our sample households received chemical fertilizers at subsidized prices.

In sum, the training project increased the adoption rate of improved cultivation practices and increased rice yield, not only among participants but also non-participants in the project villages. The difference is in the timing of such changes: the adoption rates among participants improved soon after the training, while those among non-participants did not increase in the short term. During the same period, there were no significant changes in productivity and cultivation practices in non-training villages. This suggests a spillover effect from training participants to non-participants within training villages. According to the first follow-up survey, 27% of non-participants in training villages had talked with participants about the training, and 36% of them visited demonstration plots between the baseline and first follow-up survey. This spillover effect from training participants to non-participants is considered part of the training impacts, since training participants were encouraged to train fellow farmers by the project. Therefore, it is important to estimate both the direct impact of the training on participants and spillover effect to non-participants.



## 4. Empirical Framework

### *Impact on Training Participants*

This article estimates the mean impact of the rice cultivation training project on the adoption of improved cultivation practices and productivity (average treatment effect on the treated, ATT) in the short and long term by a DID model with household fixed effects (Imbens and Wooldridge 2009):<sup>22</sup>

$$y_{it} = \beta Treat_i + \delta Post_t + \gamma Treat_i \times Post_t + \rho X_{it} + \alpha_i + e_{it} \quad (1)$$

where  $y$  is the outcome variable, such as the adoption of cultivation practices and rice production;  $Treat$  takes the value 1 if household  $i$  participated in the training, and 0 otherwise;  $Post$  takes the value 1 when  $t$  is either 2011 or 2015 (after the training), and 0 for baseline data;  $X$  is a set of household characteristics;  $\alpha$  represents unobserved household fixed effects; and  $e$  is an error term. The coefficients of the interaction terms ( $\gamma$ ) for the first and second follow-up surveys are the ATTs for the short and long terms, respectively.

Since training participation was not randomly assigned, it is expected that training participants would be different from non-participants even in the project's absence. If treatment status is correlated with the error term, the estimated impact of the training is thus biased. For mitigating this problem, propensity score weighting is applied to ensure higher weights are assigned to the households in non-project villages with similar observable characteristics to the treatment households in the pre-treatment period. Under a set of assumptions (conditional mean independence and common support), applying propensity score weights results in unbiased impact estimates for ATT (Hirano, Imbens, and Ridder 2003). Propensity scores ( $P$ )

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<sup>22</sup> We do not use Propensity Score Matching (PSM), since it is suboptimal and can increase the bias in the data under certain circumstances (King and Nielsen 2016). This regression-based methodology has advantages when the attrition problem also needs to be dealt with. The attrition weight can be multiplied by the propensity score weights to obtain a weight for the weighted regression.

are estimated by a probit model using pre-training observable characteristics as explanatory variables. The estimated propensity scores are used to construct weight,  $P/(1 - P)$ , and an unbiased estimate of ATT is obtained through a weighted regression framework.<sup>23</sup>

Even after constructing a comparable control group based on observed characteristics, it is possible that unobserved household characteristics affect training participation and outcome variables simultaneously. Since we have household-level panel data before and after training, household fixed effects are controlled to mitigate the bias due to the effect of time-invariant unobservables (Smith and Todd 2005).

Although using panel data has advantages, it can cause attrition problems since our outcome variables are observed only when households grow rice. As indicated above, not all households who cultivated rice in the pre-project period grew rice in post-project periods. If the decision to grow rice is not randomly made (i.e., better performing farmers are more likely to cultivate rice in the post-project period than the rest), then ATT can be biased. Consequently, we adopt the correction procedure suggested by Fitzgerald, Gottschalk, and Moffitt (1998) and use attrition weights in all analyses.<sup>24</sup>

As explained in the previous section, knowledge spillover from training participants to non-participants exists in training villages. This means that using non-participants residing in project villages as counterfactuals of the treatment group violates the stable unit treatment

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<sup>23</sup> The results of the probit model are shown in column 2 of Appendix Table 1. The distributions of estimated propensity scores for treatment and comparison groups are provided in the Appendix Figure, which shows considerable overlap. Average baseline characteristics between treatment and comparison groups are well balanced after applying propensity score weights (see Appendix Table 2).

<sup>24</sup> We first estimate a probit model to explain whether a household grew rice in the follow-up surveys, and obtain the predicted probability that a household does remain in the panel data. The attrition weights are calculated as the inverse of the predicted probabilities, so as to give higher weights to households who have lower probabilities of growing rice in the post-project periods but who actually grew rice. The results of the probit model are shown in column 1 of Appendix Table 1. Appendix Tables 3 and 4 show the baseline characteristics and outcome variables of households who did not grow rice in the post-project periods. In non-program villages, households with lower rice production are less likely to grow rice during the post-project period.

assumption, which can underestimate ATT (Benin et al. 2012). Therefore, we select comparable households only from non-project villages as a potential comparison group.<sup>25</sup>

***Spillover Effects (indirect effect on non-participants in the project villages)***

Although the project is designed to enhance knowledge spillover from training participants to non-participants, whether the spillover effect exists and its size are not examined in detail. Similar to Benin et al. (2012) and others, we consider non-participants in the project villages as households indirectly treated.<sup>26</sup>

The estimation model to measure the spillover effects of training is the same as in equation (1), except that *Treat* takes the value 1 if households are in villages where the project provided rice cultivation training but they did not participate in the training. Propensity score weights are estimated and comparable control households are selected from non-project villages, given baseline characteristics.<sup>27</sup>

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<sup>25</sup> In five non-project villages, there have been training and/or programs related to rice cultivation, such as NAADS. Although actual participants in such training and programs were just four households in our sample, there might be spillover effects from the program to non-participants in such communities. To avoid this possibility, we dropped these five communities from constructing control groups to estimate the effects of training. The results are qualitatively similar to the main results. We believe that contamination due to the other rice program is minor.

<sup>26</sup> Feder, Murugai and Quizon (2004) separately estimate the direct and indirect effects of FFS in Indonesia, since there is diffusion from FFS graduates to others who live in villages with FFS graduates. Benin et al. (2012) defines three control groups (non-participants who claimed to have benefited indirectly in program sub-counties, non-participants who did not claim to have benefited in program sub-counties, and non-participants in non-program sub-counties), and separately estimate the impact of the NAADS program on agricultural revenue.

