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Adoption and Impacts of Improved Potato Variety in Highlands of Guji Zone, Southern Oromia, Ethiopia

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ABSTRACT

Background and Objective: Improving the income of smallholder farmers through the introduction of improved technologies has gained increased attention in recent times. The focus now extends beyond the mere development and introduction of farming technologies to enhance production and productivity. This study was conducted in the highland areas of the Guji Zone with the objectives of identifying the extent of adoption, determining the adoption and adoption intensity determinants, and assessing the impact on major adopters of improved Gudane potato varieties in the study area. **Materials and Methods:** The data were collected from 201 farmers, including 122 adopters (60.7%) and 79 non-adopters (39.3%). Summary statistics and limited dependent models, including Tobit and logistic regression, as well as the treatment effect model of propensity score matching, were used for data analysis. Adoption, adoption intensity, and ATE parameters were estimated along with determinants. **Results:** Dependency of adoption of Gudane variety on family size, experience, land cost, input cost, farmer type, off-farm income, technology information, and education level variables were observed likewise age, family size, potato production experience, farmer type, technology information, and off-farm income involvements of family member were determinants of adoption of the variety. Gender, age, family size, education level, potato production experience, farmer type, off-farm income, and extension contact were variables that affected adoption intensity. The average treatment effect on the treated (ATT) potato yield of adopters and non-adopters for the 2022 production season has a yield difference of 136.57 qt/ha in favor of the adopters over than non-adopters. **Conclusion:** Adopters were found to produce more than non-adopters. These results imply that scaling out of Gudane production contributes to farmers' livelihood improvement through yield and farm income increment in the highland parts of Guji Zone, Southern Oromia.

KEYWORDS

Adoption, Gudane, variety, propensity score matching, Guji Zone, Southern Oromia

INTRODUCTION

The cultivation of potatoes, the fourth most important crop in Ethiopia, is well-known. Approximately 18.1 million/ha of land are used for its cultivation[1]. In Ethiopia, potatoes are primarily grown for consumption as well as to help people's livelihoods by being traded for other goods, used in markets to boost household incomes, and used as crops in areas where land grazing is an issue. In addition to

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providing financial incentives for farmers who participate in potato production, potatoes are utilized to address the issue of seasonal food shortages when other food crops are reduced from storage[2].

As a result, Ethiopia has a strong demand for potatoes, and farmers cultivate a vast quantity of land for this purpose. Because of its high yield, early maturity, exceptional food value, ability to increase household income, and ability to reduce food insecurity, potatoes have enormous potential to improve the lives of Ethiopians in a number of ways[3]. Seasonality determines the output of potatoes, and farmers are willing to adjust their cultivation schedules to accommodate climate fluctuation[4]. In Ethiopia, both traditional and scientific methods are used to grow these potatoes. With a variety of enhanced varieties from both local and foreign sources, the scientific one is mostly developed throughout the adoption procedure.

Consequently, the demand for potato cultivation within Ethiopia is exceedingly elevated, prompting producers to cultivate extensive tracts of land dedicated to potato farming. The potato crop possesses substantial potential for enhancing the socioeconomic conditions of the Ethiopian populace through various avenues: Elevated yield, rapid maturation, superior nutritional value, augmentation of household income, and mitigation of food insecurity[5,6,7].

Bore Agricultural Research Center has done adaptation, demonstration, scaling-up, and seed multiplication for the variety to create minimum access to seeds for the beneficiaries. This improved variety yields about 340 to 350 q/ha[8]. Therefore, this study is designed to undertake the adoption and impacts of the variety with objectives of assessing the extent of coverage, identifying factors affecting adoption, and identifying the impact observed by major adopters of varieties in the study area.

MATERIALS AND METHODS

Study area: The study was conducted in the highland districts of Guji Zone, Southern Oromia. The area is located at a distance of 385 km from Addis Ababa, the capital city of Ethiopia. Astronomically, the area is situated between 5°57'23" to 6°26'52" North Latitudes and 38°5'51" to 38°56'21" East Longitudes. Most of the earth's surface of the study area has an undulating land surface with an elevation ranging from 2200 to 2900 m above sea level. It has an annual rainfall of 1,250 mL and the annual temperature ranges from 15 to 24°C.

