REPORT ON A STUDY ON COST OF MILK PRODUCTION IN KENYA

By

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Executive Summary

The dairy industry accounts for 14% of Kenya's agricultural GDP. It is significant in contributing to poverty alleviation and food and nutrition security in both rural and urban areas. The industry supports a range of actors including farmers, milk traders, processors, consumers and several service providers. It is regarded as a successful and vibrant industry due to the increasing domestic milk production, processing capacity, per capita milk consumption and export potential (Corné et al, 2016). It supports the poor and smallholders who own one to three cows contribute about 80% of total milk production. Besides, it is estimated that the sub-sector employs two million people either directly or indirectly (Tegemeo, 2016). There is potential for growth of the sub-sector domestically and regionally. For instance, Kenya's per capita milk consumption of 110 litres per year is the highest in Sub-Saharan Africa and it is expected to rise to 130 litres per year by 2030 (National Dairy Master Plan, 2010-2030). In addition, Kenya can easily tap into the demand within the Eastern and Southern Africa region, estimated at two million tonnes (SNV, 2013). All these factors point to a pro-poor commercially-oriented sub-sector that can play a big role in improving the livelihoods of small-scale farmers (Leksmono et al. 2006; Ngigi, 2005). Given its importance, dairy is among those value chains prioritized for investment in the Agricultural Sector Transformation and Growth Strategy (ASTGS) (2019-2029), the Presidential Big Four Agenda and in the County Integrated Development Plans for two-thirds of the country's 47 counties. In addition, the Integrated National Export Development and Promotion Strategy (2017-2022) emphasizes the opportunity for export growth in the dairy sub-sector, particularly in the target destination markets in EAC, COMESA, ECOWAS, ECCAS and Gulf Cooperation Council (Saudi Arabia, UEA, Qatar, Bahrain, and Kuwait) and select Middle East Countries. The current value of annual exports to these markets stands at USD 9 million, but it estimated that this can grow up to USD 9.7 billion if there are investments and interventions in place to stimulate the production of dairy products for the export market.

The rising demand for dairy products presents a significant market opportunity for small-scale dairy producers who dominate the industry. However, this requires that at the minimum, farmers undertake actions to increase productivity and improve economic efficiency. Profitability of dairy farming in Kenya is affected by the high cost of milk production and frequent fluctuations in milk producer prices. A study commissioned by the Kenya Dairy Board (KDB) and conducted by Tegemeo Institute of Agricultural Policy and Development in

2014/15 established that some dairy farmers spent a lot of money on cattle feeds but barely made profits from the enterprise. In addition, milk price was found to be an important determinant of the economic performance of the dairy sub-sector. Pricing of raw milk has always been a concern for most farmers, whose view is that the prices they receive from processors are too low to cover production costs. Observations show that producer prices tend to remain relatively sticky even when production costs and consumer prices are increasing. The study by Tegemeo pointed out the need to address the issue of low producer prices paid by processors and cooperatives, with the latter deducting a management fee and so further reducing revenues that farmers receive. However, the costs of milk processing have not been studied to evaluate distribution of profits along the value chain. It is expected that improving producer prices is important in creating incentives for dairy production.

In response to the findings of the above study and the concern raised by farmers, the Dairy Industry (Pricing of Dairy Produce) Regulations 2021 were prepared. The objectives are to regulate the minimum farm gate prices for raw milk and protect the investment interests of the primary producer and purchaser of dairy produce. The regulations were gazetted in February 2021 and, therefore, were in force as per the time of submitting this final report.

The effective implementation of these regulations require updated data on the cost structure of milk production in the country. Five years have passed since the study by Tegemeo, making it necessary to update its findings to reflect the dynamics that have occurred in the industry since then. It is against this background that the KDB supported the current study to estimate the cost of producing cow milk under different production systems (zero grazing, semi-zero grazing and open grazing). Current information will be useful in guiding investments, planning and decision making by various stakeholders in the sub-sector. The objectives of the study were to: i) estimate the cost of farm-level milk production and profitability in Kenya across selected counties with varying production systems and scale; ii) establish the main factors that determine the farm-level cost of milk production and their relative importance; and, iii) identify potential interventions to manage farm-level cost of milk production and ensure competitiveness.

The study used a modified “typical” or “representative” or “prototype” farm approach. In this method, a typical farm for a country or a region is identified by a team comprising of experts and producers. The idea is to reflect the most dominant/common production structure in a particular region or country. After this identification, information is collected for typical farms mainly using focus group discussions (FGDs) or case studies. Since data from an individual

case study will always contain some particularities, this approach uses data from a group of farmers who run farms similar to the envisaged typical farm. This study is a follow up of a similar one conducted by Tegemeo in 2014/2015. Discussions between KDB and Tegemeo led to the selection of 20 counties for study implementation. This selection considered the contribution of counties to national milk production, as well as the need to have the three production systems and various production scales represented in the study. The scale of production was defined by the number of animals kept: i) small scale, less than 5 cows; ii) medium scale, 5 to 10 cows; and, iii) large scale, more than 10 cows.

The study findings are presented mainly by production system but variations across the systems, counties and scale of production are also highlighted. Results show that the gross revenue from milk was highest in the semi-zero production system and lowest among open grazers. The variation in milk revenue can be explained by differences in the average price (i.e. the average of prices offered by different market outlets used by the farmers). Also, the main buyer for majority of zero and open grazers was dairy cooperatives, whereas for semi-zero grazers (especially small-scale ones), it was direct consumers and traders, who offered relatively higher prices.

As expected, costs of production and returns vary by production system, scale and county. Results show that cost of milk production increases with intensity of production and the findings are consistent whether one considers total variable direct costs (TVDC) or total cost (TC). Considering TVDC only, the average cost of milk production was KES 13.02 per litre and ranged from KES 10.57 to 17.81 per litre. The open grazing system had the lowest costs (KES 10.57), which is mainly due to the relatively lower costs for feed concentrates. Zero grazing system had the highest cost (KES 17.81), which is about 68% higher than in the open grazing system. The average gross margin (GM) per litre of milk produced was KES 21.69. Across production systems, GM was lowest for zero grazers (KES 18.06) and highest for producers in the semi-zero grazing system (KES 26.57). The positive GM indicates that the dairy enterprise is profitable across the three systems since the producers were able to cover all the variable costs. However, the GM for semi-zero system is about 1.5 times that of zero grazers, a result driven by relatively higher gross milk revenue and lower TVCD in the semi-zero production system.

When fixed and opportunity costs were factored in, the average TC of producing a litre of milk increased to KES 22.51, which translates a 73% increase. This shows the importance of own

factors of production such as family labour and own fodder/pasture in dairy production, which are often overlooked. Across the production systems, TC was KES 27.30 among zero grazers, KES 23.00 in the semi-zero system and KES17.24 for open grazers. On average, a dairy farmer earned milk profit of KES 12.20 per litre. Semi-zero grazers returned the highest profit (KES 14.27), while zero-grazers had the lowest profit (KES 8.57). This implies that when we take into account fixed costs and value for non-purchased inputs such as family labour, and own-produced fodder, dairy farmers in all the production systems are able to cover all the total costs and hence they make a profit. With the addition of other revenues from the dairy enterprise (such as sale of livestock and manure), the average whole enterprise profit increased to KES 16.20 per litre of milk.

The proportion of gross margin to TVDC shows the contribution to the GM for every shilling invested in variable expenses. Overall, a shilling invested in variable costs to produce a litre of milk returned KES 1.81. The highest return was recorded by semi-zero grazers (KES 2.49) and the lowest by zero grazers at KES 1.01. This could be an indication that incremental efficiency gains expected from a more intensive zero grazing are not being realized.

Across the production systems, feed concentrates, hired labour, purchased fodder and health and breeding accounted for the largest cost shares. However, the cost structure for zero grazing was different from that of the other systems. Under zero grazing, the largest component of TVDC was feed concentrates accounting for 40%, followed by purchased fodder and hired labour (22% each) and health & breeding (6%). On the other hand, the largest contributors to cost in the semi-zero and open grazing systems are hired labour (46% vs. 50%), feed concentrates (21% vs. 28%) and health and breeding costs (18% vs. 16%). An observation that feed concentrates were a significant contributor to TVDC in the open grazing system may be an indication that as land sizes decline, dairying is likely to shift towards supplementary feeding to increase milk yields. However, as the results indicate, this will come at a cost in terms of decreased efficiency.

The largest components of TC varied across the production systems. For the zero grazers, the largest contributors to TC were feed concentrates (26%) followed by family labour (18%), while for semi-zero grazing system, these were family labour (27%) and own fodder/pasture (25%). In the case of open grazers, the largest components of total costs were hired labour (35%) and own fodder/pasture (33%). Overall, labour accounted for 33%, 48% and 41% of

total costs for zero, semi-zero and open grazers, respectively. Given the small herd sizes, perhaps too much labour is being used suggesting that there is inefficient allocation of labour across all production systems, which translates to an increase in unit cost of labour per litre of milk produced. This may be because farmers don't usually value family labour and other non-purchased inputs, and hence there is a tendency to use too much labour on dairy and other enterprises. It is common to have family members that are not gainfully employed off the farm and so their time is mainly spent on-farm across different enterprises. Farmers can make better decisions about the use of labour and non-purchased inputs once they begin to value them more accurately.

Simulations confirm the importance of various cost components to costs and returns. As expected, the highest reduction in TVDC for zero grazers would come from a reduction in the cost of feed concentrates (4%). For both semi-zero and open grazers, the largest decline in TVDC would result from a reduction in the cost of hired labour (4.6 vs. 5.1%), followed by feed concentrates (2.1 vs. 2.8%).

In the case of GM, the largest increase would result from a decrease in cost of feed concentrates for zero grazers (3.9%), and a reduction in cost of hired labour for semi-zero grazers (1.8%) and open grazers (2.6%). Across all the production systems, the effect of an increase in the price of milk on GM is much higher than the effect of a decrease in any of the cost components. A 10% increase in the price of milk would translate to a 19.9% increase in GM for zero grazers, 14% for semi-zero grazers and 15.1% for open grazers. This underscores the importance of good/remunerative prices in improving returns for dairy producers.

Comparison of findings between 2014 and 2019 shows that the herd size is small and has been declining, while the number of lactating cows remained the same across the two years. The production of milk per cow per day increased by 19% but it remains relatively low. This has a negative effect on farmer returns and may be an indication that the country is likely to experience milk deficit in the face of a growing demand and declining herd sizes.

Overall, costs of production declined by about 20%, while the gross revenue from milk, which represents the average of prices offered by different market outlets used by the farmers, increased by 3%. In addition, feed concentrates and hired labour remained the key components of variable costs of production. Hence, to enhance profitability of dairy farming, interventions and investments that improve productivity, lower costs of feeding and improve efficiency of

labour are important. Also, there is need to increase the herd size since a small herd may limit the profitability of the dairy enterprise, and hence the need to have a viable unit of dairy farm. One option of achieving this, particularly under small scale production systems is to form cooperative dairy farms (CODAF model/approach). The advantage of this approach is that pooled dairy farm management can increase economies of scale with a larger dairy herd and bring in good management for best dairy practices.

A number of observations were made with regard to the average price of milk between 2014 and 2019 by main buyer: (i) generally, a significant change in price was observed where there was a change in main buyer; (ii) prices offered by hotels, direct consumers and traders were relatively higher than those by cooperatives and processors; (iii) the main buyer of milk in most of the counties was cooperative societies; and, (iv) where dairy cooperatives remained the main buyer across the two periods, prices generally increased.

As land sizes decline, more farmers are likely to shift towards more intensive dairy production systems. However, as the study results show, this shift will come at higher costs and lower returns. To improve returns to production across all systems, it is important to focus on some key aspects. First, although the average milk yield per cow per day has increased, it has remained fairly low at 7.6 litres. Hence, there is a need to address this low productivity through interventions such as adoption of improved breeds and sensitization on the part of the farmers to rear dairy breeds suited to specific environments and their production capacities; better access to, and improved quality of feed concentrates; and, appropriate feeding practices. Similarly, there is need to encourage farmers have a viable unit of dairy farm. This could be done through adoption of the cooperative dairy farms (CODAF) model/approach. It was also noted that the proportion of lactating cows in the total herd was small, which could have contributed to low milk productivity. This could be due to low calving rates and long calving intervals, which constrain the amount of milk produced. Hence, there is need for information and training on proper planning and animal management to reduce calving intervals and so improve the economic performance of dairy farms.

Second, there is a need to address the high cost of inputs, the major ones being feed concentrates, hired labour, purchased fodder, and health and breeding. Interventions to address the challenge of feeds and fodder include: improvement in the quality of feed and better monitoring of its quality; better utilization of locally available feed resources by training farmers on on-farm feed formulation and fodder production; promoting local production of raw

materials for animal feed manufacturing; commercialization of fodder production through public-private partnerships; and, lowering tax regimes through exempting from VAT all raw materials used in the manufacture of feeds and the final products. The proposals by the Government to promote commercial production, conservation and distribution of fodder and to import feed raw materials in bulk can lead to lower costs of feeding. Labour was a large component of total costs across all production systems. This may require use of labour-saving technologies such as the chaff cutter as well as use of preserved feeds like silage. Farmers suggested that the high cost of inputs can also be addressed through subsidies for feeds and animal health products.

Third, results show the importance of good/remunerative prices in improving returns for dairy producers. Prices were higher where the main buyers were hotels, traders or consumers. Hence there may be need to further assess why farmers are not benefitting from economies of scale through cooperatives. It is often thought that the management fee charged by cooperatives is relatively high and could be reduced to increase farmer returns. In addition, using the example from the Murang'a County government, a negotiated contract price is one way of assuring farmers of stable prices. It is also a more practical and context-specific approach to address the problem of fluctuations in milk prices. Contracting can also create opportunities for pricing based on quality and quantity. Such contracts can incentivise farmers to invest more in the management of their dairy herds, improve milk quality and productivity per animal. Another option to stabilize milk supply and prices is to upscale the strategic milk reserves by Government through increasing resources set aside for the reserves and involving more processors. Also, given the large spread between farm gate and retail milk prices, farmers could benefit more if processing costs could be lowered and ways to do this need to be explored.

Since the informal markets are playing a role in linking producers to markets and improving profitability of dairy production, there is need to explore innovative ways of co-opting this segment of the market and bringing it into the formal sub-sector. This would entail setting standards for the segment, registering the actors in the segment and enhancing surveillance and enforcement of the standards. The result will be the creation of an enabling environment for increased private sector entrepreneurship in milk marketing and will generate employment directly and through linkages with other actors in the dairy value chain. This is in line with the proposal of establishing of a milk dealer certification system as identified in the National Dairy Development Policy Sessional Paper No. 5 of 2013. Other proposals in the Sessional Paper

include: development and adoption of low-cost technologies suited to informal traders; investment in training programmes on safe milk handling; and, market linkages with dairy processors.

From the FGDs, farmers indicated that they would be more incentivized to continue with dairy farming if returns would improve, which could be done through: imposing restrictions on the importation of cheap milk and milk products from neighbouring countries; training farmers in value addition such as packaging and preparation of mala and yoghurt in order to enhance returns from these products; pricing of milk based on quality and not quantity, which would act as an incentive to improve the quality of milk; cooperative societies to form one large union in each county and start processing milk to give farmers an edge in market price negotiations and so improve farm gate prices; and, developing a pricing policy to standardize the price of milk across the country. Although farmers suggested that this should be done by the KDB and the Ministry of Agriculture, local and context-specific solutions to milk marketing and pricing such as that adopted by Murang'a County may be what is needed for an industry that is liberalized and where dynamics vary across geographies and production systems.

Farmers indicated the need for county governments to employ more livestock extension officers to replace those exiting service in order to improve access to and effectiveness of extension services. Most counties do not have succession plans while others had no extension staff at the ward level. One option of dealing with staff shortage is to provide extension and training of dairy farmers through a public-private partnership approach. Furthermore, there is need to embrace information and communication technologies to deliver extension information to more farmers as this may be cost-effective.

Policy and regulatory interventions will continue to be critical in supporting the dairy sector. The KDB continues to play its role to advocate for policies that can help create an enabling environment for increased private sector entrepreneurship along the dairy value chain. Such policies include the Dairy Industry (Pricing of Dairy Produce) Regulations 2021; the directive by the Cabinet Secretary for Agriculture, Livestock, Fisheries and Cooperatives to the New KCC to pay minimum producer prices of KES 33 with effect from January 2020, and to cooperatives not to deduct more than KES 5.40 per litre of milk from farmers' payments. Greater policy support is also required to deal with the large and unregulated informal milk market. In line with the proposals of the National Dairy Development Policy Sessional Paper No. 5 of 2013, Blackmore et. al. (2015) showed that "working with actors from the informal

sector towards inclusive formalisation will deliver multiple wins for everyone involved". They noted that this approach (which they referred to as a light-touch approach) would be more effective in dealing with the players in the informal market instead of using "heavy-handed inspect-and-punish interventions". However, for this approach to work smoothly, there must be buy-in and commitment by all stakeholders (including the national and county governments, farmer and industry associations) to invest the required financial and human resources.