<sup>27</sup> The result of the probit model estimating the propensity score is presented in column 3 of Appendix Table 1.

## 5. Results

### *Impact of the Training Project on Adoption of Cultivation Practices*

The estimated effects of the training on cultivation practices are shown in Table 3. Panel A shows the average effect of training on training participants, while Panel B indicates the spillover effect of the training (indirect effect on non-participants in project villages). The first three columns show the results for the adoption of cultivation practices. In the short term, technology adoption increased only among the training participants. There is no spillover effect on technology adoption in the short term, while in the long term, non-participants increased their adoption rate of transplanting more than the control group. For the training participants, the adoption rates for cultivation practices increased even more in the long term. The impact of the training on technology adoption is sustainable among the training participants even in the six years after the training. For non-participants in project villages, the adoption rate of the transplanting method increased in 2015, but not in 2011. This suggests that it may take time for non-participants to learn about cultivation methods and actually implement them, even within project villages.

As previously explained, the training project did not contain modern input use (improved variety seeds and chemical fertilizers). However, it is possible that training might induce participants to change their decision on modern input use when they adopt other cultivation practices, since better cultivation practices can increase the marginal productivity of modern inputs. For training participants, the adoption rate of chemical fertilizers increased in 2011, but not in 2015.

### *Impact of the Training Project on Rice Production*

The rest of the columns in Table 3 present the estimation results on rice productivity (yield per hectare), rice income per hectare, total rice production per household, and rice revenue per adult

equivalent. Over the short term, yield and income per hectare did not increase both for training participants and non-participants, but in the long term, training participants increased rice yield by 0.47 tons per hectare and there is no spillover effect on rice production to non-participants in project villages. Given that training increased the adoption of better cultivation practices among training participants, the effect of the training on rice yield can be due to changes in cultivation practices. The differential impact on yield between participants and non-participants result from the fact that participants increased the adoption rates of both transplanting in row and bunds construction, while non-participants increased the adoption rate of only transplanting (not in row).<sup>28</sup> However, the positive effect of training on yield for training participants did not result in an increase in rice income per hectare. This may be because the costs of hiring labor also increased.

The effects of training on the total rice production of participants and non-participants are 0.6 and 0.4 tons in the short term, respectively, while we did not find the positive long-term effects for both groups. The positive short-term effect on total rice production without increasing productivity is probably because participants and non-participants increased the size of the areas under rice (see the last column). By contrast, in the long term, both participants and non-participants did not increase rice cultivation areas, thereby finding no increase in total rice production.

Since rice is locally considered as a more labor-intensive crop than other major crops (maize), a higher rice production for training participants can be due to the increased household size. If so, the welfare of each household member may not have improved significantly, even when total rice production increased. The results show that rice revenue per adult equivalent increased only for training participants.

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<sup>28</sup> This is because transplanting and bund construction are complementary practices for maximizing benefits, and because transplanting in row results in higher yield than transplanting not in row.

### ***Robustness Checks***

In this subsection, we provide the results estimated by two alternative models to check result robustness. The first controls for time-variant household characteristics ( $X$  in equation 1, the set of variables shown in Table 1). Appendix Table 4 presents the estimated results, indicating ATT and spillover effects are almost the same as the main results in Table 3.

The second method is the propensity score pre-screening DID proposed by Crump et al. (2009), where observations with estimated propensity scores outside  $[0.1, 0.9]$  are dropped. This systematic approach to prescreening the sample ensures that the regression is estimated only for the sample where the covariate distribution overlaps for the treated and non-treated. Angrist and Pischke (2009) show this approach works well in approximating experimental results obtained from a US work experience program. The results in Appendix Table 5 are similar to the main results.

Since the DID model is valid only when the common trend assumption holds, it is important to verify whether it holds or not. We have retrospective data on rice yield from 2007–2008, collected in the baseline survey. Using this variable, we can test whether the pre-training trend of rice yield from 2007–2008 to 2008–2009 for training participants is same as that for the control group. Appendix Table 7 shows no difference in the pre-training trend between training participants and control households, which assures that the estimated impacts are not due to the other over-time changes confounded by the treatment status.

### ***Mechanism***

In this subsection, we examine the possible mechanism under which training enhances technology adoption and rice production among training participants and the reasons for the limited spillover effect on rice yield, although non-participants increased the adoption rate of transplanting. First, we test whether training participants and non-participants enhanced their knowledge about rice cultivation by using the test scores constructed from four questions asked

in the pre- and post-training periods.<sup>29</sup> We adopted the same model as in equation (1) with the test score as a dependent variable, and found that the test scores of training participants increased but those of non-participants did not (Table 4). This finding suggests that non-participants might have learnt about rice practices, but the information obtained was inaccurate. Although we identified the spillover effect on the adoption of transplanting method in Table 3, non-participants might not have transplanted properly. This may partially explain why the increased adoption rate of transplanting by non-participants did not result in higher yield over the long term. This contrasts to the training participants who enhanced their knowledge on rice cultivation practices after training, and not only the adoption rate but also the yield increased in the long term.

Second, we examine how the technology spillover (the effect on adoption of the transplanting method) is realized. Because of data limitations, we can only analyze two possible pathways in which non-participants obtain information about improved cultivation practices: from demonstration plots or from training participants. We divide non-participants in training villages into two groups by (1) whether the household visited a demonstration plot, (2) whether the rice plot of the household is closer or farther to the demonstration plot,<sup>30</sup> and (3) whether the household talked about rice cultivation with training participants. These variables are obtained from the first follow-up survey. The heterogeneous spillover effect is estimated similarly to the main analyses, but these heterogeneous characteristics are interacted with *Treat* x *Post*, and the estimated coefficient measures the heterogeneous spillover effect. The results are provided in Table 5. Similar to the main results, there is no spillover effect in the short term, while the non-participants who visited demonstration plots are more likely to adopt the

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<sup>29</sup> Questions are about seed preparation before planting, best timing of transplanting (seedling age), planting space, and density of seedlings. The score takes values from 0 to 4, based on four questions related to rice cultivation, with equal weights for each question. Propensity score weighting and attrition weights are used.

