Table of Contents

Glossaries

ATT	Average Treatment Effect on the Treated
GRDP	Gross Regional Domestic Product
IDE	Institute of Developing Economies
JETRO	Japan External Trade Organization
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
KK	Kelara Karalloe
LATE	Local Average Treatment Effect
MDG	Millennium Development Goal
ODA	Official Development Assistance
PSM	Propensity Score Matching
RDD	Regression Discontinuity Design
SRI	System of Rice Intensification
SSIMP	Small Scale Irrigation Management Project
WUA	Water Users Association
WUAF	Water Users Association Federation

Authors

Kazushi TAKAHASHI

Associate Senior Research Fellow, Institute of Developing Economies, JETRO

Seiro ITO

Senior Research Fellow, Director of Development Strategies Studies Group, Institute of Developing Economies, JETRO

1. Introduction

1.1. Background

Virtually all Official Development Assistances (ODA) by developed countries have aimed at helping developing countries improve their socio-economic conditions. In recent years, international communities commonly and increasingly make stronger commitment to achieve the Millennium Development Goals (MDGs) through expanding the quantity of ODA as well as improving the quality of ODA. While it is generally expected that most ODA projects have contributed to such goals, it should be verified in a rigorous way. By rigor, we mean that any improvement in socio-economic conditions is solely attributable to the implementation of the project. Such credible impact evaluation may offer guidance to efficiently manage ODA and to formulate future project designs, not only for a donor country involved, but also for other donor countries and international organizations undertaking similar projects. In this sense, results of rigorous impact evaluation are global public goods which are beneficial beyond national and institutional borders.

Even though Japan International Cooperation Agency (JICA) has a long history in assisting developing countries through ODA, an application of quantitative and rigorous evaluation is still at its infant stage. Against such backgrounds, JICA and Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO) have agreed in 2009 to conduct project impact evaluation, using a small-scale irrigation scheme in Indonesia as a case. The overall objectives of this study are (1) to accumulate empirical micro-evidence on rigorous impacts of the JICA project, (2) to draw key lessons from such impact assessment for future JICA projects and (3) to provide Japanese experience and findings with external donor agencies.

1.2. Target Scheme and Terms of Reference

The project selected for this study is the Kelara Karalloe irrigation scheme (KK) in Jeneponto District, South Sulawesi Province of Indonesia, which is located on the south coast of South Sulawesi, with about 105 km to the south of the provincial capital, Makassar (Figure 1-1). KK was originally funded by Japan Bank for International Cooperation (JBIC)-an institution merged with JICA in 2008- and was implemented as a Small Scale Irrigation Management Project (SSIMP)-Phase III. The major objectives of SSIMP are to alleviate poverty and raise farmers' living standards through the improvement of irrigation facility. SSIMP have improved 103 irrigation facilities, including construction of new dams, rehabilitation of existing dams, and construction of groundwater wells, by 2007. Most SSIMP was managed by Nippon Koei Co., Ltd, as is the case in KK. KK was a rehabilitation scheme, which was launched in 1998 and ended in 2003 with the general untied loan of 18.8 billion Rp. The total irrigation area covers 7199 hectares with about 11000 households involved. There are 51 Water Users Associations (WUA) under 4 Water Users Association Federations (WUAF) within the scheme.

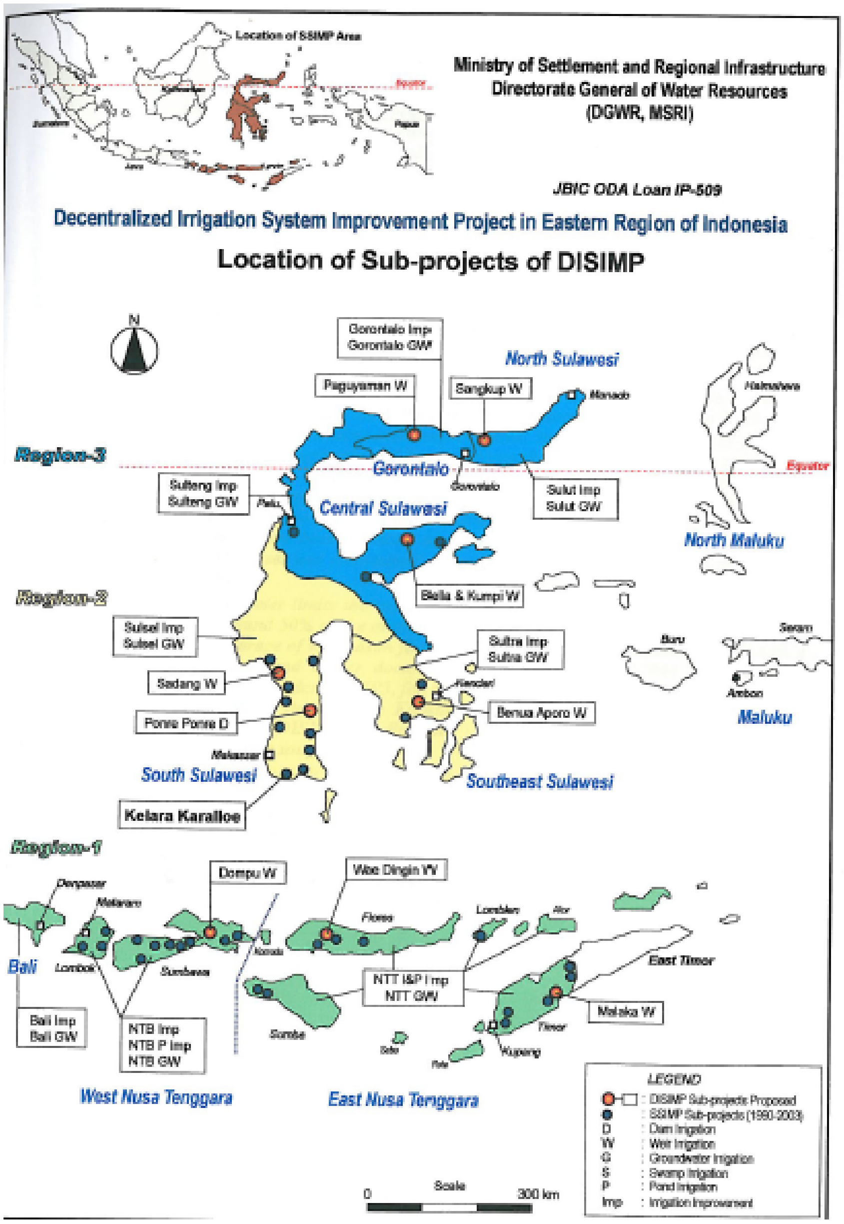

Figure 1-1. Location Map of Kelara Karalloe

Source: Nippon Koei (2007)

Along with the rehabilitation of irrigation facilities, the introduction and promotion of a rice-growing technology, called System of Rice Intensification (SRI), was undertaken in KK since 2002. SRI is a rice-growing technology developed in Madagascar in the mid 1980s and has been diffused in many countries since then. Although no uniform definition exists, the main elements of SRI are: (1) early transplanting of seedlings, 8-12 days old, (2) shallow planting (1–2 cm) of one or two seedlings, (3) parse planting in checkrows (more than 25 × 25 cm), and (4) intermittent irrigation (Alternate wetting and drying). While it is more labor-intensive than conventional practice, requiring more labor input for weeding due to (1) and (2), for transplanting due to (3) and for water management due to (4), it requires less water and other current inputs. Thus, SRI is said to be resource-saving and environmentally-friendly. In addition, it is said to be potentially high-yielding; rice yield per ha can be as high as 10 tons under favorable conditions.

As an attempt to examine the impact of irrigation under KK, the present authors conducted 390 household surveys in this area and undertaken preliminary project evaluation in 2007. The sample households consisted of 390 rice-growing farmers around KK, including 210 irrigation beneficiaries (30 upstream; 60 midstream; 120 downstream) and 180 non-beneficiaries.

Based on that experiment, the terms of references of the present study are to:

(1) construct 390 household-level panel data, by revisiting households interviewed in 2007;

(2) extend the number of sample households;

(3) deeply and robustly examine the impact of irrigation using information collected in (2) and (3);

(4) explore the impact of SRI adoption.

In these analyses, we will mainly use crop yield and agricultural incomes per hectare as outcome variables and compares them of those with/without irrigation and with/without SRI adopters. In addition, we briefly investigate who participates in SRI practice.

1.3. Organization of this Report

The rest of this report is organized as follows. In the next chapter, we will explain general characteristics of the target area and the sampling strategy of this study. In Chapter 3, we will investigate the impact of irrigation with panel data collected in 2007 and 2009, while, in Chapter 4, we will explore the impact of irrigation with cross-sectional data collected in 2009. Then, determinants and consequences of SRI adoption are explored in Chapter 5. Finally, we will summarize major findings of this report and draw some lessons in Chapter 6.

2. Characteristics of Target Area and Sampling Scheme

2.1. General Information of the Target Area

Jeneponto is one of the poorest districts in Indonesia. Per capita Gross Regional Domestic Product (GRDP) was about 3.1 million Rp in 2004, which was much lower than the provincial and national average. While the predominant source of income is agriculture, the annual rainfall is significantly few, ranging only from 1000 to 1500 mm in KK. This shortage of rainfall significantly prevents farmers from cultivating any crops in the dry season, unless irrigation water is available. Rainy season usually starts in December and ends in April next year. Major agricultural activity in the wet season is paddy production, which generally starts in around December and ends at around May. By contrast, dry season activities are more heterogeneous, depending critically on water availability. As shown in Figure 2-1, some farmers, who can get sufficient water, continue to cultivating paddy (green and green-shaded area), some, who can get access to limited water, cultivate palawija, such as maize (yellow and yellow-shaded area), and others, who cannot get access to sufficient water, leave arable land fallow (white area). According to estimates by Nippon Koei, about two-third of total KK area was left fallow in the dry season in 2007.

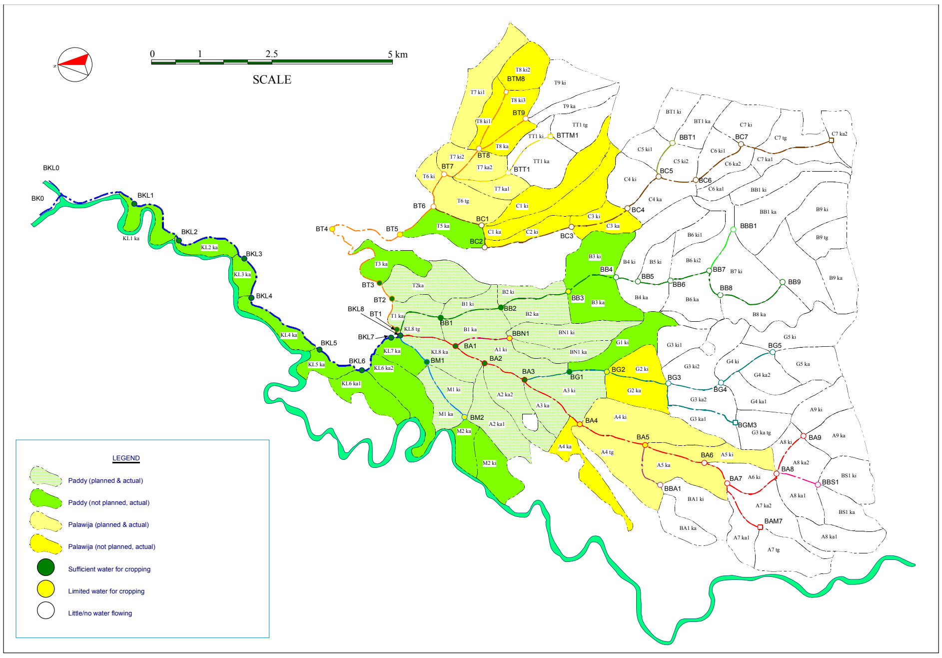

Figure 2-1. Cropping Map of the Typical Dry Season in KK

Source: Nippon Koei (2007)

The KK scheme is in hilly areas and most rice fields are terraced. Thus, size of each plot is quit small at around 0.4 ha. Given such water scarcity and limited land availability, it is not uncommon that farmers around the KK scheme migrate to Makassar in order to seek jobs in the dry season.

2.2. Sampling Strategy of the 2009 survey

In general, the population of our sample is actual cultivators, regardless of their tenancy statuses and water availability. Total sample size in 2009 is (a) 386 panel farmers, (b) 419 new farmers and (c) 98 new SRI adopters. To select these sample observations, we used different sampling strategies as will be described below.

(a) 386 Panel Farmers

The sampling method for panel farmers is simply to follow the 2007 survey. The framework of the 2007 survey is well explained in Ito and Takahashi (2008). In short, we have noticed in 2007 that there is an upland areas adjacent to the scheme boundary where neither canal-mediated nor pumped water is available, therefore is relying solely on rainfall. Thus, a discontinuity in terms of water availability and controllability exists in the wet season between beneficiaries and non-beneficiaries living around the boundary. Besides water availability, both areas seem to have the same soil and weather conditions, which were supported by soil maps provided by Nippon Koei. This observation lead us to think that the downstream area adjacent to non-beneficiaries can be the core treatment group, while non-beneficiaries serve as the control group of this survey and that we could use regression discontinuity design (RDD) to estimate the irrigation impacts in the wet season. Also, to obtain insights into how irrigation impacts are heterogeneous along the irrigation canal, we selected sample farmers from upper streams as well.

In reality, for the selection of sample beneficiaries, we took five steps as follows: (1) WUAF selection, (2) stratification according to the stream of irrigation canal, (3) WUA selection within each stream, (4) stratification by land size, and (5) random sampling of households. On the other hand, for the non-beneficiaries, we did sub-village selection and random sampling of households. Figure 2-2 illustrates outline of the sampling from in 2007 and Figure 2-3 presents a corresponding map of KK. We will describe details below.

For the beneficiaries, as a first step, we purposively selected three WUAFs as our target sample; that is Induk, Abadi, and Turbin, excluding Abulosibatang. Exclusion of Abulosibatang is partly because the cropping pattern of Abulosibatan resembles Abadi and partly because most rain-fed areas adjacent to Abulosibatang are under pump irrigation. We thought it better to exclude areas with pump irrigation because the policymakers would not consider investing on canal irrigation in the pump irrigated areas.