1. Introduction

1.1 Background

The dairy industry accounts for 14% of Kenya's agricultural GDP. It is significant in contributing towards poverty alleviation and food and nutrition security in both rural and urban areas. The industry supports a range of actors, including farmers, milk traders, processors, consumers and several service providers. It is regarded as a successful and vibrant industry due to the growing domestic milk production, processing capacity, per capita milk consumption and export potential (Corné et al, 2016). It supports the poor and smallholders who own one to three cows contribute about 80% of total milk production. In addition, it is estimated that the sub-sector employs two million people either directly or indirectly (Tegemeo, 2016). There is potential for growth of the sub-sector domestically and regionally. For instance, Kenya's per capita milk consumption of 110 litres per year is the highest in Sub-Saharan Africa and it is expected to rise to 130 litres per year by 2030 (National Dairy Master Plan, 2010-2030). In addition, Kenya can easily tap into the demand within the Eastern and Southern Africa region, estimated at two million tonnes (SNV, 2013). All these factors point to a pro-poor commercially-oriented sub-sector that can play a big role in improving the livelihoods of small-scale farmers (Leksmono et al. 2006; Ngigi, 2005). Given its importance, the dairy value chain is among those prioritized for investment in the Agricultural Sector Transformation and Growth Strategy (ASTGS), the Presidential Big Four Agenda and in the County Integrated Development Plans for two-thirds of the country's 47 counties.

Milk from livestock is estimated at 5.2 billion litres annually, of which cow milk accounts for the largest share (75%). Milk is primarily produced by an estimated 1.8 million smallholder dairy farmers under three main productions systems - zero grazing, semi-zero grazing and open grazing. Domestic and regional demand for milk is growing mainly due to population growth, increasing urbanization and rising incomes. To meet the increasing demand for milk and milk products, production and productivity need to grow. A study conducted by USAID (2014) projected that Kenya would experience a milk deficit of 675 million litres in 2017 and 1.2 billion litres by 2022 in the absence of significant improvement in milk yields. Another study concluded that increasing domestic production of milk to meet projected demand at current productivity levels would require more than doubling the current herd size in the next decade (USAID, 2018), a scenario that is not feasible given constraints in land, water and other resources.

The rising demand for dairy products presents a significant market opportunity for small-scale dairy producers who dominate the industry. But this requires that at the minimum, farmers undertake actions to increase productivity and improve economic efficiency. Profitability of dairy farming in Kenya is affected by the high cost of milk production and frequent fluctuations in milk producer prices. A study commissioned by the Kenya Dairy Board (KDB) and conducted by Tegemeo Institute of Agricultural Policy and Development in 2014/15 established that some dairy farmers spent a lot of money on cattle feeds but barely made profits from the enterprise. In addition, milk price was found to be an important determinant of the economic performance of the dairy sub-sector. Pricing of raw milk has always been a concern for most farmers whose view is that the prices they receive from processors are too low to cover production costs. Observations show that producer prices tend to remain relatively sticky even when production costs and consumer prices are increasing. The study by Tegemeo pointed out the need to address the issue of low producer prices paid by processors and cooperatives, with the latter deducting a management fee and so further reducing revenues that farmers receive. Improving producer prices is important in creating incentives for dairy production.

In response to the findings of the above study and the concern raised by farmers, the Dairy Industry (Pricing of Dairy Produce) Regulations 2021 were prepared and gazetted in February 2021. Their objectives are to regulate the minimum farm gate prices for raw milk and protect the investment interests of the primary producer and purchaser of dairy produce. The effective implementation of these regulations requires updated data on the cost structure of milk production in the country. Five years have passed since the study by Tegemeo, making it necessary to update its findings to reflect the dynamics that have occurred in the industry since then. It is against this background that the KDB supported the current study to estimate the cost of producing cow milk under different production systems (zero grazing, semi-zero grazing and open grazing). Current information will be useful in guiding investments, planning and decision making by various stakeholders in the sub-sector.

1.2 Study Objectives

The general objective of this study was to estimate the cost of milk production in Kenya. The specific objectives were to:

i. Estimate the cost of farm-level milk production and profitability in Kenya across selected counties with varying production systems and scale

ii. Establish the main factors that determine the farm-level cost of milk production and their relative importance

iii. Identify potential interventions to manage farm-level cost of milk production and ensure competitiveness

2.0 Methodology

2.1 The Typical/Prototype farm approach

There are several methods for estimating the cost of production for agricultural enterprises. A relatively new methodology is based on "typical" or "representative" or "prototype" farms (Garcia et al., 2006; Langrell et al., 2012; Zimmer, 2005). This is the method followed by some international networks such as the International Farm Comparison Network (IFCN) and Agri benchmark for dairy and crop sectors, respectively. These are worldwide associations composed of agricultural researchers, farmers and other experts. In this method, a typical farm for a country or a region is identified by a team comprising of experts and producers. The idea is to reflect the most dominant/common production structure in a particular region or country (Garcia et al., 2006). After this identification, information is collected for typical farms mainly using focus group discussions (FGDs) or case studies. Since data from an individual case study will always contain some particularities, this approach uses data from a group of farmers who run farms similar to the envisaged typical farm.

One of the main advantages of the "typical" farm approach is its international standardization, which allows for comparison (benchmarking) of costs of production for different regions, countries and over time. The methodology is also inexpensive in comparison to other methods such as representative household surveys. Using this methodology, a typical farm for a region is identified based on main characteristics such as the production system, scale of production and management system/labour organization. Data generated from a typical farm are not averages but reflect most common activities and practices among farmers in the identified production system. This study used a modified typical farm approach.

2.2 Study areas

To gain representativeness using the typical farm approach, typical farms are usually established in major production areas, which are of highest importance for the national/regional output of the product in question. Hence, the first step in this study involved identifying the most important counties for dairy production in the country under three distinct production systems: zero grazing, semi-zero grazing and open/free grazing. Discussions between KDB and Tegemeo Institute before the first wave of the 2014/15 study led to the selection of 20

counties for study implementation. This selection considered the contribution of counties to national milk production, as well as the need to have the three production systems and various production scales represented in the study. The scale of production was defined by the number of animals kept: i) small scale, fewer than five cows; ii) medium scale, 5 to 10 cows; and, iii) large scale, more than 10 cows. The 2020 follow-up survey was implemented in the same counties (Table 1). However, the typical farms for some counties had changed between the two survey periods as discussed in section 2.3.

There were three main assumptions in this study: (i) the farmers in an FGD ran dairy farms that were similar to the envisaged typical farm as defined by production system and scale within the selected regions. Hence, the reported quantities (inputs/outputs) and costs within a typical farm represent what was commonly practised by majority of farmers and are not average values; (ii) the inclusion of experts in the FGDs to validate and verify data helped in providing an accurate picture of the real farm situation in the selected areas; and, (iii) the selection of FGD participants (i.e. farmers and experts) was done properly and so there was no bias in the data collected.

Table 1: Identified areas for study implementation

County	Sub-County	Division	Location	System	Scale
Taita Taveta	Taita	Wundanyi	Wundanyi	Zero	Small
Meru	Imenti North	Miringa Mieru West	Nthibiri	Zero	Small
Nyeri	Mukuruweini	Mukuruweini Central	Muhito	Zero	Small
Muranga	Kangema	Muguru	Muguru	Zero	Small
Embu	Embu North	Runyenjes	Kyeni North	Zero	Small
Kiambu	Githunguri	Githunguri	Githunguri	Zero	Small
Nakuru	Bahati	Bahati	Kiamaina	Zero	Small
Machakos	Machakos	Central	Township	Zero	Small
Bomet	Bomet Central	Bomet Central	Ndaraweta	Semi-zero	Small
Kisii	Kitutu Chache South	Bogeka	Bogeka	Semi-zero	Small
Bungoma	Kanduyi	Kanduyi	Township	Semi-zero	Small
Kakamega	Lurambi	Lurambi	Butsotso East	Semi-zero	Small
Trans Nzoia	Trans Nzoia East	Kaplamai	Makutano	Semi-zero	Small
Nyandarua	Olkalou	Kiambaga	Kiganjo	Semi-zero	Small
Nandi	Chesumei	Kosirai	Mutwot	Semi-zero	Medium
Uasin Gishu	Ainabkoi	Ainabkoi	Olare	Semi-zero	Medium
Elgeyo Marakwet	Keiyo South	Metkei	Metkei	Semi-zero	Medium
Trans Nzoia	Trans-Nzoia East	Cherangany/Suwerwo	Cherangany/ Suwerwo	Semi-zero	Medium
Baringo	Koibatek	Eldama-Ravine	Maji Mazuri/ Mumberes	Semi-zero	Medium
Narok	Transmara West	Kilgoris Central	Shankoe	Open	Large
Uasin Gishu	Ainabkoi	Ainabkoi	Ainabkoi	Open	Large
Nakuru	Kuresoi South	Keringet	Keringet	Open	Medium

2.3 Data collection

Data for this study was collected using FGDs following the typical farm methodology. After identifying the study areas (sub-counties and wards), the first task of the data collection teams was to validate at the study sites, the information collected earlier from dairy experts through phone calls and virtual meetings. This was to ensure that: (i) the identified locations were indeed the most important for dairy production within the county (and sub-county); and, (ii) the dominant production system and scale in these areas had been correctly identified. Where necessary, adjustments were made. Such changes could be attributed to declining land sizes as a result of population increases across most counties and change of land use from agricultural to commercial, particularly in Nakuru. Other factors include training through development programs such as the National Accelerated Rural Inclusive Growth (NARIGP) that has promoted intensification of dairy production in Nakuru as well as intervention by county governments that promote dairying (e.g. Uasin Gishu).

Typical farms were then created for the purpose of undertaking FGDs. To create the typical dairy farms, a panel group of participants comprising of farmers in a selected area, and experts from the area who are knowledgeable in dairy production was used. The farmers in the panel were typical farmers in the targeted county, meaning that they were practising the most dominant production system and scale in that county. The selection of farmers to participate in the FGDs was done by the Ward Livestock Production Officers. Criteria for selection was shared with the Officers and it required that: farmers be involved in dairy farming and be practising dairy under the identified production system in the area and be living in the selected area. In addition, the FGDs were to be composed of men, women and youth. The experts included agricultural and livestock officers (from county government and cooperatives), KDB regional managers and dairy cooperative manager/leaders. The role of the experts in the panel was mainly to verify and validate the information collected from the farmers during the FGDs. Information provided by farmers was, therefore, checked and validated to ensure that it reflected the typical situation for the selected area. The data were further scrutinized at the analysis level and those that looked inconsistent were subjected to a process of data confirmation with the panel of experts.

Both qualitative and quantitative data were collected in this study. In each identified study area, a panel consisted of 10-15 participants, with at least a third of these being of either gender. A structured questionnaire was used to collect information from the established panel in an FGD

set-up. The questionnaire contained questions that elicited responses on the characteristics of the typical farms such as production levels, costs incurred in production, milk consumption and sales and use of by-products. Data was collected in August 2020 reflecting information for the period January to December 2019. Additional data was collected in mid-January 2021.

2.4 Data analysis

2.4.1 Level of analysis

The analysis was mainly done by production system despite the existence of different scales within a production system. This is primarily because some production systems were represented by only one scale. For instance, among the eight counties where typical farmers practise zero grazing, all the farmers could be categorized as small-scale. Among farmers practising open grazing only Nakuru could be categorized as medium scale and the rest (Narok and Uasin Gishu) being large scale. It is only within the semi-zero grazing system that we had a good number of counties with both small and medium-scale producers. Hence, the analysis was mainly done at the production system level but for the semi-zero grazing system, averages for the small and medium scales were presented. In addition, differences within a production system were highlighted at the county level.

2.4.2 Computation of costs and returns

The cost calculations were based on typical farm dairy enterprises that consist of the following elements: milk production, raising of replacement heifers, calves and bulls, own fodder/forage production and/or feed purchased for the entire herd, health and breeding and other costs associated with the dairy enterprise. All costs and returns were collected at a typical farm level for the year 2019 using the typical farm methodology. These were then converted to per litre of milk or lactating cow.

2.4.3 Definition of costs and returns

Total variable direct costs (TVDC): This is a summation of all variable and direct costs. The TDVC captured only explicit costs that change with level, intensity and efficiency in a production system. Indirect costs (factors not paid for directly) such as own fodder were not included in this category even if they vary with the level of production.

Total costs (TC): This is TVDC plus fixed costs (depreciation of fixed assets) and own factors of production such as family labour and own pasture. Herd depreciation was not considered in this analysis.

Depreciation of fixed assets was calculated using the straight-line method as follows: *Depreciation per annum = (Cost-residual value)/useful life)* where *cost* was the initial acquisition or construction costs related to the asset; *residual value* was the estimated proceeds expected from the disposal of an asset at the end of its useful life; and, *useful life* is the estimated time period that the asset is expected to be used starting from the date it is available for use up to the date of its disposal.

Gross milk revenue: This is the value of milk that is sold plus milk consumed by the household. For each typical farm, this was determined using the average of the milk prices offered by different market outlets used by the farmers. Milk fed to calves was considered as part of revenue but in some areas where open and semi-zero grazing are practised, this was difficult to determine since the calves suckle directly.

Other farm revenue: This includes sale of livestock and manure, manure used at own farm and bull services.

Gross margin is milk revenue less TVDC. This can also be referred to as accounting returns.

Profit from milk production only (referred hereafter as milk profit) is milk revenue less TC. This can also be referred to as economic returns.

Profit from whole dairy enterprise (referred hereafter as whole enterprise profit) takes into account other farm revenues as mentioned above.

Since the main output from a dairy enterprise is milk, gross margin and milk profit were the main units used to describe returns in this analysis.

3 Results

3.0 Overview

Table 2 presents selected characteristics of dairy farms by production system. Milk production is reported in terms of litres per cow per year and per day. On average, 50 percent of the herd size comprised of lactating cows. This is low and can be attributed to low calving rates and long calving intervals, which constrain the amount of milk produced, which are a function of factors such as heat detection, animal diet/nutrition as well as fertility and conception rates.

Overall, the average milk yield for the year 2019 was 2,850 litres per cow, which translates to an average of 7.9 litres per cow per day. As the findings indicate, milk yield and other production parameters vary by production system, and as discussed in subsequent sections, agro-ecological zone, breeds quality and feeding regimes, among other factors, affect productivity of the dairy enterprise. The average price paid by the main buyer was KES 35.50 per litre and it was highest among producers in the semi-zero production system.

Table 2: Characteristics of typical dairy farms in Kenya

	Production system			
Item	Zero grazing	Semi-zero grazing	Open	Overall
Average herd size	4	5	10	6
Average number of lactating cows	2	2	4	3
Annual milk production	7,436	6,098	9,060	7,531
Annual yield (litres/cow/year)	3,641	2,447	2,461	2,850
Average productivity (litres/cow/day)	10.1	6.8	6.8	7.9
Value of milk production (KES)	259,853	203,760	279,964	247,859
Proportion of milk sold (%)	82.8	79.4	79.9	80.7
Average price per litre by main buyer in 2019 (KES)	36.1	37.2	33	35.5

3.1 Description of prototype farms by production systems and county

Zero grazing system

The small scale zero grazing system was dominant in seven out of the 20 counties visited. It is the system with the highest output of milk in Taita Taveta[1], Meru, Nyeri, Murang'a, Embu, Kiambu and Machakos counties. In addition, data was collected in Nakuru's Bahati Sub-county, where this production system was dominant, though the predominant system in Nakuru

[1] Data for Taita Taveta County is not included in Table 3. The costs for water, own fodder/pasture and family labour were very high compared to other study areas for the small-scale zero production system. It was not possible to revise these costs even after following up with the Officers in the area, and hence this was treated as an outlier. See Table A 1.1 in the Appendix for details that include data from Taita Taveta County.

County is medium-scale open grazing. For Machakos and Nakuru, the main production system in the study areas changed from semi-zero grazing in 2014 to zero grazing in 2019 production year. In both areas, this change was attributed to declining land sizes. In addition, interventions and programs such as the National Accelerated Rural Inclusive Growth Project (NARIGP) that has promoted intensification of dairy production, may have influenced the decision of some farmers to change the production system in Nakuru.

Table 3 shows the characteristics of typical zero grazers, where on average, a farmer-owned 4 cows, out of which 2 were lactating. Under the zero grazing production system, cows are kept in a zero grazing unit where the main daily animal production activities such as feeding and milking are all carried out. The most dominant breed kept was Friesian crossbreed, although, in Nyeri and Kiambu counties, Friesian pure breed was the most common.

Table 3: Characteristics of typical farmers practising zero grazing (small-scale)

County	Machakos	Meru	Embu	Nakuru	Muranga	Nyeri	Kiambu	Average
Scale of production	Small	Small	Small	Small	Small	Small	Small	
Total cows	4	3	3	4	3	4	5	4
Number of lactating cows	2	2	2	2	1	2	3	2
Breed	Friesian cross	Friesian cross	Friesian cross	Friesian cross	Friesian cross	Friesian pure	Friesian pure	
Total fresh milk produced (litres/year)	5,280	8,400	6,240	6,990	3,450	8,130	13,560	7,436
Average productivity (litres/cow/day)	7.3	11.7	8.7	9.7	9.6	11.3	12.6	10.1
Annual yield (Litres/cow/year)	2,640	4,200	3,120	3,495	3,450	4,065	4,520	3,641
Value of milk produced	316,800	252,000	200,730	217,830	113,112	243,900	474,600	259,853
Proportion of milk sold (%)	86.4	87.1	82.7	84.5	71.3	81.2	86.7	82.8
Main buyer of milk	Hotels	Dairy Coop	Processor	Traders	Dairy Coop	Dairy Coop	Dairy Coop	
Average price of milk by main buyer in 2019 (KES/litre)	60.00	30.00	31.67	31.67	34.17	30.00	35.00	36.07

Among zero grazers, the average yield in 2019 was 3,641 litres per cow per year. The highest yield was reported in Kiambu (4,520) followed by Meru (4,200), while the lowest was in Machakos (2,640). The mean production per cow per day was 10.1 litres. Kiambu, Meru and Nyeri counties registered the highest productivity at 12.6, 11.7 and 11.3 litres, respectively, whereas, Machakos recorded the lowest productivity at 7.3 litres. The milk yield differentials could be largely driven by the genetic ability of the herd, with farmers in Nyeri and Kiambu keeping mainly Friesian pure breeds. Although farmers in this production system owned cattle of high milk production potential in terms of genetics, quantities of milk produced daily were low. This could be due to underfeeding, poor housing and sub-optimal animal husbandry. For

instance, most dairy farmers hardly feed their cows with at least 3% dry matter of body weight as recommended, partly due to the country's deficit in raw materials for feed processing, especially those for protein. Land sizes in the study areas may be too small to supply the required amounts of roughages. In addition, discussions in the focus groups showed that farmers don't generally provide cows with adequate amounts of concentrates and mineral supplements.

