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Influence of seasonal fodder scarcity on milk production among smallholder dairy farms in the north rift region of Kenya

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This study assessed the extent of seasonal fodder scarcity influence on milk production in smallholder farms (n=130) in the north rift region of Kenya. A cross-sectional survey to obtain primary data was conducted through face-to-face interviews using a structured questionnaire. Data processing was done in excel, thereafter, data was analyzed in Statistical Package for Social Sciences (SPSS version 21). Results indicated that the farms experienced 60.5% fodder deficit and milk yield gap of 117%. The deficit was greater during the rainy season (77.6%) than in the dry season (37.4%) but milk yield gap was relatively smaller in the rainy season (113%) than in the dry season (131%). Seasonal fodder scarcity was associated with low milk production, with an increase in fodder deficit resulting in a decline in milk yields (β=-6.33, p=0.007). The results indicate a persistent fodder scarcity and overstocking in these farms. Interventions on fodder scarcity will need empowering farmers to plan fodder production and conservation and to match their stocking with fodder supply, especially for those with diminishing landholdings. The farmer organizations have a role in fodder improvement for their members by investing in bulk fodder production utilizing improved varieties of certified seeds and offering storage facilities.

Key words: Feed requirement, feed supply, fodder scarcity, milk yield gap

INTRODUCTION

By 2050, it is projected that the global demand for dairy products will increase by 74% and for meat products by 58% (Coughenour and Makkar, 2012). Much of the demand is expected to occur in the developing countries where in sub-Sahara Africa (SSA), changes in agri-food systems have been observed in response to their rising population, urbanization, evolving dietary needs and consumer preferences (Kilelu et al., 2017). Kenya is one of the developing countries experiencing marked growth demand for meat and milk. The growing milk demand presents market opportunities to improve food and nutrition security and livelihoods for about 1.8 million

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smallholders dominating the Kenyan dairy sector (Kilelu et al., 2013; Wairimu et al., 2021).

Smallholder dairy production in Kenya is a mixed crop and dairy system that is heavily dependent on rain-fed forage production. This production practice exposed the system to marked seasonal feed scarcity, with milk glut during the rainy seasons and a substantial drop in milk market price (MoLD, 2010; Kashongwe et al., 2017). During dry seasons or drought periods, the available fodder is of low quality yet farmers offer only limited supplementary concentrates and minerals(Garg and Makkar, 2012). Feeds accounts for 60-70% of the cost of production in dairy, implying that supplying adequate quantity and quality feeds is a requirement to addressing production limitation in dairy production (Njarui et al., 2016). Wambugu et al. (2011) estimated the cost of concentrates and fodder feeds on smallholder dairy farms in Kenya. The authors found that concentrate feeds account for between 34 and 26% of the variable costs of production and forages account for between 12 and 14% on smallholder dairy farms. Fodder minimizes farmers' production cost because as the basal diet of the dairy cattle, it is able to meet significant requirements of the animals. Fodder produced from own farm coupled with fodder conservation may be more profitable, reliable and an effective strategy to boost milk production for smallholders because they would minimize market risks arising from price fluctuations (McDermott et al., 2010).

Grazing is the common dairy feeding system in the north rift region of Kenya. In this system, cattle graze freely on public land or on private land in paddocks or tethered. The production and use of planted fodder is limited due to low availability of labor. According to Kosgei et al. (2020), only about 30% of the farmers have adopted dairy cattle milk production technologies in Mosop sub-county, Nandi County. The strategies for increasing milk production that have been promoted include growing of leguminous crops, artificial insemination, disease and pest control and commercial feed rations. Inadequate feeding is a limitation in dairy production, attributing to huge milk yield gap (van der Linden et al., 2015; Mayberry et al., 2017; van der Linden et al., 2018). Addressing nutritional limitation with improved feeding alone can increase milk yield by up to 40% (USAID-KAVES, 2017) while adding genetic improvements to improved feeding can increase milk productivity by up to 300%. These studies suggest that for farmers with improved dairy genotypes, improvement in adequate feeding is a pathway to close the huge milk yield gap presently experienced. Several studies, for example, Lukuyu et al. (2012), Belay and Negesse (2018) and Kurgat et al. (2019) have assessed availability of feed resources and uptake of feed technologies that influence milk production on smallholder farms, but few have measured the availability of planted fodder to meet herd requirements. Appropriate feed balance requires that available feed resources match the number of animals kept with and an all-year round availability of feeds. Therefore, strategies that increase fodder yields and consistent supply across seasons to address seasonal fodder scarcity deserve attention. To identify options for bridging fodder scarcity and milk yield gaps on smallholder dairy farms, this study assessed the status of seasonal fodder availability and its influence on milk production.