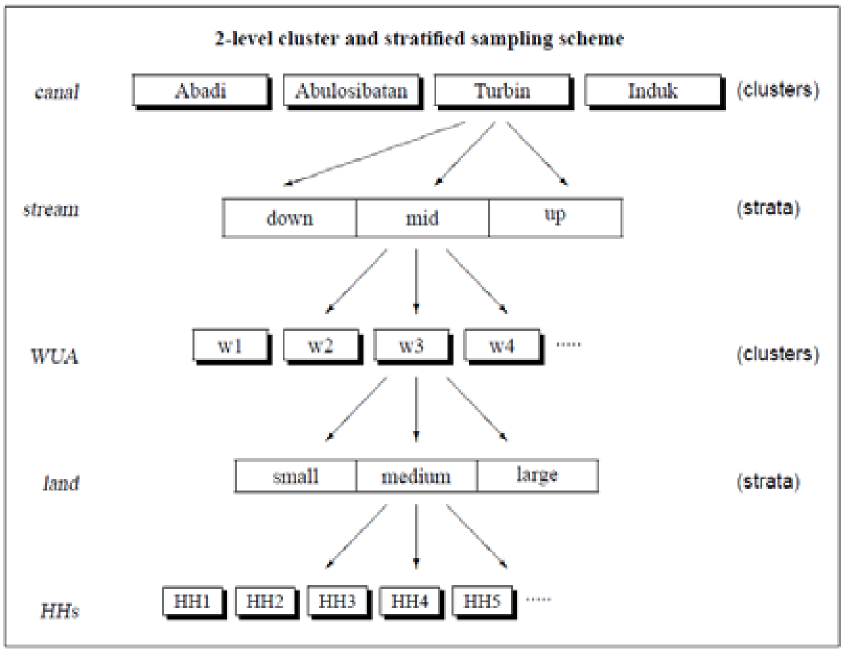

Figure 2-2. Sampling Structure in 2007

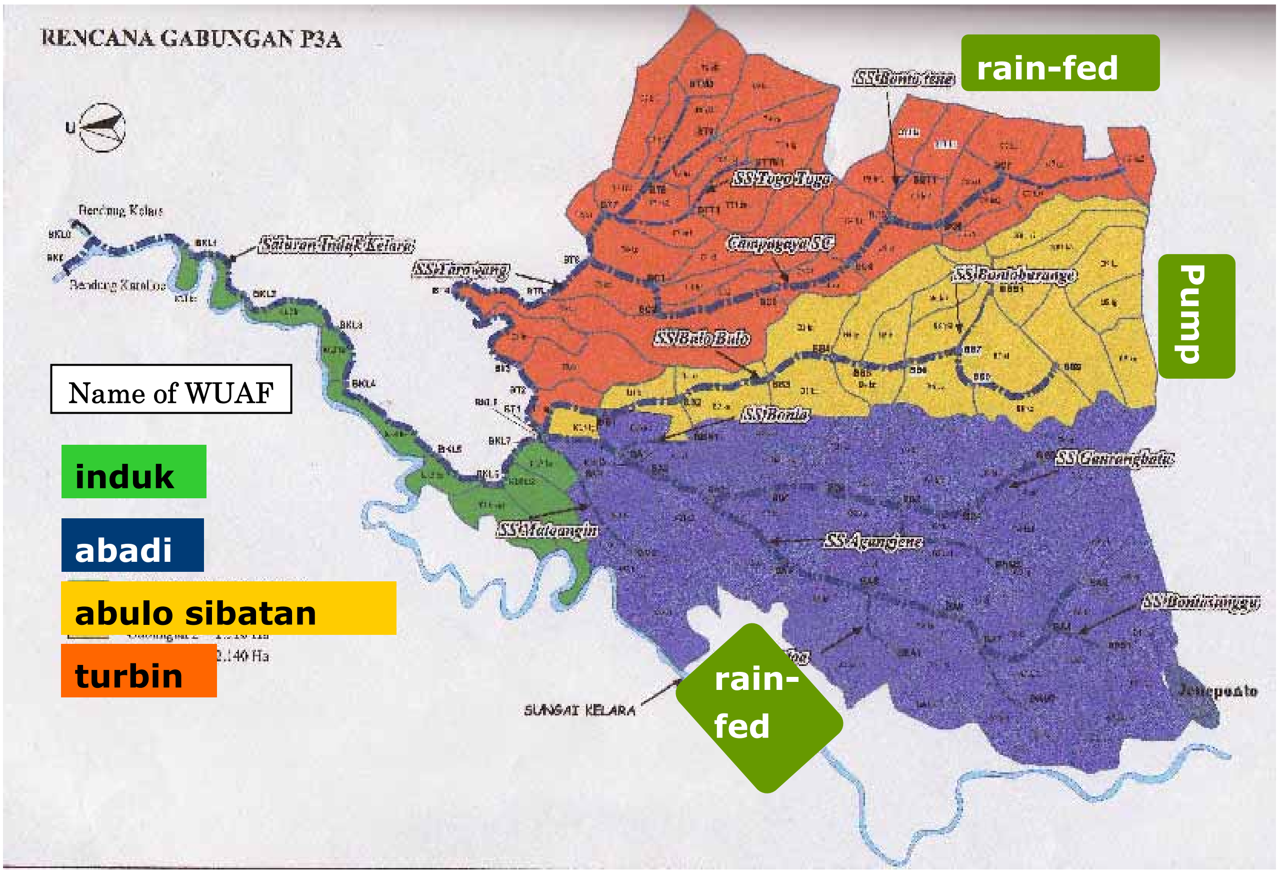

Figure 2-3. Map of KK

Then, in the second stage, we divided the selected WUAFs into strata according to the stream of irrigation canal, that is, upstream, midstream, and downstream, which is defined by the cumulative area under irrigation. Downstream is further divided into two; one for adjacent to non-beneficiaries and the other for the rest. Note that, as can be seen in Figure 2-1, upstream areas are mostly consistent with plots that can cultivate paddy in the dry season (green areas), midstream areas are mostly consistent with plots that can cultivate palawija in the dry season (yellow areas), and downstream areas are mostly plots left for fallow in the dry season (white areas).

In the third stage, then, we randomly selected WUAs across irrigation streams, with the ratio of upstream, midstream and downstream being 1, 2, and 4. Then, in the fourth stage, we classify the targeted farmers based on the landholding strata within each WUA. We did this land stratification in order to avoid accidentally unrepresentative sampling inherent in the pure random sampling method. Because the data on landholdings and land rental of all beneficiaries are available, we *a priori* know the distribution of cultivated areas. Using such information, we classify the land stratum into three; large (above 1 ha), medium (between 0.75 and 1 ha), and small (below 0.75 ha). The corresponding sampling ratios are determined to be 1, 1, and 3, respectively. Then, using a complete household list of all beneficiaries, we randomly selected the appropriate number of sample households from each land and WUA cluster.

In sampling the non-beneficiaries, we started from random selection of sub-villages (as opposed to WUAs for the beneficiary farmers) among all sub-villages nearby the boundary and next randomly draw households from each selected sub-villages. While we wished to employ land stratification as the fourth stage, we could not do so because data on landholding were not available for non-beneficiaries.

In this way, we collected information from 210 beneficiaries (30 upstream; 60 midstream; 120 downstream, of which 60 adjacent to non-beneficiaries and the other for the rest) and 180 non-beneficiaries in 2007. Although we attempted to maintain these households in 2009, 2 out of 210 beneficiaries and 2 out of 180 non-beneficiaries were dropped from the sample because the entire household members moved to other regions. Thus, we have 386 panel households for this study.

(b) 419 New Households

The above sampling framework provides a good estimation ground for Local Average Treatment Effect (LATE) through RDD especially in the wet season because there is a discontinuity in terms of water availability in the wet season between beneficiaries and non-beneficiaries living around the boundary. Estimation of LATE for the wet season is what was precisely done in Ito and Takahashi (2008) and, among others, we found that downstream farmers under the scheme do not sufficiently benefit from the irrigation water; that the difference in yield with adjacent rain-fed farmers (non-beneficiaries) is statistically insignificant; and that it is the midstream strata that have the highest yields, therefore benefiting most from the irrigation canal.

Although these findings are of importance to provide evidence on heterogeneity in irrigation impacts along the canal, we have recognized that this sampling strategy has shed only partial light on the impacts of the KK scheme. Needless to say, the significant impact of irrigation arises in the dry season as well, by differential crop choices and, thus, incomes/profits. Indeed, as Figure 2-1 shows, whether farmers cultivate paddy or palawija, or leave land fallow critically depends on water availability in the dry season.

In order to highlight the differential crop choices and resultant incomes/profits in the dry season nearby the boundary, we purposively select 7 WUAs in which (a) part of farmers cultivate paddy and the rest cultivate palawija in the dry season, and 4 WUAs in which (b) part of farmers cultivate palawija and the rest leave land fallow in the dry season. We expected that comparison between paddy and palawija plots close to each other within a same WUA would give credible identification of irrigation impacts of the LATE in the dry season, because the boundary that divides the two is constantly changing by seasons hence cannot be correlated with ability of plot owners. Meanwhile, we also expected that comparison between palawija and fallow plots located nearby should give another irrigation impacts at the margins.

To determine such WUAs, we conducted focus groups discussions for all WUAs in the KK scheme and draw cropping maps with water flows when respondents said that there is a boundary for crop choices within a WUA. Examples of the maps are shown in Figure 2-4 and 2-5 below.

In Figure 2-4, black arrow indicates water flow from the water intake within a WUA. As is clear, there is a discontinuity point by which land use pattern drastically changes due to different water availability; green area indicates land cultivated to paddy, and yellow area indicates land cultivated to palawija. Then, we selected sample plots nearby the boundary for both paddy and palawija. Figure 2-5 illustrates the actual sample plots. Note that the margins or boundary of paddy and palawija in the dry season somehow changes from Figure 2-4 to Figure 2-5, as Figure 2-4 is only based on the general information of participants in group discussion, not necessarily the farmers themselves. After the direct interview with farmers, we revise the map as in Figure 2-5 to draw more accurate line.

Having identified 7 WUAs, where some farmers plant paddy and same plant palawija, we basically interviewed 25 farmers who cultivate paddy (hereafter called “paddy” sample) and 25 farmers who cultivate palawija (hereafter called “palawija1” sample) on land nearby the boundary at each WUA. Because the sample size does not reach the target numbers in several

Figure 2-4. Example of Cropping and Water Flow Map

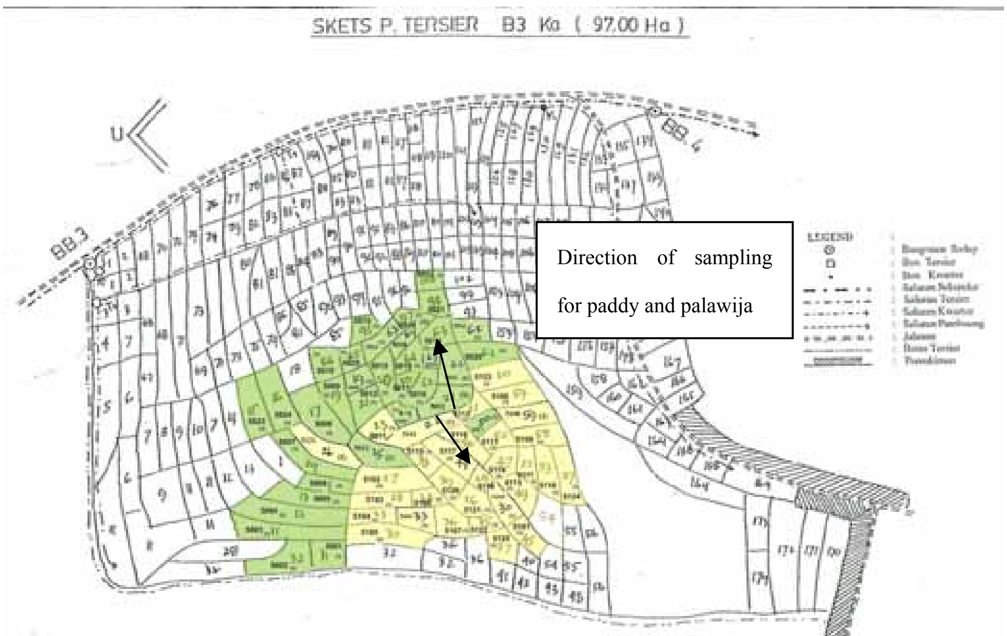

Figure 2-5. Example of Sampling New Households

WUAs (for example, there are only 20 farmers who cultivate palawija in a certain WUA), we have 71 paddy and 53 samples exactly on the boundary and 161 paddy and 160 palawija samples, including off but near the boundary, from 7 WUAs in total.

Similarly, we identified 4 WUAs in which part of farmers cultivate palawija and the rest leave land fallow, and then interview 39 farmers who cultivated palawija exactly on the boundary and 98 farmers, including off but near the boundary (hereafter called "palawija2" sample). These palawija2 samples are generally drawn from more downward along the irrigation canal than the paddy and palawija1 sample above. We did not interview farmers who leave land fallow, because their crop incomes in the dry season should be zero.

We expect that for the paddy sample, agricultural income in the dry season is higher for off boundary plots than on boundary plots because the former is located on more upward, while for the palawija1 sample, agricultural income is expected to be higher for the on boundary plots than off boundary plots due to the same reason. By contrast, for the palawija2 sample, we expect that off boundary plots generate higher income than on boundary plots because, in these blocks, off the boundary located on the more upward has better access to water. Using these sample farmers, we will later examine the impact of the KK scheme in the dry season, through the application of RDD, for paddy-palawija1 and palawija2-fallow samples.

(c) SRI Adopters

As described previously, SRI has been introduced in the KK scheme since 2002. Although it was informally reported that around 70% of farmers have adopted SRI in this area, our field survey revealed that this was overestimated. In fact, when we were in the project site for two weeks in 2009, it was quite difficult to meet SRI adopters. Thus, after we returned to Japan, we asked the staff of Pelangi – a nongovernmental organization (NGO) conducting main household surveys – to visit all influential leaders, such as WUAF leaders and WUA leaders, to list-up farmers who have adopted SRI in the previous seasons. This process came out with 112 potential new respondents, in addition to 27 panel households who have adopted SRI. However, during the direct visit to each farmer, it was found that some of them just started to apply SRI in the on-going season, i.e., out of our observation periods. Finally, we could get access to 98 new SRI adopters plus 27 panel households (hereafter called "SRI adopters" sample"), which, we believed, covered all SRI adopters in the KK scheme, at least in the last seasons.

Using these 125 SRI adopters (with 171 plots) as the treatment group, and the rest of non-adopters surveyed above as the control group, we will later examine the impact of SRI adoption on rice income and paddy yield, through the application of propensity score matching (PSM) method.

(d) Survey Schedule

Pre-survey was conducted by the present authors and the staff of Pelangi in November

2009 and the main household survey was conducted by Pelangi with instruction by the present authors from December 2009 to March 2010. Here are some pictures illustrating focus group discussion and main household surveys.

Figure 2-6. Pictures on Focus Group Discussion and Household Survey

2.3. General Characteristics of the Sample Plots

Before moving to each analysis in detail, it would be useful to examine general characteristics of the total sample plots and those by the sampling scheme, in order to obtain rough ideas on agricultural conditions around the KK scheme.

Table 2-1 shows the general characteristics of farming in the rainy and dry seasons, using the data in 2009.

As is clearly shown, the vast majority of farmers cultivated paddy in the rainy season, with only 2% choosing such palawija as maize and peanuts. This is consistent with our expectation because rice is a major staple crop in the survey area and farmers usually opt to grow paddy whenever water is available. Indeed, it is commonly said that rice-cultivation is rather a “norm” in this area, so that farmers prefer paddy, sometimes at the sacrifice of its profitability. Even so, the percentage of plots cultivated to paddy significantly declines to 25% in the dry seasons, in place of growing palawija and leaving land fallow. The percentage of plots cultivated to palawija and left fallow accounts for 35% and 41%, respectively. This may signify the importance of the availability of irrigation water in the choice of whether to cultivate or not and of which crops to be cultivated in the dry season. In fact, restricting the samples to plots cultivated to any crops, 79% of them are irrigated in the wet season, while the corresponding figure increases to 88% in the dry season. This also provides supporting evidence that unless plots are irrigated, farmers tend to leave land fallow in the dry season because stable water supply and agricultural production are difficult to expect.