Unlike in 2014 where half of the counties reported that the main buyer of milk were traders, in 2019, milk producers in 4 out of the 7 counties mainly sold milk to dairy cooperatives. This switch was attributed to concerted efforts to improve management of dairy cooperatives and interventions by some county governments in setting minimum prices for milk deliveries to the cooperatives. For instance, the Governor of Murang'a directed that all cooperatives buy milk for at least KES 33 per litre. For Machakos County, the study site was close to Machakos town where the demand for milk is high and the main buyers (i.e. hotels) offer better prices than the dairy cooperatives. Traders were the most preferred marketing outlet for milk in Bahati Sub-county in Nakuru since they offered immediate cash to farmers and most often, they would offer better prices than large processors and cooperatives. Besides, because of the proximity of Bahati to Nakuru town, the demand for raw milk is high. The average milk price in 2019 was KES 36.1 per litre, with the highest price reported in Machakos, where hotels were the main buyer. Dairy cooperatives offered a price of at least KES 30 per litre. Among those selling to cooperatives, farmers in Kiambu and Murang'a received better prices compared to those in Meru and Nyeri.

Results indicate that dairy production in Kenya is a highly commercialised enterprise. The degree of commercialisation among zero grazers was about 83%. Typical farmers in Meru and Kiambu counties were the most commercialised, selling about 87% of total milk produced. The results further reveal that the proportion of milk sold is high among farms with more lactating cows and those that spend more on feeding (see Table A1 in the appendix). This finding corroborates that of USAID-KAVES (2015), which noted that dairy farmers who sell more milk also spend more on improving the dairy herd and feed supplementation.

Semi-zero grazing system

Semi-zero grazing was the most dominant production system in ten of the twenty counties. Typical farmers in Bomet, Kisii, Bungoma, Kakamega, Trans Nzoia County and Nyandarua counties can be considered as small-scale since they kept a maximum of five cows (Table 4). The study included data for semi-zero small-scale dairy farms in Trans Nzoia East sub-county,

Kaplamai Division where this is the dominant production system. However, the predominant production system in Trans Nzoia County is medium-scale semi-zero grazing.

Table 4: Characteristics of typical farmers practising semi-zero grazing (small-scale)

County	Bomet	Kisii	Bungoma	Kakamega	Trans Nzoia	Nyandarua	Average
Scale of production	Small	Small	Small	Small	Small	Small	
Total cows	5	3	3	3	4	5	4
Number lactating	2	1	2	2	3	2	2
Breed	Friesian cross	Friesian cross	Friesian cross	Ayrshire cross	Ayrshire cross	Friesian cross	
Total fresh milk produced (litres/year)	4,140	2,430	5,490	5,280	5,730	4,920	4,665
Average productivity (litres/cow/day)	5.75	6.75	7.63	7.33	5.31	6.83	6.6
Annual yield (Litres/cow/year)	2,070	2,430	2,745	2,640	1,910	2,280	2,346
Value of milk produced (KES)	163,489	121,500	329,400	264,000	134,254	142,680	192,554
Proportion of milk sold (%)	68.8	77.8	86.9	86.4	83.8	85.4	81.5
Main buyer of milk	Traders	Consumers	Consumers	Consumers	Dairy Coop	Dairy Coop	
Average price of milk by main buyer in 2019 (KES/litre)	42.5	50.0	60.0	50.0	30.7	29.0	43.7

The typical farmer in the small-scale semi-zero grazing system owned about four cows, with two of them lactating at any one time (Table 4). Friesian crossbreed was the most common breed in Bomet, Kisii, Bungoma and Nyandarua whereas, Ayrshire crossbreed was the dominant one in Kakamega and Trans Nzoia. On average, the annual milk yield among small scale semi-zero grazers was 2,346 litres per cow with highest yield reported in Bungoma (2,745) and lowest in Trans Nzoia (1,910).

The average milk yield per cow per day was 6.6 litres. Productivity was highest in Bungoma (7.6 litres) and Kakamega (7.3 litres) and lowest in Trans Nzoia (5.3 litres). The main buyer of milk among typical farmers in Kisii, Bungoma and Kakamega were direct consumers, who paid the highest prices. Typical farmers in Trans Nzoia and Nyandarua sold milk to a dairy cooperative at a price of KES 30.7 and 29.0 per litre, respectively. About 82% of milk produced under this typical farm was sold.

Data was collected among farmers practising semi-zero medium scale production system in Nandi, Uasin Gishu, Elgeyo Marakwet, Trans Nzoia and Baringo counties. The farmers kept 7 cows on average, with three of them lactating at any one time (Table 5).

The dominant breed was Friesian crossbreed, except for Baringo and Trans Nzoia counties where Ayrshire crossbreed was the most commonly kept. The average milk yield per cow

annually was 2,549 litres, whereas the share of milk sold was 77.4%. Daily milk yield per cow was 7.1 litres, with the highest yield reported in Nandi and Baringo at 9.2 litres. On average, a typical medium scale farmer under this production system received KES 30.7 per litre of milk. Farmers in these five counties mainly sold milk to dairy cooperatives who paid between KES 27.7 and KES 33.1 per litre. The highest milk price was received by farmers in Trans Nzoia, who delivered milk to Cheranganyi Dairy Cooperative Society Limited.

Table 5: Characteristics of typical farmers practising semi-zero grazing (medium-scale)

County	Nandi	Uasin Gishu	Elgeyo Marakwet	Trans Nzoia	Baringo	Average
Scale of production	Medium	Medium	Medium	Medium	Medium	
Total cows	7	8	6	6	7	7
Number lactating	3	4	3	2	3	3
Breed	Friesian cross	Friesian cross	Friesian cross	Ayrshire cross	Ayrshire cross	
Total fresh milk produced (litres/year)	9,900	7,410	5,580	4,860	9,900	7,530
Average productivity (litres/cow/day)	9.2	5.2	5.2	6.8	9.2	7.1
Annual yield (Litres/cow/year)	3,300	1,853	1,860	2,430	3,300	2,549
Value of milk produced (KES)	297,000	201,245	152,100	119,471	269,773	207,918
Proportion of milk sold (%)	73.8	75.7	80.6	72.80	84.0	77.4
Main buyer of milk	Dairy Coop	Dairy coop	Dairy coop	Dairy Coop	Dairy Coop	
Average price of milk by main buyer in 2019 (KES/litre)	29.5	30.4	27.7	33.1	32.7	30.7

Open grazing system

The typical open grazing dairy farms were found in Narok, Uasin Gishu and Nakuru counties, with the first two counties representing large-scale production, while Nakuru had predominantly medium-scale system of production (Table 6). Friesian cross was the most common dairy breed. The average herd size for large-scale producers was 12 cows, with 4 of them lactating at any one given time. Average daily productivity was 7 litres per cow in the case of large-scale production and 6.5 litres for medium-scale producers. The annual average milk yield per cow was 2,529 litres for large scale and 2,325 litres for medium scale. The average milk price received by typical farmers selling to dairy cooperatives was KES 29.8 per litre, while traders paid KES 39.7.

Table 6: Characteristics of typical farmers practising open grazing

Item	Narok	Uasin Gishu	Average (large-scale)	Nakuru
Scale of production	Large	Large		Medium
Total cows	11	12	12	7
Number of lactating cows	4	4	4	3
Breed	Friesian cross	Friesian cross		Friesian cross
Total fresh milk produced (litres/year)	7,920	12,312	10,116	6975
Average productivity (litres/cow/day)	5.5	8.6	7	6.5
Annual yield (litres/cow/year)	1,980	3,078	2,529	2,325
Value of milk produced	259,242	369,960	314,601	210,690
Proportion of milk sold	83.0	72.0	77.5	84.6
Main buyer of milk	Traders	Dairy Coop		Dairy Coop
Average price of milk by main buyer in 2019 (KES/litre)	39.7	29.8	35.0	29.8

3.2 Costs and returns per litre of milk produced

3.2.1 Per litre costs and returns by production system

Table 7 presents the costs and returns per litre of milk by production system and the overall cost. In addition, ratios that provide more information about profitability of the different production systems were computed. The gross revenue from milk included the value of what was sold and that consumed by the typical household. The largest variation in milk revenue per litre can be explained by differences in the average price (i.e. the average of prices offered by different market outlets used by the farmers). Also, the main buyer for majority of zero and open grazers was dairy cooperatives, whereas for semi-zero grazers (especially small-scale ones), it was direct consumers and traders, who offered relatively higher prices.

Results show that costs of milk production was highest among farmers practising zero grazing and lowest for those in the open grazing production system. These findings are consistent whether one considers total variable direct costs (TVDC) or total costs (TC) (Table 7). However, the TVDC for semi-zero and open grazing systems were nearly identical.

Considering TVDC only, the average cost of milk production was KES 13.02 per litre and ranged from KES 10.57 to 17.81 per litre. The open grazing system had the lowest costs (KES 10.57), which is mainly due to the relatively lower costs for feed concentrates. Zero grazing system had the highest cost (KES 17.81), which is about 68% higher than in the open grazing system. The average gross margin (GM) per litre of milk produced was KES 21.69. Across production systems, GM was lowest for zero grazers (KES 18.06) and highest for producers in the semi-zero grazing system (KES 26.57). The positive GM indicates that the dairy enterprise is profitable across the three systems since the producers were able to cover all the

variable costs. However, the GM for semi-zero system is about 1.5 times that for zero grazers, a result driven by the relatively higher gross milk revenue and lower TVCD in the semi-zero production system.

Table 7: Costs and returns in KES per litre of milk by production system

Item	Meru, Nyeri, Muranga, Embu, Kiambu, Machakos, Nakuru	Kisii, Bomet, Kakamega, U/Gishu, Nyandarua, Bungoma, T/Nzoia, Nandi, Marakwet, Nakuru	Narok, Uasin Gishu, Nakuru	
	Zero grazing	**Semi-zero grazing**	**Open**	**Overall**
Gross revenue from milk (sold + consumed)	35.87	37.27	31.00	34.71
Purchased fodder/pasture	3.87	0.56	0.00	1.48
Feed concentrates	7.05	2.24	2.92	4.07
Mineral salts	0.56	0.69	0.21	0.49
Water (purchased)	0.62	0.04	0.06	0.24
Health and breeding costs	1.14	1.93	1.68	1.58
Milking jelly	0.26	0.16	0.22	0.22
Hired labour	3.98	4.90	5.34	4.74
Repairs on fixed assets	0.15	0.16	0.13	0.15
Other direct costs (e.g. electricity, fuel)	0.19	0.00	0.00	0.16
Total variable and directs costs (TVDC)	**17.81**	**10.69**	**10.57**	**13.02**
Gross margin (Revenue - TVDC)	**18.06**	**26.57**	**20.43**	**21.69**
Depreciation (fixed assets)	0.40	0.31	0.15	0.28
Own fodder/pasture	4.16	5.77	5.68	5.21
Family labour	4.93	6.22	0.84	4.00
Total costs (TC = TVDC + depreciation + opportunity cost)	27.30	23.00	17.24	22.51
Milk profits (revenue - TC)	**8.57**	**14.27**	**13.76**	**12.20**
Other revenue (sale of livestock, manure, bull services)	1.86	4.16	5.98	4.00
Whole enterprise profit	**10.43**	**18.43**	**19.74**	**16.20**
Gross margin/TVDC ratio	1.01	2.49	1.93	1.81
Gross margin rate (%)	50.34	71.31	65.91	62.52

When fixed and opportunity costs were factored in, the average TC of producing a litre of milk increased to KES 22.51. Across the production systems, the TC was KES 27.30 among zero grazers, KES 23.00 in the semi-zero system and KES17.24 for open grazers. On average, a dairy farmer earned milk profit of KES 12.20 per litre. Semi-zero grazers returned the highest profit (KES 14.27), while zero-grazers had the lowest profit (KES 8.57). This implies that when we take into account fixed costs and value for non-purchased inputs such as family labour and own-produced fodder, dairy farmers are able to cover all the total costs, and hence they make a profit. With the addition of other revenues from the dairy enterprise (such as sale of livestock and manure), the average whole enterprise profit was KES 16.20 per litre of milk.

The proportion of gross margin to TVDC shows the contribution to the GM for every shilling invested in variable expenses. Overall, a shilling invested in variable costs to produce a litre of

milk returned KES 1.81. The highest return was recorded by semi-zero grazers (KES 2.49) and the lowest by zero grazers at KES 1.01.

The gross margin rate (GM divided by total revenue) was 63% on average, but it was highest for the semi-zero grazing system. This means that a higher proportion of revenue in this system was available for covering fixed costs of depreciation as well as opportunity costs of family labour, fodder, and for a farmer's profit. Hence, the semi-zero grazing attained a higher profit per litre of milk compared to the other production systems.

3.2.2 Per litre costs and returns for individual counties

a) Zero grazing

The highest milk revenue was achieved in Machakos (KES 60), while the lowest was in Meru and Nyeri (Table 8). As previously indicated, this is largely a function of the milk price for a typical farm, which was computed as the average of prices offered by different market outlets used by the farmers. This was highest in Machakos (KES 60) and lowest Meru and Nyeri (KES 30).

The average TVDC for typical zero grazing farms was KES 17.81. However, this varied across the counties. Kiambu County recorded the highest TVDC (KES 25.25) per litre of milk produced, followed by Nyeri (KES 23.60) and Machakos at KES 21.05. For Kiambu, the highest cost was on feed concentrates (KES 13.82) representing about 55% of the cost, followed by hired labour and purchased fodder (Table A1 in the Appendix). In Nyeri County, the high costs were mainly due to feed concentrates (KES 11.67) and purchased fodder (KES 6.25), which accounted for 49% and 26% of the cost per litre of milk produced, respectively. In the case of Machakos County, the main cost drivers were hired labour (KES 10.23), feed concentrates (KES 3.98) and purchased fodder (KES 2.27). The three items constituted 78% of the cost per litre of milk produced.

Table 8: Summary of costs and returns in KES per litre of milk for zero grazers

Item	Machakos	Meru	Embu	Nakuru	Muranga	Nyeri	Kiambu	Average
Milk revenue per litre	60.00	30.00	32.17	31.16	32.79	30.00	35.00	35.87
Total variable direct costs (TVDC)	21.05	10.67	16.60	13.48	14.04	23.60	25.25	17.81
Gross margin	38.95	19.33	15.57	17.69	18.74	6.40	9.75	18.06
Total cost	26.40	26.39	19.22	25.92	35.56	29.68	27.93	27.30
Milk profit	33.60	3.61	12.95	5.24	-2.77	0.32	7.07	8.57
Gross margin/TVDC ratio	1.85	1.81	1.33	1.31	0.27	0.39	0.94	1.13
Gross margin rate (%)	64.92	64.42	48.41	56.76	57.17	21.34	27.85	48.70

Note: Full results are shown in Table A1 in the Appendix.

The highest GM per litre was recorded in Machakos (KES 38.95), despite the county recording the third-highest total variable expenses. The high GM is due to high milk revenue, which was 67% higher than the average of KES 35.87 in this production system. Nyeri County recorded the lowest GM of KES 6.40, which could be attributed to the high variable expenses for feed concentrates and purchased fodder as well as the relatively lower average price of milk. Despite a relatively higher price of milk, Kiambu reported low GM, mainly due to the high costs of feed concentrates and hired labor. Overall, in the short run, dairy production under the zero grazing system was economically viable in all the study areas. The returns for the enterprise covered all the variable costs and had a positive return to capital, management and risk. However, the long-run viability of the enterprise is dependent on the ability to cover all production costs.

Upon factoring fixed costs and own factors of production, the total cost of producing a litre of milk for the zero grazers increased to an average of KES 27.30, and ranged from KES 19.22 in Embu to KES 35.56 in Murang'a. Milk profits were highest in Machakos at KES 33.60 followed by Embu and Kiambu. Farmers in Murang'a recorded an economic loss from milk production. This was due to the high costs of purchased fodder/pasture and family labour (which was valued at the prevailing wage rate).

The GM/TVDC ratio shows that every shilling invested in variable expenses to produce a litre of milk had a positive average return of KES 1.13. Also, the average gross margin rate for typical zero grazers was about 49%. This means that about half of the milk revenue in this system was available to cover fixed costs of depreciation as well as opportunity costs of family labour, own fodder and for a farmer's profit.

b) Semi-zero grazing

Among the small-scale semi-zero grazers, Bomet County reported the highest TVDC of KES 14.50, while Kisii had the highest TC of KES 39.88 (Table 9). The main contributors to the variable cost in Bomet were feed concentrates and purchased fodder/pasture, which accounted for 70% of the variable cost (Table A2 in the Appendix). Except for Nyandarua, the other counties did not incur any costs on purchased fodder since most of the farmers grow fodder on their farms.

Bungoma County recorded the highest GM of KES 53.48 as a result of the high milk price and low variable expenses. The high price is mainly because Bungoma is a milk deficit area and the main marketing outlet is direct consumers who pay higher prices compared to other

outlets. Farmers in this county did not incur any expenses on hired labour and purchased fodder, which are major contributors to TVDC across the dairy production systems. Milk profit was positive in all counties, averaging KES 17.18 (Table A2), implying that typical small-scale semi-zero grazers can cover both variable and total costs, and hence the dairy enterprise is profitable in this production system.

