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Evaluation of losses of replacement heifers in pastoral and peri-urban camel herds in semi-arid northern Kenya

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Abstract

This study estimated heifer losses and associated determinants in peri-urban camel herds characterized by market orientation and domination of lactating camels grazing closer to urban market outlets for milk. In this evolving peri-urban camel production system in semi-arid Kenya, the proportion of heifers born that survives to breeding age is important in sustaining the herds and the extent to which households obtain tangible and intangible benefits from camel keeping. Data was obtained through progeny history recall on 2,000 heifer loss cases out of 4,398 heifers born between 1991 and 2009. The estimated heifer loss was 0.455 and was 11.8% higher ($P < 0.0001$) in peri-urban herds (0.505 ± 0.040) than in pastoral herds (0.387 ± 0.047). The extent of heifer loss was significantly associated with veterinary service access ($P < 0.05$), labour hire ($P < 0.01$) and state of security ($P < 0.01$). Results provide lessons for policy intervention to support evolution of peri-urban camel milk production. Improving infrastructure and the security situation is necessary to enhance delivery of veterinary service and feed supply interventions to peri-urban camel herds for production of milk and breeding stock.

Keywords: Camel heifer; Progeny history; Market-oriented production; Kenya

Background

Camels (*Camelus dromedarius*) are primary livelihood assets in the arid and semi-arid lands (ASALs) of northern Kenya. Camels provide pastoral communities with tangible benefits (income, milk, meat, hides and skins) and intangible benefits (status symbol, insurance, risk aversion and social capital). Traditionally, camels have been managed in nomadic systems characterized by subsistence production objectives and mobile herds in search of pastures, water and mineral licks in the vast rangelands of the ASALs.

Nomadic pastoral production of camels is highly vulnerable to recurring droughts and subsequent ethnic conflicts over water and pastures (Guliye et al. 2007; Thornton et al. 2007). This has contributed to forcing part of the pastoral communities to abandon the traditional nomadic pastoral production in search for businesses, employment opportunities, security and social amenities in the urban centres (Bebe et al. 2007; Seré et al. 2008). The migrating pastoral households have introduced camel keeping within the vicinity of urban centres where they keep lactating herds to supply milk to urban consumers. Grazing of the lactating herds is restricted within pastures around the urban centre, so as to remain closer to market outlets. This practice is marked with changes in production objectives from subsistence to market orientation. Breeding stock is reared within the herd (Bebe et al. 2007). The camel herd management practices just described have evolved into a peri-urban camel milk production system. In this evolving system, the proportion of camel heifers born that survive to first calving is important in sustaining the herds and the extent to which households obtain tangible and intangible benefits from their camel herds.

However, sourcing of breeding stock from pastoral herds is not a promising option for sustaining evolution of peri-urban camel herds for marketed milk production. The pre-weaning calf mortality is between 20% and 55% (Schwartz et al. 1983; Wilson 1986) and when sex

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disaggregated is between 20% and 30% for heifers (Kaufmann 2000, 2003). When post-weaning mortalities are added, the loss of potential replacement heifers in pastoral herds would be substantial, limiting the supply of breeding stock to peri-urban herds. The high loss of heifers in pastoral herds is attributed to diseases, drought starvation, predation, snake bites, theft and rustling, infertility, still births and deformities (Schwartz et al. 1983; Simpkin 1985; Baumann and Zessin 1992; Kaufmann 2003).

The nature of the heifer losses suggests a strong relationship with management practices. Because management strategies in peri-urban herds differ from those of pastoral herds, the effect on heifer production may differ and so are losses to first breeding age. Because peri-urban camel herders rear their own camel heifers (Bebe et al. 2007), they have to maximize survival rate of the heifers born to breeding age when they enter the milking herd. Therefore, the study compared the extent of camel heifer loss to first calving age and identified associated determinants of the differences between pastoral and peri-urban camel herds in semi-arid northern Kenya.

Study area

The study sampled representative peri-urban herds around Isiolo town and representative pastoral herds in the rangelands of Isiolo County of northern Kenya (Figure 1). Peri-urban herds are predominantly lactating herds kept closer to urban milk market outlets. Pastoral herds are mobile and grazed far away from urban centres. Milk from the herd is consumed by the herders and the family.