Table 2-1. General Characteristics of the Sample Plots, 2009

	Rainy	Dry
Crop		
% Paddy	97.99	24.74
% Palawija	1.85	34.54
% Fallow	0.16	40.71
of those plots cultivated		
Area (ha)	0.45	0.45
% Irrgation	78.78	88.30
Ownership		
% Own	73.69	74.47
% Share	23.84	22.89
% Lease	0.69	0.66
% Others	1.77	1.97
No. Obs	1296	769

Turing to tenure statuses, the most paddy fields are managed by owner-cultivators, followed by share-tenants (called *Tesan*). In the share-tenancy contract, net output is generally divided by half and shared between a landowner and tenant. Even though cases are not so many, there are also leasehold and land pawning contracts (called *Ta'gala*). *Ta'gala* is a system where a pawner temporarily transfers his cultivation right to the pawnee in return for a loan and can redeem these rights upon loan repayment without any interest charge.

Table 2-2 shows crop income and crop yield per hectare in the wet season, by the sampling structure. We divide the total samples into those cultivated (1) by panel households, (2) by new households located in the mixture of paddy-palawija growing areas, (3) by new households located in the mixture of palawija-no cultivation areas, and (4) by new households adopting SRI.

Panel households are further divided into five categories according to the accessibility to irrigation as well as the stream of plots along the irrigation canal. We label the sample of new households as "paddy" if these new households grow paddy in the dry season and are selected from the mixture of paddy-palawija growing areas (i.e., from 7 tertiary block explained in the previous sub-section); "palawija1" if these new households grow palawija in the dry season and are selected from the mixture of paddy-palawija growing areas (i.e., from 7 tertiary block explained in the previous sub-section); and "palawija2" if these new households grow palawija in the dry season and are selected from the mixture of palawija-no cultivation areas (i.e., from 4 tertiary block explained in the previous sub-section). We present two different statistics for those new households. One is the average of plots cultivated by such new households, including on and off boundary, and the other is the average of targeted plots cultivated on boundary by those new households. The latter includes only plots near the boundary, excluding those a bit from it.

Table 2-2. Income and Yield per Hectare in the Wet Season 2009, by Sampling Frame and Crop

	Paddy Production			Palawija		
	income/ha (000Rp)	yield	obs plot	income/ha (000Rp)	yield	obs plot
Panel Household						
Upstream	4820.38	4.53	37			
Midstream	1697.12	2.96	89			
Downstream1	1295.95	2.46	83			
Downstream2	955.18	1.86	82			
Non-Irrigated	-110.03	1.77	311			
New Hourhold						
Paddy	4697.98	4.24	161			
Palawija1	4732.85	3.73	160			
Palawija2	3522.64	3.60	98			
of which on boundary						
Paddy	5127.49	4.69	71			
Palawija1	4662.53	4.00	52			
Palawija2	3690.77	3.69	39			
SRI Household	6309.07	5.12	203			
of which adopted	6661.47	5.47	171			
Sample Mean	3138.59	3.28	1267	3206.86	2.52	25

Note Drop 4 obs which have extream values

Here, crop income is defined as the total output values (quantity * price of output) minus the total input values (quantity * price of input) of crop production. In this computation, we did not include imputed family labor and owned machinery/ draft-animal costs because they are not actually paid-out. In other words, we calculate "income" rather than "profit (which subtracts input values of owned resources from income) ".

According to the upper part of Table 2-2, the average crop income and yield of rice production significantly drop from upper to lower streams. For example, the average rice income per hectare is about Rp. 4.8 million (which is equivalent to US$ 510 as of December 2009) in the upstream, Rp. 1.7 million in the midstream, and Rp 0.95 to 1.3 million in the downstream (downstream 1 is randomly selected from the downstream areas, while downstream2 is adjacent to non-irrigated areas). This trend holds true for yield, too. Somewhat surprisingly, the average rice income of non-irrigated areas is negative. This is presumably because there was only moderate rainfall in the observation year, so that many farmers suffered from crop loss even in the wet season.

According to the middle part of Table 2-2, "paddy" and "palawija1" samples show much higher rice incomes than panel households on average. This seems to be natural because most of these new households are located in up to midstream with irrigation water. Also, consistent with our expectation, there is a significant difference between "palawija1" and "palawija2" samples especially in terms of rice income because "palawija2" are located in more downward. Importantly, our t-test on the mean revealed that there is no statistical difference in rice income in the wet season between "paddy" and "palawija1" samples. This would verify that, even though these sample households choose different crops in the dry season, they are similar in most characteristics affecting rice income, if water controllability is similar. To further check, we restrict the new sample to those on the boundary, which represent the sample plots of RDD in the strict sense. Again, we failed to reject the null hypothesis that rice income of "paddy" and "palawija1" plots are statistically not different at the conventional acceptance level (absolute t-statistics on the mean difference is 0.574).

The bottom part of Table 2-2 shows the average rice income and yield of SRI households. The first glance at the table establishes that there are marked differences in both income and yield from the overall mean. This is interesting given that many academic studies failed to show significant impact of SRI adoption. Thus, whether this holds true even controlling for relevant characteristics is one of the important issues to be addressed in this report later.

Finally, we would like to briefly examine the average differences between paddy and palawija productions in the wet season. As shown previously, since only 1.9% of plots (25 plots out of 1292 plots) are planted to palawija in the wet season, the sample size for palawija might be too small to discuss any conclusive argument. Yet, it seems still important to note that the average crop income is slightly greater for palawija than paddy, even though such difference is not statistically significant. This could be another supporting evidence that rice-cultivation is rather a "norm" in this area, so that farmers prefer paddy, sometimes at the sacrifice of its profitability.

3. The Impact of Irrigation Water- Wet Season by Panel Analysis

3.1. Introduction

In this chapter, we will examine the impact of irrigation water with the data collected in 2007 and 2009. The major objective of this chapter is to check the robustness of findings reported by Ito and Takahashi (2008). Among others, Ito and Takahashi (2008) demonstrate that downstream farmers under the KK scheme do not sufficiently benefit from the irrigation water and the difference in yield with adjacent rain-fed farmers is statistically insignificant.

One of the major advantages of the use of panel data is that they can control for time fluctuation of outputs. As is well known, agriculture is vulnerable to weather shocks, and output variables considerably differ year by year. By using the panel data and including a "year dummy" in the regression analysis, we can obtain more reliable parameters that reflect the average marginal impacts of each independent variable on outcomes over time, with any time fluctuations of outcome being captured by the year dummy. Another advantage of the use of panel data is that we can effectively control for the impacts of time-invariant unobservables, which tends to bias the estimation results. By using fixed effects, such as at the household and plot levels, any systematic differences in outcomes across households and plots resulting from unobservable and time-invariant characteristics can be eliminated.

While this fixed-effect estimation is powerful and quite credible, we would not use it in the main analyses. This is because our most interested variable on the accessibility of irrigation, captured by a set of stream dummies, does not change over time. Thus, if we include fixed-effects, those fixed-effects reflect all time-invariant impacts on outcomes and we cannot differentiate it with the exact impact of irrigation.

Since the estimation in this chapter could be considered as an example of RDD, we briefly explain its concept in the next section and present descriptive statistics and estimation results in the following sections.

3.2. Regression Discontinuity Design and Estimation Strategy

(a) Regression Discontinuity Design

Essentially, any rigorous impact evaluation has to answer "How are the lives of the participants different relative to how they would have been had the program, product, service, or policy not been implemented?" This requires the comparison of two potential outcomes, such as income, business profits, or physical and human capital investment, of the same individual, i.e., one with the treatment and the other without it. Yet, since we can never observe both statuses for a particular individual simultaneously, a major challenge for impact evaluation is to create a good counterfactual that can mirror unobservable status through the use of appropriate techniques under a set of acceptable assumptions.

RDD is an idea that individuals around some critical cut-off point for project eligibility are similar. For example, suppose that irrigation project targets individuals with less than one hectare of land and that those just above one hectare of land are ineligible to be irrigated. Since this eligibility criterion is exogenously determined by project donors, it would be reasonable to assume that both observable and unobservable characteristics of households/plots are uncorrelated with eligibility. In contrast, the probability of being irrigated as well as outcomes of just below and above the cut-off point would be quite different due to eligibility. Based on these assumptions, the regression discontinuity design compares outcomes of plots just below the cut-off point for eligibility with those just above the cut-off point for it.

Formally, let c denote some cut-off point on certain variable C, which governs the program eligibility and $d = 1$ if $C > c$ and 0 otherwise. If this rule is deterministic (sharp regression discontinuity), the impact estimator can be written by $E(y_1 | c \le C < c + e) - E(y_0 | c - e \le C < c)$ for small e.

On the other hand, if the eligibility condition $C > c$ is enforced with error (fuzzy regression discontinuity), we must scale-up the differences, by dividing the difference in the probability of treatment:

$$\beta = \frac{E(y_i | c_i \le C < c_i + e) - E(y_i | c_i - e \le C < c_i)}{E(d_i | c_i \le C < c_i + e)) - E(d_i | c_i - e \le C < c_i)}.$$

This is equivalent to the Wald estimate using a dummy for $C > c$ as an instrument for treatment status. Therefore, this assesses the mean impact on the selected subpopulation around the cut-off point rather than the mean impact on the population as a whole.

(b) Estimation Strategy

Our estimation strategies here follow the spirit of RDD. In the 2007 survey, we found that there is an upland area adjacent to the KK scheme boundary where neither canal-mediated nor pumped water is available, therefore is relying solely on rainfall. Thus, a discontinuity in terms of water availability and controllability exists in the wet season between beneficiaries and non-beneficiaries living around the boundary. We treat these non-beneficiaries living around the boundary as a control group. On the other hand, in stead of just focusing on beneficiaries near the boundary, we consider the treatment group more broadly as all beneficiaries, in order to explore heterogeneous impacts of irrigation along the canal.

To express it more formally, our regression equation can be written as:

$$y_{iht} = H_{ht}\gamma + X_{iht}\beta + \alpha D_i + \tau T_t + e_{iht},$$

where y_{iht} represents outcomes of interest, such as yield and agricultural incomes per hectare; H_{ht} denotes a vector of household characteristics; X_{iht} is a vector of farm characteristics; D_i is a set of stream dummies along irrigation canal; T_t is the year dummy equal to 1 if the observation year is 2007 and 0 otherwise; and e_{iht} is an error term. Subscripts i, h, and t denote plot, household and time, respectively, while γ, β, α, and τ are parameters to be estimated.

(c) Data and Variable Selections

Data used in this analysis are derived from the 2007 and 2009 survey. We only use the wet season data because, by construction, we expect a discontinuity in water availability in that season. As explanatory variables, we select the followings that potentially affect outcomes.

The first group consists of a set of stream dummies, i.e., upstream, midstream, downstream1, and downstream2, which are equal to 1 plots are located in the respective stream (the reference category is non-irrigated) and 0 otherwise. Downstream1 corresponds to the sample plots randomly selected from downstream areas, and downstream2 corresponds to the sample adjacent to the control group.

The second group consists of farm characteristics: (1) size of land (ha), (2) a set of tenure status dummies, i.e., owner-cultivator and leaseholders, which are equal to 1 if the plot is cutivated by landowner or leaseholder, respectively (the reference group is a share-tenant or pawnee-cultivator), and 0 otherwise, and (3) distance (meter) from irrigation intake to plot.

The third group consists of household characteristics: (1) a gender dummy for household head (1 if household head is male and 0 otherwise), (2) household head's age, (3) household size, (4) the proportion of working members defined as aged 15 years old or over and currently not in school at the time of survey, and (5) the proportions of working members whose completed education are primary school, secondary school, and tertiary school levels, respectively (the reference group is the proportion of working members with no education).

Finally, we include the year dummy as an additional regressor to difference out fluctuations over time.

3.3. Summary Statistics

The summary statistics of all variables in the regression analysis is presented in Table 3-1. Rice income per ha is deflated by the consumer price index (the base year is 2009) to convert it into the real term.

Table 3-1. Summary Statistics

	2007		2009	
	mean	s.d	mean	s.d
Rice yield	3.91	3.06	2.22	2.68
Rice icome per ha (000 Rp)	2696.63	7079.36	803.69	4947.14
Female_head	0.05	0.22	0.07	0.25
Age of head	47.94	12.13	49.61	12.86
Household size	5.26	1.82	5.37	1.97
Prop. working Mmembers	0.78	0.20	0.73	0.22
of which				
Prop. primary school	0.31	0.30	0.29	0.29
Prop. secondary school	0.43	0.31	0.46	0.32
Prop. tertiary school	0.05	0.14	0.10	0.22
Area of land (ha)	0.44	0.41	0.48	0.46
Owner	0.67	0.47	0.74	0.44
Leaseholder	0.02	0.14	0.00	0.07
Distance from intake	55.91	195.96	55.87	193.28
Upstream	0.07	0.25	0.06	0.24
Midstream	0.14	0.35	0.15	0.36
Downstream1	0.12	0.32	0.14	0.35
Downstream2	0.12	0.33	0.14	0.34
Number of plots	586		602	

It is important to observe that both rice yield and real rice income notably decline from 2007 to 2009. This is, as explained previously, due mainly to moderate rainfall in 2009, which cause many farmers to experience crop loss.

Since this table is constructed from the panel data, other household and farm characteristics do not significantly change over time. The average age of head is about 48 years old in 2007 and increases to 50 years old after two years. Household size is around 5.3 in both years. The average land size is slightly enlarged over time, with the higher proportion of plots cultivated by landowners in 2009. The proportion of working members with higher education also slightly increases over time due presumably to the increased enrollment of children in higher school.

3.4. Estimation Results

The estimation results on yield and rice income per ha are provided in Table 3-2. In both tables, Column (1) and (5) shows the results estimated by OLS, which show the mean impact of coefficients on outcomes, and Columns (2)-(4) and (6)-(8) show the results for 25%, 50%, and 75% quantile, respectively, estimated by the quantile regression, which show the impact of coefficients on outcomes at the different productivity quantile. All the estimates on stream strata dummies show the differences in yields and incomes with respect to rain-fed upland of KK (the control group).

