

Research Article

Technological Determinants of Dairy Cow Milk Production Among Small-Scale Farmers in Marakwet East Sub-County, Elgeyo-Marakwet County, Kenya

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Abstract

Small-scale dairy farming plays a critical role in food security, rural livelihoods, and nutritional improvement in many developing economies. Across Sub-Saharan Africa, the dairy sector is predominantly smallholder-based; however, productivity remains persistently low due to limited adoption of modern dairy production technologies and inadequate access to support services. In Marakwet East Sub-County, Elgeyo-Marakwet County, small-scale dairy farmers continue to experience low milk yields per cow and per household, threatening household incomes, food security, and the sustainability of the local dairy value chain. Identifying context-specific technological constraints is therefore essential for designing effective policy and extension interventions. This study examined the technological factors influencing dairy cow milk production among 196 small-scale dairy farmers in Marakwet East Sub-County. A cross-sectional survey design was employed, and primary data were collected using structured questionnaires administered to farm households. The data were analyzed using descriptive statistics to assess the level of adoption of dairy production technologies and multiple linear regression to estimate the effects of selected technological variables on milk production. The results revealed generally low adoption of key dairy technologies. Only 42.9% of farmers used artificial insemination, 28% accessed deworming services, 26% accessed vaccination services, 17.3% adopted high-yielding fodder and pasture, and 21.4% kept improved dairy breeds. Average annual milk production per household was 2,925 liters, while average milk production per cow was 975 liters per year, equivalent to 4.5 liters per cow per day, values that are substantially below the national benchmark of approximately 10 liters per cow per day. Multiple linear regression analysis indicated that use of artificial insemination, access to deworming services, adoption of high-yielding fodder and pasture, access to improved feeds such as hay and silage, and adoption of improved dairy breeds had positive and statistically significant effects on milk production. Other technologies, including mechanized milking, milk cooling facilities, and digital platforms, did not show significant effects, largely due to their very low adoption levels among farmers. The findings demonstrate that technological adoption is a critical determinant of milk productivity among small-scale dairy farmers. Addressing existing technological gaps through affordable breeding services, improved animal health management, enhanced feed systems, and strengthened extension support is essential for increasing milk production, improving household incomes, and contributing to Kenya's broader food security and agricultural transformation goals.

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Keywords

Technological Factors, Small-Scale Dairy Farmers, Livestock, Cow Milk Production, Marakwet East Sub-County, Kenya

1. Introduction

Dairy production is a fundamental component of modern food systems and makes substantial contributions to human nutrition, rural livelihoods, and economic development, particularly in low- and middle-income countries. Globally, milk production exceeded 930 million tonnes in 2021, with a significant share originating from small-scale dairy systems in developing regions [1, 2]. Despite this contribution, marked productivity disparities persist across regions. While dairy systems in high-income countries commonly achieve 20-30 liters of milk per cow per day, production levels in low-income countries often remain below 10 liters per cow per day [3, 4]. These disparities reflect structural and technological gaps rather than biological limitations, and are closely associated with limited uptake of productivity-enhancing dairy technologies.

Low adoption of key innovations such as artificial insemination, improved dairy breeds, feed conservation technologies, mechanized milking, and veterinary health services continues to constrain productivity in small-scale dairy systems [5, 6]. Empirical evidence consistently shows that adoption of improved breeding and feeding technologies leads to significant gains in milk yield, farm income, and overall production efficiency [7, 8]. However, access to these technologies remains uneven, particularly among small-scale farmers facing financial, institutional, and infrastructural constraints.

In Sub-Saharan Africa (SSA), the dairy sector is overwhelmingly dominated by small-scale producers and is characterized by persistently low productivity, with average yields ranging between 2 and 8 liters per cow per day [9, 10]. Weak veterinary infrastructure, limited availability of breeding services, and inadequate feed conservation and processing facilities further exacerbate production inefficiencies [11]. Adoption of artificial insemination and improved dairy breeds in many SSA countries rarely exceeds 25%, while uptake of improved feed technologies often remains below 20% [12, 13]. These limitations negatively affect herd health, reduce productive potential, and increase the unit cost of milk production. Studies from Uganda, Tanzania, and Ethiopia consistently identify poor technological access and low adoption rates as primary drivers of underperformance in small-scale dairy systems [14-16].

