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# Assessing the Impact of Adopting the Rutete Rice Variety on Rice Farmer Productivity: A Case Study of Rutete Variety Introduced by IRRI in Gihanga, Burundi

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## Abstract

Burundi, like other countries, invests in agricultural research and development. The adoption of the most productive varieties is one of the ways of increasing agricultural yields. Rice, because of its high productivity, is among the cereals which occupy an important place in the food security strategy in Burundi. This study aims to identify the effect of the adoption of this variety on the productivity of rice farmers. Using random sampling technique was used to select the respondents to fill the questionnaires, data were collected from 524 rice farmers spread across the five villages, namely Buringa, Murira, Nyeshanga, Ninga and Bwiza of the Gihanga commune in Bubanza, Burundi. The analysis of the determinants and the quasi-experimental method based on propensity score matching was used in the estimation of the results of the effect of adoption of the rutete variety on the productivity of rice farmers and estimate the results. The study found that the average rice yields for adopted and non-adopted farmers were respectively 9754 and 9912 kg/ha. Also, if non-adopting farmers decide to adopt the variety, their counterfactual rice yield would be 7931 kg/ha for adopters and for non-adopters reached 7927 kg/ha. The average effect of the treatment on the rice yield of the adopters was 1823 kg/ha and significant ($p<0.01$). The decision to adopt for non-adopting rice farmers could increase the average yield by 1984 kg/ha. The results imply the positive role of the adoption of the rutete rice variety on the performance of rice farmers in Gihanga. It is recommended that the government and research institutions involved in the agricultural sustainable development support rice farmers by increasing agricultural research innovation with the aim of increasing the yield of crops.

**Keywords:** Propensity Score Matching, Rutete Rice, Rice yields



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## Introduction

In sub-Saharan Africa, rice is a fundamental source and component in the diet of rural and urban households. From 2014 to 2018, the rice production increased by 22.4 million tonne in 2014, against 28.3 million tonne in 2018 (26 percent increase). The rice consumption has exceeded 37 million tonne in 2017 and should be around 39 million tonne in 2018, either 25 percent of the cereals consumed (Jégourel, 2019).

In Burundi, the rice demand has generally risen sharply due to population growth, urbanization and changing consumption patterns (MINAGRI, 2014). To respond to the rice production deficit, the government resorted to imports, especially from Tanzania and Zambia. In addition, the International Rice Research Institution (IRRI) has contributed to the promotion of the rice sector through the introduction of new rice varieties that are highly productive, resilient, and adaptive to biotic and abiotic stresses for rice-growing areas in the aim of reducing poverty and hunger, improving the health and well-being of rice farmers and consumers (IRRI, 2020). Thus, rice imports are gradually decreasing due to research agricultural technology innovation and adoption. In 2017, rice imports were estimated at 10,995.9 tonne and fell sharply down to 3,219.1 tonne in 2018 (ISTEEBU, 2018). In 2019, expenditure was estimated at 27,118.9 million Fbu and 15,346 million Fbu in 2020. Although the rice production in high and low land has reduced rice imports, Burundi is still depending on the imports. This evidence castigates that the ultimate objective of achieving potential production and food self-sufficiency in rice is far to be reached. Furthermore, there is a low level of rice yields in Burundi compared to that of the other African countries, ranging from 3.5 to 7 tonne /ha (FAO, 2016). Productivity is estimated at 4 tonne per hectare (ISTEEBU, 2015) but irrigated rice production offers a higher yield potential due to better water control. The inability to produce enough rice to meet demand is attributed to several constraints such as reliance on traditional farming techniques, land degradation caused by over-exploitation, limited access to additional services such as extension, agricultural credit (UNDP, 2012) as well as the low adoption of present agricultural technologies proposed by research centers, results of the low financial means of rice farmers (Tene *et al.*, 2013).

In Burundi, where production resources (especially land) are extremely scarce, the adoption of new agricultural technologies by farmers is the best complement to all the efforts made for self-sufficiency in terms of rice production. Moreover, Zeller *et al.* (1998) reveal that increasing agricultural yield is a difficult task and increasingly depends on the adoption of technologies with high added value. It is within this framework that support programs for the rice sector have been set up in Burundi, emphasizing the dissemination of productive varieties and related techniques that can help to significantly improve rice yields. The introduction of improved varieties of rice has been advocated in the various rice production zones. Among these, we have the varieties such as rutete, kazosi, mugwiza, gwizumwimbu, komboka, developed by IRRI in Gihanga and Hybrid rice developed by Chinese cooperation, in collaboration with Institute of Agronomic Research in Burundi (ISABU), Ministry of Environment, Agriculture and Livestock (MEAE) and Imbo Regional Development Community Tmpagny (SRDI).

This paper seeks to evaluate the contributions of IRRI research in Gihanga rice irrigation scheme and measure the impact of the adoption of the rutete rice variety on the yield of rice farmers, by estimating the difference between the yields of adopting and non-adopting households. Highly yielding rice was one of the factors that farmers chose to adopt improved varieties. Zomboudre (2017) shows that this decision is the process centered on the mental journey of the individual from the first information to the adoption. It produces change in a farmer's situation. Autissier & Moutot (2007) define change as “a rupture between an obsolete existing and a future synonymous with progress". The rupture is a transformation from one state to another to stimulate the driving force of evolution, it is a passage from a state of imbalance to another more progressive one.

