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Assessment of profit efficiency of smallholder potato farmers in Nakuru County, Kenya

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Abstract

The importance of potato (*Solanum tuberosum* L) production to the country's economic growth is quite clear, but little is known about its profitability and determinants. The current potato yields of smallholder farmers are <10 t/ha, against 40 t/ha achievable under optimum utilization of resources and recommended agronomic practices. The objective of the study was to assess the gross margin (GM) of smallholder potato farmers and estimate their profit efficiency level and influencing factors. A cross-sectional research design and multistage sampling technique were used to obtain a sample of 277 respondents for the study. Results indicated an average GM of Ksh 57,438 per ha per season, implying that potato farming is a lucrative enterprise. Despite this, the study further showed that there are profit inefficiencies in its production process. The average profit efficiency recorded was 43.5%, implying that potato farmers can potentially increase their profits up to 56.5%. Profit efficiency was found to increase significantly with access to extension and credit services, education level, non-farm income, and membership in farmer groups, while decreasing significantly with farmer age. Apart from optimizing the use of farm inputs, the profit efficiency of smallholder potato farmers can thus be improved by enhancing farmer education and extension service delivery, formulating favorable credit strategies that will make loan acquisition easier for potato farmers, and encouraging farmers to join farmer groups in order to benefit from economies of scale.

1 | INTRODUCTION

Potato (*Solanum tuberosum* L) is ranked as the third most important food crop worldwide after wheat (*Triticum aestivum*) and rice (*Oryza sativa*) (Campos & Ortiz, 2020). More than 1 billion people eat potatoes worldwide, and global total production exceeds 300 million metric tons (Getaneh & Laekemariam, 2021). In Kenya, potato has emerged as one of the key staple crops and the second most important food

and cash crop after maize (*Zea mays*) (MoALF, 2021). It is identified as one of the promising crops that will play a great role toward the realization of the set objectives of Kenya Vision 2030 under the economic pillar because of its substantial contribution to food and nutrition security in the country (Juma et al., 2016; MoALF, 2016). Nearly 2.3 million metric tons of potatoes worth over Kenya Shillings 50 billion (USD 333 million) are produced yearly in Kenya (MoALF, 2021). Aside from the 800,000 farmers who rely on potatoes directly, the crop also indirectly supports around 3.3 million Kenyans along its value chain (MoALF, 2016). In Kenya, potato production is dominated by small-scale farmers with a land size

Abbreviations: CBR, cost–benefit ratio; GM, gross margin; OLS, ordinary least square; SPF, stochastic profit frontier; TR, total revenue; TVC, total variable cost.

below 2 ha (Juma et al., 2016), producing an average of 9.8 t/ha (FAOSTAT, 2021).

Potato production and consumption have been increasing swiftly across the country as a result of the increased urban population and changing eating habits in favour of potato products (MoALF, 2021). Potato yields are declining while the area under cultivation rises (Lung'aho & Schulte-Geldermann, 2016). Statistics show that the acreage under potato production has expanded from 115,604 ha in 2014 to around 214,600 hectares in 2021, but the yields per ha have reduced from about 14.1 to 9.8 t/ha over the same period (FAOSTAT, 2021). The increase in the area under potato cultivation results from an increase in the number of farmers and the land put under the crop (Kwambai et al., 2023). Still, the rapid population growth rate experienced in the country tends to put more pressure on land use and fragmentation, leading to a continuous decline in farm size (MoALF, 2021). Therefore, the limited arable land must be made more productive and profitable.

