ORIGINAL RESEARCH ARTICLE

Economic analysis of smallholder dairy cattle farms: case study of Nandi and Makueni Counties in Kenya

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ABSTRACT

Kenya has the highest annual *per capita* milk consumption on the African continent (110 litres), and is projected to increase to 130 litres by 2030. This has supported the development of the smallholder dairy production system which supplies 80% of the milk. Dairy farming enhances nutrition and generates income for more than 1.8 million smallholder farmers in Kenya. This study aimed at analysing the economic performance of dairy cattle farms in Nandi and Makueni counties and compare their performances as farms practicing mixed farming and as dairy farming alone, using gross margins. Further, this study sought to determine exogenous variables influencing dairy farms' economic performance. The study used a mixed research design (quantitative and focus group discussions) with key informants in the dairy sector in the 2 study counties. Purposive sampling was used to select the farms and the county based dairy data gathering and monitoring harmonized profit and loss tool developed by the Kenya Dairy Board (KDB), Kenya Dairy Processors Association (KDPA) and State Department of Livestock was used to collect data. The 2 counties differ in the level of smallholder dairy development. Nandi County was classified as a highly dairy county while Makueni County as a potentially dairy county hence their selection for inclusion in this study. Gross margins were determined for all farms by total cash income less total cash costs, while multivariable regression using Akaike Information Criterion was used to determine exogenous variables influencing gross margin levels. The findings revealed that dairy enterprises alone have positive albeit minimal gross margins while the typical smallholder mixed farming (dairy and other enterprises) result in losses in both study counties. On average, a farm in Nandi and Makueni counties made a profit of Kenya shilling (Ksh.) 2,848.30 and 880.80 per year respectively. Although the differences were not statistically significant ($p>0.5$) due to high variances, incomes in Ksh. from milk (Nandi: 21,470.3, Makueni: 51,555.3) and manure (Nandi: 7,609.2, Makueni: 605.9); and costs of feed (Nandi: 23,337.0, Makueni: 37,806.4), labour (Nandi: 10,792.9, Makueni: 13,943.4), mineral salts (Nandi: 20.9, Makueni: 33.9), artificial insemination (Nandi: 770.9, Makueni: 996.0), veterinary services(Nandi: 1,541.8, Makueni: 1,991.9), transport

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(Nandi1:130.0, Makueni:2,062.2) and water (Nandi: 187.6, Makueni: 363.5) were significantly different between Nandi and Makueni counties (p=0.00). Final models with exogenous variables had low prediction of gross margins, R^2<0.30. Due to the high costs of dairy farm inputs accounting for 94% and 99% in Nandi and Makueni counties respectively, and the involvement in several farm enterprises at the same time, farmers in both counties risk making losses or getting very minimal profits. Policies focused on making farm inputs especially feed and water affordable and accessible to smallholder dairy cattle farmers are highly recommended.

Key words: Smallholder dairy, Performance, Kenya, Productivity, Profitability

1.0 Introduction

In Kenya, the agricultural sector accounts for 22% of the Gross Domestic Product (GDP) (CBK, 2022). The livestock sector alone contributes about 13% and 40% to Kenya's national GDP and agricultural GDP respectively (Kaluwa et al., 2022; Nyariki and Amwata, 2019) while the dairy industry accounts for 12%, 44% and 4% of the agricultural GDP, livestock GDP and the national GDP respectively (KDB, 2022, Odero-Waitituh, 2017). According to FAOSTAT 2022 data, Kenya is one of the largest producers of dairy products in Africa, with an annual output of about 5.6 billion litres of milk. Of this, 74.3% (4.7 billion litres) is from cattle, while 19.3%, 4.6% and 1.8% is from camels, goats and sheep respectively (FAOSTAT, 2024).

The dairy cattle herd in Kenya is made up of over 4.5 million dairy cows, mainly owned by smallholder farmers (Kagira et al., 2022; KDB, 2022; Odero-Waitituh, 2017). In a recent research conducted in central Kenya, informal markets accounted for nearly 60% of all milk sales, with around one-third of households selling their milk to both cooperatives and informal markets. Additionally, Kenya has the greatest yearly *per capita* milk consumption on the African continent, with 110 litres per person (projected to be 130 litres by 2030) in the Kenya National Dairy Master Plan 2010-2030 (2010). Dairy farming enhances nutrition and generates income for more than 1.8 million smallholder farmers, with an estimated 1.2 million people either engaging directly or indirectly through paid labour, family labour, or mobile milk trading (KDB, 2022; Otieno et al., 2021).

In Kenya, a majority of smallholder dairy cattle are raised in crop-livestock systems in areas of high agricultural potential (King'ori, 2022). In Rift Valley for instance where Nandi County is located, households combine dairy with income crops, primarily tea (van der Lee et al., 2016). According to Weiler et al. (2014) and the County Government of Nandi (2018) Households in such areas have a strong cultural attachment to cattle for a variety of reasons, including family milk, security, obtaining bank loans, and meeting urgent financial needs. Many smallholder dairy farmers are members of dairy cooperative societies which are popular as a means of addressing challenges associated with milk collection and sales as well as supporting production inputs and services (van der Lee et al., 2016). Feeding in smallholder dairy systems

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is primarily and partially free grazing on unimproved natural pastures complemented with stall-fed cut-and-carry systems supplemented with commercial concentrates (Creemers, 2019; Orodho, 2019). The agro-climatic features of the Rift Valley region including Nandi County, the capacity for land productivity, and the incidence of animal diseases all have an impact on the production systems (Muriuki and Thorpe, 2006; Mburu et al. 2007).