The highest ratio of GM to TVDC was recorded in Bungoma where every shilling invested in variable expenses in the production of a litre of milk returned KES 8.22. The average gross margin rate for typical small scale semi-zero grazers was about 73% and was highest in Bungoma (89%).

Table 9: Summary of costs and returns in KES per litre of milk for semi-zero grazers (small scale)

Item	Bomet	Kisii	Bungoma	Kakamega	Trans Nzoia	Nyandarua	Average
Milk revenue per litre	39.5	50.0	60.0	50.0	30.8	29.0	43.2
Total variable direct costs (TVDC)	14.50	12.14	6.51	7.79	13.25	9.30	10.59
Gross margin	25.00	37.86	53.48	42.20	17.56	19.70	32.63
Total cost	29.61	39.88	22.84	23.27	19.06	21.6	26.04
Milk profit	9.88	10.12	37.16	26.73	11.75	7.44	17.18
Gross margin/TVDC ratio	1.72	3.12	8.22	5.42	1.33	2.11	3.65
Gross margin rate (%)	63.31	75.72	89.13	84.40	56.99	67.86	72.90

Note: Full results are shown in Table A2 in the Appendix

Among the medium scale semi-zero grazers, the average TVDC was KES 6.90 (Table 10). Trans Nzoia County recorded the highest variable expenses (KES 12.70) in this category, followed by Baringo. Costs in Trans Nzoia were 4.3 times higher than the lowest TVDC in Uasin Gishu. This is because typical farmers in Trans Nzoia recorded very high costs for hired labour (KES 10.37) (Table A3 in the Appendix). The mean GM was KES 23.22, with the highest in Uasin Gishu at KES 27.25, followed by Baringo and Elgeyo Marakwet, mainly because farmers in these counties had no or low expenses on purchased fodder, feed concentrates and hired labour, which are generally major cost components in dairy production. Farmers in all these areas had positive milk profit, which averaged KES 14.70 per litre, with the highest being in Uasin Gishu (KES 18.24). As expected, the GM/TVDC ratio and the gross margin rate were highest in Uasin Gishu followed by Elgeyo Marakwet and lowest in Trans Nzoia.

Table 10: Costs and returns in KES per litre of milk for semi-zero grazers (medium scale)

Item	Nandi	Uasin Gishu	Elgeyo Marakwet	Trans Nzoia	Baringo	Average
Gross milk revenue per litre	28.69	30.19	27.26	32.43	32.05	30.12
Total variable direct costs (TVDC)	7.62	2.94	3.33	12.70	7.92	6.90
Gross margin	21.07	27.25	23.93	19.73	24.13	23.22
Total cost	11.16	11.95	14.44	24.34	15.23	15.42
Milk profit	17.53	18.24	12.82	8.09	16.82	14.70
Gross margin/TVDC ratio	2.77	9.27	7.19	1.55	3.05	4.76
Gross margin rate (%)	73.44	90.26	87.78	60.84	75.29	77.52

Note: Full results are shown in Table A3 in the Appendix

A comparison between small scale and medium scale semi-zero grazers showed that despite the small scale category having better gross revenue (average prices) per litre of milk, its profits were 31% lower because it recorded higher TVDC (53%) than the medium scale counterparts.

c) Open grazers

The average TVDC for large-scale open grazers was KES 8.03 per litre of milk, while the milk profit was KES18.08 (Table 11). The TVDC and the TC were higher among medium-scale producers compared to their large-scale counterparts. Consequently, the former recorded lower milk profits and returns for every shilling invested in variable costs.

Although the scale of production is different between Uasin Gishu and Nakuru areas, the TVDC and GM were very similar. However, the difference in TC was larger, mainly because the cost of own fodder/pasture in Uasin Gishu was about double that in Nakuru (Table A4 in the Appendix).

Table 11: Summary of costs and returns in KES per litre of milk for open grazers

Item	Narok (Large-scale)	Uasin Gishu Large-scale	Average (Large-scale)	Nakuru (Medium-scale)
Gross milk revenue per litre	32.73	30.05	31.39	30.21
Total variable direct costs (TVDC)	6.98	9.08	8.03	9.80
Gross margin	25.75	20.97	23.36	20.41
Total cost	12.50	14.13	13.32	19.23
Milk profit	20.24	15.91	18.08	10.98
Gross margin/TVDC ratio	3.69	2.31	3.00	2.08
Gross margin rate (%)	78.68	69.80	74.24	67.56

Note: Full results are shown in Table A4 in the Appendix

3.3 Contribution of different factors to cost of milk production

Figure 1 presents the shares of different cost components to TVDC. Across the production systems, feed concentrates, hired labour, purchased fodder and health and breeding accounted for the largest cost shares. However, the cost structure for zero grazing was different from that of the other systems. Under zero grazing, the largest component of TVDC was feed concentrates accounting for 40%, followed by purchased fodder and hired labour (22% each) and health & breeding (6%). On the other hand, the largest contributors to cost in the semi-zero and open grazing systems were hired labour, feed concentrates and health & breeding costs.

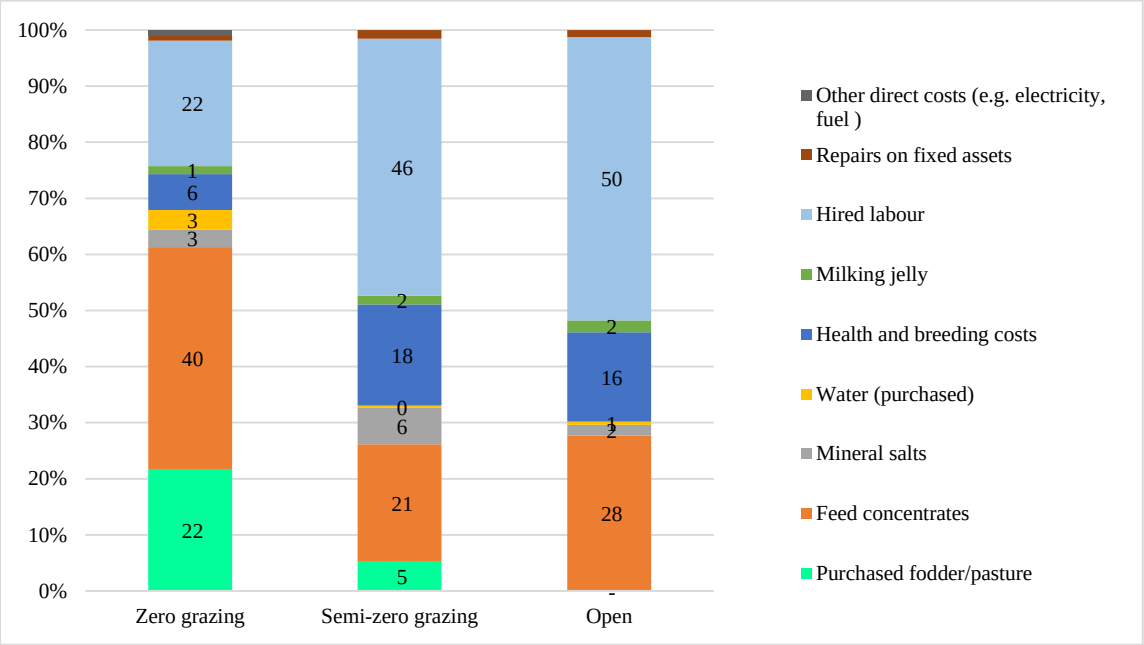

Figure 1: Share of different components to total variable direct costs (TVDC)

Although feed concentrate contributed the largest share within the zero grazing system, the costs structures varied across the counties. For instance, the share of feed concentrates in TVDC was highest in Meru (79%), followed by Kiambu (55%), Nyeri (49%) and Nakuru (46%). The share of purchased fodder within zero grazing production system was highest in Muranga (53%), followed by Nakuru (38%). Embu and Machakos had highest shares of hired labour at 51% and 49%, respectively, while the percentage of health & breeding costs was highest in Machakos (10%) (Table A1).

For the semi-zero grazing system, hired labor accounted for the largest share in TVDC (46%) followed by feed concentrates at 21% and health and breeding (18%) (Figure 1). However, there were differences in the structure of variable expenses between small- and medium-scale systems and across counties. The average TVDC for the semi-zero medium-scale system was

lower than that for the small-scale producers (Tables A2 and A3 in the Appendix). For the semi-zero small-scale grazers, feed concentrates contributed the largest share in TVDC in Kakamega, Bungoma, Nyandarua and Bomet counties at 66%, 50%, 44% and 42%, respectively (Table A2). However, hired labour was the largest component in Trans Nzoia (53%) and Kisii (49%).

For the medium-scale producers, hired labour was the largest component in Trans Nzoia (82%), Nandi (72%) and Baringo (69%). Conversely, health & breeding component constituted 80% and 70% of the TVDC, respectively, in Uasin Gishu and Elgeyo Marakwet (Table A3).

Results also show that the largest contributor to TVDC in the open grazing system was hired labour (51%) followed by feed concentrates (28%) and health and breeding (16%). Hired labour was the largest cost component across the three counties, ranging from 45 to 73%, followed by feed concentrates in Uasin Gishu (32%) and health and breeding costs in Nakuru (24%) and Narok (16%).

Overall, feed concentrates is one of the two most important variable cost components. Its high cost has a direct effect on the quantity fed to each lactating cow, consequently affecting milk productivity. This finding is consistent with Maina et al. (2019) in their study on factors that affect economic efficiency of milk production among small-scale dairy farms in Mukurweini, Nyeri County. They found that an increase in the cost of concentrates led to a decrease in economic efficiency, suggesting that high concentrate costs lower the farms' allocative efficiency, which in turn leads to a decline in economic efficiency.

The largest components of TC varied across the production systems (Figure 2). For the zero grazers, the largest contributors to TC were feed concentrates (26%), followed by family labour (18%), while for semi-zero grazing system, these were family labour (27%) and own fodder/pasture (25%). In the case of open grazers, the largest components of TC were hired labour (35%) and own fodder/pasture (33%).

Overall, labour accounted for 33%, 48% and 41% of total costs for zero, semi-zero and open grazers. Given the small herd sizes, perhaps too much labour is being used suggesting that there is inefficient allocation of labour across all production systems, which translates to an increase in unit cost of labour per litre of milk produced. This may be because farmers often don't usually value family labour and other non-purchased inputs, and hence there is a tendency to use too much labour on dairy and other enterprises. It is common to have family

members that are not gainfully employed off the farm and so their time is mainly spent on-farm across different enterprises. Farmers can make better decisions about the use of labour and non-purchased inputs once they begin to value them more accurately. In central Mexico, Posadas-Domínguez et al., (2014) found that inclusion of family labour in small-scale dairy production systems increased the private cost ratio and reduced the net profits from dairy enterprises across all production systems. Similarly, Wilson (2011) observed that UK dairy farms with larger herd sizes were more efficient in utilization of family labour. They found that for the most profitable group of farmers, the cost of farmer and spouse labour per cow was significantly lower.

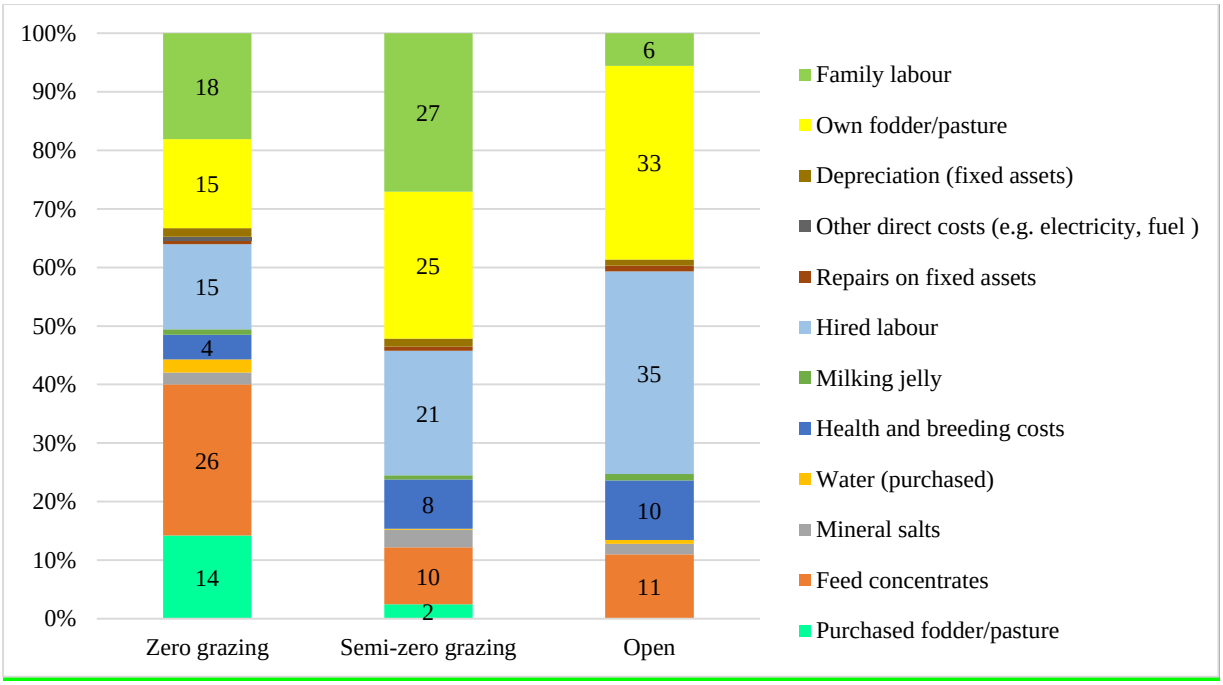

Figure 2: Share of different components to total cost (TC)

3.4. Returns per lactating cow as a proxy of efficiency in milk production

In this section, we present the costs and returns per lactating cow. The returns can be used as a proxy for efficiency. However, we note that the proxy is not a perfect indicator of efficiency because different counties received different average milk prices, and as this study has shown, milk price is an important factor in determining farmer returns. Results in Figure 3 show that milk revenue per lactating cow was highest in the zero grazing system (KES 124,215/cow/year). This is expected considering that zero grazers had the highest average productivity per lactating cow.

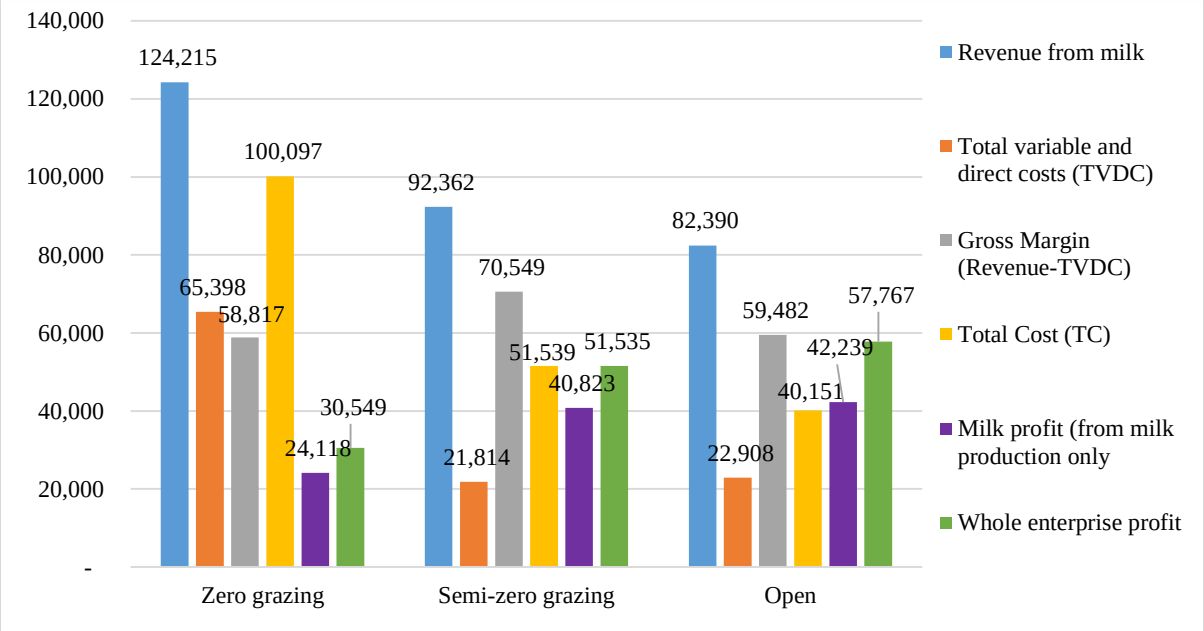

Figure 3: Costs and returns in KES per lactating cow by production system

The total cost and TVDC per lactating cow were also highest in the zero grazing system and TVDC was nearly equal among semi-zero and open grazers. The highest GM per lactating cow per year was realized in semi-zero grazing system (KES 70,549) as a result of low TDVC. Considering other costs of production (mainly own labour and fodder), milk profit was about nearly equal for semi-zero and open grazers, averaging KES 40,823 per lactating cow, which was about 1.7 times that for zero grazers. After including income from the sale of livestock and manure, open grazers made the largest annual profit of KES 57,767 per lactating cow.

Comparing efficiency within a production system shows substantial differences across counties. For instance, all typical zero grazing farms except those in Murang'a made profit (Figure 4). Milk profit per cow was highest in Machakos at KES 71,265, whereas, Murang'a posted a loss of KES 9,561. The loss in Murang'a may be attributed to very high TVDC, arising from high costs of purchased fodder and feed concentrates.