MATERIALS AND METHODS

Description of study area

This study was conducted in the north rift region of Kenya, in Mosop Sub-county of Nandi County. The selection of the sub-county was because smallholder dairy farmers here have benefitted from farmer cooperative development through Tanykina Dairy Limited, receiving milk from the different wards of the Sub-County. The area falls in the Lower Highland (LH), Agro ecological Zone (AEZ) with a cool moderately wet climate. The area records bimodal annual precipitation of about 1200 mm and experiences a dry spell between December and March accompanied with the highest temperatures of 23°C and lowest temperatures of 12°C (Nandi County Strategic Plan, 2018).

The average farm size is 2 ha representing small-scale land holdings (Nandi County Strategic Plan, 2018). Land sizes are on diminishing trend due to fragmentation forced by a rising population. The land terrain is marked by steep slopes where maize production is a priority enterprise, occupying 75% of the cropping land. Other crops grown in the area are beans, sweet potatoes, sorghum, cassava, Irish potatoes, vegetables and a variety of horticultural crops. Lukuyu et al. (2011) has ranked dairy production, the second most important enterprise after maize. Dairy production utilizes crossbreds of Ayrshire and Friesian breeds, mostly grazing kikuyu grass pastures. Some stall grazing is practiced where animals are supplemented with extra gathered forages overnight in the stalls. Milking of the dairy cows is twice a day, mostly by women (Lukuyu et al., 2011).

Survey methodology

The farm survey was cross-sectional involving a random sample of 176 farmers from a population of 3178 smallholder fodder producers in Mosop sub-County. The population comprised smallholder farmer households affiliated to eight active farmer groups and non-group affiliated members (individual farmers). Each farmer group had a registered membership of between 15 and 17 members, out of which 10 were randomly selected using a simple random sampling procedure. This sampling approach generated a total of 80 farmers to participate in the survey. To capture the diverse characteristics of dairy producers' population in the area, an equal number of 80 individual farmers were proportionately sampled from households in sub-locations with farmer group presence. The total of 160 sample farmers was inflated by 10% to 176 to account for non-response and drop-out during the research process. Of the 176 farmers, only 130 (60 farmer group affiliates and 70 non-affiliates of farmer group) could provide complete data on fodder availability; these farmers had planted fodder on their farms.

Data collection

Data collection with use of a questionnaire that was subjected to expert review and pre-testing with 30 farmers in a neighboring ward

Table 1. Dry matter yields of fodder crops.

Name of fodder	Dry matter yield (kg per Acre)
Rhodes grass	4868
Napier grass	3200
Lucerne	2718
Maize Silage	9600
Maize stover (dry)	4000
Maize stover (green)	5200

Source: Lukuyu et al. (2012).

to targeted study wards. The questionnaire was administered by six trained enumerators able to speak the local language in face-to-face interviews with farmers. The data collection was on seasonal milk and fodder yields, seasonal fodder purchase and milk sales, and herd sizes. The data collection process lasted two weeks (November 2016) and was based on farmer recall and farm observations.

Data analyses

Estimating fodder scarcity

To determine feed availability or feed balance, feed supply is estimated, accounting for seasonality and annual fodder supply compared with dry matter feed requirements of the total animals in a herd (Coughenour and Makkar, 2012). The average body weight of the animals in the herd in the study area was estimated at 400 kg provided by Lukuyu et al. (2012) while the daily dry matter requirement was estimated as 3% of the body weight (Pandey and Voskuil, 2011). The total herd maintenance requirement was computed by multiplying the average number of ruminant animals in the herd in a year or season by the daily dry matter requirement of the animal. With this information, fodder scarcity was computed as the difference between total fodder dry matter supply and the total annual dry matter requirement by the total herd both produced on-farm and purchased. For on-farm produced fodder, the total dry matter production was estimated by multiplying the size of the cultivated area with dry matter estimated yields provided in Table 1.