In the literature, several studies have found positive effects of technology adoption on farmers' yields (Wiredu *et al*., 2010; Arouna & Diagne, 2013; Ogunniyi & Kehinde, 2015; Blaise, 2016; Issoufou *et al*., 2017). The adoption of technology is anticipated to influence crop yield. Historically, impact evaluations have commonly utilized non-experimental designs. Among these approaches, propensity score matching (PSM) is frequently employed to estimate the effect of agricultural technology adoption. PSM aims to mitigate bias by matching treated and untreated groups with similar or identical observable characteristics, thus ensuring balance between the two groups based on their observable covariates. It is non-parametric tool which highlights the common support problem (Dehejia & Wahba, 1998; Smith & Todd, 2000; Sibilia & Sanofi, 2013).

Results contribute to the existing literature and serve as a basis to give a better understanding on the adoption and diffusion of the agricultural technologies in all the rice-growing areas of the country. The remaining parts are the following: The first part presents the methodology of the study; the second part presents the main results and discussion after which a conclusion and recommendations are drawn.

## Methodology

### The study area

The study was carried out in the rice irrigation scheme of Gihanga located in the south-western part of the province of Bubanza, Burundi, where the SRDI, launched a program by which rice producers receive both agricultural inputs (mainly seeds, water and fertilizers) and other essential agricultural services on credit (Fig. 1).


**Figure 1- Map of Gihanga**
Source: Extract from PDCD Report of Gihanga

The Gihanga irrigated scheme is located in the Imbo plain where most rice is produced in Burundi. Therefore, evaluating the effect of adoption of agricultural technologies in the rice sector based on the most productive varieties sheds light on the importance of rice varieties and provides useful information for research, agricultural policy and practice. Also, a large number of varieties from IRRI have been introduced in this commune than elsewhere. The data on rice production in the Gihanga irrigated scheme are realistic and updated to be consistent with the study. The institute IRRI provided most needed information on their contribution in the area and the challengers hampering the achievement of the goal of rice self-sufficiency and import-substitution.

## Conceptual and theoretical frameworks

The conceptual framework of adoption (Fig. 2) and its associated factors is illustrated in the figure below. We believe that adoption is influenced by demographic (age, gender, marital status, level of education, household size, number of household workers), socioeconomic (farm size, farming experience, possession of a mobile phone) and institutional (Credit access, extension, Membership in an association). These factors can have effects on the adoption and yield of rice farmers (Table 1).

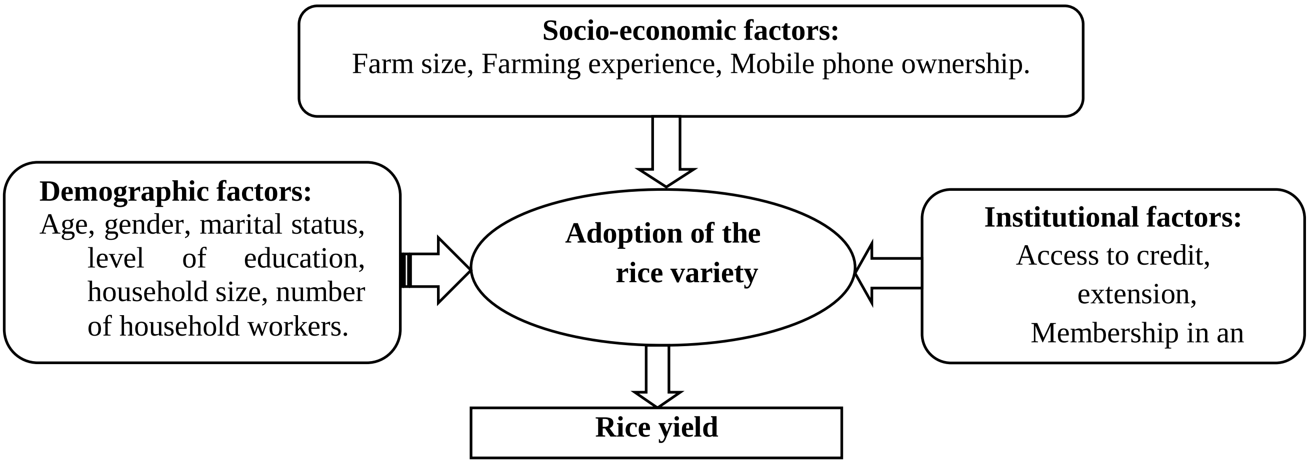



**Figure 2- Conceptual framework of the study**

The adoption of agricultural improved varieties is influenced by a range of factors (Muluken *et al.*, 2021; Ngando *et al.*, 2022; Ouma *et al.*, 2013): socio-economic, institutional and demographic factors (Fig. 1). If a farmer or institutions assisting to rice technology adoption are thriving to reconsider such factors, the crop yield will be definitively improved.

The theoretical framework borrows heavily from the theory of impact evaluation measuring whether improved rice yield is attributed the introduction of agricultural technology. We based ourselves on the theory of change which analyzes the situation of a farmer from his decision to adoption to a new situation. We apply the propensity score matching approach introduced by Rosenbaum and Rubin in 1983 to estimate the average treatment effect.

