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Effect of good agricultural practices on Irish potato production: A case study of Jyambere Muhinzi Kinoni Cooperative in Burera District in Rwanda

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Abstract

*Potato (*Solanum tuberosum L.*) is known for its efficiency in converting resources into high-quality food, which can aid in poverty reduction. However, the potato yield in Rwanda has been declining, leading to farmer dissatisfaction with trading terms and a reliance on low prices in the value chain. Moreover, the use of good agricultural practices (GAPs) has not been adopted wholly, and their contribution to yield has still not been established. Correspondingly, the driving force in the adoption scenario of GAPs and the effects of adoption have remained unclear. This study therefor aimed to examine the effect of the adoption of GAPs on Irish potato production in Jyambere Muhinzi Kinoni cooperative, Burera district. Primary data were collected from 87 respondents randomly selected in the Nkumba, Gafuka, Ntaruka and Nkenke cells of Kinoni sector in Burera district using structured questionnaires. Descriptive statistics were used to describe the respondents' socio-economic characteristics, while a logit model analysed factors influencing farmers' adoption of GAPs. The effects of GAPs adoption on potato production were assessed using propensity score matching (PSM), while the relationships between farmers' annual income and GAPs adoption were assessed using linear regression models. The findings indicate that a significant portion of respondents (64 out of 87) had accessed extension services, with a majority (60.9%) being cooperative members. PSM* *analysis revealed that GAPs adopters experienced an increase in yield of 917.56 kilograms and 5 600 kilograms more than non-adopters, using the kernel-based matching and nearest neighbour matching methods, respectively. A strong positive relationship was also identified by linear regression analysis between farmers' annual income and GAP adoption. The study emphasises the importance of providing extension services and training programmes to farmers on various aspects of GAPs, including compost and chemical fertiliser usage, farm labour management, record-keeping, and land size measurement. Such initiatives could enhance farmers' knowledge and skills, ultimately improving potato productivity in the region.*

Key words: good agricultural practices, farmers, cooperative, production, Rwanda

1. Introduction

Potato (*Solanum tuberosum* L.) is among the most efficient crops in terms of transforming resources into high-quality food, which makes them suitable for poverty reduction (FAO 2019). Potato is one of the six priority crops identified by the government of Rwanda falling under the crop intensification programme (CIP). It is also recognised as the second most important staple food after banana (Muhinyuza *et al*. 2012). In 2019, Rwanda ranked seventh out of 161 countries in terms of per capita potato consumption, reaching 96.6 kg per person (HelgiLibrary 2022). This high level of consumption underscores the significance of potato as a crucial crop in Rwandan agriculture.

The cultivation of potato in Rwanda is concentrated primarily in four north-western districts, which account for over 60% of the total production (Agriterra 2020). In 2021, the country had 1.43 million hectares of agricultural land, with 1.1 million hectares used for seasonal crops in season A, nearly 0.6 million hectares for permanent crops, and 0.131 million hectares for permanent pasture. The total cultivated area for potato in 2021A was 52 196 hectares, producing 463 562 metric tons, with an average yield of 8.9 metric tons per hectare for small-scale farmers (National Institute of Statistics Rwanda [NISR] 2021). However, in the 2023A season, the area cultivated for potato increased to 55 613 hectares, but the yield decreased by 6.5% compared to 2022A, with an average yield of 8.2 tons per hectare. Large-scale farmers had a higher average yield, of 12.2 tons per hectare (NISR 2023). This yield is significantly lower than the expected 25 to 35 metric tons per hectare at research stations (Agriterra 2020). Potato farmers in Rwanda face several challenges, including low adoption of good agricultural practices, limited use of inputs such as fertilisers, declining soil fertility, limited access to certified seeds, and pest and disease issues such as bacterial wilt, late blight and viruses (Salami *et al*. 2010). Despite government efforts to regulate potato prices and improve the value chain, farmers still struggle with low productivity (MINAGRI 2018). Research suggests that adopting good agricultural practices can improve productivity in the potato value chain (Tumukunde 2018).