Table 3-2. The Impacts of Irrigation on Yield and Rice Income per Ha, 2007-2009

	Yield				Rice Income per Ha			
	OLS	Quantile			OLS	Quantile		
	mean	25%	50%	75%	mean	25%	50%	75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Upstream (=1)	1.453***	1.978***	1.825***	1.536***	2,619.798***	2,811.435***	3,739.803***	3,667.597***
	[4.12]	[5.79]	[5.25]	[3.82]	[3.48]	[3.30]	[5.68]	[4.80]
Midstream (=1)	0.984***	0.926***	1.244***	0.935***	978.341*	937.876***	1,402.800***	1,490.830**
	[3.85]	[4.39]	[4.99]	[2.81]	[1.80]	[3.57]	[4.03]	[2.37]
Downstream1 (=1)	0.582**	0.199	0.644**	0.668*	887.207	470.283*	833.051*	2,429.644***
	[2.15]	[1.22]	[2.24]	[1.80]	[1.54]	[1.68]	[1.66]	[2.86]
Downstream2 (=1)	0.24	0.069	0.209	0.532	-97.018	20.169	50.864	628.803
	[0.88]	[0.52]	[0.61]	[1.07]	[0.17]	[0.10]	[0.18]	[1.46]
Land size (ha)	-1.376***	-0.278	-0.841***	-1.665***	-342.434	524.018***	-273.157	-1,023.254***
	[6.96]	[1.64]	[4.32]	[7.86]	[0.81]	[3.03]	[1.29]	[2.88]
Own (=1)	-0.441**	-0.154	-0.388*	-0.132	1,705.872***	-13.191	842.426***	2,547.940***
	[2.30]	[1.57]	[1.67]	[0.53]	[4.17]	[0.09]	[5.30]	[4.62]
Lease (=1)	-0.356	-0.451	-0.299	0.155	-8,513.933***	-9,195.035***	-6,469.037**	-2,936.72
	[0.45]	[0.58]	[0.20]	[0.09]	[5.09]	[2.67]	[2.14]	[1.17]
Distance from intake along canal	0.000	0.000	0.000	0.000	0.307	-0.477	0.477	-0.081
	[0.33]	[0.02]	[0.23]	[0.85]	[0.26]	[0.69]	[0.52]	[0.09]
Female_head (=1)	0.128	-0.12	1.446**	-0.151	-1,475.902*	-1,032.136***	-205.209	-185.441
	[0.36]	[0.25]	[2.28]	[0.38]	[1.95]	[2.63]	[0.27]	[0.20]
Age of head	-0.016**	-0.005	-0.013*	-0.012	-31.235**	-15.864***	-11.489	-0.838
	[2.33]	[1.06]	[1.87]	[1.18]	[2.14]	[3.82]	[1.55]	[0.05]
Household size	0.002	0.011	-0.062	0.017	17.577	49.751*	46.261	-33.514
	[0.04]	[0.44]	[1.28]	[0.22]	[0.18]	[1.90]	[0.82]	[0.42]
Proportion of working members	-0.155	0.022	-0.844*	0.395	-874.741	262.414	-576.47	-1,230.06
	[0.37]	[0.10]	[1.80]	[0.81]	[0.99]	[0.91]	[1.02]	[1.43]
with primary education	1.609***	0.239	0.827**	2.307***	2,405.280***	17.294	1,080.240***	2,533.150***
	[4.21]	[0.94]	[2.55]	[4.10]	[2.95]	[0.04]	[2.61]	[3.01]
with secondary education	2.011***	0.506	1.436***	2.762***	3,323.863***	336.667	1,576.513***	3,005.792***
	[5.68]	[1.48]	[3.54]	[6.26]	[4.40]	[0.80]	[4.22]	[3.25]
with tertiary education	2.667***	0.460	2.361***	3.476***	2,935.389***	270.12	2,428.946***	3,820.169***
	[5.14]	[1.26]	[3.71]	[3.59]	[2.65]	[0.44]	[2.62]	[3.64]
Year 2007 (=1)	1.791***	1.475***	2.038***	1.692***	2,385.064***	1,467.112***	1,677.094***	1,702.841***
	[10.69]	[9.21]	[10.02]	[5.70]	[6.67]	[7.85]	[10.76]	[6.32]
Constant	2.085***	0.092	2.094***	2.053**	-1,057.16	-1,992.497***	-1,398.322**	-332.103
	[3.48]	[0.22]	[3.33]	[2.31]	[0.83]	[4.84]	[2.46]	[0.39]
Observations	1156		1156		1156		1156	
R-squared	0.17				0.1			

Absolute value of t statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

(a) Stream Dummies

According to Column (1), most stream strata dummies are positively and significantly related with yield, holding other characteristics constant. Their magnitudes are consistent with our expectation in that the upstream plots benefit most from irrigation, followed by the midstream and then by the downstream. As is found in the cross-sectional data in 2007 (Ito and Takahashi, 2008), we again fail to find any significant impact of irrigation on the downstream plots adjacent to the boundary, indicating that there is statistically no difference in yield among plots nearby the boundary. The Quantile regression in Columns (2)-(4) show that 25% quantile and 50% quantile plots located in the upstream have larger magnitudes than 75% quantile plots, suggesting that lower productivity lands benefit more from irrigation when compared to their rain-fed counterparts, if they are in the upstream, which is also found in Ito and Takahashi (2008). This trend, however, does not hold true for other stream plots. In the midstream, for example, the coefficients are positive and significant, regardless of quantile, but the magnitude is largest in 50% quantile plots. In the downstream1, only 50% and 75% quantile plots have a statistically significant and positive impact on yield compared with non-irrigated counterparts, suggesting that the low-productivity households in the lower-downstream area do not sufficiently benefit from the scheme.

Tuning to Columns (5)-(8), we can see qualitatively rather similar results with those on yield: the upstream plots have significantly positive and largest income gains compared with the rain-fed upland of KK (the control group), followed by the midstream plots. Again, we do not see any positive impact on the downstream plots adjacent to the boundary. These robust findings suggest that it is the upstream and midstream plots that benefit more from irrigation and that the use and control of water of downstream plots adjacent to the boundary is inadequate, despite being classified as irrigation beneficiaries.

(b) Plot Characteristics

Turning to the impact of plot characteristics on yield, it is found that the land size is negatively correlated with yield on average (Column (1)), and more so for high productivity plots, such as 50% and 75% quantile (Columns (3) and (4)). Somewhat surprisingly, the average yield of owner-cultivators is statistically smaller than share-tenants/pawnee-cultivators. Yet, once focusing on rice income, owner-cultivator generates significantly more income than share-tenants/pawnee-cultivators on average (Column (5)), and more significantly so for high productivity plots, such as 50% and 75% quantile (Columns (7) and (8)). On the other hand, while the average yield of leaseholders are comparable to that of share-tenants/pawnee-cultivators (Column (1)), there is a significant gap in rice income in favor of share-tenants/pawnee-cultivators especially for low-productivity plots (Column (5)-(7)).

(c) Household Characteristics

Among household characteristics, Female-head household generally have less rice income than male-head household. Columns (1) and (4) illustrate that the age of head is negatively correlated with both yield and rice income. It is important to note that the proportion of educated working members have highly significant effects on both yield and rice income: as working members are more educated, yield and rice income become larger. This would indicate the use of more advanced technologies by these households endowed with education, but more detailed inspection of additional data should be warranted. Household size has virtually no significant impacts.

(d) Year Dummy

Finally, the year dummy, which is equal to 1 if the survey year is 2007, is consistently positive and significant across all specifications, indicating that 2009 is really a bad year causing many farmers to experience crop loss.

3.5. Summary of Major Findings and Discussion

In this chapter, we revisit the question on whether the KK irrigation scheme has a positive impact on agriculture in this district, by expanding the data period to 2009. Following the previous study (Ito and Takahashi, 2008), we estimate LATE of irrigation impacts by the use of stream strata dummies.

Our regression results indicate that upstream and midstream plots benefit most from the irrigation scheme and that there are no significant differences in terms of yield and rice income between the downstream irrigated plots and non-irrigated plots near the boundary. It is also found that yield increments are significant among high productivity plots in the downstream a bit far from the boundary (downstream1), but insignificant among low productivity plots in the same area. This in turn implies water allocation within the stratum, in addition to being at the end of canal, may not be favorable to low-productivity plots. Taken together, we may conclude that, although the KK scheme successfully improves productivity and incomes of farmers, such benefits are not distributed equally: in particular, it is the low-productivity households in the lower-downstream area who fail to benefit from the scheme, despite their being classified as the beneficiary households on the irrigation scheme map. Since the low-productivity households in the lower-downstream area is most poor, more equitable water distribution should be facilitated in the light of its stated goal of SSIMP to alleviate poverty.

4. The Impact of Irrigation Water-Dry Season

4.1. Introduction

In this chapter, we will explore the impact of irrigation water on the dry season cropping in 2009 through another trial of RDD. The objective of this chapter is to understand how irrigation water affects farmers' behavior and welfare, by differential crop choices and their resultant incomes.

As noted in Chapter 2, we have two groups for this study. Group 1 is taken from WUAs that grow both paddy (the paddy sample) and palawija (the palawija1 sample). Since there are two different crops, there must exist a boundary between the two. We have sampled from this group to understand the marginal difference between growing paddy and palawija by looking at paddy and palawija plots that are on the boundary. To get better representation of each WUAs, we also sampled from off boundary plots both for paddy and palawija. Group 2 is taken from WUAs that have palawija plots (the palawija2 sample) and fallow plots. This group also shows the marginal difference between palawija and fallow. By definition, if we sample from the boundary of palawija and fallow plots, we can get the local impact of having water available for palawija because agricultural income, which is a major outcome of our interests, should be zero for these fallow plots.

Note that, unlike the previous and subsequent chapter, which examine yield differences of paddy by irrigation accessibility and SRI adoption, this chapter does not in principal compare yield differences by samples, i.e., paddy-palawija1 and palawija2 and fallow plots, because we believe that such comparison, based on different crops, is not so meaningful. Instead, in order to gain additional insights into the irrigation impact in the dry season, we have computed revenues, by multiplying the quantity of output with its sales price. Additionally, we have attempted to compute profits, deducting imputed costs of own resources used in cultivation from incomes, such as family labor and owned machinery. This is a bit formidable task because family resource and hired resource is not generally perfectly substitutable, especially for labor, so that unobservable costs of family labor are very difficult to estimate. Yet, we have tried to compute the average daily wage of hired labor by gender and then multiply them with family labor inputs by gender to get the imputed costs of family labor.

4.2. Overview of Productivity, Profitability, and Risks

In Figure 4-1, we have plotted per hectare revenue from crop production for paddy, palawija1, and palawija2, to overview the distribution of revenues by the sample groups. The horizontal axis is the per hectare revenues (10,000 Rp), while the vertical axis is the cumulative probability. As explained, palawija1 is obtained from Group 1 WUAs where they produce both paddy and palawija. Palawija2 is obtained from Group 2 WUAs where we observe both palawija and fallow. As can be seen from Figure 4-1, paddy distribution plots become rightmost only in the limited support, which indicates that paddy is generally least productive among all crops/samples. It can be also seen that there are subtle differences between palawija1 and palawija2; the former seems to have slightly narrower support than the latter, but is difference is not so significant.

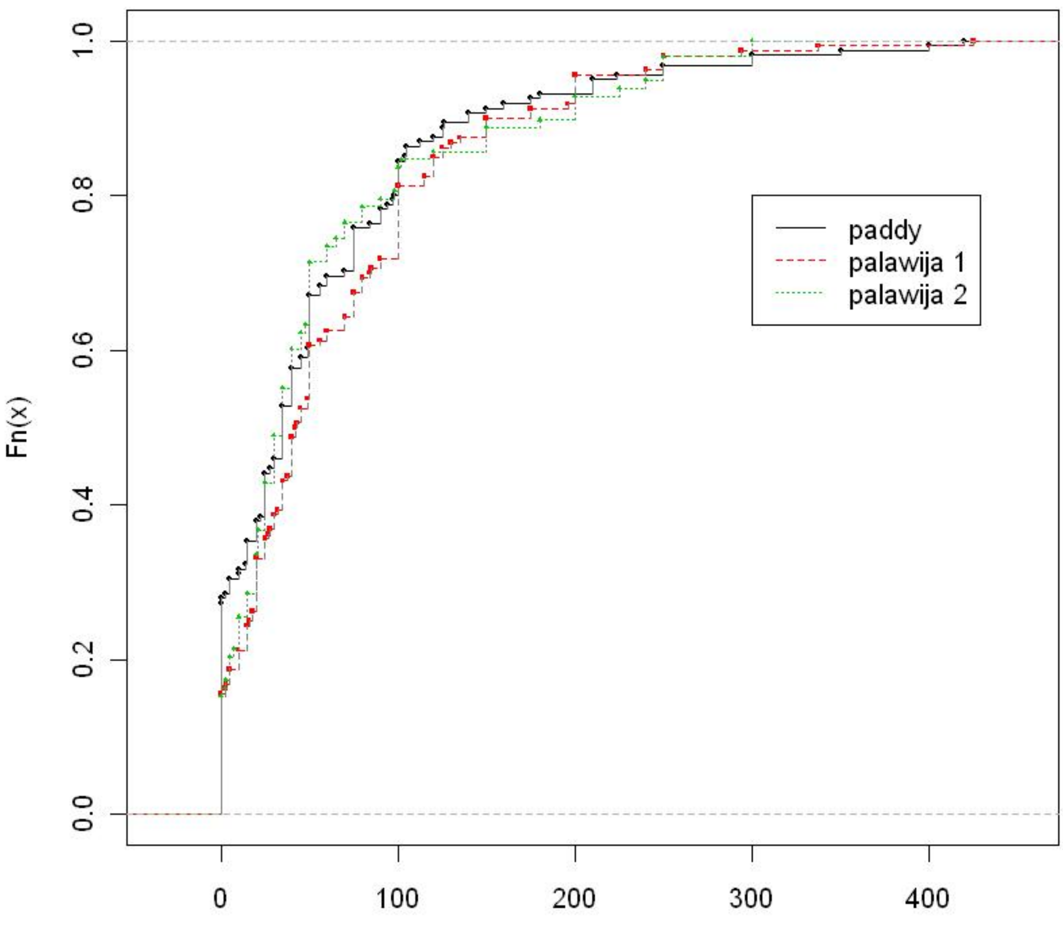

Figure 4-1. Cumulative Distribution of Per Ha Revenue by Irrigation Group

Figures 4-2 and 4-3 plot the incomes and profits, respectively. Again, collectively palawija outperforms the paddy in both outcomes. The gap between two palawijas, i.e., palawija1 and palawija2, seems to be small and two are almost identical with each other. Together with the previous result, this may show that palawija is more resistant to droughts, in which our observation year in 2009 experienced, and small changes in water availability may not affect the profitability. In Table 4-1, we tabulate the zero yield risks and crop choice. Among 321 plots that we sampled in Group 1, 50% choose paddy. Among the paddy plots, over 25% of plots suffer from zero yield, while 15% of palawija suffer from zero yield. This indicates that even though these samples are located nearby with each other, the risk of crop loss is significantly larger for paddy when water is not sufficiently available.