Therefore, participation in the treatment of a dissemination program of the rice variety rutete is represented by a random variable T. for each individual i, we have:

$$\begin{cases} T_i = 1 \; if\ rice\ farmers\ adopt\ the\ variety\ of\ rutete\ rice\ T_i \\ T_i = 0 \quad Otherwise \end{cases}$$

The effectiveness of the program is measured by the result variable $Y_i$which is a latent variable:

$$\begin{cases} Y_{T_i} if\ the\ rice\ farmer\ receives\ the\ improved\ variety\ of\ rutete\ typeT = 1 \\ Y_{NT_i} Otherwise \;\; T = 0 \end{cases}$$

These two variables correspond to the potential results. They are never simultaneously observed for the same rice farmer. A treated rice farmer $Y_{T_i}$ is observed while $Y_{NT_i}$ is unobserved.

Yield levels of rice farmers were used as outcome variables to understand the real effect of adopting the rutete variety. However, we have shown what the yield of rice farmers would be if they only participated in the use of the rutete rice variety. We then compared the means of these results found for these variables with the observed results to identify the differences that were very important in our conclusions.

Based on the return equations of two groups (groups of adopters and group of non-adopters), we estimate the effect of adoption. We compare:

- The average of the expected results of rice farmers who decided to cultivate the rutete rice variety ($E(Y_i^1 \mid T_i = 1)$ compared to those who decided not to cultivate it ( $E(Y_i^0 \mid T_i = 0)$);
- The average of the expected results of the counterfactual cases: the results that the rice farmers cultivating the rutete rice variety would have if they decided not to cultivate it ( $E(Y_i^0 \mid T_i = 1)$ ); the results that rice farmers who do not grow the rutete rice variety would have if they decided to grow it ($E(Y_i^1 / T_i = 0)$).

These different estimates lead us to make a significant comparison between the two treatment groups. The comparisons will tell us the average of the average effect of adoption on the yield of the adopting rice farmers:

$$EMTT = E(Y_I^1 - Y_i^0 | T_i = 1) = E(Y_i^1 / T_i = 1) - E(Y_i^0 | T_i = 1) \ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots..(3)$$

And the average of the average effect of adoption on the yield of non-adopting rice farmers if they adopted:

$$EMTNT = E(Y_i^1 - Y_i^0 | T_i = 0) = E(Y_i^1 / T_i = 0) - E(Y_i^0 | T_i = 0) \ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots(4)$$

To estimate the results, the nearest neighbor matching method with replacement was used because it gives individuals from the adopters' group a better chance of finding their matches in the non-adopters' group to whom they can compare themselves.

**Table 1- Description of the covariates used in the study**

| Dependent and Independent variables | Type of variables | Description |
|---|---|---|
| Rutete rice variety | Qualitative | Dependent variable: 1 if the rutete variety is adopted and 0 if not |
| Yield of rice farmers | Quantitative | The ratio of production and sown area of a rice farmer |
| Age of head of household | Quantitative | Number of years of the head of operations |
| Gender of head of household | Qualitative | 1 if the individual is a man and 0 if not |
| Marital status of head of household | Qualitative | 1 if the individual is married and 0 if not |
| Household head's level of education | Qualitative | The level of study was categorized as follows: 0= no level; 1 = primary level; 2= secondary level; 3= university level |
| Household size | Quantitative | The number of people living in the household |
| household labor | Quantitative | Number of farming people in the household |
| The sown area | Quantitative | Expressed in hectare |
| Agricultural experience of the head of household | Quantitative | Number of years of experience of a rice farmer |
| Possession of a mobile phone | Qualitative | Binary variable: 1 phone user and 0 if not |
| Membership in an association | Qualitative | Binary variable: 1= if the farmer belongs to an association; 0= no |
| Access to extension services | Qualitative | Binary variable: 1=if the farmer has access to extension services and 0=no |
| Access to credit | Qualitative | Funding for the farmer from microfinance institutions. |
| Market access | Qualitative | Binary variable: 1= if the farmer has access to the market and 0 if not |

## Data

Buringa (V1), Murira (V2), Nyeshanga (V3), Ninga (V4) and Bwiza (V6) villages. bwa Ninga (V5) villages having benefited from IRRI's program to disseminate different varieties of rice. The area of intervention and the various improved varieties of rice popularized by IRRI were drawn from its office located in Bujumbura. In addition, information on the variety of rutete rice was captured through interviews with rice farmers during the days of the pre-survey. We surveyed 105 rice farmers per village to cover the 524 adoptive and non-adoptive rice farmers of the rutete rice variety.

The sample size was calculated using Rea's formula and Parker (1997) as follows:

$$n = \frac{t_p^2 * p(1-p) * N}{t_p^2 * (1-p) + (N-1) * \gamma^2}$$

Where n = sample size; $N$ =represents the population of rice farmers in the study area, it is equal to 8224; $t_p$= value of the Student index at the significance level of 5%, it is therefore equal to 1.96; p = proportion of a given variable; $\gamma$= margin of error of the estimate of the main indicator.

Among the rice farmers surveyed, many of them are members of cooperatives supervised by the SRDI. Thus, members of SRDI cooperatives and non-members were interviewed using a well-structured questionnaire. This methodology allowed us to have fairly similar populations on average to be able to compare their results. In each village, rice farmers were randomly selected and all village residents had an equal probability of being sampled. This sampling took into account the gender aspect (men and women heads of households). The data collected are cross-sectional data and were collected following semi-structured interviews. These data grouped the demographic, socioeconomic and institutional characteristics of the households. Data were collected using KoBoCollect v1.28.0 software and analyzed with STATA 15.1 software.