In computing dry matter of fodder purchase, the estimated fresh weight of 70 kg bag of the different fodder provided by Lukuyu et al. (2012) was multiplied by the number of bags purchased. The weights obtained were converted to dry matter by multiplying with dry matter factor from conversion tables. The fodder balance indicating fodder scarcity or surplus was computed from:

$$FD = \frac{A-P}{P} * 100 \qquad (1)$$

Where FD is fodder deficit or surplus; A is total fodder dry matter supply in kg a year or per season; P is fodder dry matter requirement of the ruminant animals in kilograms in the farm in a year or season on average.

Farms were ranked in ascending order fodder deficit and the top ten percent performing farms experiencing the least deficit in fodder supply were separated from the remaining 90% representing the typical performing farms.

Estimating milk yield gap

The milk yield gaps for the top and typical performing farms were computed as a percentage from:

$$MYG = \frac{P-A}{A} * 100 \qquad (2)$$

Where MYG is percent milk yield gap, A is actual average milk yields on typical farms and P is the average milk yields on top performing farms, representing the potential milk yield.

The influence of season (rainy and dry) and farm (typical and top performing farms) on milk yield was assessed with fitting a general linear model using SPSS for the model:

Milk yield = Season + Farm + Season × Farm + Error term

Thus, the regression modeling was:

$$Yi = \beta 0 + \beta 1Xi1 + \beta 2Xi2 + \cdots + \beta pXip + \varepsilon i$$

for each observation, *i*= 1...n. The formula considers n observations of one dependent variable and p independent variables. Thus, *Yi* is the *ith* observation of the dependent variable, *Xij* is the *ith* observation of the *jth* independent variable, *j* = 1, 2... p. The values βj represent parameters to be estimated, and *εi* is the *ith* independent identically distributed normal error.

Where:
Y = Milk yield, Responses)
X = Parameters to be estimated (farm, season and farm/season interactions)
β = Fodder deficit (matrix of common parameter)
Ɛ = Error component

The means were compared with the least significant difference (LSD).

RESULTS AND DISCUSSION

The socio-economic characteristics of the respondents presented in Table 2 include: gender, age, education, income and planted fodder. The results reveal that majority were males (64.2%), almost double the number of female respondents (35.8%). These findings are consistent with an earlier report on farmer preferences and adoption of livestock feeds in the study area that observed more males (60%) than females (40%) (Kiptot et al., 2015). The majority (75.6%) of the farmers was aged between 30 and 50 years indicating a middle-aged

Table 2. Socio-economic characteristics of respondents (n=176).

Characteristics	Attribute	Percent
Gender	Male	64.2
	Female	35.8
Age (years)	Below 30	4.0
	30 - 40	31.8
	41 - 50	43.8
	51 - 60	13.6
	61 - 70	5.1
Education levels	None	1.7
	Primary	40.3
	Secondary	46.1
	Tertiary	11.9
Income	Crops	83.4
	Livestock	70.9
	Off-farm	6.3
	Remittances	1.1
Types of planted fodders	Napier grass	88.6
	Crop residue	44.0
	Rhodes grass	41.7
	Lucerne	4.6
	Desmodium	4.0
	Columbus grass	0.6

Table 3. Land and herd size of the sample farmers (n=176).

Characteristic	Mean	Standard Deviation
Land size (Acres)	4.3	2.9
Land allocated fodder (Acres)	0.76	0.8
Land allocated fodder (%)	21.0	18.7
Herd size (n)	4.3	2.7
Milking cows (n)	3.0	2.0

population. The results reveal that majority of the sample farmers (46.1%) had attained secondary education level and 40.3% of sampled farmers had attained primary education. Only a few of the sample farmers had attained tertiary level education while those without any formal education were negligible in the sample. The results further revealed that 83 and 71% of the smallholders derived their income from crops and livestock respectively; whereas less than 7% of the dairy producers were relying on off-farm and remittances as a source of income. The results show that farmers predominantly feed their cattle on Napier grass, Rhodes grass and maize residues. The type of fodder on the farm is related to the degree of fodder scarcity because of the different growth and nutrient properties of the fodders that influence levels of milk production.