Kenya provides a useful national context for understanding these challenges. The dairy sector contributes over 12% of agricultural gross domestic product and supports millions of rural households, yet average milk yields remain modest at ap-

proximately 7-8 liters per cow per day [17]. High costs of services, irregular availability of artificial insemination, limited farmer awareness, and weak extension support continue to suppress adoption of improved technologies [18, 19]. Furthermore, technologies such as feed processing, vaccination services, and mechanized milking equipment are rarely used, even in high-potential dairy regions where their economic returns would be substantial [20, 21]. Recent evidence from Meru County also demonstrates that technology adoption is clustered and strongly influenced by education levels, cooperative membership, and access to infrastructure [22, 23].

At the local level, Elgeyo-Marakwet County reflects many of these national and regional patterns. Small-scale dairy systems in Marakwet East Sub-County are predominantly characterized by indigenous or low-grade crossbred cattle, minimal feeding regimes, and limited access to veterinary and extension services [24, 25]. Although county-led programs promote artificial insemination and breed improvement, adoption remains inconsistent and uneven [26]. Uptake of feed innovations such as silage making and fodder conservation is similarly low due to capital constraints, limited technical training, and weak cooperative support structures [27]. In addition, the use of modern digital technologies for extension, pregnancy diagnosis, and feed processing is almost non-existent, restricting farmers' access to timely information and improved management practices [28]. This low-technology production environment limits productivity growth and weakens integration of small-scale dairy farmers into quality-sensitive milk markets.

There is therefore a clear need to deepen understanding of technology adoption patterns and their productivity implications among small-scale dairy farmers in Marakwet East Sub-County. Examining adoption across breeding technologies, animal health services, feeding systems, milking and cooling infrastructure, and digital communication tools provides critical insight into the technological constraints shaping milk production outcomes. This study assesses the effects of these technological factors on dairy cow milk production to inform targeted policy interventions, extension strategies, and investment priorities aimed at enhancing milk productivity, household incomes, and the long-term sustainability of small-scale dairy systems in Marakwet East and comparable rural settings.

2. Methodology

2.1. Study Area

This study was conducted in Marakwet East Sub-County, one of the administrative units of Elgeyo-Marakwet County, formerly part of the Rift Valley Province in Kenya. It is bordered by West Pokot County to the north, Baringo County to the east, Trans-Nzoia County to the west, and Uasin Gishu County and Marakwet West Sub-County to the south. According to the 2019 Kenya Population and Housing Census, the sub-county consists of four wards—Kapyego, Embobut/Embolot, Endo, and Sambirir—with a total area of 784.3 km². Kapyego covers 308.6 km², Embobut/Embolot 151.8 km², Endo 178.6 km², and Sambirir 145.3 km². The total population is approximately 97,041, with the following distribution: Kapyego 21,268, Embobut/Embolot 19,794, Endo 28,905, and Sambirir 27,709 [29].

Marakwet East Sub-County has three distinct agro-ecological zones: highlands, escarpments, and the valley floor. The highlands cover 49% of the area and include Kapyego, Chesoi, and Embobut/Embolot. These areas experience favorable climatic conditions for dairy cow rearing, sheep production, and the cultivation of maize, peas, and beans [30]. The escarpment accounts for 11% of the area and supports crops such as maize, millet, and sorghum. The valley floor is largely semi-arid, suitable for limited subsistence farming and livestock keeping.

The area is dominated by small-scale farming, with average landholdings of 1–6 acres, while few large-scale farmers possess up to 17.3 acres [31]. The main crops include maize, beans, potatoes, cowpeas, green grams, and finger millet, alongside fruits such as mangoes, avocados, bananas, and pawpaws [32]. Livestock kept includes dairy cows, local cattle, dairy goats, poultry, and sheep, producing milk, meat, eggs, hides, and skins.