The study area is also characterized by two agro-climatic zones, namely humid, which starts in early April up to October, and sub humid which starts late November up to the beginning of March. The major soils of the area are Nitosols (red basaltic soils) and Orphic Acrosols. The two soils are found on the highland areas, and they are red brown and black brown in color, and on sloping topography, and their utilization is good under natural vegetation. The farmers of this area produce cereals such as wheat, barley, and maize, pulses such as faba bean and field pea, tubers like Irish Potato and others such as highland fruits and vegetables, with enset majoring.

Data types, sources, and method of data collection: Both primary and secondary data were employed for this study. Before the actual data collection, facilitative works such as training of Development Agents, experts, and samples were given concerning interview procedures and preliminary assessment to enhance their perception regarding the objectives of the study, the content of the questionnaire, and amendments made to grasp vital facts essential for the study.

Sampling techniques and collection methods: For sample selection, multi-stage sampling was used. First, four potential potato-producing districts, Bore Ana Sora and Arda Jila Mea Boko. At the second stage

potato producing Kebeles were randomly selected to draw 201 producers randomly based on[9] formulas using a Total population of 14547 and a margin of error of 0.07 as:

$$n = \frac{N}{1+Ne^2} = \frac{14547}{1+14547\ (0.07^2)} = 201 \quad (1)$$

Where:

N = Total potato-producing population
E = Margin of error

Methods of data analysis: For data analysis, both descriptive statistics and econometrics models, such as logistic regression, Tobit model, and Propensity score matching, were used. The Tobit econometrics model was used for analyzing adoption decision and adoption intensity, whereas logistic regression was used before the Propensity score model.

Analytical techniques: Kimaru-Muchai[10], farmers who were not growing the potato improved Gudane variety were considered as non-adopters, while farmers who were producing the improved potato Gudane variety were considered adopters. Improved agronomic practices (spacing, seed rate, and fertilizer rate) were currently practiced by farmers producing the improved variety.

Adoption index scores were calculated by adding up the adoption quotient of each practice and dividing it by the number of adopted practices of each respondent, following the formula developed by Dembi *et al.*[11] as:

$$AI_i = \frac{\sum_{i=1}^{n}\left(\frac{PI_i}{TA_i} + \frac{SRA_i}{Rsr} + \frac{FA_i}{RF} + \frac{Su_i}{Rsi}\right)}{NP} \quad (2)$$

where, I is the 1, 2, 3.....n, n is the total number of respondent farmers, AI_i is the Adoption index, AH_i is Area under improved Gudane potato variety of the farmer, TA_i is at total area allocated for potato production (Local variety+improved variety) of the i^{th} farmer, SRA_i is Seed rate applied per unit area in the production of Gudane variety, Rsr is Seed rate recommended for application per unit of area, FAi is Fertilizer rate applied per unit area in the cultivation of Gudane improved potato by i^{th} farmer, RF is Amount of fertilizer recommended for application per unit of area in the production of Gudane potato variety, Sui is Average row spacing applied by i^{th} farmer, Rsi is recommended spacing for potato production in (cm) and NP is Number of practices.

The sample households' index scores were categorized into four adopter groups, namely non-adopter, low, medium, and high adopter. An adoption index score of zero points implies non-adoption of the variety, and greater than zero (>0 and≤1) implies adopters with any of the three adoption categories, namely low adopters, medium adopters, and high adopters. Adoption decisions based on the utility theory of adopter, defined as the principles of[12] and factors affecting adoption decision and adoption intensity, were followed and marginal benefit as[13].