Low crop yields are mainly attributed to various factors such as limited access to good-quality seeds of suitable varieties, seed recycling, low crop rotation, poor farmer practices, and suboptimal use of fertilizers and pesticides (Komen et al., 2017; Kwambai et al., 2023). The suboptimal use of quality inputs is the result of costly farm inputs for potato production (Kaguongo et al., 2014). The cost of certified seed potatoes is among the biggest financial outlays for Kenyan smallholder farmers (Atieno et al., 2023). Using certified seed potatoes is one way of improving productivity; however, such seeds are not easily accessible to farmers and, if available, are expensive for smallholder farmers (Kwambai et al., 2023). Smallholder potato farmers also face other challenges, such as inadequate access to extension and advisory services, limited credit services, and lack of access to product markets (Danso-Abbeam et al., 2018). Lack of access to the product market has exposed smallholder potato farmers to exploitation by brokers and traders by using extended bags and buying per bag instead of per weight, leading to reduced income (personal observations, H. Chemjor, first author). Further, the low access to extension services and imperfect information flows have resulted in a low uptake of technologies and innovations available for improving potato productivity (GIZ, 2016).

The position of the potato crop in the economic growth is remarkable; therefore, increasing its productivity and profitability will significantly contribute to increased incomes, improved livelihoods, and job creation in the country. Over the years, the Kenyan government, international development agencies, and other value chain actors have implemented several initiatives and projects to improve potato productivity and farm income. However, despite the substantial efforts and huge resources used over time, the average national potato productivity level is still low, that is, 9.8 t/ha (FAOSTAT, 2021). Efficiency is an important factor in improving pro-

Core Ideas

- Potato is second most important food crop in Kenya, employing millions of Kenyans.
- Potato production in Kenya averages <10 t/ha.
- Farmers use poor quality inputs and have low access to services such as credit and extension.
- Understanding profit efficiency level and its influence will help in making informed decisions.
- The findings from the study will provide vital recommendation for improving potato productivity and profitability.

ductivity, attained through the proper allocation of scarce resources (Mehedi et al., 2021). Proper resource allocation among smallholder farmers has a great impact on productivity (Mehedi et al., 2021). It is therefore essential to understand all factors that limit potato productivity in order to formulate hands-on recommendations for greater resource efficiency.

Profit efficiency is the most appropriate concept of efficiency for evaluating overall performance because it accounts for the impact of a firm's activity in terms of both costs and revenues, as well as their interaction, thereby better reflecting the goal of profit maximization (Antonio et al., 2021). Profit efficiency of the farm has significant implications on the productivity or viability of crop enterprises, especially smallholder farming systems, and several empirical studies have tended to ignore this fact (Mehedi et al., 2021). In contrast to many researchers' earlier work on potato production, which primarily focused on technical, allocative, or economic efficiency, this study focused on assessing farm profit efficiency level and the influencing factors on potato production. The study was conducted in Nakuru County, Molo Sub-county. This region was selected because it is one of the major potato-producing counties in Kenya, with Molo Sub-county being the top producer in the region and ranked second nationally (Chepkoech et al.,). Unlike other potato-producing counties, Nakuru County is centrally located, facilitating easy access for traders from all major potato consumer markets. For many years, smallholder potato farmers in this region have decried the high cost of potato production and high exploitation by traders, limiting the potential benefit from the crop. To improve potato productivity and potential profit realization, it is important to understand the farm profit efficiency level of potato farmers as well as the socioeconomic and institutional factors that influence it, such as the farmer's age, access to extension, household size, access to credit, distance to the market, farming experience, non-farm income, access to market information, membership in farmer groups, and gender. The findings of this study are key for policymakers

when designing policies aimed at improving potato productivity and farm income. This will also contribute to the body of knowledge about studies on profit efficiency related to potato farming in Kenya.

The concept of profit efficiency has been widely applied earlier by researchers in evaluating various agricultural firms' profit efficiency levels. Bidzakin et al. (2014) used the profit frontier model to assess the profitability of maize cultivation in Ghana, and they found that the farmers' profit efficiency was 61%. The study also showed that profit efficiency was positively influenced by household size, being a male farmer, formal education, and maize farming experience. Khounthikoumane et al. (2021) also examined the profit efficiency of rice farms in the wet-season lowlands in Champhone District, Savannakhet Province, using the profit frontier model. Results indicated a γ value of 0.6130, implying that approximately 61% of the variation in the data collected is produced from an inefficiency error term, while approximately 39% of the disparity is produced from random error. Further, the results of the inefficiency model were influenced by age, gender, education level, credit services, and extension services. Oladeebo and Oluwaranti (2012) used the Cobb–Dougllass stochastic profit function to examine the profit efficiency among cassava (*Manihot esculenta*) producers in southwestern Nigeria. The result showed that the mean profit efficiency of the farmers was 79%, which suggested a 21% loss in profit.