Results on efficiency for semi-zero grazing (small and medium) and open grazing systems are presented in Figures A1 to A3 in the Appendix. Producers in all production systems returned positive profit per lactating cow.

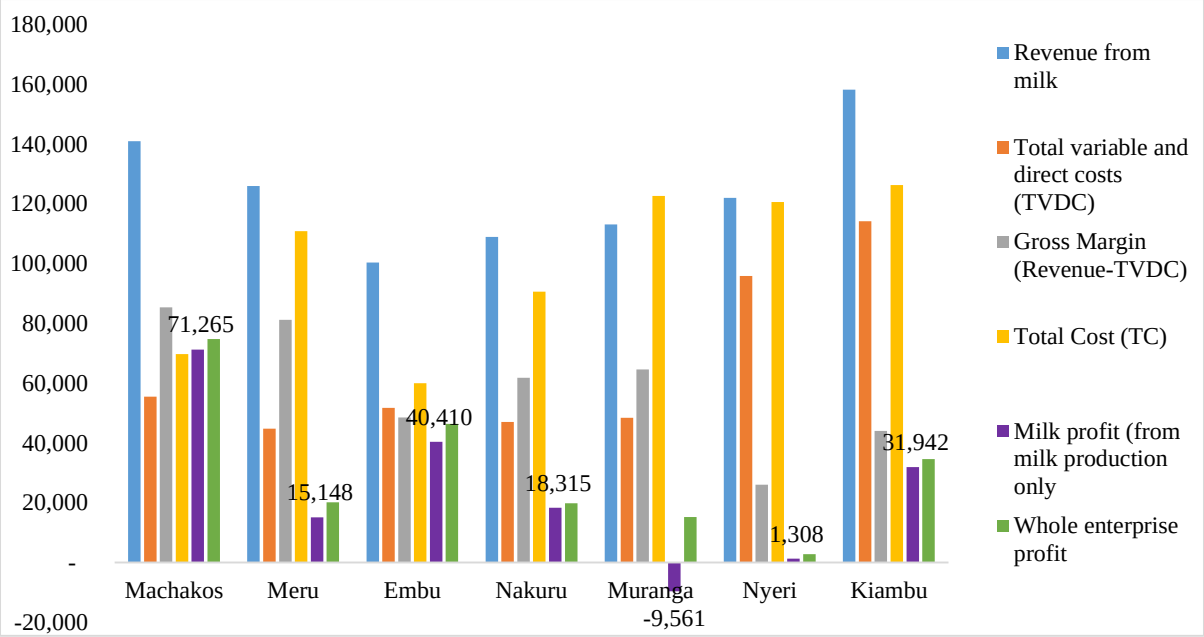

Figure 4: Costs and returns in KES per lactating cow per year for zero grazers

3.5. Changes in cost and returns as a result of changes in cost structure and milk prices

In this section, we simulate the effect of different factors on the cost of production, gross margin and profitability. This enables us to highlight the areas in which policy interventions and other investments could contribute to a reduction in costs and/or increase in returns. We simulate the effect of changing individual costs by 10% on TVDC, while keeping the cost of other factors constant. We focus only on variable direct costs, since adjustments for these factors would be easier from a policy perspective.

3.5.1 Important factors in determining total variable direct costs (TVDC)

From the analysis in the preceding section, feed concentrates, hired labour, purchased fodder/pasture and health & breeding costs were the major contributors to TVDC and so the simulation will focus on these factors. For zero grazers, the highest reduction in TVDC would arise from a reduction in the cost of feed concentrates (Figure 5). If the cost of feed concentrates would be reduced by 10%, TVDC for zero grazers would decline by 4%. Similarly, a 10% reduction in the cost of purchased fodder and hired labour (separately) would result in a 2.2% decline in TVDC. Across counties practising zero grazing, a 10% reduction in feed concentrates would result in the largest reduction of 7.9% in TVDC for farmers in Meru County, followed by Kiambu (5.5%) and about 5% in Nakuru and Nyeri (Table A7 in the Appendix). Similarly, TVDC would reduce by the largest margin of 5.3% and 3.8% in Murang'a and Nakuru, respectively, as a result of a 10% reduction in the cost of purchased

fodder. For hired labour, the highest reduction of about 5% would be realized in Machakos and Embu.

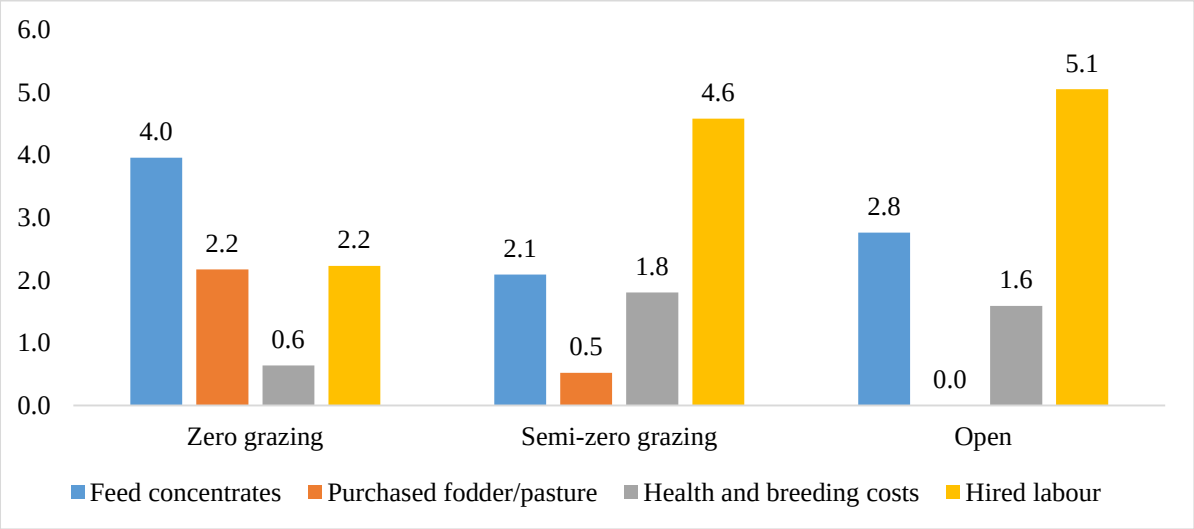

Figure 5: Changes in TVDC as a result of a reduction in costs by production system (%)

For semi-zero grazers, the largest decline in TVDC would result from a 10% reduction in the cost of hired labour (4.6%), followed by feed concentrates (2.1%) and health & breeding (1.8%). However, there are variations across the counties under this production system. For instance, under small scale semi-zero grazing, the largest reduction in TVDC (6.6%) would occur in Kakamega if the cost of feed concentrates was reduced by 10% (Table A8). The largest decline in TDVC as a result of a reduction in purchased fodder would be observed in Bomet. For Kisii and Trans Nzoia, TVDC would reduce by about 5% due to a 10% reduction in the cost of hired labour. Under the medium-scale semi-zero production, the highest reduction in TVDC would come from a reduction in hired labour (5.7%) (Table A9).

For open grazers, a 10% reduction in hired labour would lead to the highest decline in TVDC at a 5.1%, followed by feed concentrates at 2.8%, with the decline being larger for the medium-scale producers (Table A10).

3.5.2 Key factors in improving gross margin

We simulate the effect of a 10% reduction in major cost components (feeds, pasture, health & breeding and hired labour) on GM, for each component separately, while holding the other costs constant. In addition, we simulate the effect of a 10% increase in the price of milk as all costs remain constant.

If the cost of feed concentrates would reduce by 10%, the GM for zero, semi-zero and open grazers would increase by 3.9, 0.8 and 1.4%, respectively (Figure 6). Similarly, a reduction in

cost of hired labour by 10% would result in a 2.2% increase in GM for zero grazers, 1.8% for semi-zero grazers and 2.6% for open grazers. Across all the production systems, the effect of an increase in the price of milk on GM is much higher than the effect of a decrease in any of the cost components. A 10% increase in the price of milk would translate to a 19.9% increase in GM for zero grazers, 14% for semi-zero grazers and 15.1% for open grazers (Figure 6).

Figure 6: Changes in gross margin as a result of reduction in costs and milk price increase (separately) by production system

Across the counties within the zero grazing system, the greatest increase in GM would come from a reduction in the cost of feed concentrates (18%) and an increase in milk price in Nyeri (47%) (Table A7 in the Appendix). The GM in Kiambu would also increase by a large percent (36%) due to an increase in milk price. Similarly, the greatest increase in milk profits as a result reduction in cost components would be realized in Nyeri, and in Machakos, in the case of an increase in price.

For the small scale semi-zero production system, the effect of a 10% increase in price on GM would be highest in Trans Nzoia (17.5%), followed by Bomet (15.8%) (Table A8 in Appendix). For the medium scale, the greatest increase in GM and milk profit would be realized in Trans Nzoia as a result of an increase in price (Table A9). In the case of the open grazing system, the greatest increase in GM as a result of a 10% increase in price would be attained in Narok (10%).

3.6 Comparisons on selected indicators (2014 versus 2019 production years)

This section presents a comparison of indicators such as productivity, costs, returns, herd sizes and prices between 2014 and 2019. The methodology and key study areas changed between

the two periods and so it is not informative to do direct comparisons especially at disaggregated levels such as by production system. Hence, Table 12 presents overall averages across the two years.

Results indicate that the herd size is small and has been declining, while the number of lactating cows remained the same across the two years. The production of milk per cow per day increased by 19% but it remains relatively low (7.6 litres). This has a negative effect on farmer returns and may be an indication that the country is likely to experience milk deficit in the face of a growing demand and declining herd sizes.

Overall, costs of production declined by about 20%, while the gross revenue from milk, which represents the average of prices offered by different market outlets used by the farmers, increased by 3%. In addition, feed concentrates and hired labour remained the key components of variable costs of production. Therefore, to enhance profitability of dairy farming, interventions and investments that improve productivity, lower costs of feeding and improve efficiency of labour are important. Also, there is need to increase the herd size since a small herd may limit the profitability of the dairy enterprise and hence the need to have a viable unit of dairy farm. One option of doing this, particularly under small scale production systems is to form cooperative dairy farms (CODAF model/approach), where farmers contribute quality dairy cows to a central farm for best husbandry practices and professional management. The improved management ensures increased productivity per cow, better quality milk, assured supply to the cooperative and consistent income to the members. The advantage of this approach is that pooled dairy farm management can increase economies of scale with a larger dairy herd and bring in good management for best dairy practices.

Table 12: Comparison of selected indicators between 2014 and 2019

Item	2014	2019
Herd size	9	6
Number of lactating cows	3	3
Milk yield per cow per day	6.4	7.9
Total variable direct cost (TVDC)	15.4	11.8
Total cost (TC)	28.4	22.4
Gross revenue from milk/ litre (average price)	34.8	35.9
Gross margin/litre	17.4	27.7
Milk profits/litre	4.2	13.5
Whole enterprise profit	9.2	17.2
Share of major components of TVDC		
Feed concentrates	25.3	31.2
Purchased fodder	6.8	11.3
Health and breeding	15.8	12.2
Hired labour	28.7	36.4

Table 13 presents a comparison of the average price per litre of milk between 2014 and 2019 by main buyer across the counties. The following observations can be made: (i) generally, a significant change in price was observed where there was a change in the main buyer; (ii) prices offered by hotels, direct consumers and traders were relatively higher than those by cooperatives and processors; (iii) the main buyer of milk in most of the counties was cooperative societies; (iv) where dairy cooperatives remained the main buyer across the two periods, prices generally increased; and, (v) average milk price per litre increased by KES 2.90.

The relatively higher prices received by farmers in Murang'a County in 2019 production year were achieved through a negotiated contract price between the County government and farmers who deliver milk to the county owned Murang'a Cooperative Creameries. This has also influenced other milk processors to offer even higher prices to farmers within the county as reported by farmers in FGDs. Wilson (2011) found that dairy farmers in the United Kingdom were able to achieve better milk prices and higher milk quality through contracts, which enabled them to achieve higher net margins. Hence, this provides a clear opportunity for improving farmer returns in a specific context, which may be a more practical approach to deal with milk price fluctuations. In addition, such contract arrangements can be enhanced through private-public partnerships.

Prices were relatively higher in the informal markets, ranging between KES 30 and 60 per litre, which highlights their importance in linking producers to markets and improving profitability of dairy production. However, this was observed mainly in Machakos, Bungoma, Narok, Kisii and Kakamega, which are generally milk deficit areas. While the informal market may raise concerns about quality of milk handled, there is need to explore innovative ways of co-opting this segment of the market to bring it into the formal sub-sector. The options of doing this include setting standards for the segment, registering the actors in the segment and enhancing surveillance and enforcement of the standards. This is in line with the proposal of establishing a milk dealer certification system as identified in the National Dairy Development Policy, Sessional Paper No. 5 of 2013. Other proposals in the Sessional Paper include: development and adoption of low-cost technologies suited to informal traders; investment in training programmes on safe milk handling; and, market linkages with dairy processors.

Table 13: Milk prices between 2014 and 2019 by main buyer

	2014		2019		
County	**Price**	**Main buyer**	**Price**	**Main buyer**	**Change in price (KES)**
Machakos	34.7	Dairy Coop	60.0	Hotels	25.30
Muranga	28.7	Dairy Coop	33.7	Dairy Coop	4.97
Nyeri	28.9	Dairy Coop	30.0	Dairy Coop	1.10
Nakuru –Bahati (SM)	30.0	Traders	30.7	Traders	0.74
Embu	32.4	Traders	31.7	Processor	-0.73
Kiambu	36.8	Dairy Coop	35.0	Dairy Coop	-1.80
Meru	35.0	Traders	30.0	Dairy Coop	-5.00
Bomet	30.5	Processor	42.5	Traders	12.00
Bungoma	49.9	Consumers	60.0	Consumers	10.10
Nyandarua	27.5	Dairy Coop	29.0	Dairy Coop	1.50
Kisii	50.0	Consumers	50.0	Consumers	0.00
Trans Nzoia (SS)	30.7	Traders	30.0	Dairy Coop	-0.70
Kakamega	60.0	Consumers	50.0	Consumers	-10.00
Baringo	27.9	Dairy Coop	32.7	Dairy Coop	4.80
Uasin Gishu (MS)	28.5	Dairy Coop	30.1	Dairy Coop	1.60
Nandi	30.3	Dairy Coop	29.5	Traders	-0.80
Elgeyo Marakwet	29.4	Dairy Coop	27.7	Dairy Coop	-1.70
Trans Nzoia (MS)			32.7	Dairy Coop	--
Narok	30.6	Processor	39.7	Traders	9.10
Uasin Gishu (LS)			29.8	Dairy Coop	--
Nakuru (MS)			29.8	Dairy Coop	--
Average price	**34.5**		**37.4**		**2.9**

Note: The average price is based on comparable production systems and areas. Trans Nzoia (MS), Uasin Gishu (LS) and Nakuru (MS) in 2019 are excluded from the overall average for 2019.

4.0 Service delivery in the dairy sector

The Constitution of Kenya, 2010, transferred most of the agricultural functions to County governments. The aim was to bring services closer to the farmers, and access to these services has an impact on the profitability of the dairy enterprise. Literature shows that milk production in Kenya has remained low due to factors such as poor animal husbandry, low quality feeds, inadequate feeding, declining genetic base, animal pests and diseases, climate change and diminishing land sizes in high potential areas, among others. Besides, raw milk marketing also faces infrastructure bottlenecks caused by poor road networks and lack of cooling and storage facilities. Most of these challenges could be addressed through supportive service delivery that is adequate in terms of coverage, responsiveness and efficiency. This will involve an array of public and private sector actors such as national and county governments, suppliers of feeds and animal care services as well as milk aggregators, processors and retailers. Service providers support both informal and formal segments of the milk market, albeit to varying extents. In this section, we discuss the level of service delivery and challenges therein, with a focus on the production node of the dairy value chain.

4.1 Livestock extension services

Access to agricultural information influences the farming practices adopted by farmers. Providers of such extension information must ensure their adequacy, relevance and timeliness. Dairy farmers need frequent and up to date access to information on nutrition, breeding, health, environment and markets, among others, to enable them to cope with the changing production, marketing and policy environment. Inefficient access and dissemination of information can negatively affect the production level of dairy products. We established the most common sources of extension information for dairy farmers.

Across the counties, most farmers reported that the main providers of extension services were county livestock production officers, private veterinary officers and agro-dealers. Others include cooperative extension officers (in Baringo), Kenya Agricultural and Livestock Research Organization (KALRO), non-governmental organization such as Heifer International, Farm Input Promotions Africa (FIPs-Africa) Ltd, GIZ-Dairy component section, VI Agroforestry and World Vision. In most counties, farmers reported that they also received extension services through projects such as the Agricultural Sector Development Support Program (ASDSP), the Kenya Climate Smart Agriculture Project (KCSAP) and the National Accelerated Rural Inclusive Growth Project (NARIGP). There was a unique extension provision model in Kakamega County, where the county government contracted private service providers who work with dairy farmers in specific wards.

Farmers reported that they had received training on general animal husbandry practices, feeding, feed formulation, prevention and control of diseases and pests, milk handling, fodder production as well as feed management and preservation techniques. Majority of farmers in different counties were satisfied with the services offered by the extension service providers.

However, in Bomet, Narok and Trans Nzoia counties, farmers were not satisfied with the government services because the extension staff are few and could not meet the demand. In Trans Nzoia, there were no livestock officers in some wards because the officers who have retired have not been replaced. In Uasin Gishu, the County Integrated Development Plan (CIDP) listed dairy production as a priority value-chain and this has boosted budget allocation towards dairy farming. Each Ward has at least two livestock officers who have been fully facilitated in terms of equipment and transport. Furthermore, the livestock department has a succession plan and has employed staff to replace officers who are retiring.