## Results

The following results emphasize the effect of the adoption of the rutete rice variety on the yield of rice farmers who participated in our sample.

### Rice Production and Socio-Demographic Characteristics

The categorization of these induced variables in the model allows us to make an overall analysis of the rice producers in the study area. It is the analysis of quantitative and qualitative variables grouped into the demographic, socioeconomic and intentional characteristics of the respondents.

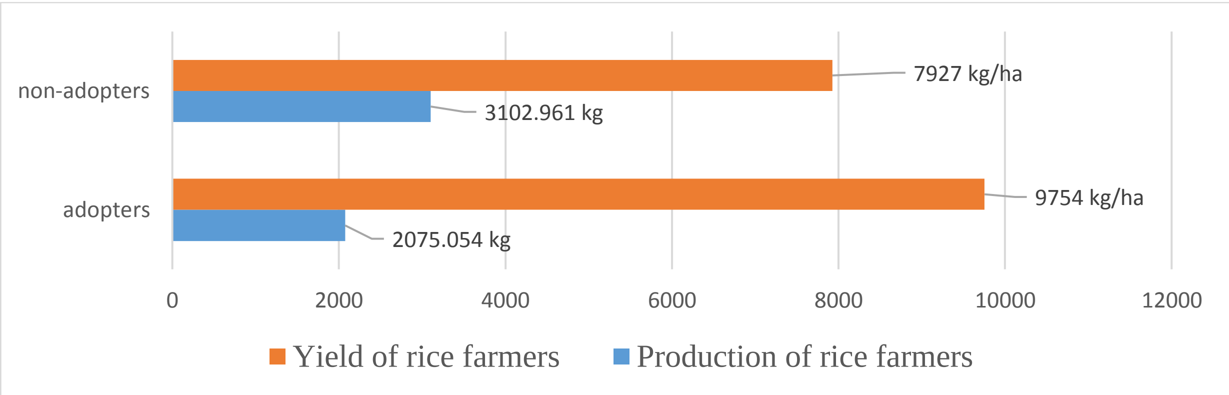



**Figure 3- Production and yield of rice farms**

On the performance, Rutete rice variety produces high quantities both in terms of production and yield compared to rice farmers practicing other varieties. However, given that the planting areas of non-adopters is greater than that of the adopters, the total production of the former is higher than their counterpart.

The analysis also shows that the households surveyed are mainly headed by men with 80.15 % against 19.85% of women (Table 2).

**Table 2- Gender and Marital Status of Respondents**

| Variables | Terms | Adopters (n=152) | | Non-adoptors (n=372) | |
|---|---|---|---|---|---|
| | | Freq | % | Freq | % |
| Gender | Women | 22 | 4.2 | 82 | 15.65 |
| | Male | 130 | 24.81 | 290 | 55.34 |
| Marital status | Single | 8 | 1.53 | 19 | 3.63 |
| | Married | 144 | 27.48 | 353 | 67.37 |

The analysis also shows that the households surveyed are mainly headed by men with 80.15

% against 19.85% of women. Men adopting and those not adopting are respectively 24.62% and 55.53% while among women, they are respectively 4.2% and 15.65%. This situation justifies that in the study area, agricultural households are largely headed by men. There is a big gender disparity in rice production.

Furthermore, marital status is an important socio-demographic factor with possibility of affecting the adoption of agricultural technology. Among the rice farmers surveyed, there were more married respondents (94.85 %) than single ones (5.15 %). However, non- adopters had a higher percentage of married respondents than adopters. It emerges from the analysis that the non-adoptors who are married represented 67.37 % of the sampled population while the adopters were 27.48 %. However, there were few single respondents: 3.63 % of non-adoptors and 1.53 % of adopters.

**Table 3- Education of Respondents**

| Household Head Education | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Adopters (*n=152*)** | | **Non-adopters (*n=372*)** | | **Total (*n=524*)** | |
| | **Frequency** | **%** | **Frequency** | **%** | **Frequency** | **%** |
| No education | 41 | 7.82 | 145 | 27.67 | 186 | 35.50 |
| Primary School | 68 | 12.98 | 158 | 30.15 | 226 | 43.13 |
| Secondary School | 38 | 7.25 | 68 | 12.98 | 106 | 20.23 |
| University | 5 | 0.95 | 1 | 0.19 | 6 | 1.15 |

As for the level of education, the study revealed that about 35.50% of the farmers had no level of education, 43.13% of the farmers had a primary education, 20.23% had a secondary education while 1.15 % of the farmers had a university education (Table 3). By adoption status, the statistics revealed that the non-adopters of all education levels are respectively represented by 27.67% of rice farmers with no level, 30.15% of rice farmers with primary level, 12.98% of rice farmers with secondary level and 0.19% of rice farmers with university level while the adopters are respectively represented by 7.82% of rice farmers with no level, 12.98% of rice farmers with primary level, 7.25% with secondary level and 0.95% with university level.