Table 3 presents the land and herd size of the sample farmers, representing their farm resource endowments. The results reveal a mean farm size of 4.3 acres with 21.2% (0.7 acres) under fodder of the total land size. The 0.7 acres of fodder supported an average herd of five animals of which an average of four was milking cows. On average, 0.76 acres of land supported about four milking animals against the recommended annual stocking rate of one acre of Napier fodder, which is the primary forage source for one milking cow (National Dairy

Table 4. Land and herd size of sample farmers.

Characteristic	Mean	
	Typical farmers n= 117	Successful farmers n=13
Herd size (n)	3.8	2.46
Milking cows (n)	2.49	2.38
Land size (Acres)	5.5	4
Land under fodder (Acres)	0.8	0.6

Table 5. Fodder balance estimates (DM kg/yr) on typical and top performing farms (n=130) during dry and rainy seasons (DM kg/season).

Factor	Total herd demand	Total supply			Surplus (Deficit)	p-value
		On-farm	Purchases	Total		
Overall	2106780	720094	111133	831227	(60.5%)	
Farm						
Typical farms (n=117)	1949100	498533	107561	606094	(68.9%)	0.025
Top farms (n=13)	157680	221561	3572	225133	42.8%	
Rainy Season	1212120	229566	41203	270769	(77.6 %)	
Typical farms (n=117)	1 121400	50674	1511	52185	(95.3%)	0.699
Top farms (n=13)	90720	178891	39692	218583	40.9%	
Dry Season	894660	490528	69930	560458	(37.4%)	
Typical farms (n=117)	827700	319641	67869	387510	(53.2%)	0.038
Top farms (n=13)	66960	170887	2061	172948	58.3%	

Farm $p<0.05$; Rainy Season p> Dry season 0.05; Farm x Season $p<0.05$; (….) Figures in brackets indicate deficit.

Development Programme - NDDP, 1992a). An earlier study of this population by Lukuyu et al. (2011 found an average farm size of four acres, one acre (25%) under grazing or pastures, three acres (75%) under crops and total herd size of nine comprising an average of four milking cows. The study of Lukuyu et al. (2011) found that a large herd size on small land sizes is likely to lead to overgrazing. Besides, the study found that high milk production was achieved in areas with high input strategies such as planted forages and purchased concentrate feeds.

Further analysis of the data was made to compare land use and herd size of successful and typical farmers. Table 4 reveals a mean farm size of 4 and 5.5 acres among the successful and typical farmers respectively. In addition, 0.6 and 0.8 acres was under fodder in the successful and typical farms respectively. The 0.6 and 0.8 acres of fodder supported an average herd of four and two animals in typical and successful farms respectively, of which an average of two were milking cows in both farms. The high stocking rates observed in the typical farms is likely to lead to overgrazing and feed deficits.

Table 5 presented the estimated fodder balance, indicating that the overall fodder dry matter deficit on these farms was 60.5% and was greater during the rainy season than during the dry season (-77.6% vs. - 37.4%). The fodder deficit was pronounced in the typical farms while the top farms had surplus fodder (-68.9% vs. 42.8%). Whereas typical farms experienced fodder scarcity in the rainy and dry seasons (-95.3% vs. - 53.2%), the top performing farms had a surplus of 40.9 and 58.3% in the rainy and dry seasons respectively. Surprisingly, fodder deficit was greater during the rainy season than during the dry season (-77.6% vs. -37.4%). The deficits in the rainy season could be attributable to the fact that only estimates of dry matter from planted fodders were considered in the study while grazing biomass could not be estimated. The fodder yields in the successful farms during the dry season were higher compared to rainy season probably due to availability of maize stovers from large acreages of maize that is characteristic of the study area. Crop residues from the maize crop formed the bulk of the feed in the dry season confirming findings by Lukuyu et al. (2011) and McIntire et al. (2016) that crop residues are an important feed

Table 6. Seasonal milk yield and yield gap on the sample smallholder farms (n=130).

Factor	Milk yield (L/cow/day)	Yield gap (%)
Rainy season		**113**
Typical farms (n=117)	6	
Top performing farms (n=13)	12.8	
Dry season		**131**
Typical farms (n=117)	5.1	
Top performing farms (n=13)	11.8	
Overall		**117**
Typical farms (n=117)	5.6	
Top performing (n=13)	12.2	

Table 7. Influence of fodder scarcity on milk production.