Good agricultural practices (GAPs) encompass regulations for on-farm production and post-production practices aimed at enhancing yield, while considering economic, social and environmental sustainability (Wollni *et al*. 2010). These practices include certified seed use, crop rotation, chemical fertilisers, manure/compost application, crop husbandry and pesticide/fungicide use (He 2012). Research indicates that adopting GAPs, particularly certified seed, fungicides, fertilisers, manure, crop rotation and crop husbandry, can more than double potato yields (Wang'ombe & Van Dijk 2013). Despite the development of GAPs over time, their overall impact on production and adoption rates are not yet fully understood (Wollni *et al*. 2010). Moreover, the collective effect of GAPs on production and the contribution of their full adoption to yield remain unclear. This study aims to examine the impact of GAP adoption on potato production, focusing on Jyambere Muhinzi Kinoni cooperative in Burera district. Specifically, the study investigates (i) the factors that influence farmers' adoption of GAPs, (ii) the effect of GAP adoption on potato production, and (iii) the relationship between farmers’ annual income and GAP adoption. By focusing on a cooperative in Burera district, this study provides a novel angle, as limited research has explored GAP adoption in this specific context. The findings can be generalised or adapted to other cooperatives, districts or crops in Rwanda and similar contexts in sub-Saharan Africa. In addition, this study includes farmers’ income as an outcome variable, contributing to a broader understanding of the economic benefits of GAPs. The study also addresses the environmental and social dimensions of GAP adoption, such as soil health, resource-use efficiency and gendered impacts. Furthermore, this research examines how the adoption of GAPs could contribute towards achieving global commitments such as the sustainable development goals (SDGs), particularly goal 2 (zero hunger) and goal 12 (responsible consumption and production).

2. Methodology

2.1 Study area

This study was conducted to Jyambere Muhinzi Kinoni Cooperative, located in Kinoni sector of Burera district, Northern Province, Rwanda. It is a cooperative that engages in the collection and commercialisation of potatoes from potato farmers in the Nkumba, Gafuka, Ntaruka and Nkenke cells of Kinoni sector. It started operating legally in 2017 with the purpose of helping its members by collecting their produce for appropriate post-harvest handling techniques, markets access, access to improved seed and fertilisers, and access to training on good agricultural practices to improve their productivity. The cooperative counts 104 formal members, of whom 37 are women and 45 are youth members younger than 35 years old. Since 2020, the cooperative has partnered with Dutch NGO Agriterra to gain support through advice, training and field exchange.

2.2 Research design

The study explored data gathered using both qualitative and quantitative primary data collection. The data were collected from various respondents at given points in the Nkumba, Gafuka, Ntaruka and Nkenke cells of the Kinoni sector in Burera district. A quantitative approach was used in computing percentages, means and measures of variability, whereas a qualitative approach was used to provide detailed information about the subject of study and to help the researchers establish trends in the patterns and relationships among the study variables.

2.3 Sample size and selection

The target population was potato farmers from the Nkumba, Gafuka, Ntaruka and Nkenke cells, and farmers were selected randomly and purposively by referring to the zones covered by the Jyambere Muhinzi Kinoni Cooperative. By using the Raosoft application, the sample size of the study was found to be 87, of whom 53 were formal members of the cooperative while 34 were not formal members but participated in cooperative activities.

2.4 Data collection methods

Data were collected by trained enumerators, who interviewed the members of the Jyambere Muhinzi Kinoni cooperative while referring to the well-organised questionnaire that included the following variables: gender, level of education, cooperative membership, predominant season, source of seed (certified seeds, farm-saved seeds and local market seeds), seed variety (gikungu, kinigi and other varieties), access to extension services, access to credit, adoption of good agricultural practices (adopters and non-adopters) and farm size.

2.5 Data analysis

Quantitative and qualitative data were tabulated and cross-tabulated using STATA. Descriptive statistic and logistic regression analysis were performed to assess the factors influencing farmers' adoption of good agricultural practices. Propensity score matching (PSM) was applied to estimate the effect of the adoption of good agricultural practices on potato production in the area, while multiple regression analysis was performed to assess the level of influence good agricultural practices on farmers' annual income. The analysis was performed at a probability level of 95% (Z-value of between -1.96 and 1.96, and a significance of at least 5%).

2.5.1 Farmers' adoption of good agricultural practices

To evaluate the factors that influence the farmers' adoption of good agricultural practices, the logit econometric model was used to determine the probability that socio-economic factors, institutional support and resource constraints would influence such adoption.

$$Y = 1 \; when \; y' \geq 0 \;, while \; Y = 0 \; when \; y' \leq 0 \tag{1}$$

Thus, Y is equal to one for adopters and equal to zero for non-adopters.

The logit model then becomes Y = β0 + βnXn + ϵ, where β0 = intercepts, β1 … βn stand for coefficients of the explanatory variables, and ϵ is the normal distribution of the error terms.