The functional formula of the logistic regression model used in this study is presented as follows:

$$Pi = \frac{e^{Zi}}{1+e^{Zi}} \quad (3)$$

Where:

Pi = Probability of being willing to adopt potato varieties of the i^{th} farmers
Zi = Function of n explanatory variables (xi)

The impact of the treatment (adoption of improved potato Gudane variety) which is the difference between the outcome (s) of the treated (adopters) and the control group (non-adopters) represented by τ, is as expressed as:

$$\tau_i = X_i - X_o \quad (4)$$

where, X_i are respondents, = 1 if treated and = 0, otherwise. To adopt or not, which is a decision of the farmer (that is observed) is depicted by the model as:

$$ARP_i^* = \beta Z_i + \varepsilon_I \quad (5)$$

Where:

ARP_i = $1, ARP_i^* > 0, ARP_i = 0, ARP_i^* \leq 0$

ARP_i = Potato adoption

Z_i = Factors affecting the adoption of potato variety

ε_I = Error term

Thus, following Rosenbaum and Rubin (1983), the equation below was applied to solve ATT:

$$ATT = E[Y_1 - Y_0 | P(Z), D = 1] = E[Y_1 | P(Z), D = 1] - E[Y_0 | p(Z), D = 0] \quad (6)$$

where, P(Z) is the probability of selection conditional on Z or it is the propensity score (Pscore) which is:

$$P(Z) = P(D \ 1|Z) \quad (7)$$

RESULTS AND DISCUSSION

Descriptive statistics: The mean age of adopters was significantly higher (35.31 years) compared to non-adopters (36.4 years), with this disparity being statistically significant at the 1% level (Table 1).

The mean years of formal education among both adopters and non-adopters are commendable (approximately 5 and 4 years, respectively). This phenomenon arises from the fact that roughly 59.2% of individuals in both the adopter and non-adopter cohorts possess some form of formal education. This finding suggests that the treated group (adopters) has engaged in a greater duration of formal education compared to the control group (non-adopters), with the observed difference in means between the two groups attaining statistical significance at the 1% level (Table 2).

Regarding the classification of farmers by the district's Office of Agriculture into model ("A and B" level farmers) and non-model ("C" level farmers) categories, a noteworthy association (dependence) has been identified between adoption and farmer type (model versus non-model) at a significance level of 1%. It has been observed that a larger proportion of adopters are classified as model farmers. The Chi-square analysis concerning off-farm income participation revealed a significant association at the 1% significance level between off-farm income and the adoption of the improved Gudane potato variety. Likewise, a significant association (dependence) has been established between adoption and the dissemination of technological information related to improved potato varieties. As can be seen in Table 3 below, those who had information on improved potato varieties are found to be more adopters than those who didn't have technology information ones.

Status of adoption and intensity of adoption: Based on the nature of the technology, the adoption index is zero for non-adopters, low for those used only improved potato varieties, medium for those used recommended fertilizer with improved varieties, and high adopters for those who have used improved

Table 1: Summary statistics of continuous variables

	N = 122(60.7%)		N = 79 (39.3%)		N = 43(21.4%)		N = 201 (100%)		
	Adopters		Non-adopters		Difference		Combined		
Variable	Means	SE	Means	SE	Means	SE	Means	SE	Test statistics
Treatment variable (ARP = potato adoption,1 if adopter, 0 otherwise)									
Outcome variables									
Yield of potato	140.26	2.75	39.4	100.9	2.86	4.48	100.6	2.75	0.00***
Independent variables									
Age	35.31	1.01	36.4	1.4	1.1	1.7	35.74	1.7	0. 0.6387
Family size	8.85	0.44	7.54	0.4	1.31	0.638	8.34	0.64	0.02**
Total Land	2.83	0.22	2.61	0.22	0.23	0.34	2.75	0.17	0.514
Experience	15.2	0.49	12.6	0.51	2.6	0.73	14.2	0.37	0.01***
Land allocation	0.4	0.04	0.38	0.03	0.03	0.05	0.4	0.03	0.29
TLU	10.55	0.48	10.15	0.36	0.4	0.82	10.4	0.4	0.4767
Distance to FTC	1.5	0.19	1.62	0.2	-0.12	0.29	1.55	0.14	0.4093
Land cost	417.65	82.9	623.7	134.0	-206.1	149.0	498.6	73.0	0.08*
Input cost	2100	183	946.42	70.7	1154.2	235	1647	121	0.00***
Labor cost	489.7	35.6	438.2	39.1	51.5	54.3	469.5	26.5	0.948
Cultivated	1.7	0.125	2	0.19	0.13	0.22	1.92	0.11	0.6149
Extension	1.75	0.11	1.72	0.14	0.024	0.18	1.74	0.09	0.1391