4.2 Health and breeding

Provision of quality artificial insemination (AI) service is critical to the growth of the dairy sector due to improved quality of animals. After devolution, most county governments came up with subsidized AI service programs to make the services more accessible and affordable to farmers, and hence improve the quality of dairy animals. Subsidized AI services were offered for KES 700 in most of the counties where KES 200 was facilitation for the inseminator. On the contrary, private providers were charging KES 1,000-1,500 for the same quality of service.

Different counties employed different models to deliver these AI services. For instance, in Kakamega and Nyandarua, the county governments contracted private practitioners to provide the services. In the case of Nyandarua, the government procures semen, which is given to contracted private inseminators assigned to specific catchment areas. Farmers are expected to take their animals to designated points for insemination. However, farmers noted that sometimes the inseminators would indicate that the subsidized semen was out of stock in order to charge/sell for them at a higher price. Besides, they did not like the idea of taking animals to a central point for insemination.

In Murang'a County, several efforts have been put in place to improve the quality of the dairy animal breeds. These include hiring and training of young people as inseminators, procuring semen and building crushes at various insemination points. However, farmers have identified three challenges in this model. First, the terrain in the county is not ideal for moving animals from their units to the serving points. Second, the inseminators were not always available at the insemination points. Finally, most of the trained AI inseminators were ladies and the majority of farmers, who are women didn't embrace the inseminators, since this has traditionally been a male-dominated profession.

Trans Nzoia, Machakos and Nakuru counties have no AI subsidy programs and farmers rely on private practitioners, who charge between KES 1,000 and 3,000 per service. Due to the high costs, farmers in Machakos use bull service, which is relatively cheaper but compromises milk production. In Narok, breeding is mainly through bull service and use of AI services is minimal since the main providers of the service come from the neighboring Kisii County. The county government intervened by providing AI kits alone but they are not in use yet. In Nyeri and Baringo, about 70% of the farmers access AI services from the dairy cooperatives societies.

Despite the provision of subsidized AI by county governments, most farmers opted for private practitioners. This was because county veterinary officers were few and could not cover wide

areas where services are needed, and they were often underfunded in terms of mobility and facilitation.

Disease and pest control was a common practice among the dairy farmers. Majority of them reported routine deworming, which is done every three months. Tick control is also a common practice but frequency of spraying or dipping was high among open and semi-zero grazers. The most common diseases across all counties were foot and mouth disease, lumpy skin disease and mastitis.

4.3 Feeds and feeding regimes

Inadequate nutrition is a major cause of low milk yields and health issues in dairy animals. Farmers usually use commercial feeds to supplement feeds from their farms in order to enhance production. The feeds need to meet animal requirements for energy, protein, minerals, vitamins and water. In all the study counties, most of the farmers could not rate the quality of manufactured dairy feeds they purchase from different outlets. However, they noted that they would consider a feed to be of good quality if its use resulted in increased milk production.

The county governments of Kiambu and Uasin Gishu as well as dairy cooperatives did quality checks on commercial dairy meal by conducting proximate analysis to confirm the information provided in the labels on the packages. In Ainabkoi, Uasin Gishu, analysis showed that crude protein (CP) level was at 8%, half of the recommended 16%. Unga feeds (Fugo) was rated the best, but it is expensive for most of the dairy farmers. Only a small percentage of farmers in Uasin Gishu were relying on commercial feeds due to high cost and influx of low-quality feeds. To improve the quality of commercial feeds, farmers recommended vetting of the feed suppliers and manufacturers and setting up laboratories for testing of feeds within the counties. The Kenya Bureau of Standards is responsible for conducting quality checks and inspection but it has limited human resource capacity to undertake this.

In all counties visited, farmers have been trained on feed formulation by livestock production officers, cooperative extension officers and other organizations such as International Fund for Agricultural Development (IFAD), Smallholder Dairy Commercialization Project (SDCP) and GIZ. They were trained through field days, demonstrations and agricultural shows. However, most of the farmers in the semi-zero grazing system are not doing feed formulation, citing low milk prices, unavailability and high cost of raw materials, and the labour-intensive processes.

In Ainabkoi, Uasin Gishu County, the cooperative formulates feeds on behalf of farmers. Several farmers had begun to purchase the locally formulated feeds from the cooperative through the check-off system. For Bahati in Nakuru County, farmers purchase formulated feeds from a local agro-dealer.

Feed preservation was a common practice among farmers due to intensified training or adequate technical skills in this practice. The most commonly preserved feeds are crops residues and hay. Very few farmers have adopted silage technology except in Nyeri and Nakuru where it is becoming popular.

Feeding

Under the zero grazing system, most farmers normally use fresh pasture instead of dry matter, mainly consisting of napier grass, Boma Rhodes, hay and maize stover. During the dry months, farmers mainly rely on maize stover that is chopped and stored in bags. Majority of farmers have planted napier grass but it is often not enough and so they rely on purchases of hay, maize stalks and napier grass, which they store for use during the dry months. The cows were provided with water ad libitum.

In the semi-zero grazing system, grazing in paddocks is the main type of feeding. The natural pasture was supplemented with napier grass and dry maize stover and watering was done once or twice a day depending on the availability of piped water in the farms. However, in Bomet and Elgeyo Marakwet counties, watering was done once at the river. In Baringo County, most farmers were practising semi-zero grazing but a few were practising pure zero-grazing. Under this system, majority of the farmers were dissatisfied with the milk prices offered by the processors, which made it difficult for them to purchase commercial feeds, mineral salts or undertake feed formulation. For open grazing, the primary feed is natural pasture and grazing is done mainly in open fields or along the road. In this system, the animals are taken to rivers/streams for watering once a day.

In most counties, feed concentrates are mainly fed to lactating cows. The amount fed to the animals is often a function of quantity of forage available, milk production level of the cow and availability of either forages or the concentrates. A general rule on feeding concentrate suggests 1kg of concentrate for 2–3 litres of milk. Contrary to these recommendations, concentrates were fed to lactating cows only during milking and the quantities ranged between 0.5 and 2 kg, suggesting that the low productivity could be attributed to poor feeding.

To improve feed supply and quality, the government is conceptualizing large scale production, conservation and distribution of affordable pastures and forages to dairy farmers. This can lead to a reduction in costs of production and hence improve profitability.

4.4 Labour in dairy production

In most of the counties, family members provided most of the labour except in Kiambu and Machakos, where they relied entirely on hired labour. A large proportion of the labour time is spent on feeding, particularly harvesting and chopping of napier grass. However, majority of the farmers in Murang'a, Nyeri, Kiambu and Nyandarua use chaff cutters as a labor-saving technology.

Other technologies adopted by farmers include paddocking, hay balers and feed preservation in form of hay and silage. Farmers who use silage in Nyeri County noted that they were able to reduce labour requirement in dairy production by more than 50%. For instance, one farmer noted that he does not grow maize to make silage but buys from neighbors and makes enough silage to feed his animals for up to six months. He indicated that one dairy animal requires five tons of silage per year and half an acre of maize produces about 6 tons of silage. With enough feedstock, he only spends about 20 minutes per day to weigh the feed and fill the feeding trough for his six dairy cows.

4.5 Milk marketing and pricing

Small-scale dairy farmers produce about 80% of all milk in Kenya. However, the pricing of the commodity is determined by the marketers/processors. Farmers are price takers and often receive prices that are low relative to production costs.

Milk prices vary by season and buyer. In 2019, the only appreciable difference in price between high and low production months was observed for the open grazing system (KES 36.5 versus 43). The prices offered by the different buyers ranged from KES 21-60 per litre. The main buyers of milk in most counties were the dairy cooperative societies, followed by traders. Prices offered by cooperative societies ranged from a high of KES 36.50 in Taita Taveta to a low of KES 21.30 in Trans Nzoia. In Nyandarua, the main buyers were processors (Nyandarua Dairies and Brookside). Prices were relatively higher in the informal markets, ranging between KES 30 and 60 per litre. This supports the earlier observation that the informal market is important in improving profitability of dairy production.

4.6 Challenges in dairy production

Discussions with farmers during the FGDs and key informant interviews with experts (livestock production officers) revealed the following challenges in dairy farming:

i. Low quality of feed concentrates

Farmers have no way of ascertaining the quality of purchased feeds except through observed yield response and most feeds did not result in expected gains in milk productivity, suggesting that they could be of low quality. Furthermore, the quantities fed to the dairy animals are very low compared to what is recommended.

ii. Poor feeding regime

It was observed that majority of the farmers feed cows on fresh pasture instead of dry matter. Besides, the forage is often in adequate in quantity and quality, which may explain the low levels of milk yields across the production systems.

iii. Low milk prices

The view is that prices are too low to cover the cost of production. This was a more serious concern in counties where the main buyer was cooperatives. It appears that some cooperatives are not taking advantage of economies of scale to bargain for better milk prices or they are charging farmers more for management fees, hence reducing farmer returns.

iv. Inadequate extension services

In counties like Trans Nzoia, this was due to lack of succession plans to replace livestock extension officers who are exiting service upon attaining retirement age. This has led to poor livestock husbandry and farming practices, which may have affected productivity.

v. Liquidity constraints

This is particularly acute where payment for milk deliveries is done monthly but the buyer does not provide inputs on credit.

vi. Poor road infrastructure

In areas like Nyandarua county, bad roads negatively affect collection and distribution of milk particularly during the wet season.

vii. High incidence of diseases

This is mainly due to changing weather patterns. High prevalence of mastitis was reported to affect both quantity and quality of milk produced.

viii. Increasing pressure on land

This has led to a reduction in herd size, low amounts of fodder produced, increase in the cost of purchased fodder and in some counties, a change in the production system (e.g. Baringo from open to semi-zero grazing, Nakuru and Machakos from semi-zero to pure zero grazing and Kiambu from medium scale to small scale zero grazing, between 2014/15 and 2019).

4.7 Limitations of the study

i) The main limitation pointed out by stakeholders is that the typical farm approach is not statistically representative. Although statistical representativeness is not an aim of the approach per se, there are two main reasons why this cannot be achieved under this approach. First, the data needed to comprehensively describe the production system is hardly documented by smallholder farms and so the approach relies on expert knowledge. Second, there isn't a national network of typical farms to represent all major differences in agro-ecological and structural conditions across the dairy production areas. This implies that the data collected under this approach will usually only represent a certain fraction of the farming population in a given country, i.e. the group that practises the most dominant/common production system in a particular region or country (Chibanda et. al., 2020). As a result, this study didn't capture any data from commercial dairy farms, which was also raised as a limitation by the stakeholders.

ii) The period between the first study and the current study was very long (i.e. five years: 2014 and 2019) yet the agri-benchmark approach requires that data is collected from the identified typical farms every production year to track changes in each production system, which arise due to changes and dynamics in factors such as weather and climate as well as local and global supply, demand and markets, among other factors.

iii) Comparison of indicators such as productivity, costs, returns, herd sizes and prices between 2014 and 2019 was limited due to adjustments in the methodology and key study areas between the two periods. This means that it was not informative to do direct comparisons across the two periods especially at disaggregated levels. Even in cases where the study areas and production systems were maintained, the panel of farmers and experts were not necessarily the same, which could introduce some bias in the data collected. However, the dedicated data validation procedures and regular data collection/updates limit the risks of data bias.

5. Summary, conclusions and recommendations

5.1 Summary and conclusions

The study assessed the costs and returns of typical dairy farmers from 20 counties, which was a follow up of a similar study conducted in 2014/15. Study findings are presented mainly by the production system. However, since costs, gross margins and economic returns are substantially different within a production system, we also highlighted performance at county level and scale of production.

The study findings are presented mainly by production system but variations across production systems, counties and scale of production are also highlighted. Results show that the gross revenue from milk was highest in the semi-zero production system and lowest among open grazers. The variation in milk revenue can be explained by differences in the average price (i.e. the average of prices offered by different market outlets used by the farmers). Also, the main buyer for majority of zero and open grazers was dairy cooperatives, whereas for semi-zero grazers (especially small-scale ones), it was direct consumers and traders, who offered relatively higher prices.

As expected, costs of production and returns vary by production system, scale and county. Results show that cost of milk production increases with intensity of production and the findings are consistent whether one considers TVDC or TC. Considering TVDC only, the average cost of milk production was KES 13.02 per litre and ranged from KES 10.57 to 17.81 per litre. The open grazing system had the lowest costs (KES 10.57), which is mainly due to the relatively lower costs for feed concentrates. Zero grazing system had the highest cost (KES 17.81), which is about 68% higher than in the open grazing system. The average gross margin (GM) per litre of milk produced was KES 21.69. Across production systems, GM was lowest for zero grazers (KES 18.06) and highest for producers in the semi-zero grazing system (KES 26.57). The positive GM indicates that the dairy enterprise is profitable across the three systems since the producers were able to cover all the variable costs. However, the GM for semi-zero system is about 1.5 times that of zero grazers, a result driven by relatively higher gross milk revenue and lower TVCD in the semi-zero production system.

When fixed and opportunity costs were factored in, the average TC of producing a litre of milk increased to KES 22.51, which translates a 73% increase. This shows the importance of own factors of production such as family labour and fodder/pasture from own farm in dairy production, which are often overlooked. Across the production systems, the TC was KES 27.30

among zero grazers, KES 23.00 in the semi-zero system and KES17.24 for open grazers. On average, a dairy farmer earned milk profit of KES 12.20 per litre. Semi-zero grazers returned the highest profit (KES 14.27), while zero-grazers had the lowest profit (KES 8.57). This implies that when we take into account fixed costs and value for non-purchased inputs such as family labour, and own-produced fodder, dairy farmers in all the production systems are able to cover all the total costs and hence they make a profit. With the addition of other revenues from the dairy enterprise (such as sale of livestock and manure), the average whole enterprise profit was KES 16.20 per litre of milk.

The proportion of gross margin to TVDC shows the contribution to the GM for every shilling invested in variable expenses. Overall, a shilling invested in variable costs to produce a litre of milk returned KES 1.81. The highest return was recorded by semi-zero grazers (KES 2.49) and the lowest by zero grazers at KES 1.01. This could be an indication that incremental efficiency gains expected from a more intensive zero grazing are not being realized.

Across the production systems, feed concentrates, hired labour, purchased fodder and health and breeding accounted for the largest cost shares. However, the cost structure for zero grazing was different from that of the other systems. Under zero grazing, the largest component of TVDC was feed concentrates accounting for 40%, followed by purchased fodder (22%), hired labour (22%) and health & breeding (6%). On the other hand, the largest contributors to cost in the semi-zero and open grazing systems are hired labour (46% vs. 50%), feed concentrates (21% vs. 28%) and health and breeding costs (18% vs. 16%). An observation that feed concentrates were a significant contributor to TVDC in the open grazing system may be an indication that as land sizes decline, dairying is likely to shift towards supplementary feeding to increase milk yields. However, as the results indicate, this will come at a cost in terms of decreased efficiency.

The largest components of TC varied across the production systems. For the zero grazers, the largest contributors to TC were feed concentrates (26%) followed by family labour (18%), while for semi-zero grazing system, these were family labour (27%) and own fodder/pasture (25%). In the case of open grazers, the largest components of total costs were hired labour (35%) and own fodder/pasture (33%). Overall, labour accounted for 33%, 48% and 41% of total costs for zero, semi-zero and open grazers. Given the small herd sizes, perhaps too much labour is being used suggesting that there is inefficient allocation of labour across all production systems, which translates to an increase in unit cost of labour per litre of milk

produced. This may be because farmers don't usually value family labour and other non-purchased inputs, and hence there is a tendency to use too much labour on dairy and other enterprises. It is common to have family members that are not gainfully employed off the farm and so their time is mainly spent on-farm across different enterprises. Farmers can make better decisions about the use of labour and non-purchased inputs once they begin to value them more accurately.

Simulations confirm the importance of various cost components to costs and returns. As expected, the highest reduction in TVDC for zero grazers would come from a reduction in the cost of feed concentrates (4%). For both semi-zero and open grazers, the largest decline in TVDC would result from a reduction in the cost of hired labour (4.6-5.1%), followed by feed concentrates (2.1-2.8%).

In the case of GM, the largest increase would result from a decrease in cost of feed concentrates for zero grazers (3.9%), and a reduction in cost of hired labour for semi-zero grazers (1.8%) and open grazers (2.6%). Across all the production systems, the effect of an increase in the price of milk on GM is much higher than the effect of a decrease in any of the cost components. A 10% increase in the price of milk would translate to a 19.9% increase in GM for zero grazers, 14% for semi-zero grazers and 15.1% for open grazers. This underscores the importance of good/remunerative prices in improving returns for dairy producers.

Comparison of findings between 2014 and 2019 shows that the herd size is small and has been declining, while the number of lactating cows remained the same across the two years. The production of milk per cow per day increased by 19% but it remains relatively low. This has a negative effect on farmer returns and may be an indication that the country is likely to experience milk deficit in the face of a growing demand and declining herd sizes.

Overall, costs of production declined by about 20%, while the gross revenue from milk, which represents the average of prices offered by different market outlets used by the farmers, increased by 3%. In addition, feed concentrates and hired labour remained the key components of variable costs of production. Hence, to enhance profitability of dairy farming, interventions and investments that improve productivity, lower costs of feeding and improve efficiency of labour are important.

A number of observations were made with regard to the average price of milk between 2014 and 2019 by main buyer: (i) generally, a significant change in price was observed where there

was a change in main buyer; (ii) prices offered by hotels, direct consumers and traders were relatively higher than those by cooperatives and processors; (iii) the main buyer of milk in most of the counties was cooperative societies; and, (iv) where dairy cooperatives remained the main buyer across the two periods, prices generally increased.