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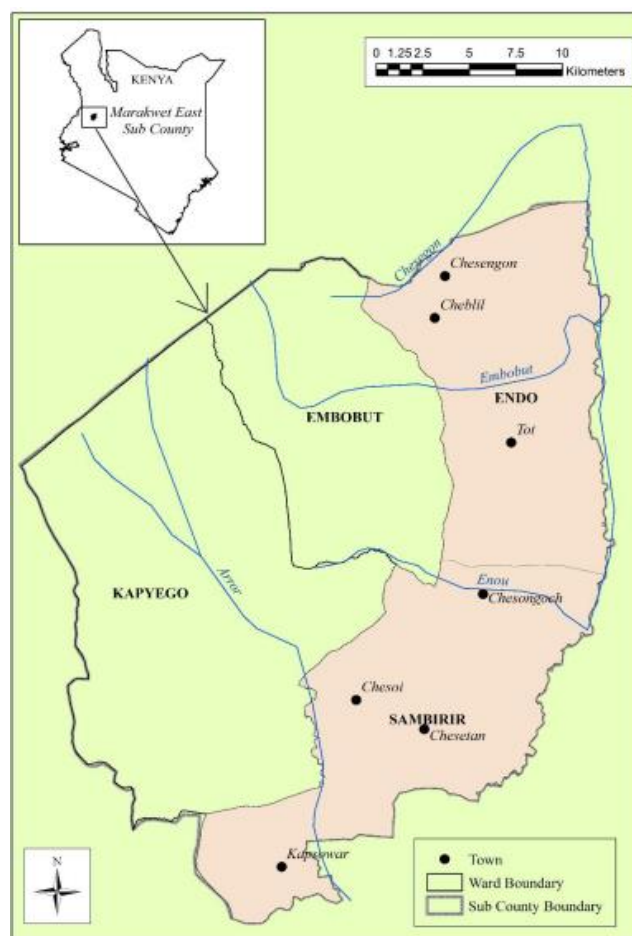


Figure 1. Map of Marakwet East Sub-County.

2.2. Research Design

The study employed a combination of observational and analytical approaches to examine milk production and technology use among small-scale dairy farmers. Specifically, a descriptive design was used to document existing production practices and levels of technology adoption, while a cross-sectional approach enabled data to be collected once from a defined population to reflect prevailing conditions during the study period [33, 34]. This design choice allowed for efficient

comparison of households with differing levels of technology use without the need for longitudinal follow-up.

2.3. Target Population

The target population comprised all households engaged in small-scale dairy farming activities within Marakwet East Sub-County. According to the Elgeyo-Marakwet Livestock and Fisheries Annual Report (2022), a total of 8,364 small-scale dairy farmers were officially registered across the four administrative wards, as summarized in Table 1 [35]. These farmers formed the sampling frame from which study respondents were selected.

Table 1. Target Population of Small-scale Dairy Farmers per Ward.

S. No	Ward	Target Population
1	Kapyego	2,108
2	Sambirir	1,419
3	Endo	2,028
4	Embobut	2,809
Total		8,364

Source: Elgeyo-Marakwet Livestock and Fisheries Annual Report (2022)

2.4. Sample Size Determination

Sample size determination followed a statistical approach

designed to balance precision with field feasibility. Nassi-uma's formula was applied because it accounts for both population variability and acceptable sampling error [36]. A coefficient of variation of 30% was selected to reflect heterogeneity among small-scale dairy farmers, while a standard error of 2% was adopted to ensure acceptable precision in parameter estimation.

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad (1)$$

Where: n = sample size

N= accessible population

C= Coefficient of Variance

e= standard error (error term)

Substituting the population parameters into the formula yielded the final sample size used in the study:

$$n = \frac{8364 \times 0.3^2}{0.3^2 + (8364-1) \times 0.02^2} \quad (2)$$

2.5. Sampling Procedure

A multi-stage sampling strategy was applied to ensure adequate representation of dairy farmers across the sub-county. First, Marakwet East Sub-County was intentionally selected due to its comparatively low milk productivity levels [37]. The population was then grouped by ward using stratified sampling to account for spatial variation, after which proportionate allocation ensured that each ward contributed respondents relative to its population size (Table 2). Finally, systematic random sampling was used to select households at regular intervals from ward-level farmer lists [38].