*Statistically significant at 0.1, **Statistically significant at 0.05 and ***Statistically significant at 0.01

Table 2: Summary statistics of categorical variables

		Adopter		Non-adopter			Total	
Variable	Category	No	%	No	%	χ^2	No	%
Gender	Male	108	88.52	63	79.75	2.91 (0.0888)	171	85.07
	Female	14	11.48	16	20.25		30	14.93
Marital status	Married	119	97.54	77	97.47	0.001 (0.974)	196	97.51
	Unmarried	3	2.46	2	2.53		5	2.49
Cooperative	Yes	55	45.08	38	48.1	0.1758 (0.675)	93	46.27
	No	67	54.92	41	51.9		108	53.73
Farm type	Model	53	43.44	14	17.72	14.28 (0.00***)	67	33.33
	Not model	69	56.56	65	82.28		134	66.67
Labor	Available	98	80.33	69	87.34	1.6784 (0.195)	167	83.08
	Not	24	19.67	10	12.66		34	16.92
Off farm	Involve	73	59.84	19	24.05	24.74 (0.00***)	92	45.77
	Not involve	49	40.16	60	75,95		109	54.23
Training	Yes	58	47.54	42	53.16	2.31 (0.316)	100	49.75
	No	64	52.46	37	45.57		101	50.25
credit utilization	Yes	49	40.16	34	43,04	0.1634 (0.686)	83	41.29
	No	73	59.84	45	56.96		118	58.71
Market access	Accessible	83	68.03	54	68.35	0.0023 (0.962)	137	68.16
	Not	39	31.97	25	31.65		64	31.84
Technology	Yes	104	85.25	38	48.1	31.9 (0.00***)	142	70.65
information	No	18	14.75	41	51.9		59	29.35
Fertility	Good	56	54.1	31	39.24	0.8667 (0.352)	87	43.28
	Poor	66	54.1	48	60.76		114	56.72
Education	Educated	86	70.49	33	41.77	16.4 (0.00***)	119	59.2
	Uneducated	36	29.51	46	58.23		82	40.8

"*,**,***Significant at 10, 5 and 1% level of significance

Table 3: Distribution of respondents by level of adoption

Adoption category	Frequency	Percent	Adoption index range
None	79	39.3	0
Low	3	1.5	0.01- 0.37
Medium	5	2.5	0.38-0.67
High	114	56.7	0.68-1
Total	201	100.0	0-1

varieties with recommended fertilizer and spacing. The actual adoption categories were categorized into four groups of non-adopters, low adopters, medium adopters, and high adopters based on the adoption index. The index score is 0.00, 0.01-0.37, 0.38-0.67, and 0.68-1.00, which represents none, low, medium, and high adopters, respectively. Similar studies used similar techniques. Based on the technology structure and previous information, the frequency of adoption index scores of non-adopters, low adopters, medium adopters, and high adopters was 39.3, 1.5, 2.5, and 56.7, respectively (Table 3).

Determinants and Intensity of adoption: The result demonstrated that variables such as cooperative member, land cost, input cost, labor availability, and total livestock unit are important variables affecting the extent of improved variety adoption. Land cost and input costs are negatively affecting the adoption, as cost increases, farmers will not going to and adopt improved varieties for cost minimization. Similar results were found in other studies.

Gender influenced the adoption intensity positively, indicating that male-headed households were more likely to adopt the improved Gudane potato variety than female-headed households. The model showed that the male gender was found to have a 16% contribution to the adoption intensity of using variety. The possible explanation might be that male-headed households have better access to information, agricultural inputs, and resource endowments. Similar results were reported by Feleke *et al.*[7].

The educational level of the household positively affects the likelihood of adoption of improved potato variety, for which educational level accounted for 9% of the variation in intensity of adoption of improved Gudane potato variety. The positive sign of education level suggests that the likelihood of adopting a variety increases as the educational level of farmers increases. This finding is in line with previous studies reported by Yamane[8].