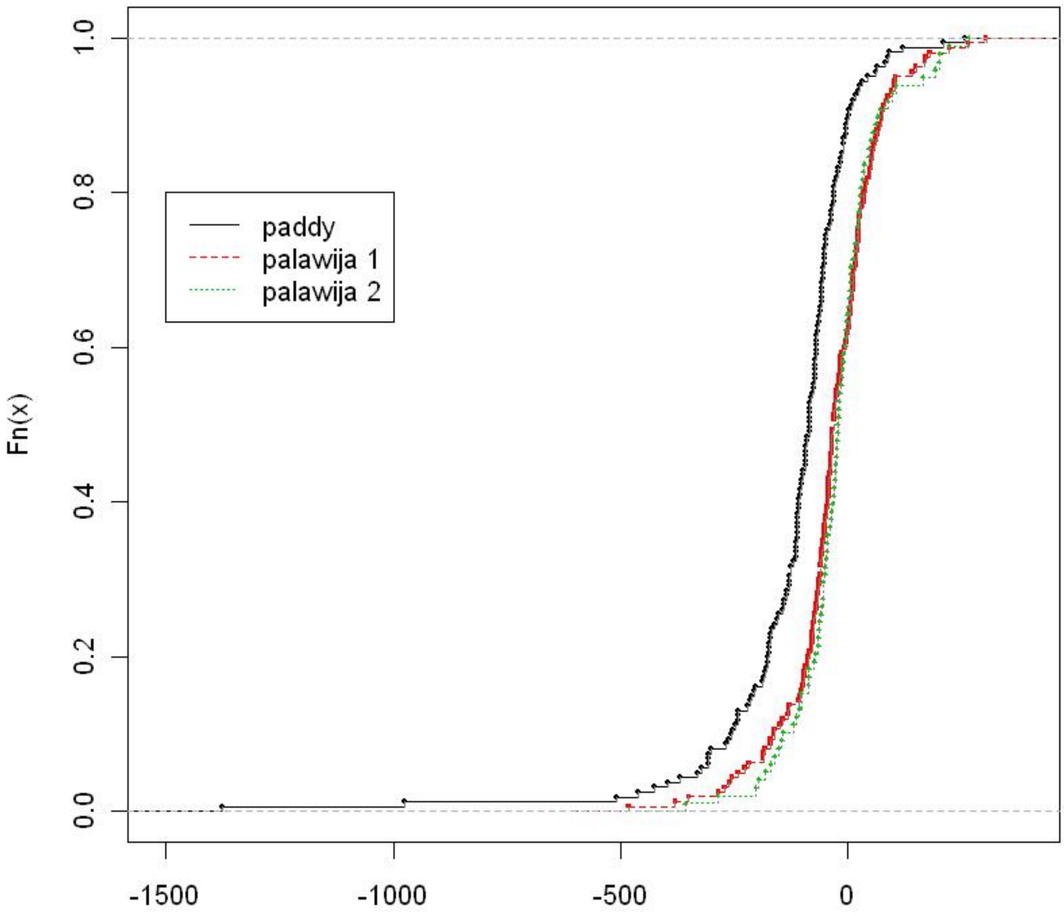

Figure 4-2. Cumulative Distribution of Per Ha Income by Irrigation Group

Table 4-1. Risks of Zero Production

		crops		**total**
		palawija	paddy	
yield	zero	0.078	0.137	0.22
	positive	0.419	0.366	0.78
total		0.50	0.50	1.00

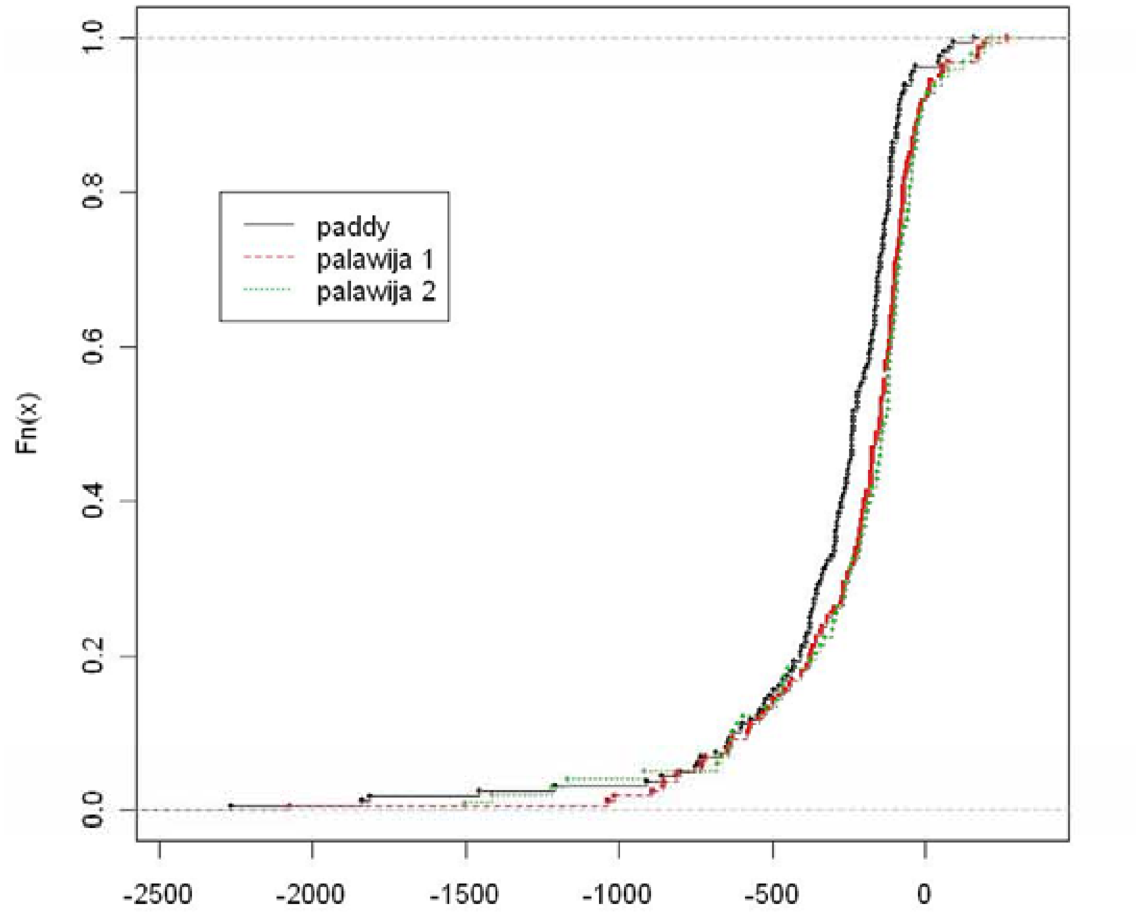

Figure 4-3. Cumulative Distribution of Per Ha Profit by Irrigation Group

4.3. Impact of Irrigation

Now, we turn to examine more detailed impacts of irrigation water in the dry season. In Figure 4-4, we compare per hectare revenue of the relevant treatment arms: from top left by clockwise, paddy and palawija1 on boundaries (left upper quadrant), paddy on and off boundaries (right upper quadrant), palawija2 in Group 2 on and off boundaries (right lower quadrant), and palawija1 in Group 1 on and off boundaries (left lower quadrant).

The fist one consists of the sample of paddy and palawija, where the former is located closer to the water source (upper land) than the latter, as paddy requires more water volume and controls. In the spirit of RDD, this comparison should give the credible identification of irrigation water impacts which prompt farmers to choose paddy over palawija, as noted in the earlier Chapter. On the other hand, the third one consists of palawija2 on and off boundary and in the spirit of RDD, on boundary plots present the credible impact of irrigation in Group 2. We add other two due to the following expectation: The upper right panel shows the comparison between off boundary paddy and the on boundary paddy, where the former is supposed to be more water abundant. This should give how availability of water may impact the outcomes for paddy plots; and in the bottom left panel, we compare the on and off boundary palawija in group 1. By our definition of boundary, on boundary palawija plots are closer to water source than off boundary palawija plots. So this comparison should give how availability of water may impact the outcomes for palawija plots.

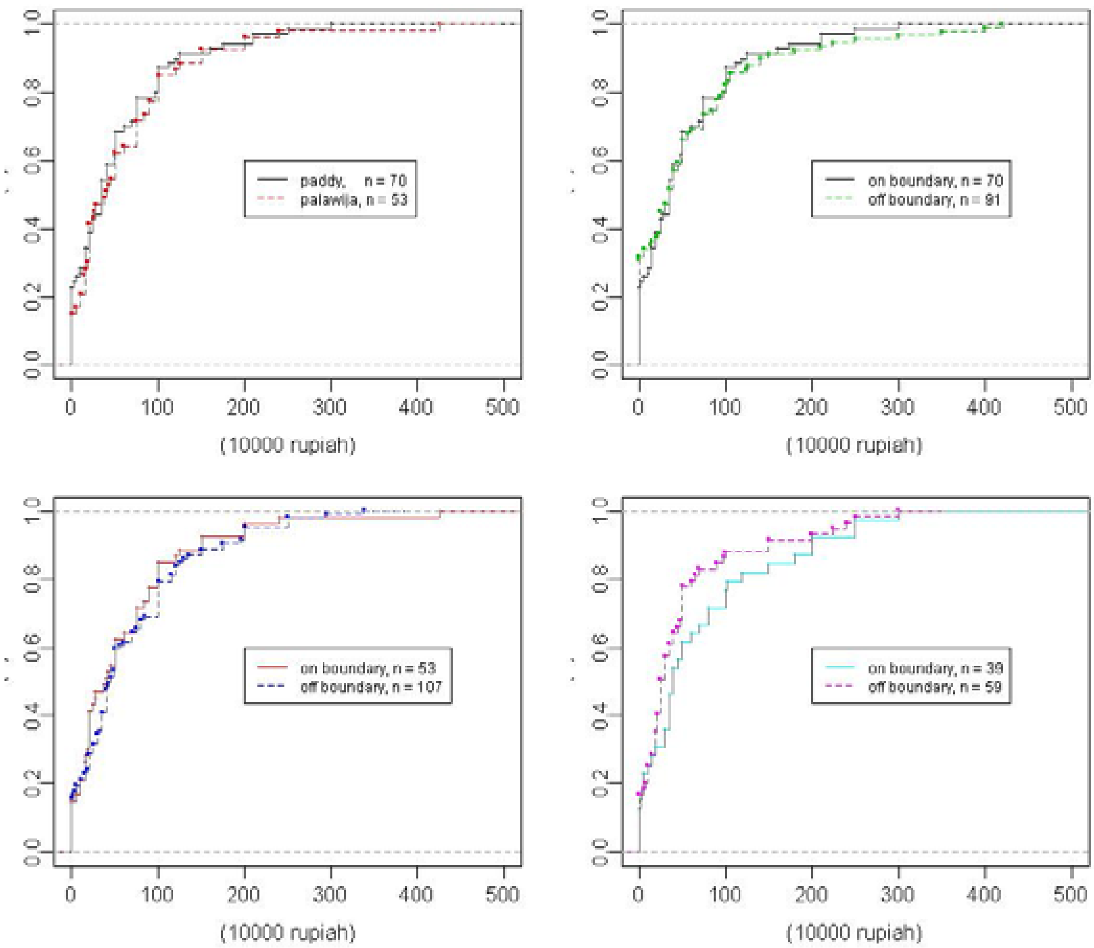

Figure 4-4. Cumulative Distribution of Per Ha Revenue, by Samples

According to the left upper quadrant, revenues per ha are slightly better for palawija than paddy, and, to our surprise, according to the right lower quadrant, palawija on boundary which is closer to fallow is more productive than off boundary palawija which should have better access to water. Other paired distributions do not show marked difference other than that off boundary paddy is more productive than on boundary paddy.

In Figures 4-5 and 4-6, per hectare income and profit distributions are compared. In the upper left, we see that palawija performs better than paddy in both profitability measures. This may be due to that, when water is relatively scarce, paddy is a risky choice and, in the drought year like we sampled, it gives the downside of the risk. The difference is smaller in profits (Figure 4-6) than in incomes (Figure 4-5), implying that palawija is more family labor intensive. The upper right panels in both figures show that water abundant, off boundary paddy is more profitable than water scarce, on boundary paddy, possibly reflecting the revenue differences. The off boundary palawija in Group 1 and on boundary palawija in Group 2 are more profitable than counterparts, somewhat puzzling yet consistent with the findings in per hectare revenues above.