Table 2. Proportionate Size Sample Distribution per Ward.

Ward	Target Population	Proportion (Percent)	Sample Size
Kapyego	2,108	25.2%	55
Sambirir	1,419	17.0%	38
Endo	2,028	24.2%	53
Embobut	2,809	33.6%	74
Total	8,364	100%	220

Source: Author's Computation from Marakwet East Sub-County Livestock and Fisheries Annual Report (2022).

2.6. Data Collection Instrument, Validity and Reliability

Data were collected using a structured questionnaire designed to capture socio-economic characteristics, technology adoption, and milk production outcomes. Content validity was ensured through expert assessment by university supervisors and comparison with instruments used in similar empirical studies [39]. To assess reliability, the questionnaire was pre-tested among 23 dairy farmers outside the study area, and internal consistency was evaluated using Cronbach's Alpha. Reliability coefficients equal to or greater than 0.70 were considered satisfactory for subsequent analysis [40].

2.7. Data Collection Procedure

Field data collection was undertaken after formal authorization was obtained from relevant regulatory and administrative bodies, including NACOSTI (Ref: NACOSTI/P/24/33043), the County Commissioner, and the Ministry of Education. Face-to-face interviews were conducted at the household level, with household heads serving as primary respondents. In cases where household heads were unavailable, informed adult members actively involved in dairy management were interviewed.

2.8. Data Analysis and Presentation

Data processing involved systematic cleaning, coding, and entry prior to statistical analysis. Analysis was conducted using SPSS version 28.0. Descriptive statistics were used to summarize distributions and patterns of technology adoption, while multiple linear regression analysis quantified the relationship between selected technological variables and milk production outcomes [41]. The analytical procedures followed standard regression guidelines.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{13} X_{13} + \varepsilon_i \quad (3)$$

Where:

Y_i = milk production (Milk yield).

X_1 = Use of Artificial Insemination

X_2 = Access to vaccination services

X_3 = Access to deworming services

X_4 = Access to curative services

X_5 = Access to milking machines

X_6 = Access to milk cooling machine

X_7 = Adoption of high yielding fodder/pasture

X_8 = Access to feed milling technology

X_9 = Access to improved feeds (Hay, Silage)

X_{10} = Adoption of improved dairy breeds

X_{11} = Access to communication services

X_{12} = Access to digital platform

X_{13} = Access to pregnancy diagnosis services

$\beta_1, \beta_2, \beta_{13}$ are the regression coefficients to be estimated.

The error (ε) term captures unobserved influences on milk yield and is assumed to satisfy the classical regression assumptions [42].

To verify model robustness, post-estimation diagnostic tests were performed, with particular emphasis on multicollinearity. Variance Inflation Factor (VIF) statistics were used, where values exceeding five indicate problematic correlation among predictors [43, 44].

3. Results and Discussion

3.1. Respondent Characteristics and Questionnaire Reliability

Out of the 230 small-scale dairy farmer households approached, 196 provided complete and usable questionnaires, yielding a response rate of 85.2%, which is considered methodologically robust for household-based socio-economic surveys [45]. The internal consistency of the questionnaire was assessed using Cronbach's alpha, which yielded a coefficient of 0.79, indicating high reliability and suitability of the instrument for further statistical analysis [46].

Descriptive statistics for continuous socio-economic variables are presented in Table 3. The average age of respondents was 47 years, indicating that dairy farming in the study area is largely managed by middle-aged and older household heads. This pattern is consistent with rural demographic trends where younger populations increasingly migrate to urban areas in search of alternative livelihoods [47, 48]. The mean household size was five members, suggesting availability of family labour for dairy-related activities, and is comparable to rural household sizes reported elsewhere in Kenya [49, 50]. Respondents reported an average of 16.8 years of dairy farming experience, reflecting substantial accumulated production knowledge that may influence technology adoption and management decisions [51].

Table 3. Socio-Economic Characteristics of the Sampled Small-Scale Dairy Farmers for Continuous Variables.