2 | MATERIALS AND METHODS

2.1 | Study area and data collection

The data used in this study were obtained from a field survey conducted in Nakuru County, Molo Sub-county. Nakuru County is the second biggest potato producer in the county, (Chepkoech et al., 2023). The research was carried out in 2021, with a focus on the planting season of April to July 2021.

Smallholder potato farmers were the target population for the study. Molo Sub-county was deliberately selected since it is the leading potato-producing sub-county in the county. In the study, smallholder potato farmers were sampled using a multistage sampling technique. First, all four wards of Molo Sub-county were purposefully selected for the study. In the second stage, all sub-locations in each ward were listed, and purposive sampling was used to select sub-locations based on the regions where the crop is mainly grown. In the third stage, all villages in the selected sub-locations were listed, and a sample of 48 villages was randomly selected for the survey. With the assistance of agricultural extension officers and local administrative leaders, all the selected villages were visited, and a complete list of 1547 smallholder potato farmers was compiled. Finally, 277 (191 males and 86 females)

TABLE 1 Sample distribution.

Name of the ward	Farmers growing potatoes (compiled data, Nakuru County)	Number of respondents
Elburgon	612	103
Molo	262	56
Turi	491	86
Marishoni	182	32
Total	1547	277

smallholder potato producers were selected for the research using a systematic sampling technique. The sample distribution per ward is shown in Table 1. All the selected farmers were visited, and face-to-face interviews were carried out. The collected data were analyzed using STATA Frontier 14.1 software, and both descriptive and inferential statistics were used to analyze the data. Inferential statistics were analyzed using the TransLog stochastic profit frontier (SPF) function to measure the level of profit efficiency and its determinants.

2.2 | Analytical framework

Gross margin (GM) is the difference between total revenue (TR) and total variable cost (TVC). The normalized GM function is assumed to be well behaved and is derived as:

$$GM = \sum (TR - TVC) = \sum (PQ - WX_i)$$

Considering the inclusion of fixed costs as an independent variable in the equation, π is GM, which is used as a proxy for profit. To normalize the profit function, (π_i) is divided by P (the market price of potato output), as shown below.

$$\begin{aligned} \frac{\pi_i(p, z)}{p} &= \frac{\sum (PQ - WX_i)}{p} = \frac{Q - WX_i}{p} \\ &= f(X_i, Z) - \sum p_i X_i \end{aligned}$$

where PQ represents total revenue, WX_i is the total variable cost (seeds, fertilizer, agrochemicals, and labor) of securing revenue, P is the price of output (Q), X_i represents the quantity of optimized input used, Z represents the price of fixed inputs used, and $P_i = W/P$ represents the normalized price of input X_i while $f(X_i, Z)$ represents the production function.

The stochastic profit function specified for a farmer is defined as:

$$\pi_i = f(P_i, Z) + e_i$$

where π_i is the normalized profit of the i th farmer, P_i , and Z are as defined above. The essential idea behind the stochastic frontier model is the “composed” error term (Aigner et al.,

1977; Meeusen & Vande Broeck, 1977). This error term is defined as:

$$e_i = v_i - u_j$$

The two components v_i and u_j are assumed to be independent of each other. The v_i is assumed to be an independent and identically distributed random error with a normal $N(0, \sigma^2)$ distribution, independent of the u_j . The u_j is profit inefficiency effect, which is assumed to be non-negative truncation of the half-normal distribution $N(\mu, \sigma^2)$.