**Table 4- Age, household size and family labor of respondents**

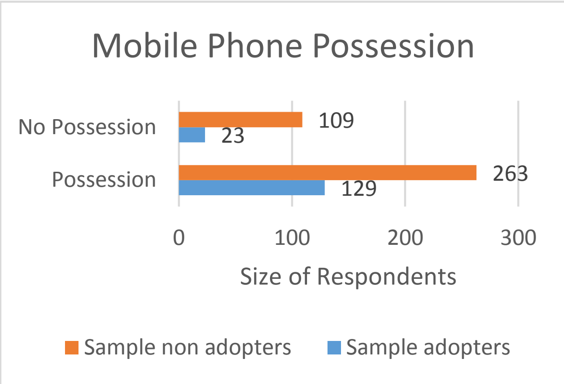
| **Variables** | **Adopters ( n =152)** | **Non-adoptors ( n =372)** |
|---|---|---|
| Age of head of household (years) | 45 | 45 |
| Household size (persons) | 8 | 8 |
| family labor (person) | 2 | 2 |

The results in Table 4 show that the entire population sampled represents the average age of 45 years. It emerges from this result that the adopters and non-adopters of the rutete rice variety have both an average of 45 years and average of 8 individuals in each household. The figures remain in both groups given that the selection has been done at random without any prior bias.

In addition, the results also show us a small average of family labor (2 individuals). Adopter and non-adoptor households have the average household size of 2 and 2 respectively. The gap between household size and family labor force is relatively large. The respondents opined that they used much more hired labor in their rice farming system. In addition, the household heads surveyed found that men are much more responsible for rice farming while women are responsible for other agricultural activities.

**Economic characteristics of respondents**

This part presents the socio-economic characteristics of rice producers, focusing mainly on the possession of a mobile phone, access to the market, the area sown for rice cultivation and the producer's experience in rice-growing activities.



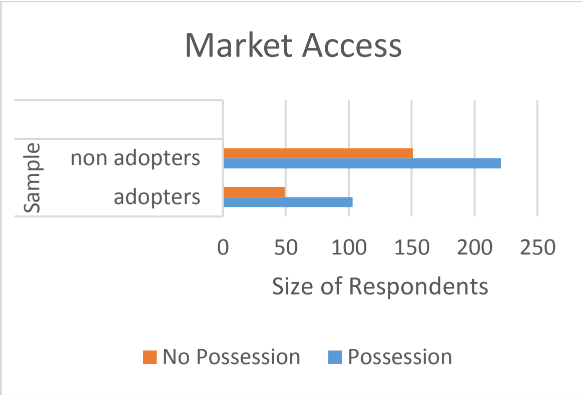




**Figure 3- Mobile Phone possession and market access of respondents**

Mobile phone is regarded as the necessary tool for communication in rural area. In the study area, the distribution of respondents based on mobile phone usage reveals that a majority are mobile phone users (74.62%), with the remaining 25.38% classified as non-mobile phone users. Among the adopters of rice farming technology, only 24.62% own mobile phones, while 4.39% do not. Conversely, among the non-adopters, 50.00% of respondents are mobile phone users, while 20.99% do not use mobile phones. The mobile phone plays an important role in the agricultural technology adoption. Cole & Fernando (2016) found that the communication tool helps in information access and awareness of agricultural technology innovation. In their study, mobile phone service was effective in nudging farmers to adopt a number of recommended agricultural technology.

Smallholder farmers often face serious difficulties in accessing markets to sell their produces in marketplace or buy crucial agricultural inputs (IFAD, 2015). The statistics also show 83.78% of respondents who have access to the market against 16.22% of respondents who do not have access to the market. This justifies that the rice cultivation practice in Gihanga is largely market oriented. According to the surveyed rice growers, a portion of the production obtained must be sold to repay debts contracted during the operating period, while another part is reserved for consumption. Based on adoption status, 25.19% of rice farmers with access to the market have adopted the rutete rice variety, whereas 58.59% of them have not adopted it. Additionally, 3.83% of rice farmers without market access have adopted the rutete rice variety, compared to 12.40% of rice farmers without market access who have not adopted it. In addition, among the rice farmers with access to the market, 25.19% have adopted the rutete rice variety while 12.40% of them have not adopted it.

The results also show that the average household in the study area has an average area of 27.71565 acres. The results in Table 9 show us that the non- adopters have an average area of 25.91 acres while the adopters have an average of 32.14 Ares. The average agricultural experience of rice farmers in the study area was 15 years. Descriptive statistics revealed an average of 16 years for the adopters while for the non-adopters the average experience was 15 years.