Variable	Mean	Std. Dev.	Min.	Max.
Age of the household heads (Years)	47	8.1	28	60
Family size (Number)	5.0	2.0	3	10

Variable	Mean	Std. Dev.	Min.	Max.
Farmer experience (Years)	16.8	8.1	3	30
Total farm income (USD)†	900	250	100	2000

Source: Author's computation from Survey Data (2024)

†Converted from Kshs to USD at the rate of 1 Kshs = 0.0078 USD.

Table 4 summarizes nominal socio-economic characteristics. Male respondents accounted for 65.8%, while females represented 34.2%, confirming that dairy production in Marakwet East remains predominantly male-managed, consistent with livestock ownership patterns in Sub-Saharan Africa [52, 53]. A large majority (90.3%) of respondents were married, indicating relatively stable household structures commonly associated with small-scale agricultural production systems [54].

Educational attainment was generally low, with 53.1% having primary education, 42.3% secondary education, and only 4.6% tertiary education. This education profile suggests potential constraints in accessing, interpreting, and applying technical information related to improved dairy technologies [55]. In terms of occupation, 63.3% of respondents were full-time farmers, while the remainder engaged in off-farm employment, part-time farming, or trading, highlighting livelihood diversification typical of rural households [56].

The mean annual household income from all sources was approximately USD 900, placing most households within low-income categories and limiting their capacity to invest in improved breeds, feeds, and mechanized technologies [57]. Overall, the respondent profile reflects a middle-aged, modestly educated, low-income farming population, consistent with small-scale dairy systems in rural Kenya and much of Sub-Saharan Africa.

Table 4. Socio-Economic Variables of Sampled Small-Scale Dairy Farmers for Nominal Variables.

Variable	Frequency (n=196)	Percent
Gender		
Male	129	65.8
Female	67	34.2
Marital status		
Single	7	3.6
Married	177	90.3
Widowed shown	12	6.1
Level of education		
Primary	104	53.1
Secondary	83	42.3

Variable	Frequency (n=196)	Percent
College	9	4.6
Farmer occupation		
Full-time farmer	124	63.3
Part-time farmer	18	9.2
Fully employed	42	21.4
Trader	12	6.1

Source: Author's computation from Survey Data (2024)

3.2. Summary of Descriptive Statistics Results for Technological Factors Affecting Dairy Cow Milk Production

Table 5 presents the descriptive statistics results for technological factors affecting milk production among small-scale farmers in Marakwet East Sub-County. Overall adoption rates across most technologies were low, indicating limited modernization of dairy production systems in the study area.

Use of artificial insemination (AI) was reported by 42.9% of respondents, while 57.1% relied on natural breeding methods. This level of adoption remains modest and mirrors patterns observed in comparable small-scale systems in Eastern Africa [58, 59]. Access to vaccination services was reported by only 26% of farmers, while 28% accessed deworming services. Low coverage of preventive animal health services exposes herds to disease risks that directly undermine productivity [60-63]. Curative veterinary services were accessed by 21.9% of respondents, a figure comparable to reports from Uganda and Ethiopia [64].

Adoption of mechanization was extremely limited. Only 2% of farmers owned milking machines, and 7.1% accessed milk cooling facilities. Such low levels of post-harvest and milking infrastructure constrain milk quality, market access, and value addition opportunities [65-67]. Feed-related technologies were also weakly adopted. Only 17.3% of farmers used high-yielding fodder or pasture, 5.6% accessed feed milling or chopping technologies, and 31.1% used improved feeds such as hay or silage. Most households continued to rely on natural pastures and crop residues, which are nutritionally inadequate for sustained milk production [68-70].

Adoption of improved dairy breeds was reported by 21.4%

of respondents, a level comparable to findings from Ethiopia and Uganda [71, 72]. Access to communication services stood at 20.4%, while only 5.6% of farmers reported using digital platforms. Limited penetration of digital tools restricts information flow, extension reach, and timely decision-making [73]. Pregnancy diagnosis technologies were accessed by only 9.7% of farmers, reflecting both high service costs and limited

local availability [74].