5.2 Recommendations

As land sizes decline, more farmers are likely to shift towards more intensive dairy production systems. However, as the study results show, this shift will come at higher costs and lower returns. To improve returns to production across all systems, it is important to focus on some key aspects:

1. Improving milk productivity

   Although the average milk yield per cow per day has increased over time, it has remained fairly low at 7.6 litres. Productivity can be enhanced through various interventions:

   a) Adoption of improved breeds that are suited to the local production environment. This can be done through collaborative breed enhancement programmes where privately-owned cattle breeding farms supply dairy stock to local farmers and train them on farm level breeding and stock management. Also, PPPs can create a market for dairy stock by specialising on breeding dairy animals for local needs and environment.

   b) Better access to quality and affordable feed concentrates

   c) Appropriate feeding practices

      Farmers need to improving feeding regimes since most of them feed the cows on fresh pasture instead of dry matter, and the amount of concentrates is usually inadequate. The cost of purchased feeds alone constitutes about 53% of the cost of milk production and up to 70% when the opportunity cost of own fodder is included. Hence, proper feeding practices can help increase productivity and bring down the cost of production.

   d) Production of more fodder

      Limited land for dairy production constrains the ability of many farmers to grow quality fodder. The government can come up with innovative ways to support pasture or fodder development including leasing public land to commercial producers of fodder.

e) Also a small herd size may limit the profitability of the dairy enterprise, and hence the need to have a viable unit of dairy farm. This could be done through adoption of the cooperative dairy farms (CODAF) model/approach. The advantage of this approach is that pooled dairy farm management can increase economies of scale with a larger dairy herd and bring in good management for best dairy practices.

f) Management of the calving interval and its optimal length

These are important aspects of the economic performance of dairy farms and can be addressed through farmer education. Information and training on proper planning and animal management such as adequate heat detection and proper nutrition may require little capital input but it will result in improved milk production and farmer return.

2. Addressing the high cost of inputs

The major inputs accounting for high cost of milk production are feed concentrates, hired labour, purchased fodder, and health and breeding. Interventions to address the challenge of feeds and fodder include:

a) Improvement in the quality of processed feed and better monitoring of its quality
b) Better utilization of locally available feed resources by promoting and training farmers on on-farm feed formulation and fodder production
c) Promotion of local production of raw materials for animal feed manufacturing
d) Commercialization of fodder production through public-private partnerships

The proposals by the Government to promote commercial production, conservation and distribution of fodder and to import feed raw materials in bulk can lead to lower cost of feeding.

e) Lowering tax regimes or exempting from VAT all raw materials used in the manufacture of feeds and the final products
f) Adoption of labour-saving technologies

Labour was a large component of total costs across all production systems and use of labor-saving technologies such as the chaff cutter as well as use of preserved feeds like silage can reduce its cost.

g) Subsidies for feeds and animal health products

3. Stabilizing milk prices

Results show the importance of good/remunerative prices in improving returns for dairy producers. Prices were higher where the main buyers were hotels, traders or consumers.

Hence there may be need to further assess why farmers are not benefitting from economies of scale through cooperatives. It is often thought that the management fee charged by cooperatives is relatively high and could be reduced to increase farmer returns. In addition, using the example from the Murang'a County government, a negotiated contract price is one way of assuring farmers of stable prices. It is also a more practical and context-specific approach to address the problem of fluctuation in milk prices. Contracting can also create opportunities for pricing based on quality and quantity. Such contracts can incentivise the farmers to invest more in the management of the dairy herd, improve milk quality and productivity per animal. Another option to stabilize milk supply and prices is to upscale the strategic milk reserves by Government through increasing resources set aside for the reserves and involving more processors in this initiative. Also, given the large spread between farm gate and retail milk prices, farmers could benefit more if processing costs could be lowered and ways to do this need to be explored.

4. Improving and supporting informal milk markets

   Informal markets play a role in linking producers to markets and improving profitability of dairy production and are key in enhancing livelihoods and food and nutrition security of many households. These markets are large and growing, and it widely acknowledged that they rival the formal sector in terms of the volumes of milk that they handle. Hence there is need to explore innovative ways of supporting the informal segment of the market to ensure that it delivers safe milk products. This can be done through setting standards for the segment, registering the actors in the segment and enhancing surveillance and enforcement of the standards. This will create an enabling environment for increased private sector entrepreneurship in milk marketing and generate employment directly and through linkages with other actors in the dairy value chain. This is in line with the proposal of establishing of a milk dealer certification system as identified in the National Dairy Development Policy Sessional Paper No. 5 of 2013. Other proposals in the Sessional Paper include: development and adoption of low-cost technologies suited to informal traders; investment in training programmes on safe milk handling; and, market linkages with dairy processors.

5. Incentivizing and enhancing support to farmers

   From the FGDs, farmers indicated that they would be more incentivized to continue with dairy farming if returns would improve, which could be done through various ways, including: imposing restrictions on the importation of cheap milk and milk products from neighbouring countries; training farmers in value addition such as packaging and

preparation of mala and yoghurt in order to enhance returns from these products; pricing of milk based on quality and not quantity, which would act as an incentive to improve on the quality of milk; cooperative societies to form one large union in each county and start processing milk to give farmers an edge in market price negotiations and so improve farm gate prices; and, developing a pricing policy to standardize the price of milk across the country. Although farmers suggested that this should be done by the KDB and the Ministry of Agriculture, local and context-specific solutions to marketing and pricing, such as that adopted by Murang'a County may be what is needed for an industry that is liberalized and where dynamics vary across geographies and production systems.

It was also evident from the FGDs that County governments need to employ more livestock extension officers to replace those exiting service in order to improve access to and effectiveness of extension services. Most counties do not have succession plans while others had no extension staff at the ward level. One option of dealing with staff shortage is to provide extension and training of dairy farmers through a public-private partnership approach. Furthermore, there is need to embrace information and communication technologies to deliver extension information to more farmers since this may be cost-effective.

5.3 Proposals for future work

Stakeholders suggested ways in which future studies can be designed and implemented in order to address the limitations of the current study. These include:

a) Conducting such studies more frequently since the cost of milk production varies greatly with climatic cycles and other variables over time
b) Improving the study methodology by:
    i) Selecting a cohort of farmers that can be interviewed regularly to allow for continuous collection and analysis of data on cost of milk production
    ii) Regularly maintaining typical farms through review and revision by regional expert groups to reflect technological advances and other changes in order to have credible time series data
    iii) Including commercial dairy farmers in the study since they employ best practices in milk production and hence can be used as benchmark for improvements in dairy production and pricing of milk in the country
    iv) Broadening the sample of farmers to include peri-urban dairy producers

v) Creating a national network of typical farms to represent all major differences in agro-ecological and structural conditions across the dairy production areas in the country

vi) Using other data collection methods such as household surveys of dairy farmers in order to deal with the challenge of lack of statistical representativeness. However, such methods will require more financial resources and time

vii) Bringing together experts representing different segments of the dairy value chain (public and private) to design and provide funding for similar studies in order to improve on depth and scope of the work

c) Undertaking peer review of draft report before the stakeholder dissemination/ validation workshop

Appendix Tables and Figures

Table A1: Costs and returns in KES per litre of milk produced for zero grazers

County	Machakos	Meru	Embu	Nakuru	Muranga	Nyeri	Kiambu	Average
Revenue from milk (sold + consumed)	60.00	30.00	32.17	31.16	32.79	30.00	35.00	35.87
Purchased fodder/pasture	2.27	0.00	3.85	5.15	7.45	6.25	2.14	3.87
Feed concentrates	3.98	8.40	2.21	6.18	3.09	11.67	13.82	7.05
Mineral salts	0.45	0.64	0.77	0.31	0.38	0.81	0.52	0.56
Water (purchased)	1.14	0.00	0.38	0.69	1.22	0.44	0.44	0.62
Health and breeding costs	2.11	0.84	0.70	0.83	1.28	0.85	1.38	1.14
Milking jelly	0.45	0.29	0.19	0.17	0.35	0.10	0.27	0.26
Hired labour	10.23	0.00	8.46	0.00	0.00	2.95	6.19	3.98
Repairs on fixed assets	0.19	0.12	0.03	0.14	0.29	0.12	0.18	0.15
Other direct costs (e.g. electricity, fuel)	0.23	0.38	0.00	0.00	0.00	0.39	0.31	0.19
Total variable and directs costs (TVDC)	21.05	10.67	16.60	13.48	14.04	23.60	25.25	17.81
Gross margin (Revenue - TVDC)	38.95	19.33	15.57	17.69	18.74	6.40	9.75	18.06
Depreciation (fixed assets)	0.64	0.54	0.12	0.14	0.56	0.67	0.10	0.40
Own fodder/pasture	4.72	8.04	1.35	5.44	5.30	1.72	2.58	4.16
Family labour	0.00	7.14	1.15	6.87	15.65	3.69	0.00	4.93
Total costs (TC = TVDC + depreciation. + opp. cost)	26.40	26.39	19.22	25.92	35.56	29.68	27.93	27.30
Milk profits (Revenue - TC)	33.60	3.61	12.95	5.24	-2.77	0.32	7.07	8.57
Other revenue (sale of livestock, manure, bull services)	1.33	1.19	1.92	0.43	7.20	0.37	0.59	1.86
Whole enterprise profit	34.93	4.80	14.88	5.67	4.43	0.69	7.66	10.44
Gross margin/TVDC ratio	1.85	1.81	0.94	1.31	1.33	0.27	0.39	1.13
Gross margin rate (%)	64.92	64.42	48.41	56.76	57.17	21.34	27.85	48.70

Table A1.1: Costs and returns in KES per litre of milk produced for zero grazers (including Taita Taveta)

County	Taita Taveta	Machakos	Meru	Embu	Nakuru	Muranga	Nyeri	Kiambu	Average
Revenue from milk (sold + consumed)	35.46	60	30	32.17	31.16	32.79	30	35	35.82
Purchased fodder/pasture	0.00	2.27	0	3.85	5.15	7.45	6.25	2.14	3.39
Feed concentrates	3.95	3.98	8.4	2.21	6.18	3.09	11.67	13.82	6.66
Mineral salts	1.94	0.45	0.64	0.77	0.31	0.38	0.81	0.52	0.73
Water (purchased)	2.12	1.14	0	0.38	0.69	1.22	0.44	0.44	0.80
Health and breeding costs	4.45	2.11	0.84	0.7	0.83	1.28	0.85	1.38	1.56
Milking jelly	0.53	0.45	0.29	0.19	0.17	0.35	0.1	0.27	0.29
Hired labour	0.00	10.23	0	8.46	0	0	2.95	6.19	3.48
Repairs on fixed assets	0.44	0.19	0.12	0.03	0.14	0.29	0.12	0.18	0.19
Other direct costs (e.g. electricity, fuel)	0.00	0.23	0.38	0	0	0	0.39	0.31	0.16
Total variable and directs costs (TVDC)	13.44	21.05	10.67	16.59	13.47	14.06	23.58	25.25	17.26
Gross margin (Revenue - TVDC)	22.02	38.95	19.33	15.58	17.69	18.73	6.42	9.75	18.56
Depreciation (fixed assets)	1.50	0.64	0.54	0.12	0.14	0.56	0.67	0.1	0.53
Own fodder/pasture	11.92	4.72	8.04	1.35	5.44	5.3	1.72	2.58	5.13
Family labour	23.84	0	7.14	1.15	6.87	15.65	3.69	0	7.29
Total costs (TC = TVDC + depreciation. + opp. cost)	50.70	26.41	26.39	19.21	25.92	35.57	29.66	27.93	30.22
Milk profits (Revenue - TC)	-15.25	33.59	3.61	12.96	5.24	-2.78	0.34	7.07	5.60
Other revenue (sale of livestock, manure, bull services)	2.65	1.33	1.19	1.92	0.43	7.2	0.37	0.59	1.96
Whole enterprise profit	-12.60	34.92	4.80	14.88	5.67	4.42	0.71	7.66	7.56
Gross margin/TVDC ratio	1.64	1.85	1.81	0.94	1.31	1.33	0.27	0.39	1.19
Gross margin rate (%)	62.10	64.92	64.43	48.43	56.77	57.12	21.40	27.86	50.38

Table A2: Costs and returns in KES per litre of milk produced for semi-zero small-scale grazers

Item	Bomet	Kisii	Bungoma	Kakamega	Trans Nzoia	Nyandarua	Average
Gross revenue from milk (sold + consumed)	39.49	50.00	60.00	50.00	30.81	29.00	43.22
Purchased fodder/pasture	4.06	0.00	0.00	0.00	0.00	2.07	1.02
Feed concentrates	6.09	1.58	3.28	5.11	3.79	4.15	4.00
Mineral salts	1.16	1.98	1.13	0.27	0.42	0.49	0.91
Water (purchased)	0.00	0.00	0.00	0.00	0.00	0.49	0.08
Health and breeding costs	2.51	2.09	1.79	2.07	1.84	1.85	2.03
Milking jelly	0.10	0.15	0.13	0.23	0.17	0.17	0.16
Hired labour		5.93			6.98		6.46
Repairs on fixed assets	0.58	0.41	0.18	0.11	0.05	0.10	0.24
Other direct costs (e.g. electricity, fuel)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total variable and directs costs (TVDC)	14.50	12.14	6.51	7.79	13.25	9.32	10.59
Gross margin (Revenue - TVDC)	25.00	37.86	53.48	42.20	17.56	19.68	32.63
Depreciation (fixed assets)	0.85	0.62	0.32	0.33	0.05	0.18	0.39
Own fodder/pasture	5.56	9.01	9.45	6.06	5.76	1.08	6.15
Family labour	8.70	18.11	6.56	9.09	0.00	10.98	8.91
Total costs (TC = TVDC + depreciation + opp. cost)	29.61	39.88	22.84	23.27	19.06	21.56	26.04
Milk profits (Revenue - TC)	**9.88**	**10.12**	**37.16**	**26.73**	**11.75**	**7.44**	17.18
Other revenue (sale of livestock, manure, bull services)	2.42	6.17	1.82	3.22	0.87	6.71	3.54
Whole enterprise profit	**12.30**	**16.29**	**38.98**	**29.95**	**12.62**	**14.15**	20.72
Gross margin/TVDC ratio	1.72	3.12	8.22	5.42	1.33	2.11	3.65
Gross margin rate (%)	63.31	75.72	89.13	84.40	56.99	67.86	72.90

Table A3: Costs and returns in KES per litre of milk produced for semi-zero medium-scale grazers

Item	Nandi	Uasin Gishu	Elgeyo Marakwet	Trans Nzoia	Baringo	Average
Revenue from milk (sold + consumed)	28.69	30.19	27.26	32.43	32.05	30.12
Purchased fodder/pasture	0.0	0.0	0.0	0.0	0.0	0.00
Feed concentrates	0.61	0.0	0.0	0.0	0.0	0.12
Mineral salts	0.08	0.32	0.75	0.49	0.55	0.44
Water (purchased)	0.0	0.0	0.0	0.0	0	0.00
Health and breeding costs	1.24	2.36	2.34	1.38	1.76	1.82
Milking jelly	0.1	0.12	0.15	0.37	0.1	0.17
Hired labour	5.55	0	0	10.37	5.48	4.28
Repairs on fixed assets	0.04	0.13	0.09	0.08	0.04	0.08
Other direct costs (e.g. electricity, fuel)	0	0	0	0	0	0.00
Total variable and directs costs (TVDC)	7.62	2.94	3.33	12.7	7.92	6.90
Gross margin (Revenue - TVDC)	21.07	27.25	23.93	19.73	24.12	23.22
Depreciation (fixed assets)	0.2	0.44	0.07	0.2	0.14	0.21
Own fodder/pasture	2.83	3.71	3.94	9.47	6.59	5.31
Family labour	0.51	4.86	7.1	1.98	0.58	3.01
Total costs (TC = TVDC + depreciation. + opp. cost)	11.16	11.95	14.44	24.34	15.23	15.42
Milk profits (Revenue - TC)	**17.53**	**18.24**	**12.82**	**8.09**	**16.82**	14.70
Other revenue (sale of livestock, manure, bull services)	5.56	3.24	1.43	9.26	5.05	4.91
Whole enterprise profit	**23.09**	**21.48**	**14.25**	**17.34**	**21.87**	19.61
Gross margin/TVDC ratio	2.77	9.26	7.18	1.55	3.04	4.76
Gross margin rate (%)	73.45	90.26	87.78	60.85	75.28	77.52

Table A4: Costs and returns in KES per litre of milk produced for open grazers

Item	Narok (Large-scale)	Uasin Gishu (Large-scale)	Average (Large-scale)	Nakuru (Medium-scale
Revenue from milk (sold + consumed)	32.73	30.05	31.39	30.21
Purchased fodder/pasture	0.00	0.00	0.00	0.00
Feed concentrates	0.00	2.92	1.46	0.00
Mineral salts	0.29	0.19	0.24	0.14
Water (purchased)	0.17	0.00	0.09	0.00
Health and breeding costs	1.14	1.56	1.35	2.35
Milking jelly	0.09	0.20	0.15	0.37
Hired labour	5.12	4.09	4.60	6.80
Repairs on fixed assets	0.16	0.10	0.13	0.14
Other direct costs (e.g. electricity, fuel)	0.00	0.00	0.00	0.00
Total variable and directs costs (TVDC)	6.98	9.08	8.03	9.80
Gross margin (Revenue - TVDC)	25.75	20.97	23.36	20.41
Depreciation (fixed assets)	0.07	0.22	0.14	0.15
Own fodder/pasture	4.75	4.06	4.40	8.24
Family labour	0.70	0.78	0.74	1.03
Total costs (TC = TVDC + depreciation + opportunity cost)	12.50	14.13	13.32	19.23
Milk profits (Revenue - TC)	20.24	15.91	18.08	10.98
Other revenue (sale of livestock, manure, bull services)	6.01	4.47	5.24	7.46
Whole enterprise profit	26.24	20.38	23.31	18.43
Gross margin/TVDC ratio	3.69	2.31	3.00	2.08
Gross margin rate (%)	78.68	69.80	74.24	67.56