On the other hand, in the lower eastern region where Makueni County is located, smallholder farming and/or keeping animals are the most important economic activities (Amwata et al., 2015). This region has a significant potential for horticulture and dairy production, particularly in the hilly areas. The lowlands are used for livestock, cotton, and fruit production, with mangoes, pawpaw, and oranges being the most often cultivated fruits. In Makueni County for instance, principal food crops include maize, green grams, pigeon peas, and sorghum (County Government of Makueni, 2013). According to Njarui and Mureithi (2006), in this region, farmers use the most fertile land for food and cash crops, while less fertile land is used for pasture. Inorganic fertiliser and manure are rarely used. Feed scarcity is compounded by low and unpredictable rainfall (500-800 mm/year), a protracted dry season, and periodic droughts. This leads to reduced pasture growth and feed production. During the dry season, the quality falls dramatically, making it insufficient for animal production (Thairu and Tessema 1987).

Seasonality in production, inadequate quantity and quality of feed, and poor animal husbandry and farming practices are the main constraints to improved milk production. These constraints affect the ability of the sector to participate and compete in the domestic and regional markets (King'ori, 2022). Other limitations include the high cost of artificial insemination (AI) services, as well as limited access to breeding, animal health, and financial services. Some regions struggle with issues such inadequate milk collection and marketing infrastructure.

The majority of the dairy cows kept in the smallholder production systems are crosses between native Zebu and exotic dairy breeds, including Friesian, Ayrshire, Guernsey, and Jersey. The use of bulls predominates over artificial insemination (AI). A study by Odero-Waitituh, (2017), in Kenya, showed that the use of AI, own bulls and hired bull was at the rate of 16.4%, 23% and 61% respectively among smallholder farmers, an indication that most farmers use bull for breeding. This finding has been highlighted in a study by Biamah et al. (2023) in Uasin Gishu County who explained that this is due to the high cost and poor accessibility to AI services. The study further notes that currently due to subsidization of AI by many county governments, this situation fast-changing.

Another constraint that is norm in smallholder dairy cattle farmers is poor herd documentation making breeding or business decision making difficult. In addition, some agro-ecological zones (AEZs) are not suitable for exotic high-yielding milk cows but can benefit from crossbred cows. Generally, Kenya's agricultural potential declines as AEZs increase. When all parameters are maintained constant, lower agro-ecological zones (AEZ 1-3) have a higher milk productivity per

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dairy cow than higher agro-ecological zones (AEZ 4-5). Milk production in Kenya varies by agro-regional zone. This is mostly owing to their varied land carrying capacity, which is determined by rainfall and soil fertility (Wambugu et al., 2018).

According to Jaetzold et al. (1983), dairy farmers in zero and semi-zero grazing areas can be categorised into three agro-ecological zones: AEZ 1 (Tea-dairy zone such as Nandi County), AEZ 2 (Coffee-tea zone), and AEZ 3 (Marginal-coffee zone) (Jaetzold et al., 1983). Makueni County is primarily located in semiarid lower midland (LM) agro-ecological zones (AEZs 4 and 5), where farmers often combine agricultural and livestock production under moderate land use conditions. LM 4 is a transitional zone between lower humidity and semi-arid zone with a mean annual rainfall of 800mm, while LM 5 is semi-arid with a mean annual rainfall of 500mm (Jaetzold & Shisanya 2006). Rain-fed agriculture is the primary system in both zones, influencing food production and subsistence-based dietary diversity. In this study, we examined the economic performance of smallholder dairy cattle farms and determined the gross margins made by individual dairy farms over the time period they were monitored. Furthermore, comparisons were made between a highly dairy county (Nandi) and a potentially dairy county (Makueni) based on their gross margins. The study aimed to gain further insights into the economic performance of dairy cattle farm enterprises between the 2 categories of counties of Nandi and Makueni Counties in order to strengthen recommendations towards a profitable and sustainable smallholder dairy cattle sector in Kenya.

2.0 Materials and methods

2.1 Study area

This study was conducted in Nandi and Makueni counties. Nandi County lies on the geographical coordinates of 0.1836° N, 35.1269° E while Makueni County lies on 2.2559° S, 37.8937° E. Nandi County is characterized by a temperature range from a mean annual minimum of 12^0 C to a mean maximum of 23^0 C, with a rainfall amount of between 1200 mm and 2000 mm per annum while Makueni County temperature ranges between a mean annual minimum of 15.4^0 C to a mean maximum of 28.7^0 C and rainfall of between 400 mm and 600 mm per year. Nandi was classified as a highly dairy county while Makueni as a potentially dairy county hence their selection for inclusion in this study.

2.2 Target population/farmers

The counties selected were among those covered by the African Dairy Genetic Gains (ADGG) an ILRI-led program whose focus is to partner with breeding stake holders in four counties (Nandi, Makueni, Narok and Kajiado) to enhance dairy genetics through innovative application of ICT and genomic technology. ADGG's vision is for smallholder dairy farmers to continuously access more productive dairy genetics, breeding, farmer education services and other related input services enabling their farm enterprises to be profitable and competitive businesses.