The logit models then become: Farmer's adoption of good agricultural practices (Y) = β0 + β1 Age + β2 Gender + β3 Educ level + β4 Exp + β5 Membership + β6 Season + β7 Seed source + β8 Variety + β9 Extension + β10 Land ownership + β11 Credit + β12 Farm size + β13 Cost of production + ϵ.

2.5.2 The effect of the adoption of good agricultural practices on potato production

In this study, propensity score matching (PSM) was used to estimate the effect of the adoption of good agricultural practices on potato production. According to Mutamuliza and Musabanganji (2020), the propensity score probability function is presented as:

$$P\,(X) = Pr\,\{D \;=\; 1 \backslash \, X\} = \; E\,\{D \backslash \, X\}, \tag{2}$$

where D = {0, 1}, that is the binary variable for whether a farmer has adopted good agricultural practices (1) or not (0), and X is the multidimensional vector of farmer characteristics.

The average treatment effect on the treated (ATT) group was computed using the nearest neighbour matching (NNM), radius matching (RM) and kernel-based matching (KBM) methods to analyse the effect of the adoption of good agricultural practices on potato production. The value of ATT is the difference between the expected outcome values of the treated group (cooperative members) and the control group (non-members).

With NNM, each treated group is matched with a control group (Caleindo & Kopeinig 2008). According to Li (2012), in radius matching, the outcome of the control group matches with the outcome of the treated group only when the propensity scores fall in the predefined radius of the treated units.

The formula can be written as:

$$ATT = \frac{1}{N^T}\left(\sum_{i=T} Y_i^T - \frac{1}{N_i^c}\sum_{j=c} Y_j^c\right), \tag{3}$$

where N^T is the number of cases in the treated group and N^c_i is a weighting scheme that equals the number of cases in the control group using a specific algorithm (Becker & Ichino 2002).

With KBM, all treated groups are matched with a weighted average of all control groups using weights that are inversely proportional to the distance between the propensity scores of the treated and control groups.

The weighting value is determined by the distance of the propensity scores, bandwidth parameter h_n, and a kernel function k (.).

The KBM estimator is given by the formulation:

$$ATT^K = \frac{1}{N^T}\sum_{I=T}\left\{Y_i^T - \frac{\sum_{i=T} Y_j^c G\left(\frac{P_j - P_i}{h_n}\right)}{\sum_{i=T} G\left(\frac{P_K - P_i}{h_n}\right)}\right\}, \tag{4}$$

where G (.) is a kernel function and h_n is a bandwidth parameter. Under standard conditions for the bandwidth and kernel, the formulation below is a consistent estimator of the counterfactual outcome, Y_{0i}:

$$Y_{oi} = \frac{\sum_{i=T} Y_j G\left(\frac{P_j - P_i}{h_n}\right)}{\sum_{K=i} G\left(\frac{P_k - P_i}{h_n}\right)} \tag{5}$$

2.5.3 Relationship between farmers' annual income and adoption of good agricultural practices

In this study, the relationship between farmers' annual income and the adoption of good agricultural practices was examined using the multiple regression model (Wooldridge 2000).

$$Yi = b_o + b_i Xi + U_i, \tag{6}$$

where i = 1, 2, 3, 4 (i is the number of variables),

Yi = farmer annual income, Xi = set of explanatory variables, and Ui = an error term with the usual OLS properties.

3. Results and discussion

3.1 Characteristic statistics of the respondent farmers

The statistics relating to the different characteristics of the farmer are set out below.

Gender: Male respondents comprised 50.6%, while females made up 49.4%. This balanced participation reflects effective gender sensitisation efforts by the government and partners promoting gender inclusion in agricultural cooperatives in Rwanda.

Cooperative membership: A total of 60.9% of farmers were formal members of Jyambere Muhinzi Kinoni Cooperative, while 39.1% were informal members who access benefits but are unregistered as they had not paid membership fees. These results conform with the findings of Kayitesi (2015), who stated that the significantly high numbers of informal cooperative members are associated with the high membership fees, that limit some farmers from joining the cooperative.

Age range: Most of the respondents (64.4%) were aged 31 to 49 years, followed by 20.7% aged 18 to 30 and 14.9% older than 50, indicating a mature and diverse pool of perspectives.

Predominant growing seasons: Potatoes are grown in two main seasons: season A (47.2%, August to February) and season B (47.1%, February to July), with a small percentage (5.7%) grown in season C, which is a short season extending from June to August that is used for quick-growing crops.