Table A5: Share of different cost components to TVDC, by county (%)

County	Purchased fodder	Feed conc.	Mineral salt	Water (purchased)	Health & breeding	Milking jelly	Hired labour	Repair	Other direct cost
Machakos	11	19	2	5	10	2	49	1	1
Meru	0	79	6	0	8	3	0	1	4
Embu	23	13	5	2	4	1	51	0	0
Nakuru	38	46	2	5	6	1	0	1	0
Muranga	53	22	3	9	9	2	0	2	0
Nyeri	26	49	3	2	4	0	13	1	2
Kiambu	8	55	2	2	5	1	25	1	1
Bomet	28	42	8	0	17	1	0	4	0
Kisii	0	13	16	0	17	1	49	3	0
Bungoma	0	50	17	0	28	2	0	3	0
Kakamega	0	66	3	0	27	3	0	1	0
Trans Nzoia	0	29	3	0	14	1	53	0	0
Nyandarua	22	45	5	5	20	2	0	1	0
Nandi	0	8	1	0	16	1	73	1	0
Uasin Gishu	0	0	11	0	80	4	0	5	0
E/ Marakwet	0	0	23	0	70	5	0	3	0
Trans Nzoia	0	0	4	0	11	3	82	1	0
Baringo	0	0	7	0	22	1	69	1	0
Narok	0	0	4	2	16	1	73	2	0
Uasin Gishu	0	32	2	0	17	2	45	1	0
Nakuru	0	0	1	0	24	4	69	1	0

Table A6: Share of different cost components to TC, by county (%)

County	Purchased fodder	Feed conc.	Mineral salt	Water (purchased)	Health & breeding	Milking jelly	Hired labour	Repair	Other direct cost
Machakos	9	15	2	4	8	2	39	1	1
Meru	0	32	2	0	3	1	0	0	1
Embu	20	12	4	2	4	1	44	0	0
Nakuru	20	24	1	3	3	1	0	1	0
Muranga	21	9	1	3	4	1	0	1	0
Nyeri	21	39	3	1	3	0	10	0	1
Kiambu	8	49	2	2	5	1	22	1	1
Bomet	14	21	4	0	8	0	0	2	0
Kisii	0	4	5	0	5	0	15	1	0
Bungoma	0	14	5	0	8	1	0	1	0
Kakamega	0	22	1	0	9	1	0	0	0
Trans Nzoia	0	20	2	0	10	1	37	0	0
Nyandarua	10	19	2	2	9	1	0	0	0
Nandi1	0	5	1	0	11	1	50	0	0
Uasin Gishu	0	0	3	0	20	1	0	1	0
E/Marakwet	0	0	5	0	16	1	0	1	0
Trans Nzoia	0	0	2	0	6	2	43	0	0
Baringo	0	0	4	0	12	1	36	0	0
Narok	0	0	2	1	9	1	41	1	0
Uasin Gishu	0	21	1	0	11	1	29	1	0
Nakuru	0	0	1	0	12	2	35	1	0

Table A7: Changes in TVDC and returns as a result of reduction in costs and milk price increase for zero grazers

Item	Machakos	Meru	Embu	Nakuru	Muranga	Nyeri	Kiambu	Average
				% reduction in TVDC as a result of 10% reduction in cost of:				
Feed concentrates	1.9	7.9	1.3	4.6	2.2	4.9	5.5	4.0
Purchased fodder/pasture	1.1	0.0	2.3	3.8	5.3	2.6	0.8	2.3
Health and breeding costs	1.0	0.8	0.4	0.6	0.9	0.4	0.5	0.7
Hired labour	4.9	0.0	5.1	0.0	0.0	1.3	2.5	2.0
					% increase in GM as a result of 10% change in:			
Feed concentrates	1.0	4.3	1.4	3.5	1.6	18.2	14.2	3.9
Purchased fodder/pasture	0.6	0.0	2.5	2.9	4.0	9.8	2.2	2.1
Health and breeding costs	0.5	0.4	0.4	0.5	0.7	1.3	1.4	0.6
Hired labour	2.6	0.0	5.4	0.0	0.0	4.6	6.4	2.2
Milk price (*increase*)	15.4	15.5	20.7	17.6	17.5	46.9	35.9	19.9
					% increase in milk profits as a result of 10% change in:			
Feed concentrates	1.2	23.3	1.7	11.8	--	>100	20	58.5
Purchased fodder	0.7	0.0	3.0	9.8	--	>100	3	26.3
Health & breeding	0.6	2.3	0.5	1.6	--	26	2	4.1
Hired labour	3.0	0.0	6.5	0.0	--	92	9	15.7
Milk price (*increase*)	45.0	22.3	18.8	20.8	22.0	9.4	13.2	21.6
Initial profit/loss/litre	33.6	3.6	5.2	13.0	-2.8	0.3	7.1	8.6

Table A8: Changes in TVDC and returns as a result of reduction in costs and milk price increase for semi-zero grazers, small-scale

Item	Bomet	Kisii	Bungoma	Kakamega	Trans Nzoia	Nyandarua	Overall
				% reduction in TVDC as a result of 10% reduction in cost of:			
Feed concentrates	4.2	1.3	5.0	6.6	2.9	4.5	3.8
Purchased fodder/pasture	2.8	0.0	0.0	0.0	0.0	2.2	1.0
Health and breeding costs	1.7	1.7	2.7	2.7	1.4	2.0	1.9
Hired labour	0.0	4.9	0.0	0.0	5.3	0.0	2.0
					% increase in GM as a result of 10% change in:		
Feed concentrates	2.4	0.4	0.6	1.2	2.2	2.1	1.2
Purchased fodder/pasture	1.6	0.0	0.0	0.0	0.0	1.1	0.3
Health and breeding costs	1.0	0.6	0.3	0.5	1.0	0.9	0.6
Hired labour	0.0	1.6	0.0	0.0	4.0	0.0	0.7
Milk price (*increase*)	15.8	13.2	11.2	11.9	17.5	14.7	13.3
				% increase in milk profits as a result of 10% change in:			
Feed concentrates	6.2	1.6	0.9	1.9	3.2	5.6	2.3
Purchased fodder	4.1	0.0	0.0	0.0	0.0	2.8	0.6
Health & breeding	2.5	2.1	0.5	0.8	1.6	2.5	1.2
Hired labour	6.2	1.6	0.9	1.9	3.2	5.6	2.3
Milk price (*increase*)	40.0	49.4	16.1	18.7	26.2	39.0	25.2
Initial profit/loss/litre	9.9	10.1	37.2	26.7	11.8	7.4	17.2

Table A9: Changes in TVDC and returns as a result of reduction in costs and milk price increase for semi-zero grazers, medium-scale

Item	Nandi	Uasin Gishu	Elgeyo Marakwet	Trans Nzoia	Baringo	Overall
			% reduction in TVDC as a result of 10% reduction in cost of:			
Feed concentrates	0.8	0.0	0.0	0.0	0.0	0.0
Purchased fodder/pasture	0.0	0.0	0.0	0.0	0.0	0.0
Health and breeding costs	1.6	8.1	7.0	1.1	2.2	2.8
Hired labour	7.3	0.0	0.0	8.2	6.9	5.7
			% increase in GM as a result of 10% change in:			
Feed concentrates	0.3	0.0	0.0	0.0	0.0	0.1
Purchased fodder/pasture	0.0	0.0	0.0	0.0	0.0	0.0
Health and breeding costs	0.6	0.9	1.0	0.7	0.7	0.8
Hired labour	2.6	0.0	0.0	5.3	2.3	1.8
Milk price (increase)	13.6	11.1	11.4	16.4	13.3	13.0
			% increase in Milk Profits as a result of 10% change in:			
Feed concentrates	0.3	0.0	0.0	0.0	0.0	0.1
Purchased fodder	0.0	0.0	0.0	0.0	0.0	0.0
Health & breeding	0.7	1.3	1.8	1.7	1.0	1.2
Hired labour	0.3	0.0	0.0	0.0	0.0	0.1
Milk price (increase)	16.4	16.6	21.3	40.1	19.1	20.5
Initial profit/loss/litre	17.5	18.2	12.8	8.1	16.8	14.7

Table A10: Changes in TVDC and returns as a result of reduction in costs and milk price increase for open grazers

Item	Narok	Uasin Gishu	Average (Large)	Nakuru (Medium)
	% reduction in TVDC as a result of 10% reduction in cost of:			
Feed concentrates	0.0	1.4	0.6	0.0
Purchased fodder/pasture	0.0	0.0	0.0	0.0
Health and breeding costs	0.4	0.7	0.6	1.2
Hired labour	2.0	2.0	2.0	3.3
	% increase in GM as a result of 10% change in:			
Feed concentrates	0.0	1.4	0.6	0.0
Purchased fodder/pasture	0.0	0.0	0.0	0.0
Health and breeding costs	0.4	0.7	0.6	1.2
Hired labour	2.0	2.0	2.0	3.3
Milk price (*increase*)	10.0	7.9	9.0	5.6
	% increase in Milk Profits as a result of 10% change in:			
Feed concentrates	0.0	1.8	0.8	0.0
Purchased fodder	0.0	0.0	0.0	0.0
Health & breeding	0.6	1.0	0.7	2.1
Hired labour	2.5	2.6	2.5	6.2
Milk price (*increase*)	23.5	18.9	21.2	14.0
Initial profit/loss/litre	20.2	15.9	18.1	11.0

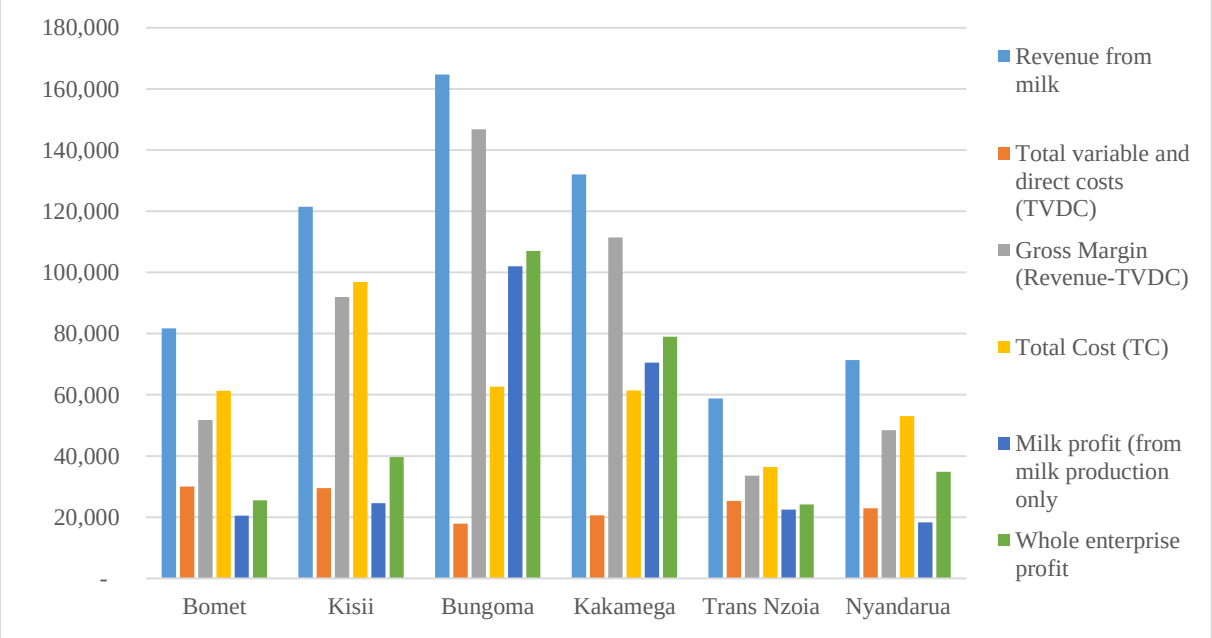

Figure A1: Costs and returns in KES per lactating cow per year for semi-zero grazers (small)

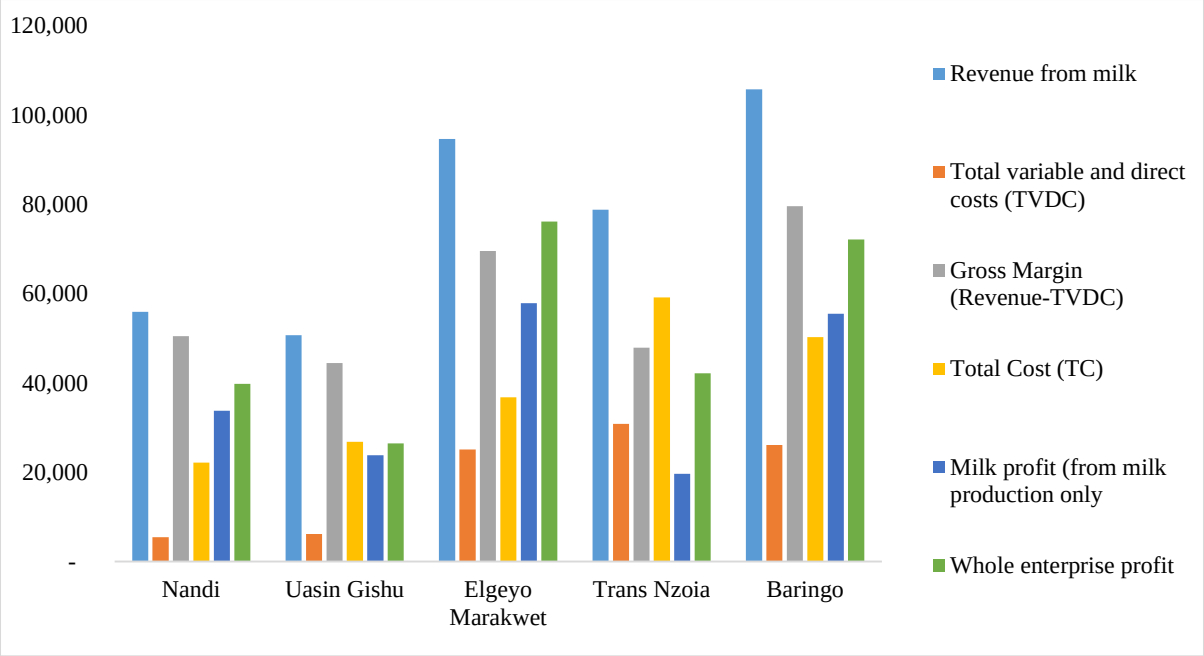

Figure A2: Costs and returns in KES per lactating cow per year for semi-zero grazers (medium)

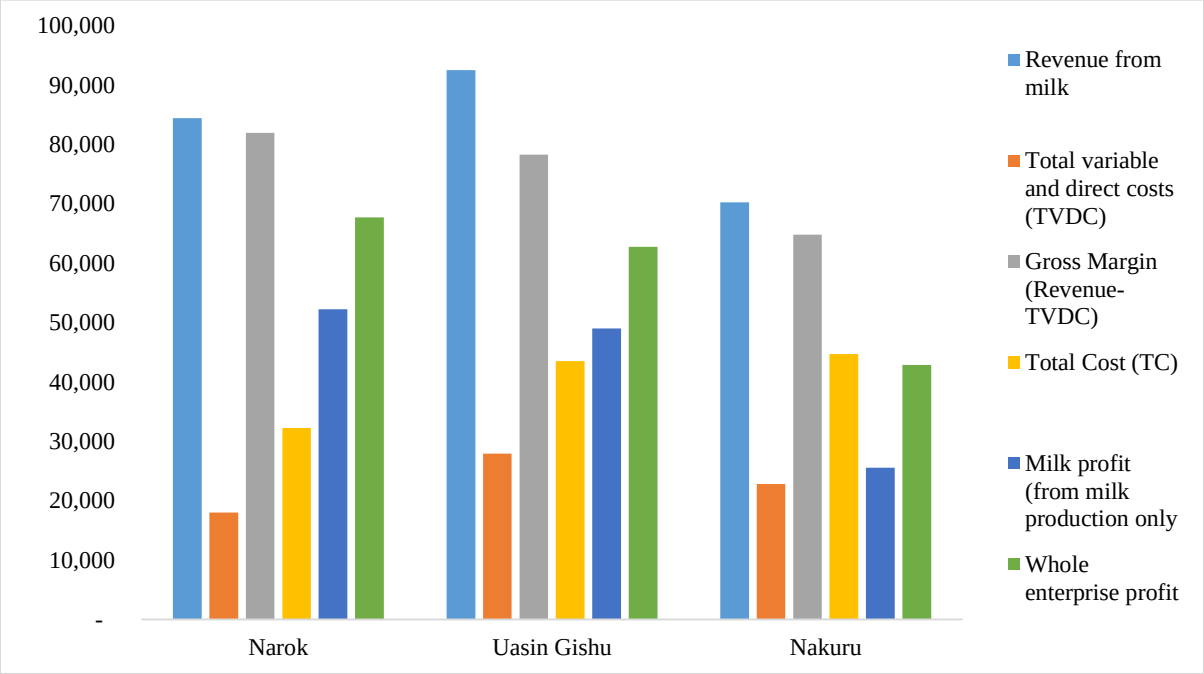

Figure A3: Costs and returns in KES per lactating cow per year for open grazers

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