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The ADGG program is implemented through selected cooperatives in the counties of Nandi (Lessos) and Makueni (Makueni Creameries cooperative). Approximately 500 farmers were identified in each cooperative based on proportion of the membership and consistency of milk supply to the respective cooperative. The 500 farmers were grouped into 50 farmers based on milk supply route to form 10 groups per cooperative. The cooperative identified a technical assistant to work with each of group of 50 to enhance dairy profitability through increased productivity and enhanced genetics using innovative application of ICT and genomic technology.

2.3 Data collection

The county based dairy data gathering and monitoring harmonized Profit and Loss (P&L) tool developed by the Kenya Dairy Board (KDB), Kenya Dairy Processors Association (KDPA) and State Department of Livestock was used to collect data in this study. The tool is an excel gross margin template that has scientific formulae whose cost variables are varied to indicate the effect of the production inputs, productivity and breed effect on farm profitability. The tool was able to guide the technical assistant and the farmers on the intervention required to improve the farm profitability status. Each technical assistant visited each farm once a week to monitor progress on implementation of the recommended intervention and carry out gross margin analysis once a month to monitor profit status and propose new intervention. The process would start with farmer registration, cow registration, farm feed gap analysis and baseline gross margin for each farm. The tool was developed to guide counties on data gathering and dairy strategic development. It captures all the key dairy parameters at ward, sub-county, county and national levels which includes information on the milk marketing, crop production, herd composition, animal sale, animal feed, animal health care, farm input transport, farm labour and other farm enterprises, current feeds and feeding practices, farm sizes, milk marketing and existing groups engaging in dairy activities.

Each of the 2 counties hosted 4 fora. The first involved training sub-county technical teams on how to collect accurate information after being issued with the data collection template. The second was a one-day ward stakeholder forum where the data templates were filled at the ward level and which gave the sub-county technical teams to compile the ward data into sub-county data. The third, forum was held to enable compilation of the data from each sub-county and to validate the data for reliability, a ward stakeholder forum. The fourth stakeholders' forum was at the county level which was attended by all the stakeholders who attended the first forum. The main aim of this forum was to present the dairy data to the stakeholders for validation and approval. Consequently, 1065 farmers (560 for Makueni and 505 for Nandi counties) were registered and their P &L determined. Out of these farmers, 260 farmers and 205 farmers from Makueni and Nandi counties respectively were dropped from the final analysis for having a standard deviation greater than 3.5 for any of their cost or income components.

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Farmer registration checklist gathered information on land size in (ha) under, silage, hay, napier, protein fodder, fruits, horticultural crops, maize and tea. Further, information was collected on the production system, total number of dairy cows, lactating cows, dry cows, in-calf heifers, yearlings, weaners, calves, sheep, poultry and donkeys. Additionally, the checklist gathered information in litres/day on total milk produced and the average milk fed to calves, consumed by family, sold to neighbours, spoiled and that sold to cooperatives. Lastly, information was gathered in (Ksh) on monthly earnings from dairy, horticultural crops, maize and tea; and on current bank balance, monthly bank saving, savings in Savings and Credit Cooperative Organization (SACCO), current loan due, and monthly loan repayment. The information was collected directly from the respondents by technical assistants using the Profit and Loss (P&L) tool.

2.4 Determination of economic performance of the dairy farms

The first economic performance was calculated at farm level as Farm Gross Margins (FGM). This included other farm enterprises such as different crop production in addition to dairy. The dataset used for this analysis was obtained from 439 farmers from Nandi County and 300 farmers from Makueni County. The GM per farm per annum (pfpa) was calculated as:

$$GM_{pfpa} = \left[I_{tea\ sale,pfpa} + I_{maize\ sale,pfpa} + I_{poultry\ sale,pfpa} + I_{fruits\ sale,pfpa} + I_{milk\ sale,pfpa} + I_{manure\ sale,pfpa} + I_{bull\ calves'\ sale,phpa}\right] - \left[C_{labour,pfpa} + C_{dairymeal,pfpa} + C_{dairy\ mineralsalt,pfpa} + C_{salt\ lick,pfpa} + C_{hay,pfpa} + C_{artificial\ insemination,pfpa} + C_{veterinary\ care,pfpa} + C_{vaccination,pfpa} + C_{water,pfpa} + C_{vector\ control,pfpa} + C_{deworming,pfpa} + C_{transport,pfpa}\right]$$

Equation 1

The second economic performance was determined while considering dairy production only by excluding other farm enterprises such as crop production. It was calculated for each farm as Dairy Gross Margins (DGM). All calculations were computed per annum as per farm per annum (pfpa). All analyses were done using the R statistical package, R Core Team (2021). DGM per annum was calculated as below:

$$DGM_{pfpa} = \left[I_{milk\ sale,pfpa} + I_{manure\ sale,pfpa} + I_{bull\ calves'\ sale,phpa}\right] - \left[C_{labour,pfpa} + C_{dairymeal,pfpa} + C_{dairy\ mineralsalt,pfpa} + C_{salt\ lick,pfpa} + C_{hay,pfpa} + C_{artificial\ insemination,pfpa} + C_{veterinary\ care,pfpa} + C_{vaccination,pfpa} + C_{water,pfpa} + C_{vector\ control,pfpa} + C_{deworming,pfpa} + C_{transport,pfpa}\right]$$

Equation 2

GM per cow per annum was calculated in a similar manner.