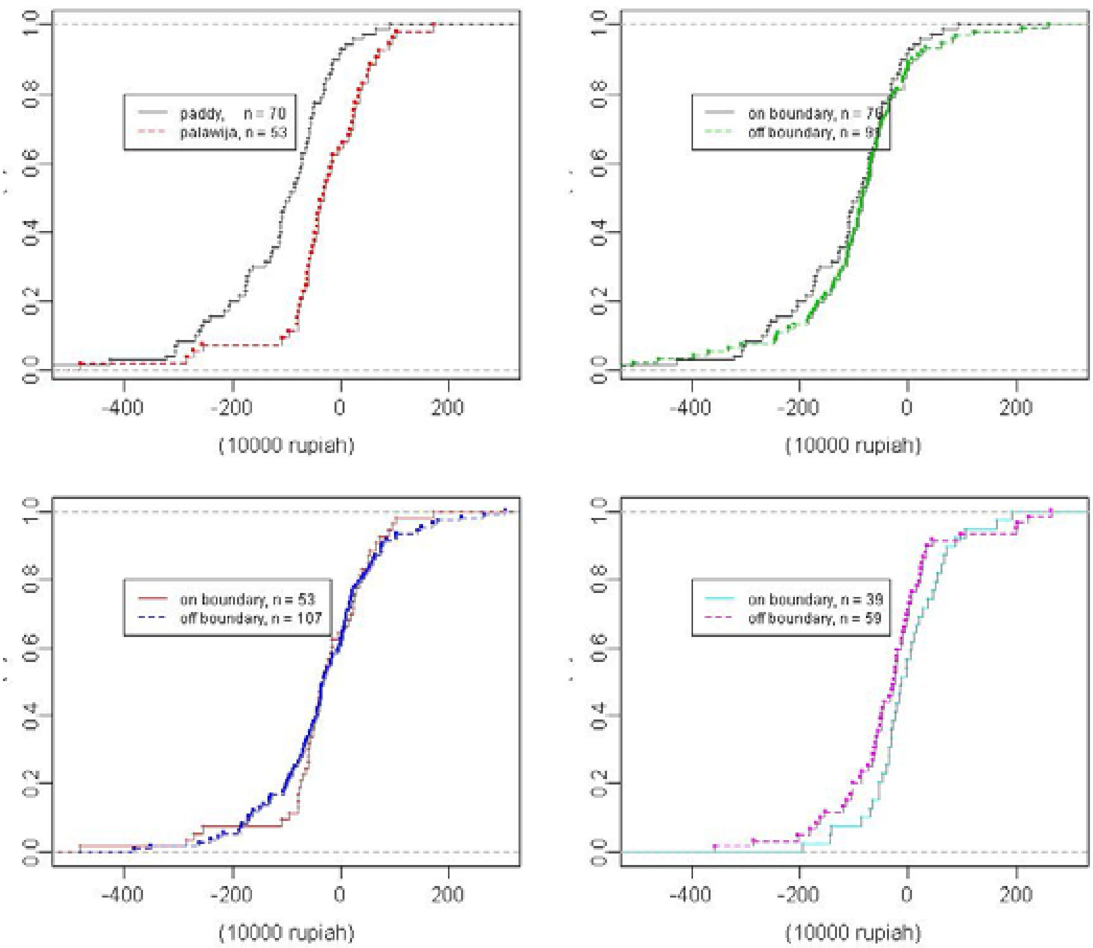

Figure 4-5. Cumulative Distribution of Per Ha Income, by Samples

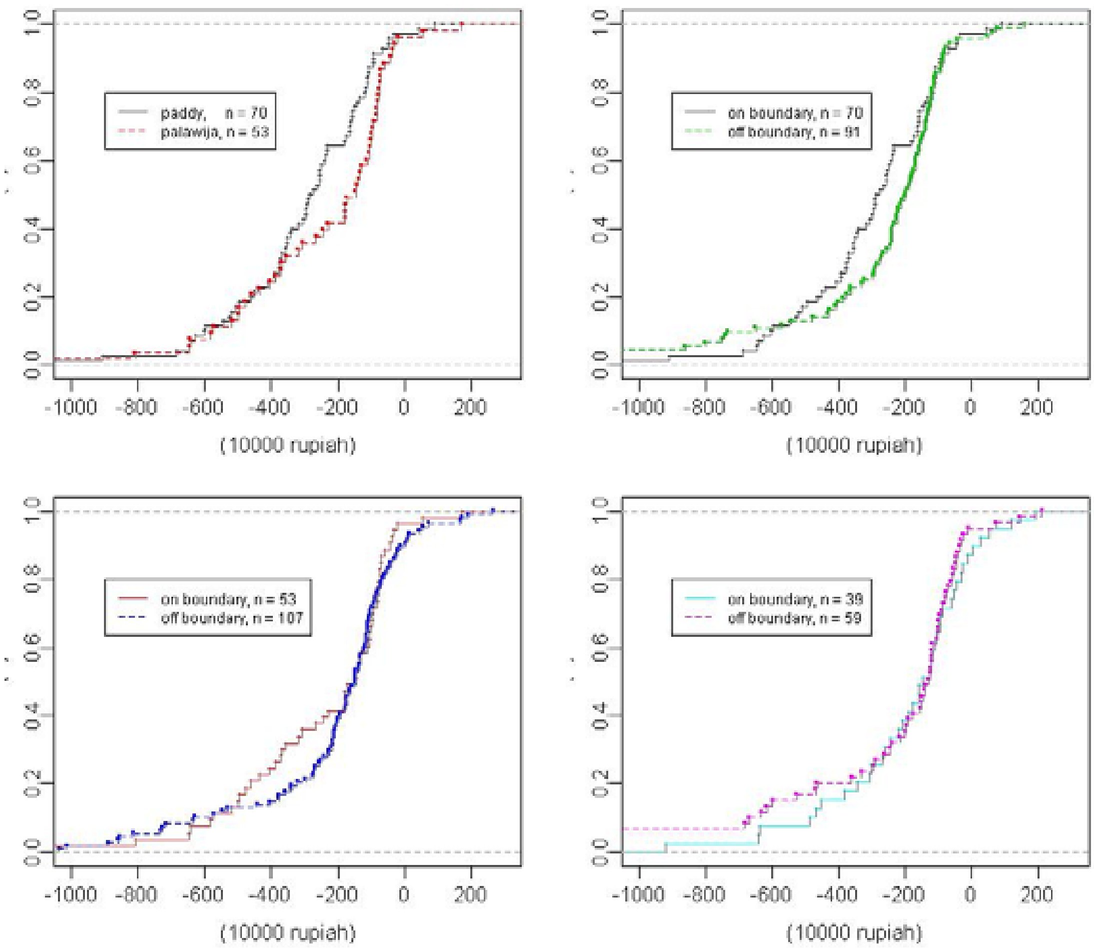

Figure 4-6. Cumulative Distribution of Per Ha Profit, by Samples

4.4. Robustness Check: Controlling for Observables

Different from our expectation, the results so far indicate that palawija is more profitable than paddy. Although the critical assumption of RDD is that household and plot characteristics are similar between samples near the cut-off point/boundary, one possibility of this unexpected result comes from differential household and plot characteristics between them. To examine this possibility, we have regressed profits on the observable characteristics of plots and households, and plotted the residuals in Figure 4-7. These observable characteristics include family structure and land class denomination which reflect the general evaluation for water availability. For the overall evaluation purpose, regression results are tabulated in Appendix 4-1.

Figure 4-7 shows the profit distributions after controlling for the observables. In the upper left quadrant, where we compare paddy and palawija on the boundary, we see that palawija has smaller downside risks yet smaller median residuals. This again shows that palawija is a safer crop. Both on and off boundary comparison for paddy and palawija (upper right and lower left quadrant) show that two distributions of per ha profits on paddy and palawija1 on and off boundary are not markedly different. This is interesting, because, for the upper right panel, we have seen in Figure 4-6 that profits are greater for off boundary paddy, but after controlling for plot and household characteristics, such profit differences almost disappear. This shows that the plot and household denominations, among other observable characteristics, generally accords with the measured profitability which effectively canceled the profitability differences. Group 2 comparison of on and off boundary palawija (the lower right panel) shows some difference, where on boundary palawija is more concentrated about the median, which illustrates that for the high productivity households, profits are larger for on boundary plots.

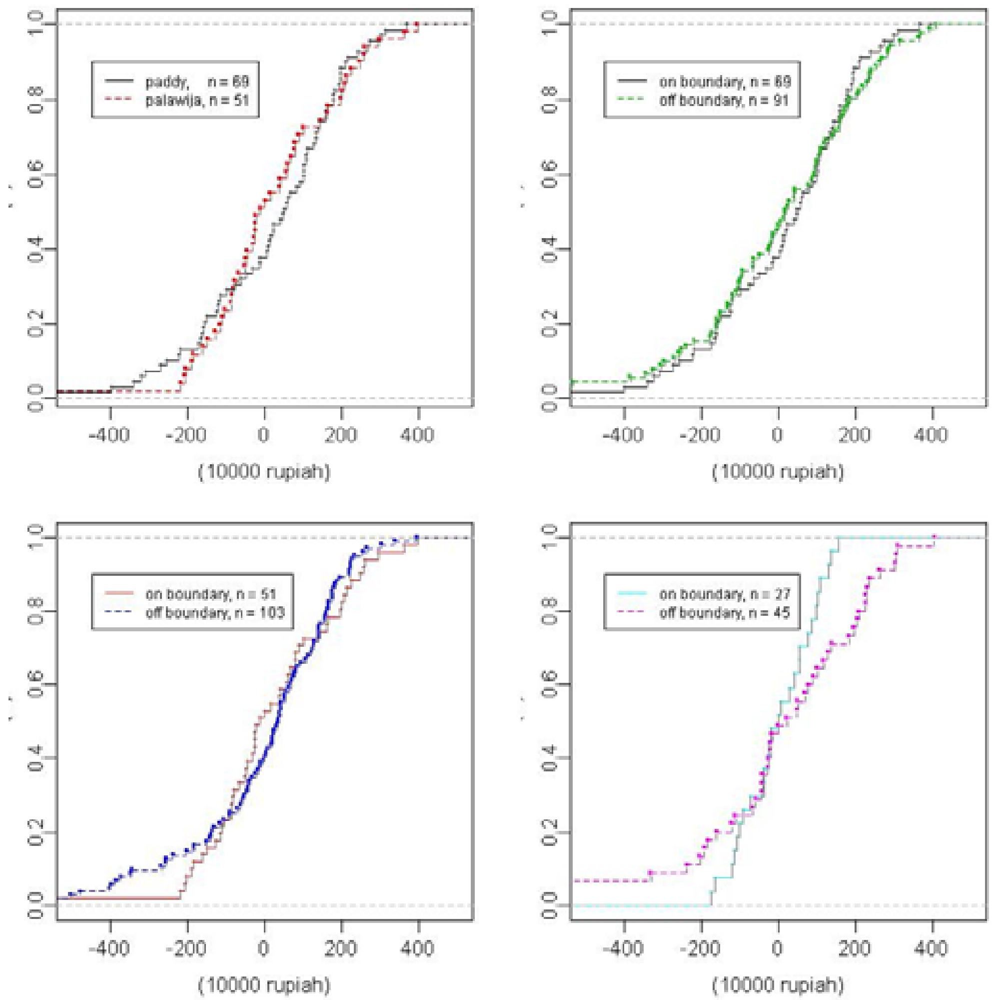

Figure 4-7. Cumulative Distribution of Per Ha Profit, after Controlling for Observables

So the examination between the distributions in RDD samples shows that palawija is a safer crop. It is also a more profitable crop for the year we have collected data, which has turned out to have a severe drought, even controlling for observable characteristics. Both the profitability and revenue for all crops have declined, but disproportionately so for paddy.

4.5. Discussion on Identification Assumptions and Their Credibility

RDD estimates clearly show what can happen in bad times. Paddy is a risky crop that is susceptible to drought while palawija is a safer crop that can withstand the fluctuation of rainfall. Within a narrow band of a few hundred meters, upstream farmers chose paddy and downstream farmers chose palawija. If we consider that there is a threshold level of water below which paddy is too risky, or, equivalently, a threshold date after which is too late to receive water to plant paddy, we can expect a natural boundary within which paddy is a natural choice. Of course, there is no observable boundary marked in the field, and its precise location is unknown to all farmers. Farmers close to the boundary use their best information and expertise to judge up to which plot it makes sense to plant paddy. We assume that all farmers have the same information set regarding the water availability, which is highly realistic given that such information is disseminated through WUAs. To makes the exposition easy, we call the plots within the paddy-feasible boundary as paddy-water sufficient, plots beyond the boundary but within palawija-feasible boundary as palawija-water sufficient.

Our identification strategy depends on the assumption that, given the location of boundary, there is no correlation between risk preferences nor ability of paddy-water sufficient plot owners and of palawija-water sufficient plot owners. This is highly likely because, not just the location of boundary changes in every year, but also it is not determined until a few weeks into the cropping season, resulting in no opportunity for the farmers to sort themselves over their self-perceived boundaries even in the presence of active land markets. So we believe that we have credible identification of the local impact of irrigation, as there should not be any systematic correlation, within a narrow band about the true boundary, between owner characteristics of paddy-water sufficient and palawija-water sufficient plots. This should also hold for the second boundary that divides palawija-water sufficient plots and fallow plots.

Appendix 4-1. Regression on Output, by Samples

	(1)	(2)	(3)	(4)	(5)	(6)
	group 1, paddy, on boundary	group 1, paddy, off boundary	group 1, palawija on boundary	group 1, palawija off boundary	group 2, palawija, on boundary	group 2, palawija, off boundary
(Intercept)	-425.2217 ***	-334.4920 ***	-661.5324 ***	-523.1246 ***	-642.6348 ***	-649.8151 ***
	(80.9877)	(93.6488)	(147.0856)	(95.3448)	(115.6614)	(204.5610)
area	251.5047 ***	589.1756 ***	326.4104 ***	501.5986 ***	375.8023 ***	490.1513 ***
	(72.5213)	(173.5254)	(63.4207)	(83.0990)	(93.1700)	(119.9451)
owned	26.2390	-10.8921	-138.8907 ***	80.2192	186.2624	-132.0438
	(51.3496)	(55.9671)	(51.1984)	(71.0701)	(57.6614)	(162.8103)
leased		9.6238		84.1526	52.8399	94.3499
		(82.5210)		(75.4124)	(85.7105)	(225.1528)
class1 land	-127.2105	-96.8728	457.3520 ***	13.5893	211.7017 ***	287.7759 **
	(100.3304)	(80.9638)	(125.5635)	(55.9722)	(66.3501)	(147.5657)
class2 land	-156.3464 *	-0.1686	258.8824 **	63.4751	209.5962 **	259.2631 **
	(107.3738)	(57.0123)	(126.2679)	(57.0594)	(86.3236)	(139.7663)
working members	-45.7624	-68.2889 *	-46.3693	10.4079	-54.7330	85.0049
	(36.9127)	(40.9143)	(48.4016)	(59.2379)	(62.5400)	(94.2429)
of which male	-24.0918	-68.2734	-4.4199	23.4382	45.7633 *	-2.7985
	(30.3523)	(56.3821)	(34.4132)	(27.0432)	(28.1497)	(39.6390)
of which with primary education	21.0238	58.4218 *	38.0872 **	5.7029	72.3864 ***	53.8909
	(20.2223)	(39.2403)	(19.0851)	(19.9080)	(20.5048)	(43.2594)
of which with tertiary education	-9.5140	-56.1664	47.2014 *	-12.6922	5.1583	-20.0702
	(32.8354)	(73.1481)	(30.0167)	(24.3562)	(21.0694)	(69.6943)
household size	64.4010 *	34.0949	40.1917	-42.8620	31.3241	-99.4063
	(41.1373)	(48.0524)	(37.4004)	(41.9784)	(44.7207)	(81.0684)
number of adult male members	25.5090	25.2637	-139.0138 ***	6.2121	-28.4188	11.8761
	(32.9941)	(46.4933)	(39.4364)	(34.0170)	(40.9724)	(72.0761)
number of adult female members	-40.0370	0.2638	54.4056 *	65.2517 **	-13.2620	35.5167
	(41.7768)	(50.8770)	(37.8381)	(36.9776)	(29.1487)	(76.9448)
female headed household	29.6442	-109.2894 *	84.0637 *	70.6082	-147.1832 *	243.8999 **
	(93.0353)	(80.4425)	(56.4876)	(60.7445)	(91.2997)	(115.9464)
n	69	51	91	103	27	45

Absolute standard erros in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

5. The Determinants and Impacts of SRI Adoption

5.1. Introduction

In this chapter, we will examine covariates and impacts of SRI adoption, which is a relatively new rice-growing technology with the merits of high-yield potentials. It is reported that rice productivity of SRI in controlled experimentation can be 200% larger than the conventional practice (e.g., Uphoff and Randriamiharisoa, 2002). This tremendous productivity increase has attracted much attention by scholars and practitioners and there has been a great enthusiasm to promote this technology widely as a break-through towards worldwide food shortage as well as improvements of peasant's living standards.

Nonetheless, many agronomists question whether its merits really deserve attention. For example, based on three experimental stations in China, an agricultural scientist group at the International Rice Research Institute, led by Sheehy, shows no significant differences in yield between SRI and the conventional practice (Sheehy et al. 2004). McDonald et al. (2006) review 40 published journal articles on SRI and conclude that outside of Madagascar, where SRI has been enthusiastically promoted and widely diffused, SRI has little impact on yield.

In the KK scheme, Sato (2006) argue that, at the farmer's field, SRI can increase the average rice productivity from 3.9 ton/ha to 7.2 ton/ha or by about 84%. Given controversy among scientists described above, a natural question arises as to whether this productivity increase in the KK scheme can be truly attributable to the SRI technology or not, which is a fundamental issue we will explore in this chapter.

There are potentially two important factors that might make the positive relationship spurious: farmer heterogeneity and plot heterogeneity. It can be possible if farmers who adopt SRI are more talented and more endowed with educated laborers, their average productivity would be higher than non-adopters. Also, it can be possible if plots on which SRI was adopted are in more favorable conditions, their average productivity would be higher than non-SRI plots. In order to control for such heterogeneity, we apply the PSM method and compare yield and agricultural income of those with similar farmer's and plot's characteristics.