Table 1*:* **Summary characteristics of the respondents**

Variable		Frequency	Percentage (%)
Gender	Male	44	50.6
	Female	43	49.4
Average age (years)	18–30	18	20.7
	31–49	56	64.4
	50 and over	13	14.9
Cooperative membership	Formal members	53	60.9
	Informal members	34	39.1
Education level	Not completed primary school	40	46.0
	Completed primary school	23	26.4
	Completed O level (S3)	8	9.2
	Completed high school (S6)	13	14.9
	Completed university course	3	3.4
Predominant season	Season A	41	47.2
	Season B	41	47.1
	Season C	5	5.7
Potato variety	Gikungu	1	1.1
	Kinigi	75	86.2
	Other: Gisubizo, Kirundo, Peko and Twihaze	11	12.6
Extension services	Participated	64	73.6
	Not participated	23	26.4
Source of seed	Certified seed producers	48	55.2
	Farm saved seeds	21	24.1
	Local market (informal seeds)	18	20.7
Farming experience (years)	Zero to one year	5	5.7
	Two to four years	18	20.7
	Five to 10 years	41	47.1
	More than 11 years	23	26.4
Land ownership	Own	64	73.6
	Rent	23	26.4

Note: These data were obtained from the NISR (2023) survey, the Seed Potato Fund (SPF-IKIGEGA) LTD (a company that provides certified seed potatoes), and Rwanda Agriculture and Animal Resources Development Board (RAB) (a government agency responsible for agricultural development and animal resources in Rwanda).

Potato variety**:** The majority (86.2%) grow the Kinigi variety, with 1.2% growing Gikungu and 12.6% cultivating other varieties like Gisubizo, Kirundo, Peko and Twihaze.

Access to extension services: Training by Agriterra and other partners reached 73.6% of the respondents, who attended different extension training sessions mostly offered by Agriterra, Holland

Greentech Rwanda and other partners in the potato value chain in support of their engagement in the potato value chain.

Seed sources: Over half (55.2%) of the respondents used certified seeds from institutions like SPF-IKIGEGA and RAB. Others relied on saved seeds (24.1%) or informal seed suppliers in local markets (20.7%).

Education level: About 46% of the respondents had not completed primary education, 26.4% had completed primary school, and only 3.4% had attained a university education, indicating that education may influence record-keeping and data quality.

Farming experience: More than 50% of the respondents had more than five years of experience, with 47.1% having farmed for five to 10 years and 26.4% for more than 11 years.

3.2 Adoption of good agricultural practices (GAPs)

The farmers had adopted various good agricultural practices to improve potato yields, including land preparation, planting calendars, seed spacing, weed control, pest and disease management, soil and water conservation, fertiliser management, and post-harvest handling (Nyongesa *et al*. 2012). Training has led farmers to adopt certified seeds, crop rotation, chemical fertilisers, compost, crop husbandry, and pesticides/fungicides.

All farmers recognised the importance of pesticides and fungicides, with 97.7% using chemical fertilisers. However, only 55.2% used certified seeds due to limited availability, forcing others to rely on saved or seeds from informal markets (Figure 1). These findings align with Agriterra's (2020) observation of challenges in certified seed production in Rwanda

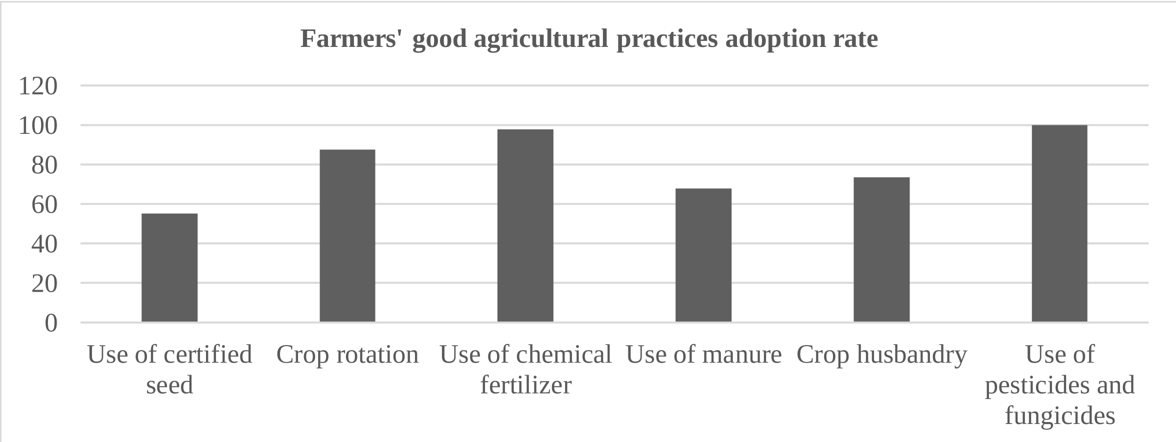

Figure 1: Number of selected good agricultural practices adopted by potato farmers in Jyambere Muhinzi Kinoni Cooperative