2.5 Exogenous determinants of net returns

Multi-variable regression analysis was used to determine what other factors other than those used directly for GM calculations are associated with GM_{pfpa} and DGM_{pfpm}. See Tables 1 and 2 for the list of independent variables included in the full models for the farms and the dairy enterprises respectively. For Makueni County, the authors also considered including

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cooperative society to which the farmers belonged. However, for Nandi County cooperative was excluded because all the farmers belonged to only one cooperative society. The final (reduced) models were determined using stepwise regression with backward elimination based on Akaike's Information Criterion (AIC), in R Core Team (2021) and the MASS package (Venables and Ripley, 1999). The dataset that met the criteria for exogenous variables regression analysis came from 279 dairy farmers from Nandi County and 184 farmers from Makueni County while the final analysis for the dairy gross margin analysis used 183 farm records from Nandi County and 150 farms from Makueni County. No incomplete (missing records) form was considered in the analyses.

Table 1: Exogenous variables included in the full models for the regression analysis of Gross margins for farms

		Description [a]	
Independent variable	Class	Nandi	Makueni
Farmer gender	Discrete	2: Male (205), Female (234)	Male (202), Female (98)
Production system	Discrete	2: Mixed (423), Dairy (16)	Mixed (113), Dairy (187)
Keeps sheep	Discrete	2: Yes (142), No (297)	Yes (129), No (171)
Keeps poultry	Discrete	2: Yes (294), No (145)	Yes (106), No (194)
Farmer age	Continuous	49.7 (12.3)	55.5 (12.5)
Total household members (male and female)	Continuous	5.0 (1.6)	5.1 (2.1)
Land size	Continuous	6.2 (5.6)	10.6 (16.0)
Area on silage (ha)	Continuous	1.1 (1.0)	1.2 (1.5)
Area on hay (ha)	Continuous	0.9 (0.9)	4.3 (7.8)
Area on Napier (ha)	Continuous	0.4 (0.4)	0.8 (1.2)
Area on maize (ha)	Continuous	1.6 (1.2)	1.7 (2.2)
Area on tea (ha)	Continuous	2.3 (2.8)	-
Area on protein fodder	Continuous	-	0.9 (0.9)
Area on fruit	Continuous	-	1.8 (2.0)
Cooperative Society	Discrete	-	5:Kalawani (51), Mbitini(48), Nguu Masumba (53), Makueni (46), Makiou (51), Kaiti (51)

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ha= Hectares; [a] Discrete variable - the number of levels, their names and, in brackets, numbers within each level; Continuous variables - the mean and, in brackets, standard deviation.

Table 2: Exogenous variables included in the full models for the regression analysis of Gross margins for dairy

		Description [a]	
Independent variable	Class	Nandi	Makueni
Farmer gender	Discrete	2: Male (132), Female (147)	Male (117), Female (67)
Production system	Discrete	2: Mixed (264), Dairy (15)	Mixed (113), Dairy (73)
Keeps sheep	Discrete	2: Yes (86), No (193)	Yes (96), No (88)
Keeps poultry	Discrete	2: Yes (205), No (74)	Yes (54), No (130)
Farmer age	Continuous	51.4 (13.1)	55.1 (13.0)
Total household members (male and female)	Continuous	4.9 (1.6)	5.4 (2.3)
Land size	Continuous	6.3 (5.6)	13.5 (18.9)
Area on silage (ha)	Continuous	1.0 (1.0)	1.4 (1.7)
Area on hay (ha)	Continuous	1.2 (1.0)	5.6 (8.9)
Area on Napier (ha)	Continuous	0.4 (0.5)	1.0 (1.5)
Area on maize (ha)	Continuous	1.7 (1.4)	2.2 (2.6)
Area on tea (ha)	Continuous	2.3 (2.8)	-
Area on protein fodder	Continuous	-	1.0 (1.0)
Area on fruit	Continuous	-	2.0 (2.0)
Cooperative Society	Discrete	-	5: Kalawani (7), Mbitini(20), NguuMasumba (50), Makueni (24), Makiou (50), Kaiti (33)

ha = Hectares; [a] Discrete - the number of levels, their names and, in brackets, numbers within each level; continuous - the mean and, in brackets, standard deviation.

3.0 Results

3.1 Gross margins per farm per annum

Economic analysis for farms which practiced other farm enterprises to supplement dairy production such as tea, fruit, maize or poultry farming in both Nandi and Makueni counties made losses. On average a farm in Nandi and Makueni counties made a loss of Ksh. 381,805.60 and Ksh.175, 950.40 per year respectively, (Table 3). There was a higher variance in the losses made by farms in Makueni, SD=479,029.20 compared to that made by farms in Nandi SD=373,717.60. It is notable that in this study, tea was the only other income component not grown by dairy farmers in Makueni County while poultry and fruits were the only other income components not valued as farm enterprises by dairy farmers in Nandi County. It is notable that at farm level income components such as milk sale and manure sale were higher for Makueni County compared to Nandi County albeit with higher variances. For cost components, it is notable that water cost was the only cost markedly higher in Makueni County compared with that for Nandi County.