Taken together, these results indicate that low adoption across breeding, health, feeding, mechanization, and digital technologies collectively constrains dairy productivity in Marakwet East. Addressing these gaps requires coordinated efforts in extension delivery, affordability of services, and targeted public and private sector support [75, 76].

Table 5. Descriptive Statistics Results for Technological Factors Affecting Milk Production among Small-Scale Dairy Farmers.

Variable	Frequency (n = 196)	Percent
Use of Artificial Insemination		
Yes	84	42.9
No	112	57.1
Access to vaccination services		
Yes	51	26.0
No	145	74.0
Access to deworming services		
Yes	55	28.0
No	141	72.0
Access to curative services		
Yes	43	21.9
No	153	78.1
Having milking machines		
Yes	4	2.0
No	192	98.0
Access to milk cooling facilities		
Yes	14	7.1
No	182	92.9
Adopted high-yielding fodder/pasture		
Yes	34	17.3
No	162	82.7
Access to feed chopping/milling technology		
Yes	11	5.6
No	185	94.4
Access to improved feeds		
Yes	61	31.1
No	135	68.9
Adopted improved dairy breeds		
Yes	42	21.4
No	154	78.6
Access to communication services		

Variable	Frequency (n = 196)	Percent
Yes	40	20.4
No	156	79.6
Access to a digital platform		
Yes	11	5.6
No	185	94.4
Access to pregnancy diagnosis technology		
Yes	19	9.7
No	177	90.3

Source: Authors computation from Survey Data (2024)

3.3. Descriptive Results for Dairy Cow Milk Production

Table 6 presents the key indicators of dairy cow milk production in Marakwet East Sub-County, including average annual milk production per household, average annual milk production per cow, and average daily milk production per cow. The results indicate generally low milk productivity across all measured indicators.

Table 6. Milk Production Statistics in Marakwet East Sub County.

Milk production (litres)	Mean	Std. Dev
Average annual milk production per household	2,925	211
Average annual milk production per cow	975	101
Average daily milk production per cow	4.5	0.4

Source: Author's computation from Survey Data (2024)

As shown in Table 6, the average annual milk production per household was 2,925 litres, reflecting limited overall output among small-scale dairy producers in the study area. This level of production is considerably lower than the 4,500-7,574 litres per household reported in other Kenyan dairy-producing regions such as Bomet, Nakuru, and Nyeri [77]. The disparity suggests substantial differences in production intensity, technology use, and herd management practices. Household milk output in Marakwet East is also markedly lower than levels reported in developed dairy economies, including the United States and the European Union [78, 79].

The average annual milk production per cow, as indicated in

Table 6, was 975 litres, which is less than half of the Kenyan national average and far below yields reported in leading global dairy producers such as the USA, Israel, and European Union countries [80, 81]. This wide productivity gap reflects underlying constraints related to feed quality, genetic potential of dairy cows, and access to animal health services [82, 83].

Daily milk production per cow averaged 4.5 litres (Table 6), a level that falls below the 10-12 litres per cow per day achievable under optimal Kenyan small-scale dairy conditions and the 14.3 litres per cow per day reported in Murang'a County [84]. In comparison, daily milk yields reported for small-scale systems in Oromia Region, Ethiopia (6.3-6.7 litres), and in Tororo and Mbarara Districts of Uganda (approximately 6.5 litres), are also higher than those observed in the current study [85, 86].

Taken together, the indicators presented in Table 6 demonstrate that dairy cow milk production in Marakwet East Sub-County operates well below both national and international benchmarks. These findings underscore the combined effects of limited adoption of improved feeding systems, low uptake of artificial insemination, inadequate veterinary support, and minimal mechanization, all of which constrain productivity in the study area. Addressing these structural and technological limitations is therefore essential for improving milk yields and overall efficiency of small-scale dairy systems [87, 88].

3.4. Diagnostic Test Results

Multicollinearity diagnostics for the regression model were assessed using tolerance values and Variance Inflation Factors (VIFs) for each explanatory variable. As reported in Table 6, VIF values ranged from 1.070 to 1.967, while tolerance values ranged from 0.508 to 0.935.