Note: These data were obtained from the NISR (2023) survey

3.3 Characteristics of potato production by respondent farmers

The findings indicate the production characteristics of members of the Jyambere Muhinzi Kinoni Cooperative as the following (see also Table 2):

Farmers cultivated a mean land area of 24.2 ares, using 734.6 kg of seeds, 574 kg of compost, 79.47 kg of chemical fertilisers, and 8.5 kg of fungicides, with an average labour input of 78 workers, resulting in a yield of 18.6 metric tons of potatoes.

The smallest recorded inputs and outputs were 2 ares of cultivated land, 6 kg of seeds, no use of compost or chemical fertilisers, 1.5 kg of fungicides, and a yield of 0.15 metric tons, while the highest values included 102 ares of cultivated land, 3 000 kg of seeds, 6 200 kg of compost, 565 kg of chemical fertilisers, 25 kg of fungicides, and a yield of 31 metric tons per hectare of potatoes.

Table 2*:* Summary statistics of variables in the potato production function of the respondent farmers

Production function variables	Unit	Mean	Min	Max
Land size	Are	24.2	2	102
Quantity of seed	Kg	734.6	6	3 000
Quantity of compost	Kg	574	0	6 200
Quantity of chemical fertilisers	Kg	79.47	0	565
Quantity of fungicides	Kg	8.5	2	25
Labour	Number	78	1.5	192
Yield	MT/hectare	18.16	0.15	31

Note: These data were obtained from the NISR (2023) survey. The "**are**" (symbol: a) is a unit of area used in the metric system. It is equal to 100 square metres (m^2) and is primarily used to measure land area. One **are** is equivalent to 0.01 hectares (ha) or 0.0247 acres. "kg" stands for kilogram, which is the base unit of mass in the International System of Units (SI). One kilogram is equal to 1 000 grams. It is commonly used worldwide for measuring weight and mass.

3.4. Consistent use of good agricultural practices by the respondents

Figure 2 highlights the average potato yields achieved by two value chain partners (Agriterra and NISR) compared to farmers in Jyambere Muhinzi Kinoni Cooperative. Demonstration plot records, monitored by agronomists, revealed that adopting good agricultural practices significantly boosted yields. Specifically, yields increased from the national average of 10.87 metric tons per hectare (NISR 2022) to 22.40 metric tons per hectare (Agriterra 2020) on demonstration plots. Respondent farmers reported an average yield of 18.16 metric tons per hectare, underscoring the positive impact of good agricultural practices on productivity.

3.5 Factors influencing farmers' adoption of good agricultural practices

The maximum likelihood estimates of the logit model are presented in Table 3. The following factors were statistically significant at 1% and 5%.

Education level: Education was a significant factor, positively influencing GAP adoption at a 5% level of significance ($p \leq 0.05$). Educated farmers were more likely to adopt GAPs, as education enhances the understanding of technology, information processing and decision-making. The study revealed that 54% of respondents had attended school, highlighting the importance of education in increasing the likelihood of adopting improved practices. This confirms the report that the influence of education level on adoption decisions varied according to the form of technology presentation, information, its content, motivation, and frequency of use (Khanna 2001).