<sup>30</sup> The distances between rice plots are measured using their GPS coordinates in the baseline survey. We divide non-participants into two using the median distance as a cutoff point.

transplanting method. In the long term, non-participants increased their adoption rate as per the main results, while we do not identify any heterogeneous impacts. Since the demonstration plot is prepared mainly for field training, it may not be used after training. If so, the information spillover from the demonstration plot can decay over time, as Table 5 shows.

## **6. Conclusion**

This study examines the short- and long-term impacts of the rice training project on the adoption of improved cultivation practices and rice productivity. To mitigate the bias caused by the non-randomness of project assignment, we estimate ATT by a DID model with household fixed effects, combined with propensity score weighting. Due to the project design that participants were encouraged to share information with fellow farmers, the comparison group is selected from non-project villages. For assessing whether the training project creates knowledge and technology spillovers within the community, the effects of the training on non-participants in project villages are estimated. Our results show that training participants adopted the improved cultivation practices taught by the project even in the short term. By contrast, we did not identify spillover effects to non-participants in the short term. In the long term, the training participants increased the adoption rates of cultivation practices, while non-participants increased the adoption of the transplanting method, but not of bunds construction.

In terms of the effects on rice production, both training participants and non-participants did not increase rice yield in the short term. In the long term, only training participants increased rice yield by 0.465 tons per hectare compared with the pre-project period. Since the training did not induce modern input use, the long-term effect on yield enhancement can be explained by the increased adoption of better cultivation practices. To understand why an effect on yield was not identified among non-participants, we determined that knowledge on rice cultivation measured by test scores was improved only among training participants. Although



non-participants increased the adoption rate of transplanting, it is likely that they did not conduct transplanting properly, which may be the reason why rice yield did not increase among them.

One of the objectives of the SIAD project was to increase total rice production for households. The results show that the project achieved its objective, since not only training participants but also non-participants had higher total rice production. Increased total rice production without improving productivity (yield) among non-participants was realized by expanding rice cultivated areas. However, as the lowland areas suitable for rice production become scarcer, yield enhancement is indispensable for increasing rice production sustainably.

Although this article did not examine the impact of information sharing via social networks on technology adoption, the results of the heterogeneous effects on technology adoption show that short-term spillover effects are found only for non-participants who visited the demonstration plots. By contrast, talking with training participants did not make any significant difference in the adoption rate of transplanting. Combined with the results on test scores, this result suggests training projects using demonstration plots are effective in promoting easily-observable agricultural technology to non-participants, but the unobservable part of the technology is difficult to transfer from training participants to non-participants.

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**Table 1. Household Characteristics in 2009 by Training Participant Status**

	Training participants	(a)	Non-project villages	(b)	Non-participants in project villages	(c)
Rice experience in years	12.09		9.841		11.64	
	(8.09)		(8.89)		(9.557)	
HH head's age	40.93		43.18		40.31	
	(12.99)		(12.04)		(14.46)	
Head's years of education	5.622		5.970		5.742	
	(3.904)		(3.261)		(3.234)	
No. of HH members	8.933		8.797		8.000	
	(3.627)		(4.075)		(3.595)	
Share of male aged 15-64	0.231		0.243		0.249	
	(0.105)		(0.133)		(0.176)	
Share of female aged 15-64	0.229		0.231	*	0.264	
	(0.108)		(0.095)		(0.158)	
Size of land owned (ha)	2.013		1.881		2.087	
	(1.810)		(2.486)		(1.753)	
Share of lowland size owned	0.197		0.215		0.235	
	(0.318)		(0.322)		(0.283)	
Local group member (dummy)	0.711	*	0.513	*	0.641	
	(0.458)		(0.501)		(0.484)	
Ownership of bulls (dummy)	0.511	*	0.353	*	0.500	
	(0.506)		(0.479)		(0.504)	
Distance to demo plot (km)	0.681				1.291	*
	(0.590)				(0.495)	
# observation	45		232		64	

*Notes:* The figures are means and those between parentheses are standard deviations. \* in columns (a), (b), and (c) indicates that mean differences between training participants and households in non-project villages, between non-participants and households in non-project villages, and between participants and non-participants in the project villages, respectively, are significantly different from 0 at the 5 % significance level.

**Table 2. Rice Yield and Cultivation Practices by Year and Training Participation Status**

2008/9 (pre-training period)	Broad- casting	Trans- planting	Transpla nting in row	Bunds constr uction	Chemical fertilizer application	Yield (ton/ha)	Rice income per ha	Total rice production (ton)	Rice revenue per adult equivalent	Rice cultivation area (ha)	Number of obs
Training participants	0.333	0.667	0.000	0.511	0.000	1.239*	1.143	0.522*	0.117	0.451*	45
Non-project villages	0.483	0.517	0.030	0.483	0.009	1.596*	1.294	1.073*	0.169	0.684*	232
Non-participants in project villages	0.375	0.637	0.016	0.609	0.031	1.354	1.298	0.49	0.121	0.383	64
2011/2 (1 <sup>st</sup> follow-up)											
Training participants	0.205*	0.795	0.205*	0.897*	0.154*	1.946	2.116	1.322	0.249	0.698	39
Non-project villages	0.528*	0.472*	0.051	0.680	0.017*	1.840*	2.348	1.148	0.240	0.619	178
Non-participants in project villages	0.339	0.661	0.102	0.678*	0.085	1.575	1.875	0.961	0.240	0.637	59
2015/6 (2 <sup>nd</sup> follow-up)											
Training participants	0.083*	0.917*	0.222*	0.889*	0.222	2.068	2.466	1.140	0.301	0.545	36
Non-project villages	0.454*	0.546*	0.075	0.546	0.167	1.859	2.013	1.378	0.354	0.700	174
Non-participants in project villages	0.226	0.774	0.075*	0.623*	0.283	2.029	2.455	1.117	0.281	0.592	53

*Notes:* The figures in the table are means. \* in columns of training participants, non-project villages, and non-participants indicates that mean differences between training participants and households in non-project villages, between non-participants and households in non-project villages, and between participants and non-participants in the project villages, respectively, are significantly different from 0 at the 5 % significance level.