None of the reported VIF values exceeded the commonly accepted threshold of 5, and all tolerance values were above 0.25, indicating that problematic linear dependence among predictors was absent. The highest VIF value (1.967) was associated with access to pregnancy diagnosis technology,

whereas the lowest (1.070) was recorded for access to deworming services. These statistics indicate minimal correlation among the explanatory variables included in the model.

Overall, the diagnostic results confirm that the regression model satisfies the assumption of low multicollinearity, implying that the estimated coefficients are stable and that standard errors and significance tests are not distorted by intercorrelations among predictors [76]

Table 7. Estimates of Multicollinearity Statistics.

Variables	Multicollinearity statistics	
	Tolerance	VIF
Access to Artificial Insemination	0.690	1.450
Access to vaccination services	0.789	1.267
Access to deworming services	0.935	1.070
Access to curative services	0.729	1.372
Access to milking facility	0.755	1.325
Access to milk cooling facilities	0.674	1.483
Adopted high-yielding fodder/pasture	0.705	1.419
Access to feed milling technology	0.766	1.305
Access to improved feeds (Hay, silage)	0.738	1.356
Adopted improved dairy breeds	0.695	1.438
Access to communication services	0.700	1.428

Variables	Multicollinearity statistics	
	Tolerance	VIF
Access to a digital platform	0.626	1.598
Access to pregnancy diagnosis technology	0.508	1.967

Source: Author's Computation from Survey Data (2024)

3.5. Econometric Model Analytical Results

The estimated effects of technological factors on dairy cow milk production are presented in Table 7. The model exhibited strong explanatory power, with an R-squared of 0.733 and an adjusted R-squared of 0.715, indicating that 71.5% of the variation in household milk production was explained by the technological variables included in the analysis. The ANOVA results further confirm that the overall model was statistically significant at the 1% level ($F = 38.661$, $p < 0.01$), demonstrating that technological factors jointly exert a substantial influence on milk production outcomes [77].

Five technological variables were statistically significant and positively associated with milk production at the 1% significance level: use of artificial insemination, access to deworming services, adoption of high-yielding fodder and pasture, access to improved feeds such as hay and silage, and adoption of improved dairy breeds. These results indicate that technologies directly linked to genetics, animal health, and feed quality have the strongest effects on productivity. Other variables—including vaccination services, curative services, mechanized milking, milk cooling facilities, feed milling technologies, digital platforms, and pregnancy diagnosis services—did not show statistically significant effects in this model, largely reflecting their low adoption levels within the study population [78].

Table 8. Estimated Results on Effects of Technological Factors on Dairy Cow Milk Production Production.

Regression Statistics					
Model summary					
Multiple R					0.857
R Square					0.733
Adjusted R Square					0.715
Observations					196
Standard Error					1.266
ANOVA					
	SS	df	MS	F	P-value
Regression	805.805	13	61.985	38.661	<0.001

Residual	291.803	182	1.603		
Total	1097.608	195			
	Unstandardized Coefficients		Standardized Coefficients	t Stat	P-value
	Beta	Std. Error	Beta		
(Constant)	2.222	0.149		14.934	0.000
Use of Artificial Insemination	0.690	0.220	0.144	3.137	0.002**
Access to vaccination services	-0.046	0.232	-0.009	-0.200	0.842
Access to deworming services	0.684	0.208	0.130	3.285	0.001**
Access to curative services	0.459	0.256	0.080	1.793	0.075
Access to milking machines	-0.428	0.736	-0.026	-0.581	0.562
Access to milk cooling machine	0.757	0.428	0.082	1.770	0.078
Adoption of high yielding fodder/pasture	1.834	0.285	0.294	6.448	0.000***
Access to feed milling technology	0.272	0.449	0.026	0.607	0.545
Access to improved feeds (Hay, Silage)	1.780	0.227	0.348	7.827	0.000***
Adoption of improved dairy breeds	1.672	0.264	0.290	6.324	0.000***
Access to communication services	-0.071	0.268	-0.012	-0.263	0.793
Access to digital platform	0.687	0.497	0.067	1.383	0.168
Access to pregnancy diagnosis services	0.502	0.429	0.063	1.170	0.243

Source: Author's Computation from Survey Data (2024)

As shown in Table 7, the coefficient for artificial insemination ($\beta = 0.690$) indicates that farmers using AI achieved substantially higher milk production compared to non-users. Artificial insemination enhances genetic improvement by enabling access to superior dairy germplasm, a finding consistent with empirical evidence from multiple regions within and outside Kenya [79-88].