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Table 3: Farm gross margins per farm per annum

Mean (SD) in Kenya Shillings per farm per annum		
County	Nandi (N = 439)	Makueni (N = 300)
INCOME COMPONENTS		
Tea	168,467.4 (211635.8)	-
Maize	71,451.6 (86279.2)	34,828.0 (156,661.5)
Poultry	-	211,324.0 (303,390.5)
Fruits	-	56,114.0 (185,145.0)
Milk sale	83,941.9 (91853.7)	123,650.0 (241,840.9)
Heifers sale	37,243.7 (36557.5)	7,543.3 (6,212.4)
Bull calves' sale	12,414.6 (12185.8)	10,200.0 (12,482.5)
Manure sale	8,767.5 (5768.0)	30,600.0 (37,447.5)
Total farm income	376,375.9 (301,245.3)	474,259.3 (665,439.7)
COST COMPONENTS		
Hay	547,090.9 (359,920.9)	470,704.0 (387,652.5)
Dairy meal	97,474.1 (57,574.6)	74,117.1 (61,228.1)
Labor	42,095.7 (2,004.6)	42,280.0 (3,423.5)
Veterinary cost	28,824.6 (18,963.2)	24,800.0 (20,424.3)
Dairy mineral salts	15,430.8 (10,151.6)	13,276.3 (10,933.8)
Artificial Insemination	10,797.3 (6,377.6)	8,210.0 (6,782.3)
Transport	4,418.0 (4,834.4)	4,946.0 (9,673.6)
Deworming	3,896.7 (2,563.5)	3,352.6 (2,761.1)
Water	3,507.0 (2,307.2)	4,526.0 (3,727.4)
Vaccination	2,402.1 (1,580.3)	2,066.7 (1,702.0)
Vector control	1,753.5 (1,153.6)	1,508.7 (1,242.5)
Salt licks	491.0 (323.0)	422.4(347.9)
Total farm cost	758,181.5 (458,188.0)	650,209.8 (499,838.6)
Farm Gross Margins	-381,805.6 (373,717.6)	-175,950.4 (479,029.2)

N=Number of households that had responses for a particular cost or income component. The values are given as means and in brackets standard deviation. SD=Standard deviation.

3.2 Herd structure and milk production levels

Save for the average total number of dairy and lactating cows which were higher for Nandi County compared to Makueni County, the average total number of in-calf heifers, yearlings, weaners and calves was approximately equal for the counties (Table 4). Further, although the average milk in litres on a farm per day in Makueni (16.0) was higher than Nandi (13.1); there was a larger variation in milk production levels within farms in Makueni compared to Nandi judging from the larger standard deviations (25.8 for Makueni) and (10.7 for Nandi). In this

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study, the purchase price per litre of milk at cooperatives was used to calculate the price per litre for each county. On average, a farm in Nandi and Makueni counties sold 7.6 litres and 13.3 litres respectively. Similarly, it is notable that there was a higher variation in the value for Makueni County shown by the higher standard deviation. Considering the purchase and sale prices, a litre of milk in Nandi County was sold at an average price of Ksh.38, while in Makueni County, it averaged at Ksh. 50. In both counties, a male calf was sold at Ksh. 20000, while an in-calf heifer was sold at Ksh. 60000. These milk sale prices and the amounts sold at cooperatives, could be used in part to explain why there was a higher milk sale per annum in Makueni County compared to Nandi County.

Table 4: Nandi and Makueni counties herd structure descriptive statistics

Herd structure descriptive statistics				
Herd structure component	Nandi		Makueni	
	Mean (SD)	N	Mean (SD)	N
Total number of dairy cows	5.0 (3.4)	437	4.6 (4.2)	300
Lactating cows	2.5 (1.6)	431	2.0 (1.5)	253
Dry cows	1.7 (1.0)	301	1.8 (1.3)	168
In-calf heifers	1.5 (0.9)	129	1.5 (0.8)	74
Yearlings	1.5 (0.7)	107	1.6 (0.7)	67
Weaners	1.6 (0.8)	94	1.6 (1.0)	117
Calves	1.9 (1.0)	294	1.8 (1.2)	174
Total milk produced per day	13.1 (10.7)	433	16.0 (25.8)	255
Average milk sold to cooperatives per day	7.6 (8.1)	417	13.3 (18.8)	186
Price per litre of milk	38.0 (0)	417	50.0 (0)	186
Price per heifer	60,000.0 (0)	294	60,000.0 (0)	174
Price per bull calf	20,000.0 (0)	294	20,000.0 (0)	174

N=Number of households that had responses for a particular herd structure component. SD=Standard deviation.

3.3 Dairy Gross Margins per farm per annum

Economic analysis for dairy farms excluding other farm enterprises in both Nandi and Makueni counties showed that the dairy enterprise is marginally gainful. On average, a farm in Nandi and Makueni County made a profit of Ksh. 2,848.30 and Ksh. 880.80 per year respectively (Table 5). Although the farm gain in Nandi County is higher than that in Makueni County, the difference is not statistically significant (p-value=0.5) due to the higher variance estimated from data obtained from farms in Makueni County (SD=39,515.4) compared to data collected from Nandi County (SD=19,644.8). Milk sale is the main income component while hay cost is the main cost component for both Nandi and Makueni counties. It is notable that animal sales (heifers and bull calves) costs were higher in Nandi County than in Makueni County but not statistically significant (p-value>0.05). Additionally, manure sale and veterinary services costs

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were statistically significantly higher for Nandi County farmers compared to those from Makueni County. Conversely, milk sale and the costs of hay, labour, dairy meal, transport, salt/mineral licks, AI, deworming, water, vaccination and vector control were statistically significantly higher in Makueni County compared to Nandi County (p-value=0.00).