**Table 3. Average Impact of Training on Participants (DID Model with Household Fixed Effects)**

Panel A: Participants vs. Control in non-project villages	Transplanting	Transplantin g in row	Bunds constructi on	Chemical fertilizer application	Yield (ton/ha)	Rice income per ha (million shilling)	Total rice production (ton)	Rice revenue per adult equivalent (million shilling)	Rice cultivation area (ha)
Participants x 2011	0.148** (0.074)	0.143* (0.076)	0.376*** (0.108)	0.177* (0.099)	0.347 (0.266)	-0.235 (0.314)	0.622*** (0.207)	0.116** (0.051)	0.305*** (0.105)
Participants x 2015	0.186* (0.101)	0.211** (0.087)	0.422*** (0.131)	-0.036 (0.085)	0.465* (0.265)	0.452 (0.398)	0.251 (0.272)	-0.086 (0.072)	0.178 (0.122)
Year 2011	-0.023 (0.026)	0.026 (0.024)	0.131*** (0.044)	0.013 (0.023)	0.276** (0.115)	0.854*** (0.166)	0.021 (0.127)	0.064** (0.026)	-0.083 (0.066)
Year 2015	-0.063** (0.029)	0.025 (0.035)	-0.010 (0.049)	0.201*** (0.043)	0.072 (0.129)	0.696*** (0.180)	0.144 (0.226)	0.197*** (0.055)	-0.129 (0.108)
Constant	0.595*** (0.016)	0.029** (0.014)	0.501*** (0.023)	0.012 (0.013)	1.496*** (0.051)	1.222*** (0.074)	1.058*** (0.059)	0.171*** (0.014)	0.726*** (0.033)
Number of obs.	704	704	704	704	677	642	694	694	704
R-squared	0.035	0.068	0.153	0.135	0.058	0.157	0.019	0.094	0.024
Number of HHID	277	277	277	277	277	275	277	277	277

*Notes:* The figures between parentheses are standard errors. \*\*\*, \*\*, and \* indicate the coefficients are significant at the 1, 5, and 10% levels, respectively. Propensity score weighting and attrition weights are used. Income and revenue are in million Ugandan shilling at 2009 price level.

**Table 3. Average Impact of Training on Non-Participants (DID Model with Household Fixed Effects), cont.**

	Transplanting	Transplanting	Bunds	Chemical	Yield	Rice income per	Total rice	Rice revenue per	Rice
Panel B: Spillover effects		in row	construction	fertilizer	(ton/ha)	ha (million	production	adult equivalent	cultivation
				application		shilling)	(ton)	(million	area (ha)
								shilling)	
Non-participants x 2011	0.037	-0.011	-0.010	0.047	-0.220	-0.375	0.344**	-0.005	0.322***
	(0.061)	(0.025)	(0.077)	(0.040)	(0.219)	(0.275)	(0.144)	(0.062)	(0.116)
Non-participants x 2015	0.140***	0.004	0.099	0.066	-0.046	0.355	0.301	-0.038	0.283**
	(0.052)	(0.040)	(0.067)	(0.077)	(0.236)	(0.300)	(0.194)	(0.045)	(0.114)
Year 2011	-0.026	0.027	0.162***	0.001	0.369***	0.791***	0.029	0.074***	-0.036
	(0.031)	(0.020)	(0.049)	(0.021)	(0.117)	(0.146)	(0.101)	(0.022)	(0.061)
Year 2015	-0.056	0.048*	-0.025	0.172***	0.578***	0.744***	0.149	0.124***	-0.069
	(0.034)	(0.026)	(0.047)	(0.039)	(0.164)	(0.194)	(0.171)	(0.031)	(0.077)
Constant	0.553***	0.022***	0.526***	0.017	1.537***	1.285***	0.944***	0.181***	0.637***
	(0.014)	(0.008)	(0.018)	(0.012)	(0.053)	(0.068)	(0.042)	(0.011)	(0.025)
Number of obs.	760	760	760	760	726	691	750	742	760
R-squared	0.019	0.018	0.060	0.144	0.081	0.160	0.020	0.075	0.037
Number of HHID	296	296	296	296	296	294	296	296	296

*Notes:* The figures between parentheses are standard errors. \*\*\*, \*\*, and \* indicate the coefficients are significant at the 1, 5, and 10% levels, respectively. Propensity score weighting and attrition weights are used. Income and revenue are in million Ugandan shilling at 2009 price level.

**Table 4. Test Score in 2009 and 2011 (DID Household Fixed Effects Model)**

Panel A	Participants vs. control	Non-participants vs. control
Participants x 2011	0.541*** (0.168)	
Non-participants x 2011		-0.286 (0.176)
Year 2011	-0.043 (0.103)	0.063 (0.098)
Constant	1.353*** (0.042)	1.322*** (0.041)
Number of obs.	434	592
R-squared	0.063	0.015
Number of HHID	217	296
Mean test scores	Pre-training	Post-training
Participants	1.322 (0.782)	1.820 (0.839)
Non-participants	1.347 (0.822)	1.244 (0.775)
Control	1.365 (0.839)	1.322 (0.846)

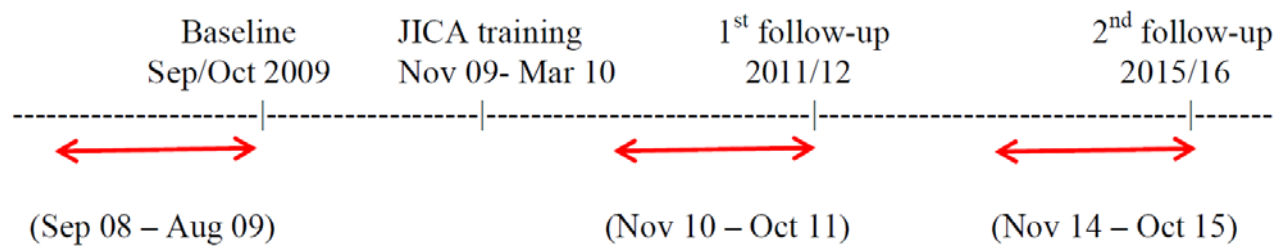
Notes: Robust standard errors between parentheses. \*\*\* p < 0.01, \*\* p < 0.05, \* p < 0.1.