Age influenced the adoption of improved potato varieties and their intensity. Age accounted for about 10% of the variation in the adoption and intensity of adoption of the improved potato variety. From the result, it can be indicated that age negatively affects the adoption decision of the farmer's household. As age is increased by 1 year, the adoption of improved potatoes is decreased by 10%, and the adoption intensity of adopters is increased by 10%. This implies that as farmers get older age they become less likely to adopt new technology. This result indicated that younger farmers are more likely to adopt improved potato varieties than older farmers, where younger farmers are more likely to allocate their land for the improved Gudane potato variety. This could be because older farmers are less flexible in allocating a large portion of their land to improved varieties than younger farmers due to fear of risk, labor, and input costs.

Family size of the sample population positively and significantly associated with the adoption and intensity of improved potato variety. The nature of the improved potato variety is labor-intensive. Therefore, as the family member increases active family labor force may increase, and the family labor force increases the likelihood of planting an improved potato variety. A similar finding was reported by Dembi *et al.*[11]. Potato production experience accounted for about 2 and 1% of the variation in the adoption and intensity of adoption, respectively. The probable reason might be that the production of improved technology is that, as farmers have experienced crop production, the probability of adopting and intensifying the technology is increased.

Farmer's contact with extension agents was found to be positive and significantly influenced on intensity of adoption of improved potato variety (Table 4). The positive association indicates that as farmers' contact with extension agents increases, the adoption intensity increases. This variable accounted for about 4% of the intensity of adoption. This indicates that the number of extension contacts significantly

Table 4: Estimation results of smallholders' intensity of technology adoption

	Adoption determinants					Adoption intensity			
Explanatory variable	Coefficient	P>t	dy/dx	P>t	χ	Coefficient	P>|t|	dy/dx	χ
Gender	-0.01	0.94	-0.01	0.943	0.9	0.16**	0.015	0.16**	0.89
Age	-0.01***	0.01	-0.01***	0.008	35.7	0.01***	0.004	0.006***	35.3
Education level	-0.04	0.61	-0.04	0.612	0.6	0.09*	0.097	0.1*	0.705
Cooperative user	-0.03	0.64	-0.03	0.641	0.5	0.01	0.842	0.01	0.451
Family size	0.03***	0.00	0.03***	0.00	8.3	0.01*	0.052	0.011*	8.85
Total land	-0.01	0.59	-0.01	0.589	2.7	-0.01	0.304	-0.01	2.83
Potato production experience	0.02***	0.00	0.02***	0.001	14.2	0.01***	0.002	0.014***	4.7
Farmer rype	0.18***	0.01	0.18	0.005	0.3	0.06*	0.109	0.063*	0.43
Labor availability	-0.02	0.79	-0.02	0.787	0.8	0.12	0.014	0.12	0.803
Technology information	0.28***	0.00	0.28***	0.002	0.7	0.09	0.167	0.1	0.85
Involvement in off-farm income	0.22***	0.00	0.22***	0.002	0.5	0.10**	0.041	0.1**	0.6
Extension contact	0.03	0.23	0.03	0.227	1.7	0.04**	0.019	0.04**	1.75
Training	-0.03	0.55	-0.03	0.553	0.6	0.001	0.936	-0.0035	0.48
Credit access	-0.03	0.65	-0.03	0.651	0.4	0.05	0.183	0.054	0.4
Total livestock unit	0.01	0.47	0.01	0.47	4.1	0.01	0.092	0.01	3.8
Number of observations	201				122.00				
F(15, 186), F(15, 107)	35.35				174.60				
Prob>F	0.00				0.00				
Pseudo R2	0.564				1.11				

Source Survey data of 2022, ***,**,*Significance level at 1, 5 and 10%, respectively

Table 5: Prospensity score match test after matching

Sample	PsR^2	LR χ^2	p>χ^2	Mean bias	Med bias	B	R	Var (%)
Unmatched	0.146	37.42	0.000	20.3	17.5	94.1*	1.00	36
Matched	0.042	9.81	0.633	12.2	10.7	48.6*	0.78	36

*Significance difference at the 10% level of significance

Table 6: Estimated yield of ATT and unmatched samples

Variable	Sample	Treated	Controls	Difference	SE	T-stat
Yield (Qt/ha)	Unmatched	166.67	48.94	107.73	7.96	13.54
	ATT	179.42	42.85	136.57	14.76	9.25

affected farmers' decisions to allocate a large portion of their land, with which they adopted it. This suggests that potato farmers who have more contact with extension agents have more technology information about their production and productivity.