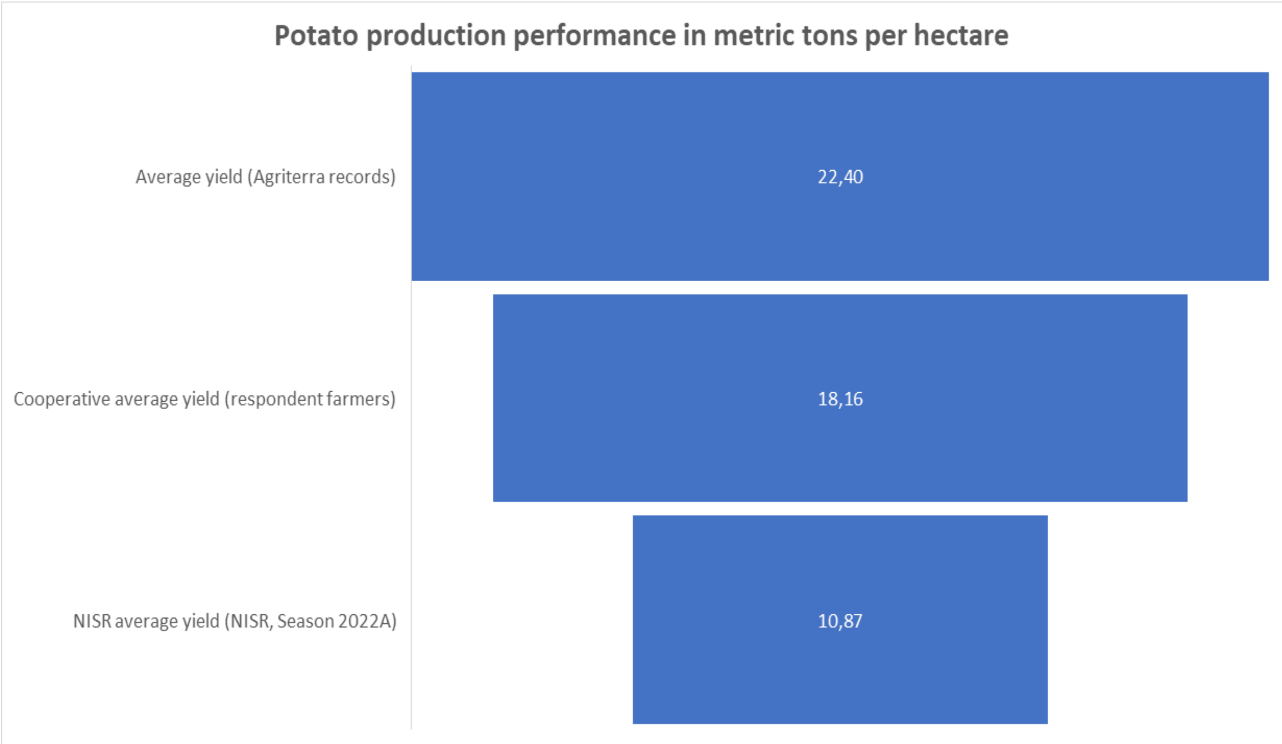

Figure 2: **Effect of consistent adoption of good agricultural practices on potato production performance**

Note: These data were obtained from the NISR (2023) survey

Cooperative membership: Membership of agricultural cooperatives significantly influenced GAP adoption at a 1% level of significance ($p \leq 0.01$). Cooperative members benefited from training provided by organisations like Agriterra and Holland GreenTech, which enhance members' capacity to implement GAPs. Approximately 75% of respondents reported receiving such training. Agriterra (2020) indicated that cooperative membership increases the likelihood of adopting GAPs by over 400%. This demonstrates the critical role cooperatives play in knowledge dissemination and capacity building.

Access to extension services: Access to extension services was another significant factor that positively influenced GAP adoption at a 1% level of significance ($p \leq 0.01$). Extension services provide farmers with critical information, technical support, and demonstrations that improve their understanding of agricultural innovations. Increased interaction with extension personnel through frequent visits and training programmes, such as on-farm trials and farmer field schools, significantly boosts the adoption of GAPs. This aligns with previous findings by Bonabana-Wabbi (2002) that highlighted the vital role of extension agents in promoting integrated pest management and other agricultural technologies.

The study confirmed that socio-economic and institutional factors, such as education level, cooperative membership and access to extension services, play a critical role in influencing the adoption of GAPs by farmers in the Jyambere Muhinzi Kinoni Cooperative. Therefore, the hypothesis that these factors do not influence GAP adoption is rejected.

Table 3: Logit estimates of factors influencing farmers in the Jyambere Muhinzi Kinoni Cooperative to adopt good agricultural practices

GAP adoption	Coefficient	Std. error	z	P > |z|	[95% confidence interval]	
Age	.0234822	.0513696	0.46	0.648	-.0772003	.1241647
Gender	1.318696	1.019139	1.29	0.196	-.6787786	3.316171
Education level	2.300331	1.049134	2.19	**0.028****	.2440671	4.356596
Farming experience	.5312219	.6175464	0.86	0.390	-.6791467	1.741591
Coop membership	4.048411	1.534492	2.64	**0.008*****	1.040862	7.05596
Predominant season	.5569328	1.053276	0.53	0.597	-1.507451	2.621316
Seed variety	.2133778	.7402342	0.29	0.773	-1.237455	1.66421
Extension service	3.170321	1.209745	2.62	**0.009*****	.7992643	5.541377
Credit	.3249937	1.307638	0.25	0.804	-2.23793	2.887917
_cons	7.663812	3.103287	2.47	**0.014****	13.74614	1.581481

Note: Log likelihood = -17.090741, number of observations = 87, LR chi^2 (9) = 73.59, prob > chi^2 = 0.0000, Pseudo-R^2 = 0.6828.
*, ** and *** represent significance at the 10%, 5% and 1% levels respectively.