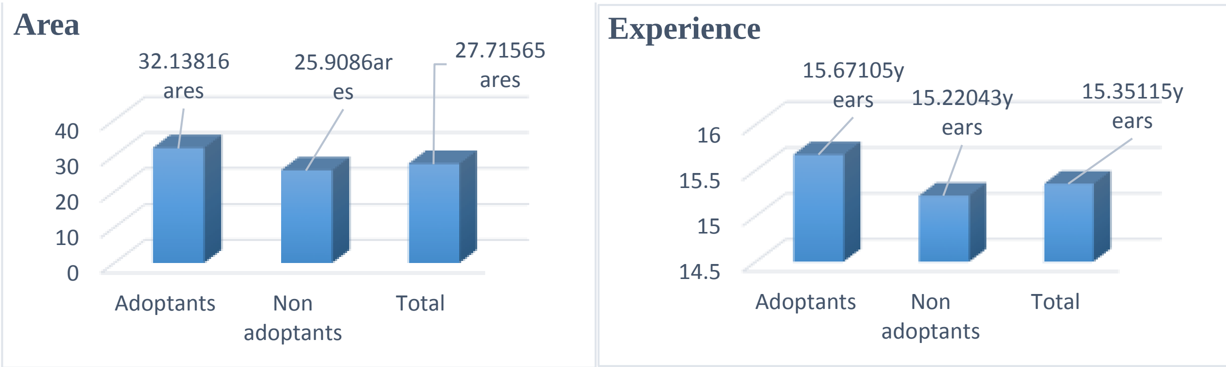



**Figure 4- Area and agricultural experience among respondents**

### Features of Financial Institutions, Farmers'Associations and SRDI's Extension Service

In the population surveyed, farmers obtain agricultural credit through SRDI cooperatives, local lenders, and micro-finance institutions. Credits from the SRDI are often seeds and pesticides. These the latter are supposed to be repaid after the harvest. The rice farmers complain that the price recorded by the SRDI on the loan payment is so low (1300 Burundi Francs) compared to that of the local market (2200 Burundi Francs). Also, local lenders demand loan repayments at a high rate that rice farmers are unable to pay. However, we based ourselves on credit in monetary terms.

**Table 5- Institutional characteristics**

| Variables | Terms | Adopters (n=152) | | Non-adoptors (n=372) | |
|---|---|---|---|---|---|
| | | Freq | % | Freq | % |
| Access to credit | Access to credit | 101 | 19.27% | 220 | 41.98% |
| | No access to credit | 51 | 9.73% | 152 | 29.01% |
| Popularization | Access to extension | 99 | 18.89% | 171 | 32.63% |
| | No access to extension | 53 | 10.11% | 201 | 38.36% |
| Membership in an association | Membership | 121 | 23.09% | 254 | 48.47% |
| | Not membership | 31 | 5.92% | 118 | 22.52% |

In this study, information on access to credit was collected. Table 5 shows the number of respondents who requested agricultural credit during the last season of the year 2022 and others who did not request it. In the population surveyed, 61.26 % of farmers had access to credit against 38.74 % of farmers who did not have access to credit.

By adoption status, among the adopters, 19.27% of adopting rice farmers had access to agricultural credit against 9.73% of rice farmers who did not have access to agricultural credit. However, 41.98% of non- adopters had access to agricultural credit against 29.01% of rice farmers who did not have access to agricultural credit.

As for membership in an organization, the statistics showed 71.56% of the respondents who belong to a rice farmers' association and 28.44% of the respondents who do not belong to any rice farmers' association. By adoption status, 23.09% of adopters belong to an association against 5.92% of adopters who do not belong. In addition, 48.47% of non-adoptors belong to an association against 22.52% of non-adoptors who do not belong to any association. An extension service to rice farmers is an incentive for the adoption of improved rice varieties. In the study area, 48.47% declared that they did not benefit from these services from the extension agents while in the counterpart, the number who benefited from at least one extension agent was only 51.53%. By adoption status we noticed 18.89% of adopters who received at least one extension worker against 10.11% of adopters who did not. On the side of non-adopters, 32.63% benefited from extension services while 38.36%

answered that they never benefit from them. These services are supposed to be provided by SRDI agents as said the farmers. Those who said they don't get the extension service reveal of their non-participation in workshop or field demonstration the lack of extension services has been linked to inefficient production agricultural. Since the aftermath of the civil war in Burundi, the delivery of extension services has declined due to the dwindling of the number of extension workers and lack of funds to access at least private extension service.

## Adoption Impact Analysis

First of all, we carried out matching quality tests that justify the use of the quasi-experimental method based on propensity score matching in estimating the results.

**Table 6- Standardized bias control of the independent variables**

| Sample | PS R2 | LR chi2 | *p* >chi2 | Average Bias |
|---|---|---|---|---|
| Unmatched | 0.091 | 57.19 | 0.000*** | 16.2 |
| Matched (nearest neighbor) | 0.022 | 9.20 | 0.757 | 6.4 |