Farmer's type is positively and significantly related to adoption decision and adoption intensity. This implies the need to change the negative attitude held by non-adopters of the technology package. Model farmers have more exposure with extension agents and timely released information. Additionally, in extension methods like demonstration and scale-up of technology popularization model, farmers are selected over non-model farmers and are more likely to adopt and intensify improved varieties than non-model farmers. The result from this test in the model shows that farmer's type was found to have an 18% and 6% contribution to the adoption and intensity of using the improved potato variety. The result of this study coincides with previous findings[12].

Involvement of family in off-farm income accounted for about 22 and 10% of the adoption decisions of farmers, as well as adoption intensity of the variety, respectively. This may be due to the family members involved in off-farm income having more purchasing power for improved potato seed than those who don't have involvement[2]. Also reported that having off-farm income increases the likelihood of adopting improved seed and soil water conservation technologies in the Bore district.

Technology information accounts for 28% of the variation indicating that the farmers who have technology information are more likely to adopt than those who have no technology information because the technology information of its agronomic practices, its production and productivity and yield advantages of the improved variety than the local variety (Table 4). Therefore framers having delivered this technology information have the likelihood to decide to adopt the variety than others.

Matching algorithm: The treatment and control homes were matched within the shared support zone using a variety of alternative matching estimators. Several criteria, including matched sample size and the equal means test, also known as the balance test pseudo-R^2, influenced the eventual selection of a matching estimator[9]. In particular, it is better to use a matching estimator that produces a high matched sample size, has a low pseudo-R^2 value, and balances the majority of explanatory factors (i.e., produces negligible mean differences between the two groups). Based on the performance standards listed below, Table 5 displays the estimated outcomes of tests of matching quality. Therefore, the kernel matching estimator with band size 0.001 was selected as the optimal estimator for matching exercises based on these results.

Impact of adoption on tuber yield: The average treatment effect on the treated (ATT) potato yield of adopters and non-adopters for the 2022 production season has a yield difference of 136.57 qt/ha in favor of the adopters over the non-adopters (Table 6). This result indicates that the improved Gudane potato variety is worth adopting due to the production of the crop being very useful in improving income and livelihood owned to its higher productivity.

CONCLUSION

The enhancement of income for smallholder farmers through the implementation of advanced agricultural technologies has garnered significant scholarly interest in recent times. The emphasis has now shifted beyond the sole development and implementation of such agricultural technologies aimed at augmenting productivity. This study indicated that there is a significant association (dependency) of adoption of improved Gudane potato variety with family size, potato production experience, land cost, and input cost, farmer type, off-farm income, technology information, and education level of the household. These variables are important variables that determining the adoption of the improved Gudane potato variety. Generally, the production of an improved Gudane potato variety has a positive and significant effect on the farm yield, by which adopters are better off than non-adopters of the variety. This study proves that further promotion Gudane potato variety needs urgent action. However, to boost production and productivity of the crop, attention should be given to alternative ways of accessing complementary inputs. Furthermore, enhancing the capacity of farmers through training with strong institutional support is recommended. During the study, researchers are limited by the availability of data on the improved Gudane variety. To curve this future research should rely on the completed information, the variety extension goes further.

SIGNIFICANCE STATEMENT

By considering the adoption and impact of the improved Gudane potato variety in the study area, it helps in quantifying adopters and non-adopters of the variety and factors influencing adoption of the improved potato variety. It also provides detailed information on how the potato improved potato variety impacted producer's income. In order to sustain potato productivity and production, the study provided information for policymakers and agricultural development agents in creating agriculturally based technology development programs and guidelines for interventions that would enhance effective technology adoption with its entire package. The study's conclusions assisted farmers in making the right choices regarding the adoption of enhanced seed and the distribution of the product. Finally, this study also serves as a reference for researchers in related studies.

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