Table 5: Dairy gross margins per farm per annum in Kenya Shillings

County	Nandi (N = 183)	Makueni (N = 150)	p-value
INCOME COMPONENTS			
Milk sale	21,470.3 (12,283.9)	51,555.3 (33,582.6)	0.00*
Heifer sale	14,824.4 (6,180.1)	12,398.1 (9,703.4)	0.06
Manure sale	7,609.2 (2,094.6)	605.9 (233.4)	0.00*
Bull calves sale	4,941.5 (2,060.0)	4,132.7 (3,234.5)	0.06
Total income	48845.3 (14775.6)	68692.0(38219.2)	0.00*
COST COMPONENTS			
Hay	23,337.0(8021.4)	37,806.4(14,561.3)	0.00*
Labor	10,792.9 (2708.4)	13,943.4 (5,370.3)	0.00*
Dairy meal	6,959.6 (1746.5)	8,991.1 (3,463.0)	0.00*
Veterinary cost	1,541.8 (386.9)	1,991.9 (767.2)	0.00*
Transport	1,130.0 (646.5)	2,062.2 (1,343.3)	0.00*
Dairy meal salt	825.4 (207.1)	1,066.3 (410.7)	0.00*
AI	770.9 (193.5)	996.0 (383.6)	0.00*
Deworming	208.4 (52.3)	269.3 (103.7)	0.00*
Water	187.6 (47.1)	363.5 (140.0)	0.00*
Vaccination cost	128.5 (32.2)	166.0 (63.9)	0.00*
Vector control	93.8 (23.5)	121.2 (46.7)	0.00*
Salt licks	20.9 (7.2)	33.9 (13.1)	0.00*
Total cost	45997.0 (12339.9)	67811.2 (25613.6)	0.00*
Gross Margins	2848.3 (19644.8)	880.8 (39515.4)	0.50

N=Number of households that had responses for a particular cost or income component. The values are given as means and in brackets standard deviation. SD=Standard deviation.

3.4 Exogenous factors influencing Gross Margin levels

Generally, the final reduced regression models could only explain a small proportion of the FGMpa and DGMpa for Nandi and Makueni (<30%, that is, R^2 less than 0.30) as seen in the final models and the specific independent variables left in the final models in the following equations.

Final/reduced model for FGM per annum Nandi

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$$FGM_{pa} = -440689.0 + production\ system(216443.0\ if\ mixed, 0\ if\ dairy) + 40275.0(Size\ of\ land\ used\ for\ tea - 149796.0(Size\ of\ land\ used\ for\ silage\ fodder) - 3070.0(Age\ of\ the\ farmer)$$

Equation 3

Adjusted R^2 0.117
Final/reduced model for FGM per annum Makueni

$$FGM_{pa} = -97703.0 + 101922.0(Size\ of\ land\ used\ for\ silage\ fodder) + Cooperative\ (621200.0\ if\ Makiou, 82231.0\ if\ Kalawani, 98930.0\ if Mbitini, -67275\ if\ Nguu\ Masumba) - 3969.0(Age\ of\ the\ farmer)$$

Equation 4

Adjusted R^2 0.202
Final/reduced model for DGM per annum Nandi

$$DGM_{pfpa} = -31892.0 + farmer\ keeps\ sheep\ (18054.0\ if\ yes, 0\ if\ no) + 1706.0(Size\ of\ land\ used\ for\ silage\ fodder) + 14081.0\ (size\ of\ land\ for\ hay) + 10746.0(Size\ of\ land\ used\ for\ nappier)$$

Equation 5

Adjusted R^2 0.275
Final/reduced model for DGM per annum Makueni

$$DGM_{pfpa} = -75446.0 + farmer\ keeps\ sheep(30997\ if\ yes, 0\ if\ no + Cooperative\ (-59021.0\ if\ Mbitini, -30761.0\ if\ Kalawani, -14771.0\ if\ Nguu\ Masumba, 4125\ if\ Makiou, 17323\ if\ Makueni)$$

Equation 6

Adjusted R^2 0.183

4.0 Discussion

4.1 Farm characteristics

In this study, slightly more women (53.3% and 52.7% at farm and dairy enterprise level respectively) were involved in dairy farming activities compared to men in Nandi County, Table 1. In contrast, in Makueni County more men compared to women (67.3% and 63.6% at farm and dairy enterprise level) are involved in dairy farming, Table 1. This difference could be due to availability of other jobs such as tea factory jobs in Nandi County which is agriculturally high potential area. The tea sector mostly employs men leaving the women in-charge of the dairy farming as a supplementary household income source.

The respective average ages of the interviewed dairy farmers (household heads) were 51.4 and 55.1 years in Nandi and Makueni counties (Table 1). This finding corroborates well with what is reported by Byaruhanga et al. (2020) from a study conducted in Uganda which revealed that the average age of dairy farmers was 51 years. In terms of dairy production, the ages of farmers may have a significant impact on a number of variables, including managerial skills, the efficacy of improved production, processing, and milk marketing, and the rate of adoption of

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innovations in dairy production (Sisay et al. 2018) which may increase milk production and the profitability of the dairy enterprise.