The TransLog profit frontier functional form for estimation used in this study is specified as:

$$\begin{aligned} \ln \pi = & \beta_0 + \sum_{i=1}^n \beta_{1i} \ln Z_i + \sum_{i=1}^n \beta_2 P_i + 1/2 \left[\sum_{i=1}^n \sum_{i=1}^n \beta_i (\ln Z_i)^2 \right. \\ & \left. + \sum_{i=1}^n \sum_{i=1}^n \beta_2 (\ln P_i)^2 \right] + \sum_{i=1}^n \sum_{i=1}^n \beta_i \ln Z_i \ln P_i + (v - u) \end{aligned}$$

where \ln denotes natural logarithm and P are conditional factors. The model specification is defined as follows:

$$\begin{aligned} \ln \pi = & \beta_0 + \beta_1 \ln Z_1 + \beta_2 \ln P_2 + \beta_4 \ln P_3 + \beta_5 \ln P_4 + 1/2 \left[\beta_{11} \ln Z_1^2 + \beta_{22} \ln P_1^2 + \beta_{33} \ln P_2^2 + \beta_{44} \ln P_3^2 + \beta_{55} \ln P_4^2 \right] \\ & + \beta_{12} \ln Z_1 * \beta_{12} \ln P_1 + \beta_{13} \ln Z_1 * \beta_3 \ln P_2 + \beta_{14} \ln Z_1 * \beta_4 \ln P_3 + \beta_{15} \ln Z_1 * \ln P_4 + \beta_{23} \ln P_1 * \ln P_2 + \beta_{24} \ln P_1 \\ & * \ln P_3 + \beta_{25} \ln P_1 * \ln P_4 + \beta_{34} \ln P_2 * \ln P_3 + \beta_{35} \ln P_2 * \ln P_4 + \beta_{45} \ln P_3 * \ln P_4 + (v - u) \end{aligned}$$

where β_i are parameters, π represents normalized profit (GM), Z_1 represents farm size (ha), P_1 represents the normalized price per man-day of labor, P_2 represents the normalized price per kilogram of fertilizer, P_3 represents normalized price per kilogram of seed potato, P_4 represents the normalized price per kilogram of the agrochemical, v is the random error term while u representing the inefficiency.

The inefficiency model (u) is defined as:

$$\begin{aligned} u = & \partial \theta + \partial_1 M_1 + \partial_2 M_2 + \partial_3 M_{13} + \partial_4 M_4 + \partial_5 M_5 + \partial_6 M_6 \\ & + \partial_7 M_7 + \partial_8 M_8 + \partial_9 M_9 + \partial_{10} M_{10} + \partial_{11} D \end{aligned}$$

where $M_1, M_2, M_3, M_4, M_5, M_6, M_7, M_8, M_9,$ and M_{10} represent age, educational level, farming experience, household size, extension contacts, distance to the market, access to credit, non-farm income, membership in farmer group, and access to market information, respectively. D represents the gender of the farmer, which is a dummy variable defined as $D1 = 1$ male and $D2 = 2$ female. ∂ stands for profit inefficient intercept, while $\partial_{1...11}$ is the coefficient of the respective parameter. These socioeconomic variables were included in the model to indicate their possible influence on the profit efficiencies of smallholder potato farmers.

The variance of the random errors $\sigma^2 v$ and that of the profit inefficiency effect $\sigma^2 u$ and overall variance of the model σ^2 are related; thus, we have

$$\sigma^2 = \sigma^2 u + \sigma^2 v$$

This measures the total variation of the profit from the frontier, which can be attributed to profit inefficiency Battese and Coelli (1992). The log-likelihood function estimates the gamma (λ)

$$\lambda = \sigma^2 u / (\sigma^2 v + \sigma^2 u)$$

The value of gamma (λ) represents the share of inefficiency in the overall variance, with values in range between 0 and 1. A value close to or equal to 0 indicates that profit inefficiency is absent and that ordinary least square (OLS) estimation would be appropriate, and a value close to or equal to 1 indicates that the frontier model is appropriate.