The peri-urban grazing areas receive median annual rainfall between 400 and 600 mm (Herlocker et al. 1993), while the rangeland grazing areas receive median annual rainfall of 150 to 250 mm. In both peri-urban and rangeland grazing areas, the dominant vegetation are shrubs of *Acacia reficiens*, *Acacia tortillis*, *Cammiphora* spp. and *Duospherma eremophilum* and grasses of *Aristida* spp., *Leptothrium senegalese*, *Sporobolus* spp. and *Lintonia nutans* (Herlocker et al. 1993).

Methods

The data was processed and analyzed using STATA software (StataCorp LP, College Station, TX, USA) and fitted Tobit model to estimate heifer losses and to identify the determinants of heifer losses.

Sampling procedure

The desired sample size was determined on the basis of average female calf mortality estimate of 30% taken from Kaufmann (2003) for pastoral camels in northern Kenya. Sampling was for two independent samples represented by pastoral and peri-urban herds. For economically important difference, we allowed for a 95% chance of detecting mortality rate with a difference of 20% at 5% level of significance (Petrie and Watson 1999). Computation of the desired sample size with this approach yielded sample herds of 171, of which 94 were portioned to pastoral herds and 77 to peri-urban herds on proportional basis.

The herds representing pastoral and peri-urban camel production were sampled randomly with the help of the district veterinary and animal production officers in Isiolo. Herds were visited in the morning during times of milking. In each herd visited, the owner together with the herder was asked to recall progeny history of each breeding female for all calves born. The progeny history technique of Swift (1981) has been used successfully for herd dynamics data in pastoral systems and applied successfully for collecting progeny history because of good memory about individual animals by pastoralists (Kaufmann 2003, 2005; Tura 2008). Progeny history enabled profiling cases of female and male calves born by each of the breeding females in the herd. Case profiling captured the number of calves born by sex, the number lost before first calving, the age at time of loss, the cause of loss and access to support services in the grazing areas.

Implementation of the progeny history recall profiled 2,887 cases of breeding female camels and heifer losses of 729 and 1,271 in pastoral and peri-urban herds, respectively, between 1991 and 2009. The camels profiled were aged between 5 to 26 years, which represent 18 years record of calving.

Theoretical framework and the Tobit model

The individual herd owner's decision to enhance survival of breeding stock to first calving age was modelled using random utility model where utility of each option is assumed to be a linear function of observed individual characteristics plus an additive error term (Verbeek 2000). Random utility model assumes that decision-makers choose options that maximize their perceived utility. In addition, decision-makers are assumed to know better the opportunities that meet their objectives. Since the exact form of a decision-maker utility function is not known, some assumptions were made where a random element to reflect the unobservable part of an individual's utility function was included and represented as Equation 1:

$$U_{ij} = \overline{U_{ij}} + \varepsilon_{ij} \qquad i = 1, \ldots N \quad i = 1, 0, \tag{1}$$

where U_{ij} is the utility received by the ith individual decision-maker from the jth alternative options for securing survival of breeding stock, $\bar{U}_{ij}$ is the systematic part of the utility function and ε_{ij} is the random part.

The individual's utility is also a function of the attributes to the alternative to the individual herd and herd