**Table 5. Heterogeneous Average Impact of Training on Adoption of Transplanting by Non-Participants (Household Fixed Effects Model, Inverse Probability Weights for Attrition)**

Z (non-participants' characteristics)	Visit demo plot	Plot near demo plot	Talk with participants
Non-participants x 2011	-0.069 (0.071)	0.015 (0.075)	0.038 (0.077)
Non-participants x 2011x Z	0.251** (0.105)	0.066 (0.101)	-0.009 (0.071)
Non-participants x 2015	0.086* (0.046)	0.144** (0.058)	0.153** (0.060)
Non-participants x 2015 x Z	0.129 (0.090)	-0.011 (0.087)	-0.045 (0.071)
Year 2011	-0.026 (0.031)	-0.026 (0.031)	-0.026 (0.031)
Year 2015	-0.056 (0.034)	-0.056 (0.034)	-0.056 (0.034)
Constant	0.554*** (0.014)	0.553*** (0.014)	0.553*** (0.014)
No. of Observations	760	760	760
R-squared	0.042	0.021	0.020
Number of HHID	296	296	296

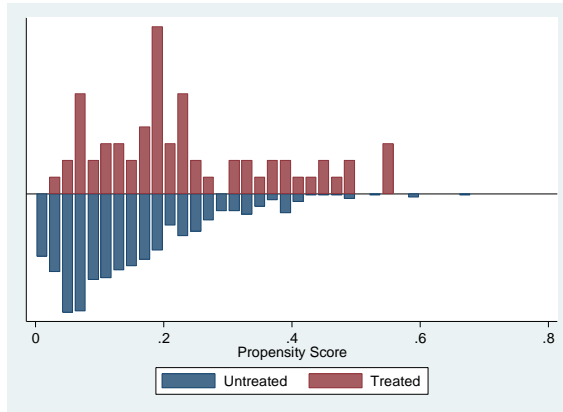
*Notes:* Figures between parentheses are t-statistics. \*\* and \* indicate coefficients are significant at the 1 and 5% levels, respectively. Among non-participants (64), 25 households visited demonstration plots between 2009 and 2011. Propensity score weighting and attrition weights are used.



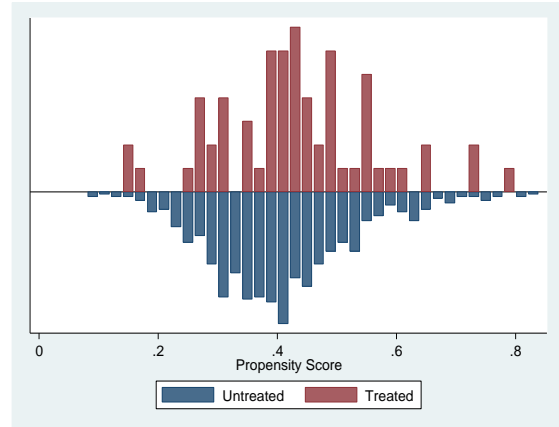
**Figure 1. Timeline**

*Note:* The arrows indicate the production period inquired during the survey.

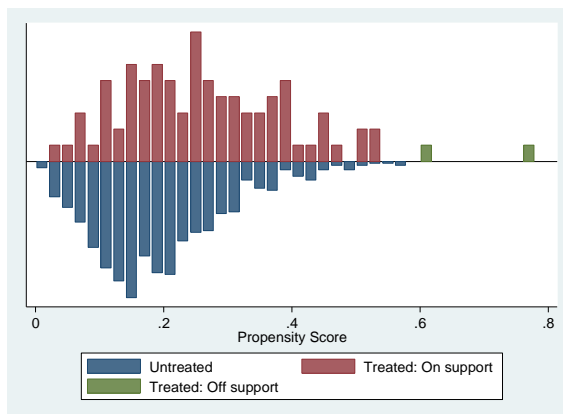
A. Participants vs. non-JICA villages



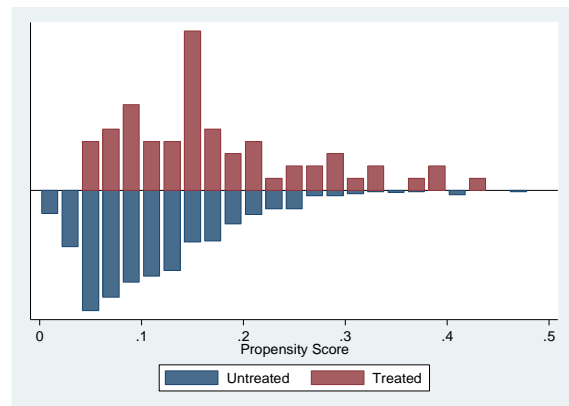
C. Participants and Non-participants in Project villages



B. Non-participants in JICA village vs. non-JICA villages



D. Participants and all other samples  
(non-participants in project villages and households in non-project villages)



**Appendix Figure. Distribution of propensity scores**

**Appendix Table 1. Results of Attrition Regression and Propensity Score for Participation in Training Program (Probit Model)**

	Attrition (rice was cultivated only in 2009)	Training participants vs. Control	Non-participants vs. Control
	(1)	(2)	(3)
Rice experience	-0.029** (0.012)	0.025 (0.015)	0.021 (0.016)
Head age	0.019*** (0.006)	-0.025*** (0.008)	-0.019* (0.011)
Head years of education	0.031 (0.058)	-0.173* (0.099)	-0.011 (0.067)
Head education squared	-0.003 (0.004)	0.011* (0.006)	-0.001 (0.005)
Number of HH members	-0.080*** (0.026)	0.004 (0.028)	-0.037 (0.032)
Share of male aged 15-64	-2.401*** (0.614)	0.015 (0.580)	-0.106 (0.622)
Share of female 15-64	0.762 (0.635)	-0.428 (1.191)	1.149** (0.492)
Size of land owned (ha)	0.031 (0.034)	0.029 (0.034)	0.038 (0.032)
Share of lowland owned	-0.113 (0.228)	-0.087 (0.333)	0.022 (0.291)
Local group membership	-0.131 (0.164)	0.509*** (0.144)	0.232 (0.225)
Ownership of bulls	-0.057 (0.161)	0.448 (0.369)	0.394* (0.212)
Constant	-0.659 (0.464)	-0.154 (0.636)	-0.423 (0.767)
No. of Observations	394	277	296

*Notes:* \*\*\*, \*\* and \* represent statistical significance at the 1, 5, and 10% levels, respectively. The figures are coefficients and those between parentheses are standard errors.