3.6 The effect of the adoption of good agricultural practices on potato production

Table 4 illustrates the impact of good agricultural practices on potato yield, as analysed using the propensity score-matching estimation with a kernel model algorithm. The results indicate a goodness-of-fit index pseudo R^2 value of 0.6856. Key factors significantly influencing the adoption of good agricultural practices include cooperative membership, education level and access to extension services. These findings highlight the critical role of these variables in promoting the adoption of practices that enhance potato yield, with the model showing a statistically significant relationship with the response variable.

Table 4: Estimates of propensity score matching: Logit model dependent on farmers' adoption of good agricultural practices

GAP adoption	Coef.	Std. error	z	P > |z|	[95% confidence interval]	
Age	.011689	.0298823	0.39	0.696	-.0468793	.0702573
Gender	.657403	.5440336	1.21	0.227	-.4088832	1.723689
Education level	1.343291	.5644258	2.38	**0.017****	2370363	2.449545
Farming experience	.3045479	.321974	0.95	0.344	-.3265096	.9356055
Coop membership	2.368517	.7114132	3.33	**0.001*****	.9741726	3.762861
Predominant season	.2301884	.520173	0.44	0.658	-.7893319	1.249709
Seed variety	.1188054	.3632143	0.33	0.744	-.5930815	.8306923
Extension service	1.759103	.6381697	2.76	**0.006*****	.5083139	3.009893
_cons	4.097417	1.729961	-2.37	0.018	-7.488079	-.7067556

Note: Log likelihood = -16.9, number of observations = 87, LR chi^2 (8) = 73.89, prob > chi^2 = 0.0000, pseudo R^2 = 0.6856.
*, ** and *** represent significance at the 10%, 5% and 1% levels respectively.

Table 5 highlights the impact of adopting good agricultural practices (GAPs) on potato production using the kernel and nearest neighbour matching models. The outcome variable is "Total production per season", as the results in the table indicate that the adoption of good agricultural practices has positively increased the production of potato farmers

Table 5: **Estimation of average treatment effect on the treated (ATT)**

	ATT using kernel model algorithm	ATT nearest neighbour matching algorithm
Treated	5 480	9 150
Controls	4 562.43205	3 550
Difference	**917.57**	**5 600**
Standard error	2 184.0816	4 271.39572
T-stat	**0.42*****	**1.31*****

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Kernel model algorithm matching showed that the average treatment effect (ATT) of 917.57 kg with its t-statistic equal to 0.42 was significant at the 1% level, indicating an increase in yield per season for farmers adopting GAPs compared to non-adopters.

The results using nearest neighbour matching showed an ATT of an 5 600 kg increase in yield for GAP adopters, with a t-statistic of 1.31 significant at the 1% level. Both models indicate a significant positive effect of GAP adoption on seasonal potato yields. This evidence supports rejecting the second hypothesis, which claimed no effect of GAP adoption on potato production by members of the Jyambere Muhinzi Kinoni Cooperative.

3.7 Relationship between farmers' annual income and adoption of good agricultural practices

Table 6 presents the results of a linear regression analysis examining the relationship between farmers' annual income and the adoption of good agricultural practices (GAPs). The findings indicate that GAP adoption and farm size are highly significant ($p \leq 0.01$), while cooperative membership and access to credit are significant at a lower threshold ($p \leq 0.1$). The results of the linear regression estimates show that 55% (Adj. $R^2 = 0.55$) of the variation in farmers' annual income is explained by the inputs modelled in the analysis (GAP adoption, age, gender, education level, farming experience, cooperative membership, predominant season, seed variety, access to extension services, access to credit and farm size).