Milk yield	Estimates	Standard error	T	Sig
Fodder deficit	-6.33	2.90	-2.181	0.007
Typical farm	0.81	0.26	3.073	0.015
Dry season	3.75	0.83	4.524	0.001
Farm × Season				
Constant	2.991		2.219	0.001

Model fitting: N= 130; F value = 451; p value =0.001; Adj R^2 =0.94.

resource in mixed crop-livestock smallholder farms. These observations indicated that fodder scarcity remains a pervasive production challenge for smallholder dairy farmers and top performing farms are better placed to address scarcity by fodder establishment and probably stocking feeds for dry seasons.

Table 6 presents seasonal milk yield and yield gaps on the sample farms. The results show an overall yield gap of 117% with a larger gap during the dry season relative to the rainy season (131% vs. 113%). This is an indication that the top performing farms likely stock surplus fodders for use in the dry season hence attain higher milk yields. Interventions on fodder scarcity should target the dry season to increase milk production in order to close the annual yield gap of 117%. Such feed intervention would benefit the typical farms to improve milk yield and narrow the yield gap in the dry season. In a yield gap analysis, Paul and Chandel (2010) found that improving socio-economic conditions and management practices including feeding and disease control would increase the actual milk production by 66%, which concurs with modeling studies in Ethiopia and India (Mayberry et al., 2017) and in mixed livestock systems (Van der Linden et al., 2018).

The regression results of the influence of fodder scarcity on milk yield (Table 7) show significant influence of fodder deficit, season and farm. Fodder deficit show negative influence on milk production (β=-6.33, p=0.007); with 1% increase in fodder deficit being associated with a drop in milk yield of 6.33% points. This is an indication that dairy cows require adequate fodder to support milk production. The fodder on offer should be highly digestible to ensure utilization of the nutrients in milk production. Therefore, for dairy enterprises to thrive sustainably, investments that support adequate fodder production and quality are beneficial.

Relative to typical farms, top farms attain 0.81 liters more milk yield (β = 0.81, p=0.015) and the milk yield is 3.75% points more during rainy season relative to the dry season. This could indicate better fodder quantity and quality in the rainy season relative to the dry season, consequently improving milk production. The results were consistent with the findings of a study by Mulwale et al. (2014) on the relationship between fodder and dairy production in Homa Bay and Ndhiwa which found a significant relationship between fodder and dairy production. The results also agree with Njarui et al. (2016) findings that link low milk production in the central highlands, coastal region and northwestern highlands of Kenya to low rainfall in the dry season and a decline in nutritive quality of fodder. To boost milk production, farmers should strive to produce and utilize fodder on their own farms. The government should facilitate access to fodder, especially during the dry season, by supporting farmer organizations to construct fodder storage facilities facilitating infrastructural development, access to improved varieties of certified fodder seeds and develop capacities for fodder establishment and management.

The study findings further show that the interaction between farm and season ($p<0.05$) is in agreement with the findings by Elkhair et al. (2017) in Sudan, such that the higher rainfall was accompanied with higher average milk production of 3.2±1 L/day compared with dry seasons (3.0±1.8 and 2.6±1.2 L/day). However, the findings are contrary to those observed by Mwangi et al. (2018) that rainfall and milk can show negative relationship. In that study, the prevailing rainfall patterns had substantial influence on amount of milk produced. Rainfall did not have immediate effect on milk production because the regeneration of pastures requires time. Moderate to low rainfall was associated with relatively high milk production due to the availability of pasture of relatively high dry matter content and rich in nutrients while high rainfall led to decline in milk production. The study attributed the decline in milk production during periods of high rainfall to seasonal diseases, floods, and cold weather. These results suggested that research and extension programs that foster participatory selection of drought-tolerant and high yielding fodder species suited to the local conditions are desired to ensure availability of fodder in the dry season. Promotion of fodder conservation and ration formulation are desired to develop a combination of feeds that supply adequate nutrients to support sustainable milk production throughout the year.

Conclusion

Seasonal feed scarcity is high among smallholder dairy farms resulting in low milk production particularly during the dry season. The results indicated a persistent fodder scarcity and overstocking in the smallholder farms. Fodder scarcity could be decreased by empowering farmers to plan fodder production and conservation and to match their stocking with the fodder supply, especially for those with diminishing landholdings. The farmer organizations have a role in fodder improvement for their members by investing in bulk fodder production utilizing improved varieties of certified seeds and offering storage facilities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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