3 | RESULTS AND DISCUSSION

3.1 | Characteristics of the sampled potato farmers

Table 2 presents the characteristics of the respondents in the research area. The study showed that male farmers (69%) dominate potato production in Molo Sub-county. Further, the study showed that only 44% (62% male and 38% female) of the farmers had access to extension services, and only 14% (68% male and 33% female) had access to credit services. This indicates that the acquisition of capital for procuring farm inputs in the study area seems to be limited. The survey further revealed that 90% of the sampled farmers obtain market information. Only 22% (64% male and 36% female) of the sampled farmers belonged to farmer organizations. Finally, 68% (70% male and 30% female) of the sampled farmers had alternative non-farm revenue sources. The study revealed that male farmers dominate in various aspects of the study region. This might be linked to the fact that women do not often own farmlands, and they have little influence on decisions relating to land use and other resource allocation.

TABLE 2 Gender, access to extension, credit services, and membership of a farmer group.

Characteristics	No. of farmer	Percent (%)		
Gender of farmer				
Proportion of female farmers	86	31		
Access to extension services				
No	155	56		
Yes	122	44		
Access to credit services				
No	238	86		
Yes	39	14		
Access to market information				
No	29	10		
Yes	248	90		
Member in a group				
No	216	78		
Yes	61	22		
Non-farm income				
No	57	32		
Yes	120	68		
Variables	Mean	SD	Min	Max
Age of the farmer (years)	44	12	21	78
Land under potato (ha)	0.6	0.4	0.1	2.8
Labor (Ksh/man day)	264	36	200	300
Seed potato (Ksh/kg)	27.4	8.5	15	70
Fertilizer (Ksh/kg)	61.4	5.7	40	80
Fungicides (Ksh/L)	885	184	650	1200

Source: Computed from field survey data, 2021.
Abbreviations: Max, maximum; Min, minimum.

The average potato land acreage recorded by the sampled farmers was 0.6 ha, indicating that most potato growers are smallholders. The average cost of seeds per kilogram was Ksh 27, and the vast majority (96%) of farmers used low-quality, low-cost seeds that did not result in significantly higher yields. On average, labor costs of Ksh 264 per man-day, fertilizer of Ksh 61 per kilogram, and fungicide per liter of Ksh 885 were recorded.

3.2 | Profitability analysis of ware potato production

Table 3 presents the results of the profitability analysis of ware potato production in the study area. According to the survey, the average revenue for ware potato farming in the research area was Ksh 163,116 per ha. The study revealed an average yield of 8.6 t/ha with a deviation of 2.3 t/ha, indicating that potato farmers in the study area use different input levels and management practices, leading to high yield differ-

TABLE 3 Profitability analysis of potato production in one season.

Variable	Mean	SD	Min	Max
Total variable cost per hectare (Kenya shillings)	105,678	20,530	68,213	208,562
Yield per hectare (kilograms)	8587	2299	4250	16,000
Total revenue per hectare (Kenya shillings)	163,116	43,559	87,500	303,000
Gross margin per hectare (Kenya shillings)	57,438	37,532	1125	166,250
Cost–benefit (ratio)	1.6	0.4	1.0	2.7
Cost per kilograms	12.9	4	9.8	18.6
Returns per kilograms	19.2	3.1	14	28

Source: Computed from field survey data, 2021.

Abbreviations: Max, maximum; Min, minimum.

ences. These results are consistent with the findings of other researchers like Kaguongo et al. (2014), FAOSTAT 2021, and Technoserve (2018), which indicated potato yields of <10 t/ha.

In this study, GM is defined as the difference between TR and total variable expenditures. The total variable expenditures are the sum of variable costs, such as seed potatoes, fertilizer, agrochemicals, and labor used per hectare. The cost–benefit ratio (CBR) is the ratio of revenue to cost of cultivation. The findings indicated a mean GM of Ksh 57,438 per ha per season and a CBR of 1.6, implying that potato farming is lucrative in the research area. According to the survey, 1 kg of potatoes in the study area typically costs Ksh 13 to produce, with an average revenue of Ksh 19. These findings are in accordance with those of Njagi et al. (2018), who reported that the average cost of producing 1 kg of potatoes in Nakuru County was approximately Ksh 12.06.