Table 6: Relationship between farmers' annual income and adoption of good agricultural practices

Annual income	Coefficient	Std. error	t	P > |t|	[95% confidence interval]	
GAP adoption	1 410 257	431 460.1	3.27	0.002***	550 744.2	2 269 769
Age	-6 536.198	10 423.53	-0.63	0.533	-27 300.93	14 228.53
Gender	-18 089.48	238 767.3	-0.08	0.940	-493 738.3	457 559.3
Education level	46 819.31	325 037.3	0.14	0.886	-600 688.2	694 326.8
Farming experience	71 094.54	150 707.4	0.47	0.638	-2 29130	371 319.1
Coop membership	-767 498.7	386 373.4	-1.99	0.051*	-1 537 194	2 196.554
Predominant season	106 348.9	240 015	0.44	0.659	-371 785.6	584 483.3
Seed variety	-145 471.8	181 203.3	-0.80	0.425	-506 447.2	215 503.6
Access to extension service	85 062.68	339 109.8	0.25	0.803	-78 576.81	760 604.1
Access to credit	561 802.2	321 458.9	1.75	0.085*	-78 576.81	1 202 181
Farm size (are)	48 501.98	5 678.838	8.54	0.000***	37 189.16	59 814.81
_cons	414 826.4	592 361.6	0.70	0.486	-1 594 871	765 218.3

Number of observations = 87, F (11, 75) = 10.93, Prob > F = 0.0000, R^2-squared = 0.6158, Adj. R^2 = 0.5595.
*, ** and *** represent significance at the 10%, 5% and 1% levels respectively.

The result reveal a positive relationship between the adoption of GAPs and farmers' annual income, showing that greater adoption of GAPs contributes to higher income levels. Additional factors, such as age, gender, education, farming experience, predominant season, seed variety, extension services, access to credit and farm size also influence income outcomes.

Our findings are similar to those in the study by Okello *et al*. (2017), which showed that, as far as farmers adopted good agricultural practices, their production increased and the amount of money received by the farmer increased every year. Hence, the hypothesis that there is no relationship between the annual income of famers in Jyambere Muhinzi Kinoni Cooperative and their adoption of good agricultural practices was rejected.

4. Conclusions and recommendations

This study investigated the impact of good agricultural practices (GAPs) on the production of Irish potato in the Jyambere Muhinzi Kinoni Cooperative in Burera District, Rwanda. The findings demonstrate that the adoption of GAPs significantly enhances potato yields and farmers' incomes, contributing to both economic and social sustainability. Specifically, practices such as the use of certified seeds, crop rotation and appropriate fertilisation were found to be particularly effective in improving productivity.

However, the study also identified a negative relationship between GAP adoption and market participation. This could be attributed to the higher costs associated with GAPs, which can limit market entry for some farmers, or the low demand for GAP-certified potatoes in the local market. Further research is needed to substantiate this hypothesis and explore the underlying factors affecting market participation.

The study did not capture information on the cost implications of GAP adoption due to time constraints. It is important to recognise that costs for seeds, fertilisers, and pesticides are key factors that can affect the overall feasibility and adoption rates of GAPs. Future studies should address this gap by exploring whether the benefits of GAP adoption, in terms of increased yield and income, outweigh the costs.

The average yield in the Jyambere Muhinzi Kinoni Cooperative was 18.16 metric tons per hectare by GAP adopters, who gained a yield of 5 600 kg more than non-adopters. The observed average yield was significantly higher than the reported national average yield of 10.87 metric tons per hectare in the 2022A growing season, but still fell below the expected yield at research stations, which ranges from 25 to 35 metric tons per hectare. This suggests that there are still substantial gaps that need to be addressed, such as issues of resource access, knowledge, and market constraints. Bridging these gaps could help farmers achieve higher yields closer to those observed in controlled research environments.

While the study has highlighted the positive impact of GAP adoption on yields and income, it has not fully explored how socioeconomic or demographic factors, such as age, education and farm size, influence GAP adoption. Future research should investigate these factors to provide a more comprehensive and nuanced understanding of adoption dynamics.

Furthermore, the long-term impacts of GAP adoption on environmental sustainability, including soil health and resource-use efficiency, as well as the social dimensions such as gendered impacts and community resilience, should also be explored.

To sum up, this study has revealed that the adoption of GAPs among potato farmers holds significant potential for enhancing agricultural productivity and improving livelihoods. Thus, the study recommends that policy makers and stakeholders prioritise support for GAP adoption through comprehensive agricultural policies, capacity-building initiatives, and investment in agricultural research and development to contribute to achieving the sustainable development goals (SDGs), particularly goal 2 (zero hunger) and goal 12 (responsible consumption and production).

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