5.2. Treatment Effect and Propensity Score Matching

A major purpose of this chapter is to estimate the average treament effect (ATT) of SRI adoption on yield and rice income. ATT is defined as:

$$ATT = E(y_{1i} - y_{0i} \mid D_i = 1)$$

$$= E(y_{1i} \mid D_i = 1) - E(y_{0i} \mid D_i = 1),$$

where $E(\cdot)$ denotes an expectation operator, y_{1i} is an outcome of interest of plot i if adoped SRI, y_{0i} is the outcome of the same plot without SRI, and D is a treatment indicator equal to 1 if the plot is actually adopted SRI and 0 otherwise. The problem in estimating the above equation is that it is never possible to observe the outcome of SRI-plots had they not adopted SRI, $(y_{0i} \mid D_i = 1)$. Thus, many program evaluations treat non-SRI plots as the control group and compares outcome of $E(y_{1i} \mid D_i = 1) - E(y_{0i} \mid D_i = 0)$. Yet, this tends to result in serious bias represented by

$$ATT = E(y_{1i} \mid D_i = 1) - E(y_{0i} \mid D_i = 1)$$
$$= [E(y_{1i} \mid D_i = 1) - E(y_{0i} \mid D_i = 0)] - [E(y_{0i} \mid D_i = 1) - E(y_{0i} \mid D_i = 0)].$$

The last term of the right-hand side of the above equation indicates the magnitude of potential bias when $E(y_{1i} \mid D_i = 1) - E(y_{0i} \mid D_i = 0)$ is simply treated as ATT.

In general, matching-based techniques create a missing counterfactural from the pool of non-SRI plots comparable in a set of essential characteristics, x, to SRI-plots. A practical shortcoming of such a method is that if x is high-dimensional, and the number of characteristics in the match increases, it is difficult to find non-SRI plots having exactly the same or sufficiently close"x"s as SRI-plots in all dimensions. However, Rosenbaum and Rubin (1983) show that matching on a single index that captures the propensity to adoption conditional on x yields consistent estimates of the treatment effect in the same manner produced by matching on all x s. This is referred to as the PSM method. Let $p(x_i)$ denote the probability of SRI adoption given observable covariates x, i.e., $\Pr(D_i = 1 \mid x_i) = p(x_i)$. The validity of PSM rests on the following two assumptions.

The first is called "conditional mean independence." That is, conditional on the probability of SRI adoption given observable covariates, an outcome of interest in the absence of treatment, y_{0i}, and adoption, D_i, are mean independent, $E(y_{0i} \mid D_i = 1, p(x_i)) = E(y_{0i} \mid D_i = 0, p(x_i))$. This assumes that selection can be explained purely by observable characteristics. In other words, once all relevant observable characteristics are controlled, SRI adoption is not correlated with the outcome without treatment. Thus, satisfaction of "conditional independence" effectively eliminates bias caused by the difference in observable characteristics between SRI and non-SRI plots.

The second is termed "common support." That is, all treated households have a counterpart control group and households with the same x have a positive probability of adoption such that $p(x_i) < 1$. PSM entails the obvious disadvantage of a reduction in sample size because observations that are unmatched or outside common support are not used in the analysis. However, restricting the comparison to differences within carefully selected pairs might significantly improve the quality of impact evaluation. Moreover, estimating determinants of SRI adoption is valuable in its own right in order to understand what kind of people and plots choose SRI.

Propensity scores are estimated with a probit model using relevant household and plot haracteristics as independent variables, which is followed by creation of matched observations. It is well known that there are different matching algorithms, each with positive and negative attributes. Among available options, the one-to-one nearest neighbors matching method without replacement is used in this research. This allows finding the counterfactual of SRI-plots from non-SRI plots which lie within the predetermined tolerance level (caliper) and is closest in terms of propensity scores. The appropriate tolerance level is a priori undetermined, but following the conventional practice, we set it at 0.01 in this research. As a robustness check, we also examine the impact of SRI with the kernel matching method, which uses the weighted averages of all control groups to estimate counterfactual outcomes, where the weight is calculated by the propensity score distance between treatment and control groups.

5.4. Data and Variables Selection

(a) Data

This chapter mainly uses the wet season data collected in 2009 partly because the majority of farmers do not cultivate paddy in the dry season and partly because, among rice-growing farmers, SRI is mostly adopted in the wet season. We limit the sample to those who cultivate paddy, excluding those cultivate palawija in the wet season, in order to make comparisons relevant.

(b) Variables

One of the most important criteria for selecting covariates in PSM is that all factors explaining SRI adoption and outcomes be included in x. Also important is the criterion that there is no systematic differences in covariates after the matching procedure, in order to ensure that any differences in outcome can be attributable to SRI adoption. So, after estimating determinants of SRI adoption, we will conduct a balancing test to explore whether there are statistical differences in covariates between the matched SRI adopters and non-adopters.

The most independent variables explaining SRI adoption are the same as those used in Chapter 2. In addition, exploiting the fact that the 2009 survey expands questionnaires to include potential factors affecting technology adoption, we add several variables to regressors as follows: (1) The number of technology advisors with whom farmers often consult about farming as well as a dummy variable equal to 1 if at least one of the technology advisors have ever adopted SRI, (2) distance from market, (3) a dummy variable equal to 1 if there is coordination of crop schedule and water distribution within a WUA as well as a dummy variable equal to 1 if the farmer participated in WUA meetings in the wet season, and (4) a dummy variable equal to 1 if the respondent is risk-loving. The last variable is constructed by asking whether the respondent prefer 50,000 Rp with sure to 75,000 Rp or 15,000 Rp with each 50% probability. Because the expected pay-off is higher for the former, a risk-neutral person would choose the former option, while a risk-loving person would chose the latter option. Thus, if the respondent selects the latter, we consider the person as risk-loving.

(c) Several Hypotheses

Since SRI is characterized by intermittent irrigation, timely irrigation management would be the key for its adoption. In this regard, we expect that water availability and collective action in terms of rice cropping schedule and water management are positively related to SRI adoption. Also, because SRI will require intensive labor input, SRI is not selected if opportunity costs of labor are remarkably high. We, thus, expect that distance from market, which is a proxy of the development of rural areas and labor market, is negatively correlated with SRI adoption, and that endowment of family labor would be positively correlated with SRI adoption. Besides, because SRI is a new technology, farmers unfamiliar with this method may be afraid to adopt due to unforeseen risks. Thus, risk-loving persons would be more likely to adopt SRI. Furthermore, technology advisors who have ever adopted SRI would mitigate such risks to some extent, facilitating farmers to adopt SRI through learning-from-others effect.

5.5. Determinants of SRI Adoption

(a) Estimation Results

The estimation results on the determinants of SRI adoption by a probit model are shown in Table 5-1. Column (1) uses the same independent variables as in Chapter 2, while Column (2) includes additional independent variables discussed above. All values represent marginal effects, i.e., the change in the probability of SRI adoption for the marginal change in continuous variable and the discrete change in the probability for dummy variables.

The qualitative implications between Columns (1) and (2) are largely similar, except for several variables, such as stream dummies and the proportion of education. However, judged by a Pseudo R-squared, Column (2) have much higher explanatory power (0.10 in Column 1 vs 0.38 in Column 2) . Hence, the estimation result based on Column (2) is used in interpretation.

Table 5-1. Determinants of SRI Adoption

	SRI Adoption	
Upstream (=1)	0.262***	0.138***
	[5.12]	[3.17]
Midstream (=1)	0.123***	0.058**
	[4.57]	[2.54]
Downstream1 (=1)	0.158***	0.042
	[3.07]	[1.10]
Downstream2 (=1)	0.099**	0.065
	[2.07]	[1.61]
Land size (ha)	0.011	0.021
	[0.56]	[1.36]
Own (=1)	-0.011	-0.016
	[0.59]	[0.94]
Lease (=1)	0.079	0.16
	[0.76]	[1.49]
Distance from intake along canal	-0.205***	-0.103**
	[3.23]	[2.23]
Female_head (=1)	-0.174***	-0.085
	[3.11]	[1.63]
Age of head	0.000	0.001**
	[0.60]	[2.05]
Household size	-0.007	-0.001
	[1.59]	[0.26]
Proportion of working members	0.089**	0.062*
	[2.16]	[1.78]
with primary education	0.049	-0.004
	[1.12]	[0.12]
with secondary education	0.077*	0.008
	[1.91]	[0.25]
with tertiary education	0.045	-0.012
	[0.90]	[0.28]
Number of technology advisors		-0.003
		[0.41]
Advisors ever adopted SRI (=1)		0.426***
		[12.81]
Distance from market		-0.003
		[1.43]
Participate in WUA (=1)		0.054***
		[3.38]
Water Coordination (=1)		0.007
		[0.47]
Crop Schedule Coordination (=1)		-0.013
		[0.77]
Risk-loving (=1)		0.049**
		[2.07]
Observations	1211	1203

Absolute value of z statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Consistent with our expectation, water availability significantly matters for the decision whether to adopt SRI or not. In particular, plots located on the upstream and midstream, where irrigation water is more abundant, are more likely to apply SRI. Also, distance from water intake on irrigation canal is negatively related to SRI adoption, indicating that within each WUA, plots near water intake has a higher probability of employing SRI presumably because water management is much easier under such conditions.

The age of household head has a positive impact on SRI adoption. More importantly, the proportion of working members is positively and significantly related to SRI adoption, which is also consistent with our hypothesis. It seems reasonable that, given imperfect substitutability between family labor and hired labor inherent in agricultural labor markets and given intensive labor-use in SRI technology, farmers with abundant labor are more likely to adopt SRI.

While the number of technology advisors *per se* has no impact, it is important that at least one of them have ever adopted SRI to facilitate SRI adoption. This will be because farmers can learn how to practice SRI and how much they can expect to earn through learning from such advisors.

Different from our expectation, coordination of cropping schedule and water distribution in WUA do not affect SRI adoption, while participation in WUA meeting does. This is difficult to interpret, but it may be that community meeting participation will intensify communication among peers, so that they could more directly exchange information about SRI methods or agree with water/crop schedule with neighbors. Another interpretation is that farmers who are willing to participate in WUA meeting generally put more efforts on rice-cultivation, which are indirectly correlated with willingness to apply SRI, which requires more labor efforts.

Last but not least, risk-lovingness is positively related with SRI application. As is precisely pointed out by Sato (2006), the result implies the importance of removing anxiety about SRI methodologies to further facilitate SRI in the KK scheme.

(b) Balancing Test

Using parameters obtained by the estimation model in Column (2), propensity scores (probability of adoption) are computed for all plots. To impose common support conditions, observations in the treatment group (those adopting SRI) with propensity scores higher than the maximum or lower than the minimum of the control group (those not adopting SRI) are dropped.

We perform a series of balancing tests on the differences in means based on t-statistics. T-statistics are calculated for each independent variable to investigate whether the matched control group has similar characteristics to the matched treatment group. If the difference between the matched treatment and control groups is statistically insignificant, it could be safely claimed that there is no systematic difference between these two groups, at least in terms of observable characteristics. The results in Appendix 5-1, based on one-to-one nearnest neighbor matching, and in Appendix 5-2, based on kernel matching, show that although may characteristics statistically differ between treatment and control groups before matching, few variables are statistically different at the 10% level after matching. Only two execptions are the household size and the proportion of working members by the kernel matching in Table 7. This is a fairly good match and it seems rather reasonable to presume that this may not jeopardize accurate estimates of the impact of SRI to a significant extent.

5.6. Impact of SRI Adoption and Discussion

We now turn to discuss the results of impact of SRI adoption. The outcomes of interests are paddy yield and rice income per hectare. For the comparison purpose, we also present outcome differences before the match. As shown in Table 5-2, paddy yield differs by 2.6 ton/ha in favor of those adopting SRI before the match, and its difference is highly statistically significant. Even though this yield difference reduced to 2.1 ton/ha by the one-to-one nearest neighbor matching and to 1.9 ton/ha by the kernel matching, they are still significant at the 1% level. This suggests that yield increments by the SRI method are not due to differential observable characteristics between those adopters and non-adopters but is likely to be attributable to the SRI method *per se*.

Table 5-2. The Impact of SRI Adoption

Variable	Sample	Mean		Diff in Mean	t-value
		SRI Group	Non-SRI Group		
Yield	Unmatched	5.49	2.94	2.55	11.71 ***
	One-to-One	5.50	3.37	2.14	6.62 ***
	Kernel	5.22	3.32	1.90	5.08 ***
Rice income per ha (000 Rp)	Unmatched	6679.36	2447.48	4231.88	9.31 ***
	One-to-One	6680.80	3365.68	3315.12	4.49 ***
	Kernel	6027.22	3107.07	2920.16	3.05 ***

* significant at 10%; ** significant at 5%; *** significant at 1%

Similarly, rice income per ha is greater for the SRI plots by about Rp 4.2 million before the match and it is highly significant. Again this income increment reduces to Rp 3.3 million by the one-to-one nearest neighbor matching and to Rp 2.9 million by the kernel matching; however, they are statistically significant at the 1% level, implying that the SRI method would allow farmers to generate more income than the conventional practice.

These results provide supporting evidence of technological merits of the SRI method. It might be cautioned, however, that this matching method cannot control for differential outcomes due to unobservable characteristics, such as farmer's talent. It would be the case that more talented farmers tend to adopt SRI, in which the estimation result presented here will be biased upward (overestimated). This is one of the limitations of this study that rely on the cross-sectional data. Another caution would be that we do not deduct family labor costs from rice income, so that the actual profitability would slightly change if we take them in to account. As the SRI method requires more intensive labor inputs, it is likely that family labor is more used in the SRI plots. This conjecture is partly supported by Table 5-3, which shows hours of family labor input by gender and by the SRI status. After the matching procedure, it is revealed that family labor input is significantly higher for the SRI method by 58 hours in total and by 45 hours for male in particular, according to the kernel matching. Even though this evidence is not robust in that it is not reproduced by the nearest neighbor matching, one may still need to keep it in mind when interpreting our results.

Table 5-3. Difference in Family Labor Input

Variable	Sample	Mean SRI Group	Mean Non-SRI Group	Diff in Mean	t-value	
Total family labor (hours)	Unmatched	231.32	196.28	35.04	2.00	**
	One-to-One	217.52	190.15	27.37	1.02	
	Kernel	248.44	190.12	58.32	1.72	*
Male family labor (hours)	Unmatched	171.20	143.48	27.73	2.33	**
	One-to-One	163.77	139.49	24.28	1.37	
	Kernel	183.67	137.88	45.79	2.10	**
Female family labor (hours)	Unmatched	60.12	52.81	7.31	0.97	
	One-to-One	53.75	50.66	3.09	0.26	
	Kernel	64.77	52.23	12.53	0.83	

* significant at 10%; ** significant at 5%; *** significant at 1%

Finally, it should be also worth noting that we were reported in advance that about 70% of farmers adopted SRI in KK scheme, but we have problems to find such farmers as mentioned in Chapter 2. If the report is true, a natural question arising is why so many farmers quit the SRI method. So, analysis of dynamics of SRI adoption and disadoption should be an important agenda to pursue in the future research.