3.3 | Maximum likelihood estimates of stochastic frontier profit function

Table 4 presents the results of the maximum likelihood estimates of the TransLog SPF function. The dependent variable used in the study is normalized profit, while independent variables taken into consideration are the prices for each variable input and a fixed factor used in the production process, that is, the price of labor per man-day, seed potato price per kilogram, fertilizer price per kilo, fungicide price per liter, and

TABLE 4 Estimates from stochastic profit frontier model of potato production.

Variables	Coef.	Std. Err.	Z	P > z
lnLand	1.18*	0.71	1.66	0.00
lnSeed	-3.68***	1.25	-3	0.00
lnFertilizer	-6.90*	3.92	-1.8	0.08
lnFungicides	-0.28	0.63	-0.4	0.66
lnLabor	5.51	3.76	1.46	0.14
½*lnLand ²	0.01	0.05	0.16	0.87
½*lnSeed ²	-1.11**	0.48	-2.3	0.02
½*lnFertilizer ²	-5.51**	2.44	-2.3	0.02
½*lnFungicides ²	0.79	0.67	1.18	0.24
½*lnLabor ²	-1.15	1.77	-0.7	0.52
lnLand*lnSeed	0.21	0.15	1.41	0.16
lnLand*lnFertilizer	0.67*	0.38	1.75	0.08
lnLand*lnFungicides	-0.23	0.20	-1.1	0.27
lnLand*lnLabor	-0.40	0.29	-1.4	0.17
lnSeed*lnFertilizer	-3.06	2.19	-1.4	0.16
lnSeed*lnFungicides	1.01*	0.59	1.7	0.09
lnSeed*lnLabor	1.51*	0.86	1.76	0.08
lnFertilizer*lnFungicides	1.41	1.14	1.24	0.22
lnFertilizer*lnLabor	3.61***	1.24	2.9	0.00
lnFungicides*lnLabor	-1.92**	0.94	-2.1	0.04
_cons	8.09*	4.44	1.82	0.07
Variance parameters				
sigma_u2 (σu^2)	1.42	0.41	3.45	
sigma_v2 (σv^2)	0.04	0.03	1.22	
$\sigma^2 = \sigma^2 u + \sigma^2 v$	1.46	0.44	4.67	0.00
$\sigma^2 u / (\sigma^2 v + \sigma^2 u)$	0.98	0.02	52.8	0.00
	-292.66			
N	277			

Note: Wald $\chi^2(20) = 74.92$ Prob > $\chi^2 = 0.000$.

Significance levels indicated by * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Computed from field survey data, 2021.

the farm size in hectares. An appropriate frontier model was selected after the evaluation of various null hypotheses to determine the appropriateness and significance of the model to be adopted.

The gamma test was used to determine whether the observed variation in inefficiency was purely random or systematic. Piesse and Thirtle (2000) argue that the gamma value is confined between 0 and 1, where a value close to or equal to 0 indicates that profit inefficiency is absent and that ordinary least square estimation would be appropriate, and a value close to or equal to 1 indicates that the frontier model is appropriate. The recorded γ value in this study (0.975), statistically significant at a 1% level of significance, is high and indicates that there are inefficiencies in the profits obtained by the sampled potato farmers. As a result, OLS was rejected

TABLE 5 Distribution of profit efficiencies.

Profit efficiency	Frequency	Percentage (%)
0.01–0.20	64	23.10
0.21–0.40	72	25.99
0.41–0.60	66	23.83
0.61–0.80	45	16.25
0.81–1.00	30	10.83
Total	277	
Minimum		1.1
Maximum		93.7
Mean		43.5

Source: Computed from field survey data, 2021.

in favor of the stochastic frontier function. This suggests that 97.5% of the variation in the data is due to inefficient error terms, whereas just 2.5% of the variation is due to random shocks beyond farmers' control, such as climatic conditions, floods, and pest infestations. The value of σu^2 (1.417) shows that the inefficiency component strongly dominates the total variance.