**Appendix Table 2. Balancing Test Results**

Panel 2009 and 2011	Partici-			Non-		
	pants	control	t-stats	partici-	control	t-stats
	pants			pants		
Rice experience years	11.38	10.53	0.87	10.24	10.43	0.83
HH head's age	40.42	41.10	0.38	40.72	42.58	0.13
Head's years of education	6.032	5.932	0.25	5.957	5.888	0.83
No. of HH members	8.191	8.51	0.85	8.222	7.617	0.06
Share of male aged 15-64	0.225	0.234	0.71	0.236	0.239	0.85
Share of female aged 15-64	0.241	0.234	0.58	0.254	0.268	0.22
Land owned (ha)	2.161	2.154	0.03	1.976	2.089	0.57
Share of lowland size	0.203	0.178	0.77	0.252	0.181	0.01
Local group member	0.730	0.700	0.65	0.617	0.608	0.83
Ownership of bulls	0.429	0.487	1.13	0.358	0.398	0.36

*Notes:* t-stats for the mean are different between two groups.

**Appendix Table 3. Baseline Characteristics of Non-Panel of Households (Who Grew Rice in 2009 but not in 2011 and/or 2015)**

	Participants in JICA training in 2009	(a) Non-program villages	(b) Non-participants in training	(c)
Rice experience in years	7.666 (11.55)	7.170 (9.213)	5.500 (4.950)	
HH head's age	42.67 (20.67)	45.30 (14.88)	45.00 (11.31)	
Head's years of education	5.667 (5.508)	5.596 (3.082)	1.500 (2.121)	
No. of HH members	7.000 (2.000)	7.404 (3.228)	* (2.828)	4.000
Share of male aged 15-64	0.225 (0.977)	0.199 (0.105)	* (0.118)	0.083
Share of female aged 15-64	0.266 (0.145)	0.247 (0.136)	0.333 (0.236)	
Size of land owned (ha)	1.990 (1.724)	1.885 (1.796)	1.214 (0.286)	
Share of lowland size owned	0.172 (0.299)	0.187 (0.317)	0.000 (0.000)	
Local group member	1.000 (0.000)	0.468 (0.504)	0.500 (0.707)	
Ownership of bulls	0.667 (0.577)	0.319 (0.471)	0.500 (0.707)	
No. of observations	3	47	2	

*Notes:* \* indicates mean difference between rice panel households for each treatment status (shown in table 1) at the 5% level based on the t-test. For example, \* in column (b) indicates that the mean characteristics of households in non-program villages between the rice panel and non-panel samples are statistically different.

**Appendix Table 4. Rice Yield and Cultivation Practices in 2009 of Non-Panel of Households (Grew Rice in 2009 but not in 2011 and/or 2015)**

	Participants in JICA training	(a) Non-program villages	(b) Non-participants in training	(c)
Broadcasting	0.000	0.596	1.000	
Transplanting in row	0.000	0.064	0.000	
Bunds	0.333	0.426	0.000	
Improved variety use	0.000	0.106	0.000	
Chemical fertilizer use	0.000	0.000	0.000	
Rice area size (ha)	0.236	0.522	0.253	
Number of rice plots	1.333	1.132	1.000	
Rice yield (ton/ha)	0.843	1.054	*	1.779
Rice income per ha	1.064	0.756		2.278
Rice produced (ton)	0.202	0.460	*	0.555
Rice revenue	0.059	0.090	*	0.216
No. of observations	3	47	2	

*Notes:* \* indicates mean difference with rice panel households (shown in table 2) at the 5% level based on the t-test.

**Appendix Table 5. Average Impact of Training (DID, Household Fixed Effects Model, with Inverse Probability Weight) with Other Controls**

	Trans-planting	Trans-planting in row	Bunds construction	Chemical fertilizer application	Yield (ton/ha)	Rice income per ha	Total rice production (ton)	Rice revenue per adult equivalent	Rice cultivation area (ha)
Participants x 2011	0.142** (0.070)	0.132* (0.072)	0.379*** (0.108)	0.169* (0.101)	0.421 (0.257)	-0.395 (0.335)	0.621*** (0.211)	0.119** (0.053)	0.265** (0.104)
Participants x 2015	0.200* (0.110)	0.201** (0.089)	0.385*** (0.120)	-0.067 (0.088)	0.553** (0.270)	0.469 (0.430)	0.119 (0.296)	-0.056 (0.078)	0.070 (0.139)
Year 2011	-0.010 (0.027)	0.008 (0.031)	0.147*** (0.048)	0.002 (0.021)	0.199* (0.117)	1.023*** (0.220)	-0.177 (0.148)	0.042 (0.031)	-0.207*** (0.071)
Year 2015	-0.034 (0.049)	-0.003 (0.062)	0.038 (0.070)	0.194*** (0.063)	-0.167 (0.156)	0.695** (0.323)	-0.066 (0.237)	0.112* (0.059)	-0.229 (0.144)
Head age	-0.004 (0.003)	0.007 (0.005)	-0.003 (0.004)	0.002 (0.006)	0.017 (0.015)	-0.009 (0.031)	0.037** (0.019)	0.010* (0.005)	0.026** (0.012)
Head's years of education	-0.005 (0.004)	0.002 (0.012)	0.030*** (0.009)	-0.005 (0.007)	-0.102*** (0.024)	-0.081 (0.053)	-0.032 (0.031)	-0.015* (0.008)	0.034 (0.029)
No. of HH members	-0.001 (0.006)	-0.008 (0.006)	-0.014* (0.007)	0.009 (0.009)	0.039* (0.020)	0.025 (0.034)	0.106** (0.041)	-0.011 (0.008)	0.030 (0.018)
Share of male aged 15-64	-0.363**	-0.166	0.283	0.354*	1.137*	0.482	0.453	-0.037	-0.382