Appendix 5-1. Balancing Test (one-to-one nearest neighbor matching)

Variables	Sample	Mean SRI Group	Mean Non-SRI	% difference	% bias reduced	Diff in Mean t-value	Diff in Mean p-value	
Upstream (=1)	Before	0.166	0.078	26.90		3.680	0.000	***
	After	0.162	0.099	19.40	27.80	1.390	0.165	
Midstream (=1)	Before	0.609	0.478	26.60		3.190	0.001	***
	After	0.568	0.631	-12.80	52.10	-0.960	0.340	
Downstream1 (=1)	Before	0.095	0.079	5.40		0.680	0.499	
	After	0.081	0.081	0.00	100.00	0.000	1.000	
Downstream2 (=1)	Before	0.065	0.089	-9.00		-1.030	0.304	
	After	0.090	0.090	0.00	100.00	0.000	1.000	
Land size (ha)	Before	0.492	0.445	10.30		1.350	0.176	
	After	0.495	0.496	-0.20	97.90	-0.020	0.988	
Own (=1)	Before	0.686	0.746	-13.10		-1.620	0.105	
	After	0.685	0.685	0.00	100.00	0.000	1.000	
Lease (=1)	Before	0.012	0.006	6.40		0.890	0.372	
	After	0.009	0.009	0.00	100.00	0.000	1.000	
Distance from intake along canal	Before	0.040	0.161	-37.80		-3.550	0.000	***
	After	0.048	0.058	-2.90	92.30	-0.540	0.590	
Female_head (=1)	Before	0.012	0.118	-12.40		-1.140	0.253	
	After	0.018	0.005	1.60	87.30	1.000	0.316	
Age of head	Before	47.651	48.898	-9.50		-1.160	0.245	
	After	47.847	48.757	-7.00	27.00	-0.490	0.623	
Household size	Before	4.947	5.349	-20.30		-2.250	0.025	**
	After	5.225	5.414	-9.50	53.00	-0.740	0.461	
Proportion of working members	Before	0.752	0.725	13.10		1.580	0.114	
	After	0.741	0.716	11.80	9.80	0.900	0.369	
with primary education	Before	0.272	0.288	-5.50		-0.640	0.524	
	After	0.291	0.291	-0.20	95.50	-0.020	0.985	
with secondary education	Before	0.502	0.451	16.40		1.940	0.053	*
	After	0.492	0.494	-0.80	95.20	-0.060	0.954	
with tertiary education	Before	0.119	0.107	5.80		0.700	0.482	
	After	0.101	0.107	-2.60	54.50	-0.220	0.823	
Number of technology advisors	Before	1.290	0.739	59.40		6.460	0.000	***
	After	1.243	1.234	1.00	98.40	0.070	0.942	
Advisors ever adopted SRI (=1)	Before	0.728	0.094	168.10		24.040	0.000	***
	After	0.586	0.586	0.00	100.00	0.000	1.000	
Distance from market	Before	2.488	3.360	-29.30		-2.910	0.004	***
	After	2.710	2.375	11.20	61.60	1.370	0.171	
Participate in WUA (=1)	Before	0.568	0.272	62.80		7.890	0.000	***
	After	0.541	0.586	-9.60	84.80	-0.670	0.501	
Water Coordination (=1)	Before	0.675	0.679	-0.90		-0.110	0.911	
	After	0.667	0.712	-9.60	-933.00	-0.720	0.471	
Crop Schedule Coordination (=1)	Before	0.207	0.266	-13.90		-1.620	0.105	
	After	0.234	0.234	0.00	100.00	0.000	1.000	
Risk-loving (=1)	Before	0.154	0.115	11.40		1.430	0.152	
	After	0.189	0.189	0.00	100.00	0.000	1.000	

* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 5-2. Balancing Test (kernel matching)

Variables	Sample	Mean SRI Group	Mean Non-SRI	% difference	% bias reduced	Diff in Mean t-value	Diff in Mean p-value	
Upstream (=1)	Before	0.166	0.078	26.90		3.680	0.000	***
	After	0.168	0.132	11.10	58.60	0.920	0.357	
Midstream (=1)	Before	0.609	0.478	26.60		3.190	0.001	***
	After	0.611	0.593	3.60	86.40	0.330	0.740	
Downstream1 (=1)	Before	0.095	0.079	5.40		0.680	0.499	
	After	0.090	0.108	-6.40	-17.60	-0.550	0.582	
Downstream2 (=1)	Before	0.065	0.089	-9.00		-1.030	0.304	
	After	0.066	0.085	-7.00	21.40	-0.650	0.518	
Land size (ha)	Before	0.492	0.445	10.30		1.350	0.176	
	After	0.468	0.482	-3.00	70.60	-0.300	0.763	
Own (=1)	Before	0.686	0.746	-13.10		-1.620	0.105	
	After	0.689	0.677	2.60	79.90	0.230	0.816	
Lease (=1)	Before	0.012	0.006	6.40		0.890	0.372	
	After	0.012	0.008	4.00	37.30	0.340	0.731	
Distance from intake along canal	Before	0.040	0.161	-37.80		-3.550	0.000	***
	After	0.040	0.065	-7.80	79.40	-1.510	0.133	
Female_head (=1)	Before	0.012	0.118	-12.40		-1.140	0.253	
	After	0.012	0.014	-0.20	98.20	-0.060	0.951	
Age of head	Before	47.651	48.898	-9.50		-1.160	0.245	
	After	47.491	46.700	6.10	36.50	0.540	0.586	
Household size	Before	4.947	5.349	-20.30		-2.250	0.025	**
	After	4.928	5.307	-19.10	5.90	-1.840	0.067	*
Proportion of working members	Before	0.752	0.725	13.10		1.580	0.114	
	After	0.749	0.696	25.50	-94.60	2.330	0.021	**
with primary education	Before	0.272	0.288	-5.50		-0.640	0.524	
	After	0.272	0.281	-3.10	43.90	-0.280	0.781	
with secondary education	Before	0.502	0.451	16.40		1.940	0.053	*
	After	0.504	0.511	-2.40	85.20	-0.210	0.832	
with tertiary education	Before	0.119	0.107	5.80		0.700	0.482	
	After	0.118	0.111	3.20	44.80	0.310	0.758	
Number of technology advisors	Before	1.290	0.739	59.40		6.460	0.000	***
	After	1.281	1.370	-9.60	83.90	-0.940	0.349	
Advisors ever adopted SRI (=1)	Before	0.728	0.094	168.10		24.040	0.000	***
	After	0.725	0.729	-1.30	99.20	-0.100	0.922	
Distance from market	Before	2.488	3.360	-29.30		-2.910	0.004	***
	After	2.482	2.407	2.50	91.40	0.270	0.787	
Participate in WUA (=1)	Before	0.568	0.272	62.80		7.890	0.000	***
	After	0.563	0.595	-6.90	89.00	-0.600	0.549	
Water Coordination (=1)	Before	0.675	0.679	-0.90		-0.110	0.911	
	After	0.671	0.684	-2.80	-201.70	-0.260	0.798	
Crop Schedule Coordination (=1)	Before	0.207	0.266	-13.90		-1.620	0.105	
	After	0.210	0.210	0.00	99.70	0.000	0.997	
Risk-loving (=1)	Before	0.154	0.115	11.40		1.430	0.152	
	After	0.150	0.209	-17.40	-53.00	-1.410	0.159	

* significant at 10%; ** significant at 5%; *** significant at 1%

6. Conclusions

6.1. Summary of Major Findings

In this report, we have examined (1) the impact of irrigation water in the wet season activities, with the panel data in 2007 and 2009, (2) the impact of irrigation water in the dry season activities, with the date in 2009, and (3) the impact of SRI adoption with the data of the wet season in 2009.

The first two analyses employ the concept of RDD and basically compare outcome differences of the plots near the boundary. More specifically, the control group in the first analysis is the non-beneficiaries in upland areas adjacent to the scheme boundary, where irrigation water is unavailable. While the core treatment group is the beneficiaries in the downstream adjacent to the boundary, we define the treatment group more broadly as all beneficiaries in the main analysis and estimate the heterogeneous impacts of irrigation along the irrigation canal by OLS and Quantile regression. Consistent with findings in the previous analysis (Ito and Takahashi, 2008), we have found, among others, that the downstream farmers adjacent to the scheme do not benefit from the irrigation, judged by insignificant differences in yield and rice income between their plots and the non-irrigated counterparts. We have also found that the irrigation water positively and significantly affect the upstream and midstream plots and that yield increments can be significant among high productivity plots in the downstream a bit far from the boundary, but insignificant among low productivity plots in the same area. Thus, even though irrigation water contributes to the improvement of farmers, especially those in upper stream strata, it is implied that water allocation within the stratum, in addition to being at the end of canal, may not be favorable to low-productivity plots and that it is the low-productivity households in the lower-downstream area who fail to benefit from the scheme, despite their being classified as the beneficiary households on the irrigation scheme map.

In the second analysis, we focus on differential crop choices and their resultant incomes of plots near the boundary of water availability, at which crop choice clearly change from paddy to palawija as well as at which land utilization clearly change from palawija-growing to fallow. Since more upland farmers choose to grow paddy, we had expected that agricultural income per hectare is greater for them than those choose to grow palawija, and the differences in agricultural income can be considered as the impact of irrigation water in the dry season. Unexpectedly, however, revenues, incomes, and profits are on average larger for those cultivate palawija than paddy. This is mainly because palawija is a safer crop and more resistant to drought, which has turned out to happen in our observation year. Thus, we did firmly conclude that irrigation water has a definitely positive impact on plots near the boundary of paddy-palawija by allowing farmers to cultivate paddy. Also, from the palawija-fallow samples, we have found that on boundary which is closer to fallow is more productive than off boundary palawija which should have better access to water. This implies that small improvement in water accessibility would not result in a significant improvement of farmer's income for palawija.

In the third analysis, we turn to examine the determinants of SRI adoption and their impacts on yield and rice incomes. We use the PSM method to take into account for selection on observable characteristics. We have found that water availability, the endowment of family labor, the technology advisors who have ever adopted SRI, and risk-lovingness are key determinants of promoting SRI. The former two factors are largely consistent with our expectation because SRI requires intensive labor inputs and timely irrigation management. Also the latter two are consistent with our expectation because SRI is a relatively new technology to the sample farmers, and risk-lovers or farmers who can mitigate unforeseen technology risks by learning from advisors would be more likely to adopt. Then, after matching SRI adopters with non-adopters who have similar observable characteristics, represented by the propensity score (the probability of SRI adoption), we have found that yield and rice income of SRI are significantly larger than non-SRI. This implies that yield and income increments by the SRI method are not due to differential observable characteristics between those adopters and non-adopters but is likely to be attributable to the SRI method *per se*. A remaining puzzle here is that if SRI is really better, why only small portion of farmers adopt SRI. This should be carefully considered when SRI will be promoted by JICA under the KK and other schemes.

6.2. Lessons Learned

So what lessons can be drawn from those findings?

First, regardless of a good and bad rainfall year, in the wet season, the KK scheme does not have any significant impacts in terms of yield and rice income on the downstream plots near the boundary compared with non-irrigated areas, while it does have impacts on upper stream plots. As noted previously, water is taken up first by the upstream farmers, and after they fulfilled their requirement, the rest is passed on the downstream farmers. Thus, water is obviously distributed unequally among the stream strata.

Moreover, in the dry season, the upper stream farmers tend to cultivate paddy, presumably because of better water availability. The rest of farmers are, then, forced to cultivate palawija or leave land fallow. This indicates that the size of canal service area is not matched with water capacity or coordination among stream strata is not sufficient. Otherwise, we should not observe boundaries between paddy, palawija, and fallow plots. In any way, the presence of these boundaries indicates that farmers are challenged to decide whether growing a riskier crop, a safer crop, or doing nothing, given the limited irrigation capacity in the dry season.

It must be also recognized that even if farmers choose to grow a riskier paddy, the average income of paddy is not necessarily greater than palawija, as we have found especially in Chapter 4. We still believe that we have credible identification of marginal impacts of irrigation specifically at the boundary. In a sense, irrigation impacts for these marginal plots are the availability of a risky choice. Since we are looking at the outcomes that are contingent on rainfall, drought like 2009 could reduce the productivity, and we wound up having negligible impacts. At the same time, one should also admit that, regardless of rainfall and consequent water availability, there is a good chance that the marginal, in terms of water availability, paddy plots can become less profitable than neighboring palawija plots. The same holds true for comparison of marginal palawija plots over fallow plots.

In any case, to combat unequal water distribution, one possible resolution would be that upstream farmers switch to palawija in the dry season, which would require less water usage and possibly less risky than paddy. This in turn will enable more farmers in the downstream to effectively use land in the dry season, by cultivating palawija. Because agriculture is a major source of income for the majority of the population in this area, such arrangement would significantly improve the welfare of the downstream farmers, who could not benefit from the scheme in the wet season and who would be poorer than the upstream farmers.

Second, if upland farmers stick to grow paddy, it might be recommended to promote the SRI method since it is said to be a water-saving technology and since it would produce higher outcomes than the conventional practice. In this regard, a practical problem would be that only farmers who have better water accessibility are willing to adopt it, as evidenced by coefficients of stream dummies and distance from water intake in Chapter 5. In all likelihoods, even though SRI has technically water-saving potentials, coordination of water distribution among farmers is not well implemented, so the downstream farmers who have difficulties in access to irrigated water cannot benefit from such a technology. It is advisable that technological leaders, who know well about the SRI method, play a key role in practicing SRI with less water, which in turn would affect farmers surrounding them through learning-from-others effects, and allow SRI to be diffused among a large number of farmers.

Overall, more equitable distribution of irrigation water is one of the major issues arising in the KK scheme and further assistance on operation and management will be required toward that goal. Such needs would become more acute during the drought years like 2009. Having said that, it is also important to emphasize that to assess more balanced measurement of impacts and, thereby, reaching more robust conclusions, it will be better to obtain more samples from non-drought years as well. This follow-up survey help examine who disadopt SRI and why, which is important if JICA would like to further promote SRI.

References

Ito, S., and Takahashi, K. [2008]. "The Application of Quantitative Impact Evaluation: A Case Study from Two Irrigation Projects in Rural Indonesia." Tokyo: JBIC.

McDonald, P.R. Hobbs and S.J. Riha. [2006] "Does the System of Rice Intensification Outperform Conventional Best management?: A Synopsis of the Empirical Record." *Field Crop Research*. 96(1): pp 31–36.

Nippon Coei. [2007]. "Kelara Karalloe Irrigation Improvement Sub-Project: Current Status and Background Details." Unpublished manuscript.

Rosenbaum, P.R., and Rubin, D.B. [1983]. "Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrica* 70 (1): pp41–55.

Sato, S [2006]. "Experience and Challenge of the System of Rice Intensification in Eastern Indonesia" (in Japanese) 佐藤周一[2000]「東方インドネシアにおけるSRI稲作の経験と課題」『根の研究』Vol.6 :pp1-7.

Sheehy, J.E., Peng, S., Dobermann, A., Mitchell, P.L., Ferrer, A., Jianchang, Y., Zou, Y., Zhong, X., and Huang, J. [2004]. "Fantastic Yields in the System of Rice Intensification: Fact or Fallacy?" *Field Crop Research*. 88: pp 1-8.

Uphoff, N., and Randriamiharisoa, R. [2002]. "Reducing Water Use in Irrigated Rice Production with the Madagascar System of Rice Intensification". In: Bauman, B.A.M., et al. (eds). *Water-Wise Rice Production: Proceedings of the International Workshop on Water-Wise Rice Production*: pp 8-11.