At dairy enterprise level analysis most farms in Nandi and Makueni counties practiced mixed farming 94.6% and 60.8% respectively, where dairy cows, among other livestock such as poultry and sheep were reared alongside crop farming, Table 2. In contrast, at farm level analysis, farms which practiced mixed farming in Makueni County were fewer (37.7%) while for Nandi County, their proportion remained proportionately high (96.4%), Table 1. The probable reasons for practicing mixed crop-livestock farming were either that the farmers focus was on food and nutrition security or because they lacked incentives to specialize in pure dairy production as shown by (Kimenchu et al. 2014). The crop-livestock system has the benefits of permitting risk diversification, recycling wastes to reduce nutrient losses, increasing the value of crops and crop products, and generating income for the purchase of farm inputs. The crop-livestock farming system offers a climate-change buffer, multiple sources of income, and a different use for low-quality roughage (Golshani et al.2023). The financial impacts of the benefits were excluded in the current study implying that these findings should be alongside practical considerations. However, because of the rising demand for the amount of land needed for a given production level, it is difficult to scale up either of the two (livestock or crops). The majority of Kenyan communities have kept livestock for subsistence, social status, and as a sort of drought insurance. The animals also fulfilled other social functions, such as covering the cost of weddings and performing rituals (Becker, 2023).

Dairy farming is seen by many farmers in both Nandi and Makueni counties as a creative way to increase income through the maintenance of animals that make use of otherwise lost farm goods like bean crop residues and maize stover. The average farm size and the area used for dairy in Makueni County was larger (10.6 ha and 13.5 ha respectively) compared to that of Nandi County (6.2 ha and 6.3 ha respectively), Table 1and Table 2. This is expected given that Nandi County is an agriculturally high potential county with a higher population pressure on land hence, the lower land sizes compared to Makueni County. Similarly, the average areas of land that the farmers in this study used to cultivate hay, Napier grass and maize, which were the main roughages fed to animals, were higher in Makueni County than in Nandi County both at farm and dairy enterprise levels. Roughages constitute the bulk of the feeds to dairy cattle (Bye, 2022). According to Njarui et al. (2011), farmers in semi-arid regions of Kenya, such as those in Makueni County have larger pieces of land to grow fodder. They generally do not provide Napier grass to livestock when other natural pastures are available; they only do it during the dry season and do not store.

4.2 Economic analysis of dairy production

In this study, farms in both Nandi and Makueni counties made losses (Ksh. 381,805.60 and Ksh. 175, 950.40) per annum respectively, Table 3. This could be an indication that dairy is not the main economic activity on the farms and that farms have other parallel farm enterprises such

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as crop farming to which income from dairy is diverted to resulting to the losses since in this study most farmers practiced mixed farming. Although the crop-livestock farming system buffers against climate fluctuations and offers diversified income sources and alternative use for low-quality roughage, it requires 'double' expertise and is hard to upscale either of the crop or livestock components. This is because upscaling either would result to an increase in competition for the limited land space. This challenge, coupled with the high cost of inputs would further increase losses at farm level. In most cases, farmers opt to concentrate on crop production which requires minimal expertise and is relatively less costly compared to dairy production.

The losses in this study could also be an indicator of poor management at farm level where farmers may be keeping dairy cattle on the farm for other reasons other than as a business as shown in a study by (Radolf et al. 2022). The higher loss in Nandi County compared to Makueni County could be explained by the unaccounted (data scarcity) for poultry and fruit farming enterprises carried out by the farmers in Makueni. Poultry and fruit farming can be a source of quick liquid cash at the farm which can be used to purchase farm inputs on a daily basis compared to tea whose payment may only come at the end of the year.

This study found out that when the farmers who practice mixed production choose to specialize in dairy production, marginal profits (Ksh. 2,848.30 in Nandi County and Ksh. 880.80 in Makueni County) are realized, Table 5. This specialization is difficult for most farms, since the different enterprises on the farms depend on each other for sustenance e.g. the dairy enterprise depends on crop residues, while crop production depends on manure from the dairy enterprise. This finding agrees with those presented in the study by Hawkins et al. (2022) in Tanzania that specialization in dairy comes with improvement in breeds kept, feeds and feeding methods of the cows and is associated with increased incomes to farmers. In contrast to the findings in this study, a report by , KDB (2021) noted that that regardless of the systems of production, the dairy business is successful (positive GM). The findings by the Kenya Dairy Board further noted that the gross margin in high potential areas is always substantially greater than that of potentially dairy regions, which in part concurs with the results obtained in this study as Nandi County had higher gross margins. It is notable that smallholder dairy farmers in Kenya practice mixed farming and have limited abilities to specialize in dairy due to the high cost of inputs among other challenges. This explains the high losses evidenced in this study (Table 3).

It is evident from the results in this study that the main income and cost components at dairy enterprise level were milk sale and hay purchase respectively (Table 5). In Nandi County milk sale and hay costs accounted for 44% and 51% of the total income and costs respectively. Similarly, in Makueni county, milk sale and hay cost accounted for 75% and 56% of the total income and cost respectively. The relatively higher milk sale income by farmers from Makueni County compared to those in Nandi County could be explained by the availability of several

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cooperatives which offer different and higher prices for milk than in Nandi County which had one main cooperative that buys milk.