	(0.166)	(0.207)	(0.240)	(0.182)	(0.607)	(1.032)	(0.604)	(0.166)	(0.311)
Share of female aged 15-64	-0.056	-0.108	-0.170	0.434**	1.263**	1.958*	1.076	0.113	0.023
	(0.136)	(0.158)	(0.228)	(0.173)	(0.614)	(1.014)	(0.859)	(0.198)	(0.319)
Size of land owned (ha)	0.004	0.024***	-0.008	-0.002	-0.002	0.029	0.062	0.016**	0.080
	(0.009)	(0.008)	(0.009)	(0.010)	(0.017)	(0.029)	(0.050)	(0.008)	(0.049)
Share of lowland size owned	0.020	-0.058	-0.100	-0.053	0.217	0.284	0.052	0.029	-0.116
	(0.055)	(0.059)	(0.079)	(0.056)	(0.182)	(0.292)	(0.211)	(0.054)	(0.125)
Constant	0.885***	-0.174	0.609***	-0.307	0.448	1.141	-1.742*	-0.112	-0.885
	(0.153)	(0.227)	(0.214)	(0.252)	(0.674)	(1.484)	(0.970)	(0.253)	(0.560)
Number of observations	700	700	700	700	673	650	690	690	700
R-squared	0.059	0.121	0.195	0.164	0.135	0.184	0.081	0.130	0.184
Number of HHID	277	277	277	277	277	275	277	277	277

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*Notes:* Figures between parentheses are standard errors. \*\*\*, \*\* and \* represent statistical significance at the 1, 5, and 10% levels, respectively. Propensity score weighting and attrition weights are used.

**Appendix Table 5. Spillover effects (DID, Household Fixed Effects Model, with Inverse Probability Weight) with Other Controls, cont.**

	Transplanting	Transplanting in	Bunds	Chemical	Yield	Rice income	Total rice	Rice revenue	Rice cultivation
		row	construction	fertilizer	(ton/ha)	per ha	production (ton)	per adult	area (ha)
				application				equivalent	
Non-participants x 2011	0.035	-0.011	-0.011	0.090*	-0.099	-0.389	0.486***	0.045	0.275***
	(0.066)	(0.027)	(0.080)	(0.049)	(0.237)	(0.302)	(0.155)	(0.049)	(0.081)
Non-participants x 2015	0.156**	0.021	0.071	0.060	0.058	0.411	0.308	0.001	0.181
	(0.063)	(0.042)	(0.079)	(0.081)	(0.241)	(0.296)	(0.211)	(0.048)	(0.114)
Year 2011	-0.016	0.019	0.185***	0.013	0.458***	0.878***	-0.074	0.078***	-0.138***
	(0.029)	(0.023)	(0.049)	(0.020)	(0.141)	(0.171)	(0.117)	(0.026)	(0.050)
Year 2015	-0.046	0.017	0.047	0.196***	0.713***	0.919***	0.051	0.119***	-0.165*
	(0.043)	(0.039)	(0.062)	(0.053)	(0.261)	(0.314)	(0.192)	(0.045)	(0.097)
Head age	-0.003	0.003	-0.010*	0.001	-0.041	-0.050	0.005	0.000	0.009*
	(0.002)	(0.002)	(0.005)	(0.004)	(0.025)	(0.032)	(0.013)	(0.004)	(0.005)
Head's years of education	-0.002	0.002	0.015	-0.007	-0.031	-0.081*	-0.017	-0.003	0.008
	(0.006)	(0.006)	(0.010)	(0.007)	(0.032)	(0.044)	(0.029)	(0.007)	(0.013)
No. of HH members	0.000	-0.003	0.002	-0.002	0.037	0.056*	0.074**	-0.017***	0.015
	(0.004)	(0.004)	(0.007)	(0.007)	(0.024)	(0.029)	(0.032)	(0.005)	(0.016)
Share of male aged 15-64	-0.172*	-0.084	0.250*	0.073	0.713*	0.001	0.204	0.002	-0.653***
	(0.101)	(0.075)	(0.150)	(0.118)	(0.368)	(0.641)	(0.330)	(0.107)	(0.213)
Share of female aged 15-64	0.195**	0.046	-0.174	0.252**	0.423	0.388	0.526	0.172	-0.240

	(0.079)	(0.062)	(0.139)	(0.126)	(0.404)	(0.687)	(0.362)	(0.110)	(0.196)
Size of land owned (ha)	-0.011	0.002	-0.011	-0.008	-0.056*	-0.006	0.085	0.020**	0.144***
	(0.010)	(0.005)	(0.012)	(0.013)	(0.030)	(0.033)	(0.057)	(0.008)	(0.040)
Share of lowland size owned	0.048	0.013	-0.042	-0.067	0.333*	0.306	0.117	-0.013	-0.050
	(0.060)	(0.034)	(0.071)	(0.053)	(0.193)	(0.231)	(0.167)	(0.038)	(0.092)
Constant	0.693***	-0.100	0.837***	-0.019	2.842**	3.188**	-0.168	0.234	0.038
	(0.106)	(0.095)	(0.209)	(0.174)	(1.163)	(1.582)	(0.649)	(0.169)	(0.262)
Number of observations	752	752	752	752	718	688	742	737	747
R-squared	0.039	0.025	0.090	0.168	0.121	0.199	0.063	0.135	0.265
Number of HHID	296	296	296	296	296	294	296	296	296

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*Notes:* Figures between parentheses are standard errors. \*\*\*, \*\* and \* represent statistical significance at the 1, 5, and 10% levels, respectively. Propensity score weighting and attrition weights are used.