Note: *** significant at 1%

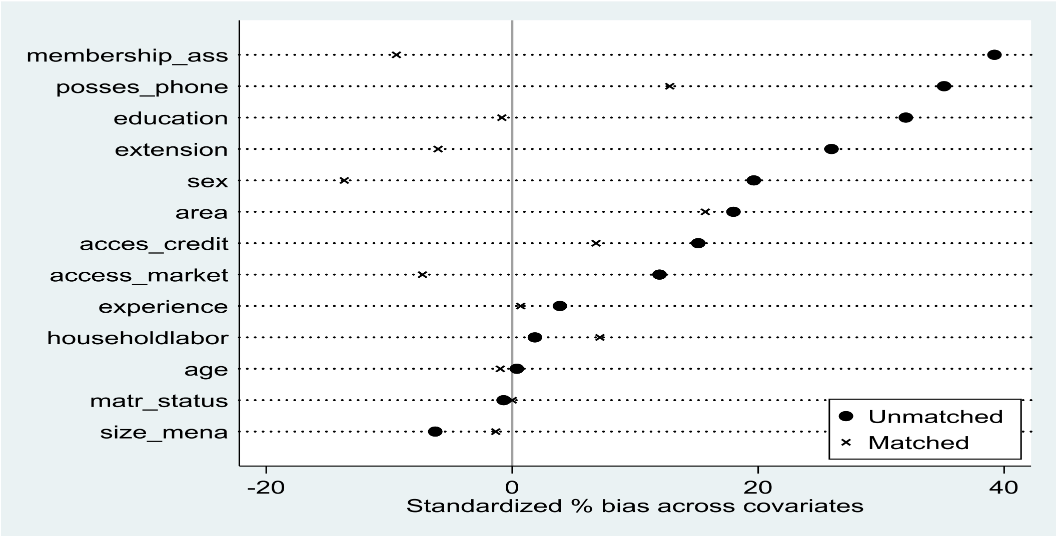



**Figure 5- Standardized bias before and after matching**

This Table 6 relates the observable differences between rice farmers adopting and non-adopting improved varieties of rutete rice. The results indicate a good quality of the pairing of the rice growers of the surveyed population. Indeed, the pseudo R2 decreases significantly after the pairing going from a value of 9.1% to a value of 2.2%. In addition, the matching quality test before and after the matching of the covariates considered in the study shows a satisfactory balance after the match between the adopting and the non-adopting groups used in the match, The standardized mean difference for the overall covariates used for the matching reduced from 16.2% before matching to 6.4% after matching. In addition, the joint significance test of the variables after matching [1] is rejected (P-value greater than 5%), which justifies the effectiveness of the PSM method for estimating results without bias. In other words, the unobserved characteristics do not have significant effects on the yield of rice farmers.

The graph shows us a considerable reduction in the selection biases because after matching, the biases are concentrated very close to zero or

1- Maximum likelihood tests are rejected before matching but not after even negative.

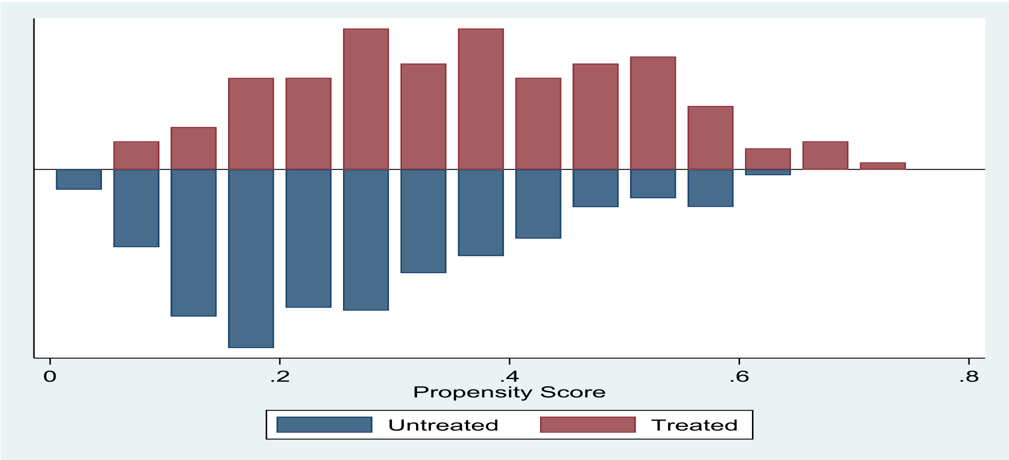



**Figure 6- Distribution of propensity scores and common support**

We define the "Untreated" to refer to non-adopters (the control group) and "Treated" refer to adopters (treatment group) who are in the common carrier. Adopters who should be outside of the common support are not present. This means that all adopters have related matched from the control group with identical or nearly similar characteristics with which they can compare. This justifies a good quality of the pairing. These results indicate that the required balancing property of the propensity score distribution is satisfied and that the estimated results are reliable and unbiased.

The various matching quality assessment criteria were met by the model. The common support is respected, which therefore makes it possible to calculate the Mean Treatment Effect on the Treated (the EMTT) and the Mean Treatment Effect on the untreated (EMTNT).

These results are estimated using the nearest neighbor matching technique with replacement.

**Table 7- Results of estimation of the effect of adopting the rutete rice variety**

| **Algorithm type** | **Variable** | **Effects on types of rice-growing households** | **Adopters** | **Non-adoptors** | **Average treatment effect** | **Prob** |
|---|---|---|---|---|---|---|
| nearest neighbor | Yield(kg/ha) | Households of adoptive rice farmers (EMTT) | 9754 kg/ha | 7931 kg/ha | 1823 kg/ha | 0.000*** |
| | | Household of non-adopting rice farmers (EMTNT) | 9912kg/ha | 7927 kg/ha | 1984 kg/ha | |

Note: *** significant at 1%

The interpretation of this Table is made in three categories. First, the average yield for rice farmers who adopted the rutete variety is 9754 kg/ha, while those who did not have an average of 7927 kg/ha. Second, adopting households if they decided not to adopt this variety, their counterfactual rice yield would be 7931 kg/ha, while non-adopting rice farmers if they decided to adopt, their counterfactual rice yield would be 9912 kg/ha. Third, the average effect of the treatment on the rice yield of the adopters corresponds to 1823 kg/ha and it is positive and significant ($p<0.01$). The decision to adopt for non-adopting rice farmers could increase the average yield by 1984 kg/ha. The results indicate that the yield of households that adopted the rutete rice variety increased relatively compared to those that did not. This implies the positive role of the adoption of the rutete rice variety on the performance of rice farmers in Gihanga. This could be interpreted as the result of technical change brought about by the adoption of the rutete rice variety and IRRI's agronomic research on the most productive varieties that have multiple benefits for rice farmers in Burundi. Moreover, knowing that farmers are financially poor, the results found reveal that the multiplication of the most productive improved varieties of rice from IRRI plays a key role in improving the yield of low-income rice farmers. Furthermore, the adoption of the most productive variety of rice contributes to the reduction of poverty and hunger, enhances the health and well-being of rice farmers and consumers alike. Similar results were found by Zegeye *et al.* (2022) in their study on the impact of agricultural technology adoption on wheat productivity in Ethiopia. More Awotide *et al.* (2012), reported that the adoption of improved rice varieties has a positive and significant impact on productivity (358.89 k/ha) in Nigeria. For its part, FAO (2013) specifies that an increase of more than 25% in yield can be obtained if producers in Niger use improved varieties of millet and cowpea. In Benin, Arouna & Diagne (2013) showed that seed multiplication of improved varieties allows rice farmers to increase their rice yield by 1924 kg/ha. Tesfaye *et al*. (2016) in Ethiopia highlighted that an increase of 1 to 1.1t/ha can be obtained if wheat producers use new varieties resulting from agronomic research.