The coefficient of the variable representing the price of fertilizer was negatively related to the profitability of potato farming and was significant at 10%. The results show that a rise in the price of fertilizer by 1% will decrease the profitability of potato production by 6.9%. The influence of the price of seed potatoes on the profitability of potato farming was also negative and significant at 1%. This shows further that a 1% increase in the price of seed potatoes will cause a decline in the profit from potato farming by 3.67%. The coefficient of land size was positively related to the profitability of potato production, significant at 10%, which implies that a unit increase in potato land size in the study area will increase potato farm profits by 1.18%.

3.4 | Distribution of profit efficiencies of the potato farmers

The distribution of profit efficiencies of potato farmers in the study area is shown in Table 5. Profit efficiency was classified into categories with a range of 0%–100% in increments of 20%. The mean profit efficiency of the sampled farmers was 43.5%, indicating that the profits obtained by potato farmers in the research area are way below the frontier, with as much as 56.5% of the maximum profit potential being lost due to inefficiency. Profit efficiency ranged widely from 1.1% to 93.7%. The findings further showed that about 27% of the farmers had a profit efficiency of 61% and above, indicating slightly more than a quarter of the farmers in the region were profit efficient. However, about 23% of the sampled farmers recorded a low profit efficiency level of <20%. Nyagaka et al. (2009)

TABLE 6 Determinants of profit inefficiency for potato farming.

Profit	Coef.	SE	Z	P > z
Gender (male = 1)	-0.23	0.31	-0.73	0.46
Extension services	-1.00**	0.35	-2.53	0.01
Credit service (yes = 1)	-0.23**	0.12	-1.96	0.05
Membership_group (yes = 1)	-0.21**	0.10	-2.04	0.04
Non-farm income (yes = 1)	-0.17**	0.08	-2.02	0.04
Market_info (yes = 1)	0.05	0.39	0.15	0.88
Age_of_farmer	0.015*	0.09	1.69	0.09
Household_size	0.034	0.05	0.75	0.46
Farming experience	-0.04	0.025	-1.57	0.12
Distance_to_market	0.50	0.59	0.83	0.40
Education level	-0.33*	0.18	-1.84	0.07
Constant	2.42	1.38	1.76	0.08

Significance levels indicated by * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Computed from field survey data, 2021.

reported almost similar results, with an average economic efficiency level of 38.1% for potato farming in Nyandarua County.

3.5 | Determinants of profit inefficiency among smallholder potato farmers

The findings on the factors influencing potato farmers' ability to maximize profits are presented in Table 6. It was essential to pinpoint the sources of variation in profit inefficiency among potato farmers in order to make sound recommendations. Therefore, various key socioeconomic and institutional variables were examined to determine their effect on the profit efficiency of potato growers in the study area. The coefficients of the variables included in the model were estimated concurrently by the maximum likelihood technique using estimated levels of profit inefficiency as the dependent variable. The predicted variable is the portion of the overall error term that is related to profit inefficiency and is estimated along with the profit frontier; therefore, coefficients show the impact of each individual variable with respect to profit inefficiency.

The findings obtained from the inefficiency model showed that the profit efficiency of potato farmers was significantly influenced by access to extension services, access to credit services, education level, non-farm income, being a member of a farmer group, and the age of the farmer. The presence of a statistically significant negative sign denotes a significant negative correlation between the respective variable and the profit inefficiency, and vice versa. The findings proved that the profit efficiency of potato farmers in the study area increased with access to extension services, education level, access to credit services, non-farm income, and being a mem-

ber of a farmer's organization, while it decreased with the farmer's age.

The significant and negative impact of extension services on profit inefficiency implies that potato farmers who access extension services are profit efficient. Extension officers play an important role in disseminating information about good agronomic practices, optimal use of inputs, and consulting directly with farmers on specific production problems, thus facilitating a shift to more efficient production methods. This is in agreement with the findings of other studies such as Khounthikoumane et al. (2021), who found a positive influence of extension on profit efficiency among rice growers in Wet-Season Lowlands of Korea, and Mehedi et al. (2021), who also reported a negative effect of extension on the profit inefficiency of maize production in Bangladesh.