**Appendix Table 6. Average Impact of Training (Pre-Screening DID, Household Fixed Effects Model)**

Panel A: Impact on	Transplanting	Transplanting	Bunds	Chemical	Yield	Rice income per ha	Total rice	Rice revenue per adult equivalent	Rice
Participants		in row	construction	fertilizer	(ton/ha)		production		cultivation
				application			(ton)		area (ha)
Participants x 2011	0.131*	0.203**	0.332***	0.145**	0.251	-0.089	0.689***	0.128**	0.331***
	(0.079)	(0.083)	(0.101)	(0.070)	(0.246)	(0.336)	(0.255)	(0.064)	(0.096)
Participants x 2015	0.223**	0.253***	0.396***	0.047	0.588**	0.485	0.295	-0.056	0.182*
	(0.087)	(0.091)	(0.106)	(0.090)	(0.278)	(0.360)	(0.333)	(0.090)	(0.110)
Year 2011	-0.014	0.026	0.117**	-0.000	0.338***	0.946***	0.058	0.072***	-0.092
	(0.031)	(0.023)	(0.052)	(0.021)	(0.120)	(0.172)	(0.128)	(0.023)	(0.059)
Year 2015	-0.044	0.042	-0.048	0.179***	0.063	0.661***	0.299	0.218***	-0.058
	(0.037)	(0.030)	(0.051)	(0.042)	(0.124)	(0.176)	(0.263)	(0.055)	(0.086)
Constant	0.576***	0.028**	0.537***	0.018	1.522***	1.200***	1.079***	0.174***	0.712***
	(0.016)	(0.012)	(0.023)	(0.014)	(0.049)	(0.069)	(0.070)	(0.015)	(0.030)
Number of obs.	464	464	464	464	443	420	458	458	464
R-squared	0.031	0.087	0.110	0.130	0.065	0.167	0.021	0.104	0.017
Number of HHID	179	179	179	179	179	177	179	179	179

*Notes:* Figures between parentheses are standard errors. \*\*\*, \*\* and \* represent statistical significance at the 1, 5, and 10% levels, respectively. Propensity score weighting and attrition weights are used.

**Appendix Table 6. Average Impact of Training (Pre-Screening DID, Household Fixed Effects Model), cont.**

Panel B: Spillover effects	Transplanting	Transplanting in row	Bunds construction	Chemical fertilizer application	Yield (ton/ha)	Rice income per ha	Total rice production (ton)	Rice revenue per adult equivalent	Rice cultivation area (ha)
Non-participants x 2011	0.041 (0.059)	-0.010 (0.025)	-0.048 (0.067)	0.055 (0.043)	-0.207 (0.183)	-0.378 (0.281)	0.427*** (0.140)	0.060 (0.041)	0.311*** (0.067)
Non-participants x 2015	0.152*** (0.051)	0.010 (0.052)	0.069 (0.062)	0.107 (0.081)	0.327 (0.208)	0.369 (0.308)	0.707*** (0.225)	0.039 (0.052)	0.190** (0.077)
Year 2011	-0.003 (0.027)	0.024 (0.019)	0.187*** (0.047)	0.005 (0.013)	0.461*** (0.116)	0.783*** (0.152)	0.011 (0.100)	0.065*** (0.020)	-0.097** (0.047)
Year 2015	-0.048 (0.032)	0.052** (0.023)	0.020 (0.046)	0.167*** (0.039)	0.442*** (0.136)	0.759*** (0.200)	0.015 (0.149)	0.113*** (0.029)	-0.062 (0.065)
Constant	0.555*** (0.013)	0.025*** (0.008)	0.516*** (0.018)	0.014 (0.011)	1.551*** (0.044)	1.294*** (0.071)	0.985*** (0.049)	0.169*** (0.009)	0.632*** (0.023)
Number of obs.	672	672	672	564	643	609	663	656	668
R-squared	0.018	0.021	0.059	0.150	0.090	0.164	0.029	0.083	0.023
Number of HHID	261	261	261	207	261	259	261	261	261

*Notes:* Figures between parentheses are standard errors. \*\*\*, \*\* and \* represent statistical significance at the 1, 5, and 10% levels, respectively. Propensity score weighting and attrition weights are used.

**Appendix Table 7. Pre-Project Yield Trend (Dependent Variable,  $\Delta\text{yield} = \text{yield 2008/9} - \text{yield 2007/8}$ )**

	Participants vs. Non-participants	
	control	vs. control
Participants	0.046 (0.079)	
Non-participants		0.166 (0.094)
Constant	0.175* (0.053)	0.152* (0.049)
Number of obs.	129	126
R-squared	0.003	0.034
Mean Yield (ton/ha) 2008		
Participants/		
Non-participants	1.078 (0.743)	1.075 (0.893)
Control	1.424 (0.806)	1.437 (0.794)

*Notes:* Robust standard errors between parentheses, \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Propensity score weighting and attrition weights are used.

## Abstract (in Japanese)

### 要約

本研究は、JICA が東部ウガンダにおいて実施した稲作技術研修プロジェクトの技術普及と生産性への影響を、2009、2011、2015年に収集したパネルデータを使用し検証している。対象のプロジェクトでは研修参加者が近隣の農家に習得した知識を広めることが推奨されていたため、プロジェクト実施村においては研修に参加しなかった農家も研修により恩恵を受けた可能性がある（スピルオーバー効果）。そこで、研修に参加した農家への影響のみならず、スピルオーバー効果があるかどうかも分析している。プロジェクト実施村の選択と研修に参加するかどうかの決定はランダムに割り振られなかったことにより生じうるバイアスを緩和するため、プロジェクトの効果は、差分の差分分析に傾向スコアウェイト法と家計固定効果モデルを合わせ推定している。研修参加者の稲作技術の普及率が短期・長期ともに高くなった。また研修参加者の1ヘクタールあたりの平均収量が0.47トン増加した。プロジェクト村の研修不参加農家の移植栽培法（Transplanting）の採用率は長期において高くなったが、彼らの稲作技術に関する知識と生産性の改善はみられなかった。また、不参加者の中で移植栽培法の採用が高くなったのは、研修で設置したデモンストレーション圃場に行ったことがある農家であることがわかった。

**キーワード：**農業技術研修プロジェクト、インパクト評価、サブサハラアフリカ

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