The results of our study allow us to conclude that the multiplication and knowledge of the most productive rice varieties (rutete) in the region plays an indispensable role in increasing farmers' yields.

## Conclusions and Recommendations

In this study, we were motivated to analyze the adoption of the improved rice variety rutete. The objective was to assess the effect of adopting the rutete rice variety on the yield of rice farmers in Gihanga. The study shows that adopters are different from non-adopters in terms of characteristics such as sex, age, marital status, education of household head, household size, household labor force, area, experience, access to credit, market access, association membership, access to extension services and mobile phone ownership. In the estimation procedures, we used the propensity score matching method, which allowed us to eliminate selection bias that could lead to biased results estimates. The observation is that the decision to adopt this variety allows rice growers to increase their yield by 1.823 kg/ha. Rice farmers who did not adopt this variety, if they decided to adopt it, could produce higher yields than the adopters, i.e. increase their yield by 1.984 kg/ha. The adoption of the most productive varieties could therefore constitute an important instrument of agricultural policies aimed at food security and the sustainability of production. It therefore becomes urgent that political decision-makers and organizations working in the Burundian agricultural sector can intensify actions to popularize improved varieties of rice accompanied by modern agricultural techniques and dissemination of IRRI varieties in rural areas in order to increase rice yields.

One of the shortcomings of the study is that it does not distinguish between the different varieties introduced into the study area in order to detect the real effect of each of them. In addition, the use of other non-experimental methods that can take into account unobserved characteristics, could produce good results in future research. In the end, other similar studies of this one are necessary in Burundi to have a general view of the country as to the importance of the agricultural technologies popularized on the yields of the farmers. The results could influence policy makers from organizations in charge of agricultural sector development to make decisions.

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# ارزیابی تأثیر پذیرش رقم برنج اصلاح شده بر عملکرد کشاورزان در بروندی: مطالعه موردی رقم معرفی شده توسط مؤسسه بین‌المللی تحقیقات برنج در منطقه گیهانگا کشور بروندی

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## چکیده

کشور بروندی مانند بسیاری دیگر از کشورها در تحقیقات و توسعه کشاورزی سرمایه‌گذاری زیادی می‌کند و کاربرد ارقام بذر پرمحصول یکی از مهم ترین روش‌ها برای بهبود عملکردها در کشاورزی است. محصول برنج به دلیل راهبرد امنیت غذایی در بروندی از اهمیت بیش‌تری در میان سایر غلات برخوردار است. هدف این مطالعه شناسایی تأثیر کاربرد رقم بذر اصلاح شده برنج بر بهره‌وری کشاورزان است. داده‌های این مطالعه با استفاده از روش نمونه‌گیری تصادفی و پرکردن پرسشنامه از ۵۲۴ کشاورز برنج کار در پنج روستای بورنیا، موریرا، نیشانگا، نینگا و بوئیزا واقع در منطقه گیهانگا، بوهانزا، انجام شد. این مطالعه برای تخمین تأثیر رقم بذر اصلاح شده برنج بر متغیرهای هدف از روش جورسازی نمره گرایش استفاده کرده است. نتایج نشان داد متوسط عملکرد برای کشاورزان تحت تیمار و کشاورزان شاهد، به‌ترتیب، ۹۷۵۴ و ۷۹۲۷ کیلوگرم در هکتار بود. اگر خانوارها تیمار شده تصمیم به عدم استفاده از بذر اصلاح شده بگیرند، عملکرد این خانوارها به ۷۹۳۱ کیلوگرم در هکتار کاهش می‌یابد. همچنین، اگر کشاورزان شاهد تصمیم به استفاده از رقم بذر اصلاح شده بگیرند عملکرد برنج آن‌ها به ۷۹۳۱ کیلوگرم در هکتار افزایش می‌یابد. تأثیر متوسط تیمار بر عملکرد برنج برای گروه تیمار ۱۸۲۳ کیلوگرم در هکتار و معنی‌دار است. به همین ترتیب، تصمیم برای پذیرش رقم بذر اصلاح شده برای کشاورزان شاهد متوسط عملکرد را تا ۱۹۸۴ کیلوگرم در هکتار افزایش می‌دهد. این نتایج به نقش مثبت استفاده از رقم برنج اصلاح شده بر عملکرد کشاورزان در گیهانگا اشاره دارد. از توصیه‌های این مطالعه آن است که دولت و مؤسسه‌های پژوهشی دست‌اندرکار توسعه پایدار کشاورزی از تحقیقات نوآورانه در راستای افزایش عملکرد کشاورزان حمایت کنند.

**واژه‌های کلیدی:** رقم اصلاح شده برنج، روش جورسازی، عملکرد برنج، نمره گرایش

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