A report by KDB (2021) notes that the cost of milk production increases with intensity of production which can in part explain the higher losses at farm level for farmers in Nandi County which is a high potential area, Table 3. The finding that hay was the highest cost component in smallholder mixed production at farm level in Nandi and Makueni counties is in line with the findings of studies conducted in other countries which showed that feed costs cover the largest share of the expenses in milk production (Oğuz and Yener 2017, 2018; Mat et al. 2021; Mat and Cevger 2022; Kokemohet al. 2022; Malenje et al. 2022). However, this finding is contrary to a study by Waiswa and Günlü (2022) in Uganda who found out that veterinary costs accounted for the largest proportion of the dairy cost components although the location of the study in Western Uganda had a lot of disease vectors besides the fact that much of milk production from the country comes from grazing systems. According to a study in Central Kenya by Kimenchu et al. (2014), roughages alone represented 53.9% of the daily cost of dairy production, and this increased to 73% when concentrates and mineral supplement prices were considered. Similarly, according to Lucila et al. (2005) while conducting research in Thailand noted that the average cost of feed (all feeds included) for smallholder dairy farms was 63% of the overall expenses. Therefore, the finding of high feed costs in this study implies that dairy farming in both counties is highly dependent on affordable and appropriate roughages. These roughages can be cultivated widely in areas where farm sizes are not severely constrained such as Makueni County if water is availed.

Apart from animal feed (which includes dairy meal), the second most expensive component both at farm and dairy enterprise levels was labour (Table 3 and Table 5). At farm level, labour accounted for 5.6% and 6.5% of the total costs for Nandi and Makueni counties respectively while at dairy enterprise level, it accounted for 23.5% and 20.6% for Nandi and Makueni counties respectively. This finding can be explained by the increasing rise in the cost of labour in Kenya due to farm labour being costed at the same rate as other more lucrative jobs which the labourers could have worked instead. Indeed, dairy farming, according to Staal et al. (2008), is a labour-intensive business that would be replaced by any new enterprise that is less time-consuming and more profitable.

4.3 Exogenous variables driving gross margin levels

The relatively low R^2 (<0.30) in this study for exogenous variables influencing GM at both farm and dairy enterprise levels is similar to a finding in a study by Malenje et al. (2022) on exogenous factors affecting smallholder dairy production in eri-urban regions of Senegal which had an R^2 of (0.20). The low R^2 could be expected given the type of factors included in the model (that is, exogenous to those including in the economic analysis, and only a limited sub-set of all possible factors included, as per data availability).

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The FGMpa was higher albeit negative in mixed production systems (Ksh. -224246.0) in Nandi County when compared to dairy only systems (Ksh. -440689.0), (Equation 3). Further, farms characterized by larger areas in tea had higher FGMpa (Ksh. -400414.0) compared to those that had larger areas used for cultivating fodder used for silage making (Ksh. -590485.0) in Nandi County. Farms managed (owned) by older farmers (farmer age ranged between 25 to 90 years) tended to have lower (Ksh. -443759.0) FGMpa in Nandi County.
The FGMpa in the reduced model for Makueni County was affected by area on fodder used for silage making as well as to the specific cooperative which smallholder dairy farms belonged to. For instance, farms that had larger areas for cultivation of fodder and crops for silage making, and belonged to Makiou, Kalawani or Mbitini cooperatives had a higher FGMpa (Equation 4). In contrast, farms who were members of the Nguu Masumba cooperative had relatively lower FGMpa. As in Nandi County, gross margins tended to reduce with increase in farmer age in Makueni county (farmer age ranged between 25-86 years).

Nandi County being a high potential area affords most dairy farmers the use of crop residues such as maize stover for feeding reducing dairy production costs. This can be used to explain why FGMpa tended to increase with the practice mixed farming as compared to pure dairy. Additionally, it is highly likely that farms with larger tea farms in Nandi County have higher incomes from tea sales with some income being directed to the dairy enterprise through purchase of feed and better animal health care hence higher milk sales leading to increased FGMpa as shown by the model in equation 3. In Makueni County, due to the relatively drier climatic conditions, FGMpa tended to increase with increase in the size of the area used to cultivate crops and fodder used for silage making. Silage making which is a conservation practice can highly reduce costs of dairy production during periods of drought. In both study counties, keeping sheep increases DGMpa (Equation 5 and Equation 6) as sheep can be sold to get quick cash to buy other farm/dairy inputs such as animal feed or in meeting labour costs. Like for FGMpa, DGMpa reduced with increasing age of farmer. This is expected since as age of farmers' increase, the ability to adopt new dairy technologies reduces besides slowing down on keeping of accurate farm records which are critical for farm profitability. It was not very unclear why different cooperatives had different correlations with GM with the most plausible explanation being differences in general management.

5.0 Conclusion

This paper presents an outlook on the economic viability of dairy cattle enterprises between highly potential county (Nandi) and potential county (Makueni). Our analysis shows that while farms that focus solely on dairy farming have a positive gross margin, the margins are too small to provide a sustainable livelihood for households in both Nandi and Makueni counties.
The marginal profits in this study were mostly attributed to the high production costs, especially the expenses on feed and labour.

6.0 Limitations and assumptions:

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1. The tool used to collect data did not include value of non-cash costs involved in dairy production such as milk consumed at household, household labour, milk given to calves and animals given away (dowry or gifts). The value of these variables would have enabled the calculation of net returns which is more informative than gross margins.
2. The values that were lacking for specific income or expense categories were calculated using the mean or median (where applicable) of other relevant data. These assumptions may imply that the actual gross margin reached by farms in the survey differed from that computed, although the discrepancies are likely to be minimal.

7.0 Recommendation

A longitudinal study is recommended which can give information over a longer period of time as a loss for a particular household in this study may mean that the household was stocking any of the cost components for a future profitable dairy enterprise. Policies to address availability of water capable of supporting dairy feed production during dry periods in Makueni County and reducing the cost of farm inputs for both counties are highly recommended.

8.0 Conflict of interest

The authors declare that there is no conflict of interest.

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