Access to deworming services also showed a strong positive association with milk production ($\beta = 0.684$). Regular parasite control improves nutrient utilization, animal health, and overall lactation performance, thereby translating into higher milk yields [89-93].

Adoption of high-yielding fodder and pasture had the largest positive coefficient ($\beta = 1.834$), indicating that feed quantity and quality are central drivers of milk productivity. Adequate and nutrient-dense forage supports sustained lactation and improved animal condition, as documented in several African and international studies [94-98].

Use of improved feeds such as hay and silage was similarly associated with higher milk production ($\beta = 1.780$). Feed conservation stabilizes nutrient supply across seasons, reduces reliance on low-quality roughage, and enhances milk output and farm profitability [99-103].

Adoption of improved dairy breeds was positively associated with milk production ($\beta = 1.672$), indicating that genetic

upgrading through crossbreeding offers substantial productivity gains under small-scale management conditions. Cross-bred cows often balance higher milk yields with resilience to local climatic and disease pressures [104-108].

Overall, the econometric results demonstrate that targeted adoption of breeding, feeding, and animal health technologies significantly enhances milk productivity among small-scale dairy farmers. Technologies with the strongest effects are those that directly improve genetic potential and nutritional status, underscoring the importance of prioritizing these interventions [109].

4. Conclusion and Recommendations

The findings of this study confirm that technological adoption is a critical determinant of dairy cow milk production among small-scale farmers in Marakwet East Sub-County. Regression results demonstrate that technologies related to breeding, animal health, and feeding systems exert the strongest positive influence on milk productivity. Specifically, use of artificial insemination, access to regular deworming services, adoption of high-yielding fodder and pasture, use of improved feeds such as hay and silage, and adoption of improved dairy breeds were all positively associated with increased milk production.

Based on these findings, the study recommends that county-level interventions prioritize expanding access to affordable and reliable artificial insemination services, in collaboration with national agencies and private sector providers. Improved AI coverage will accelerate genetic improvement, enhance disease resistance, and reduce risks associated with uncontrolled natural breeding. There is also a need to strengthen delivery of routine deworming and veterinary services at the farm level, as effective parasite control improves feed efficiency, animal health, and milk yield.

Furthermore, supporting farmers to access improved dairy breeds and well-managed crossbreeds suited to local production conditions is essential for sustainable productivity gains. Genetic improvement efforts should be complemented by training on appropriate feeding and herd management practices to maximize returns from improved breeds.

The study also recommends promoting adoption of improved pasture and fodder varieties with higher biomass yield and nutritional value. Investment in fodder production will enhance feed availability, reduce seasonal fluctuations in milk production, and lower pressure on natural grazing resources. Extension services should emphasize fodder establishment, management, and conservation techniques.

Finally, county governments and development partners should promote feed conservation practices such as hay and silage making to address seasonal feed shortages. Conserved feeds help stabilize milk supply throughout the year, reduce labor demands associated with daily forage collection, improve feed hygiene, and enhance milk quality. Facilitating farmer training and access to feed conservation equipment will further strengthen dairy productivity and household incomes.

Abbreviations

MMT	Million metric tonnes
AI	Artificial Insemination
VIF	Variance Inflation Factor
ANOVA	Analysis of Variance
OLS	Ordinary Least Squares
SSA	Sub-Saharan Africa
ECM	Energy Corrected Milk

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Author Contributions

Richard Kaino Chelanga: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resource, Software, Writing - original draft, Writing - review & editing

Elijah Kiplangat Ng'eno: Supervision, Validation, Visualization, Writing - review & editing

Joseph Amesa Omega: Supervision, Validation, Visualization, Writing - review & editing

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest

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Biography



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