The negative and significant impact of credit services on profit inefficiency suggests that potato farmers accessing credit services can more easily embrace efficient technologies like mechanization and afford to buy and use high-quality farm inputs, among others. Having access to credit services helps to ease cash flow constraints leading to untimely acquisition of inputs, late planting, and poor crop management, which typically result in inefficiencies. This result is consistent with those reported by Khounthikoumane et al. (2021) and Mehedi et al. (2021), who also noted a positive effect of access to credit services on the profit efficiency in the production of various crops.

Farmer organizations are essential for collective action, which benefits farmers more. Farmers in farmer groups can more easily obtain financial services by guaranteeing one another, purchasing inputs together, which lowers transaction costs, and having easier access to extension services because it is easier for extension service providers to reach them as a group. The findings from this study concur with that of Mwitwa (2016), who observed the negative effect of being a member of a farmer organization on the profit inefficiency of passion fruit (*Passiflora edulis*) farmers in Embu County, Kenya. Potato growers who have higher alternative non-farm revenue sources were more profit efficient than their counterparts with lower sources. They probably achieved this by using these sources to overcome financial constraints in their potato production process. Indeed, they can finance their potato production activities with funds from other sources to ensure the timely purchase of inputs, the utilization of high-quality farm inputs, and the application of proper crop management techniques. These results are consistent with those of Ogunniyi (2011), who found a positive effect of non-farm income on the profit efficiency of maize producers in Nigeria.

The study's findings also show that older farmers are less profit efficient compared to younger farmers. This result can be elaborated in terms of the uptake of innovations, with younger farmers embracing new technologies faster than older ones. Younger farmers tend to be more enlightened

and exposed through the accessibility of information and communication technologies, which increases their search for information and knowledge, hence making them more efficient in production. This result is in agreement with the findings of Khouthikoumane et al. (2021), Mehedi et al. (2021), and Mwita (2016), who reported a positive effect of farmers' age on profit inefficiency.

Finally, more educated farmers had higher profit efficiency compared to less educated farmers. This suggests that more educated farmers have better-organized farming operations, a better understanding of the information available, and are more open to adopting new technologies. This result agrees with the findings of other studies such as Mehedi et al. (2021) which also reported positive effects of education on profit efficiency.

4 | CONCLUSION AND RECOMMENDATIONS

According to this study, potato farming is a profitable enterprise in Nakuru County. However, farmers are producing more than 50% below the profit frontier. Potato farmers need to be supported to increase their productivity and, hence, achieve higher levels of profit efficiency. Formal education is one of the main aspects that contribute significantly to the profitability of potato growers. Education increases human capital, which enhances the farmer's ability to comprehend and apply new agricultural technologies. Access to extension services enables farmers to learn about innovations that have been proven to increase yields. This study has shown that improved access to extension and credit services significantly improves the profitability of potato farming. Thus, it is necessary to improve potato farmers' access to extension services. Farmers also need to be able to obtain loans so they can afford and use high-quality inputs, timely implement farm operations, and adopt good management practices. Farmers also need to be mobilized into farmer groups to benefit from collective actions and reduced transaction costs. Finally, female farmers need to be empowered so that they can contribute to decision-making in relation to land use and other resource allocation, as well as have better access to supportive services such as extension and credit services. Policymakers in Kenya should abide by the aforementioned recommendations to enhance potato farmers' profit efficiency and make the potato subsector an improved source of employment, food and nutrition security, and long-term economic growth.

AUTHOR CONTRIBUTIONS

Henry Chemjor: Conceptualization; data curation; formal analysis; methodology; resources; writing—review and editing. **Jared Mose:** Conceptualization; investigation; method-

ology; supervision; validation; visualization; writing—review and editing. **Vincent Ngeno:** Conceptualization; formal analysis; investigation; methodology; software; supervision; validation; visualization.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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