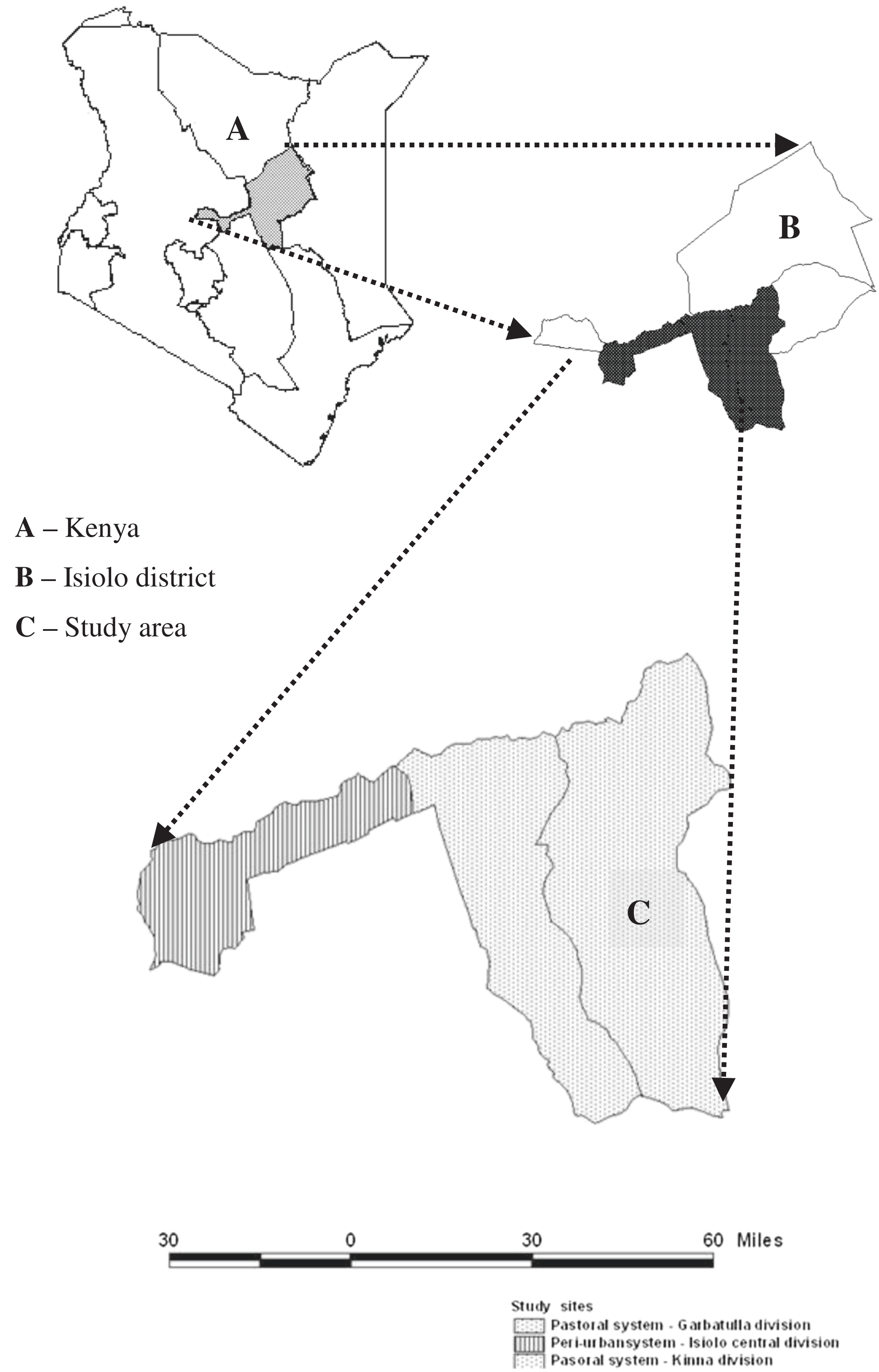

Figure 1 Map of the study area showing pastoral and peri-urban camel systems.

owner characteristics and livestock support programmes. The indirect random utility model for U_{ij}, the unobservable economic variable utility, was represented as Equation 2:

$$U_{ij} = z'_{ij}\alpha + c'_i\beta_j + \varepsilon_{ij}, \tag{2}$$

where z_{ij} represents the vector of attributes of alternative j to the individual decision-maker i, c'_i is the vector of characteristics of individual herd and herd owner characteristics and livestock support programmes i and α, and β_j (j = 1, 0) are vectors of unknown parameters. An earlier study of the same camel herds had indicated that peri-urban camel herds rear their own heifer replacements (Bebe et al. 2007). This heifer management practice requires that a camel keeper maximizes the survival rate of heifers born to the age at which they enter the milking herd. Therefore, an individual decision-maker who owns a camel will maximize his/her utility by maximizing the survival of replacement heifers born which will support tangible and intangible benefits.

The owner maximizes his/her utility subject to constraints on voluntary losses, involuntary losses, herd and herd owner characteristics and support programmes. The individual herd owner's utility of options for securing survival of breeding stock was assumed to be a linear function of the herd owner's decision to reduce losses that resulted from voluntary and involuntary reasons, herd and herd owner characteristics and access to support services. Maximization of heifer survival Ω_r is therefore a function of age class (x_a), voluntary losses (x_v), involuntary losses (x_i), herd and herd owner characteristics (x_h) and support services (x_s) expressed in Equation 3:

$$\max\ \Omega_r(x_a, x_v, x_i, x_h, x_s). \tag{3}$$

The heifers lost as a proportion of those born potentially range from 0 to 1. The Tobit model was used on the basis of measurement of the dependent variable y (ranging between 0 and 1) which was the proportion of heifers that failed to reach first calving age. Appropriateness of this model has been recommended where the dependent variable is proportionately determined, allowing for a lower limit of 0 and an upper limit of 1 (Maddala 1992; Gujarati 2003). The Tobit model was created by Tobin (1958) and has been applied in household purchasing decisions, extramarital behaviour, labour supply and criminal activities (Greene 1993, 2003). In context of agricultural economics, it has been applied in adoption studies (Ransom et al. 2003), commodity supply decisions (Mundlak 2002), disequilibrium models (Fair and Jafee Fair and Jaffee 1972), production economics (Paris 1992) and development economics (Goetz 1992) among others. Based on Maddala (1992) the standard Tobit model was thus defined as Equation 4:

$$Y_i = Y_i^* = \beta x_i + u_i \ \text{ if } \ Y_i^* > 0.$$

Otherwise,

$$Y_i = 0 \ \text{ if } \ Y_i^* \leq 0. \tag{4}$$

Y_i^* is a latent variable which cannot be observed, β is a vector of unknown parameters to be estimated, x_i is a vector of explanatory variables and u_i is the random error term.

The model assumes the random error term u_i and is normally and independently distributed with mean = 0 and constant variance δ^2 that is $u_i \sim \mathrm{IN}(0, \delta^2)$. If the non-observed latent variable Y_i^* is greater than 0, the observed qualitative variable Y_i, which is indicative of the proportion of heifers lost, becomes a continuous function of the explanatory variables; X_i represents vectors of herd type, herd characteristics and livestock support services accessible as Equation 5:

$$\begin{aligned} Y_i^* > 0 &=> Y_i = Proportion\ \ of\ \ heifers\ \ lost \\ &= Y_i^* = X'_i\beta + \varepsilon_i. \end{aligned} \tag{5}$$

On the other hand, for Y_i^* which was less than or equal to 0, Y_i was 0, and when Y^* was negative, the heifer losses in the camel herds were 0 which implied that all heifers reached the first calving age as Equation 6:

$$\begin{aligned} Y_i^* \leq 0 &=> Y_i \\ &= 0(Y^*\, can\, be\, negative\, only\ if\ \ Y = 0). \end{aligned} \tag{6}$$

The Tobit model was estimated using the reduced Equation 7:

$$Y = \beta_i X_i + \beta_j X_j + \beta_k X_k + \varepsilon, \tag{7}$$

where Y is the proportional loss (proportion of loss relative to births), X_i is a vector of herd (pastoral and peri-urban), X_j is a vector of herd owner characteristics, X_k is a vector of support services accessed and ε is the error term which is normally and independently distributed. The explanatory variables were as follows: X_i = X_1 pastoral herds, X_2 peri-urban herds; X_j = X_1 herd size, X_2 level of education of the owner of the camel herd, X_3 attendance to trainings/workshops/seminars on camel calf management by the herd owner and X_4 type of labour used to carry out camel production activities; X_k = X_1 access to veterinary services/interventions, X_2 distance to watering points, X_3 distance to the nearest market and X_5 security situations for camel herds. A summary of description and

Table 1 Description and measurement of variables used in the study

Variable acronym	Variable meaning	Variable description	Variable measurement
Herd	Grazing area where the herd is managed	Pastoral herd (0) peri-urban herd (1)	Categorical, dummy
Proploss	Proportional loss	Proportion of female calves lost relative to female calves born	$\left(\frac{\text{Total number lost}}{\text{Total number born}}\right)$
Agec	Age class of heifer at the time of loss	1 = pre-weaning <3 months; 2 = yearling, three to two years; 3 = three years; 4 = four years; 5 = age at first calving	Categorical
Reason	Reason that led to loss of heifer	Involuntary losses: 1 = death from diseases, 2 = death from predation/injury/poisoning, 3 = deaths from drought starvation, 4 = infertility/deformities, 5 = theft/rustling, 6 = voluntary losses (slaughtered for ceremonies, gift out, leased, dowry payment)	Categorical
Mktdist	Market distance	Distance to the nearest market: 0 = not far, 1 = far, 2 = moderately far, 3 = very far, 4 = extremely far	Ordinal measure, Likert scale rating by camel herd owners
Veterinary	Access to veterinary interventions	Frequency of treatment of camel calves against diseases: 0 = None, 1 = less frequently, 2 = fairly frequently (average), 3 = frequently, 4 = more frequently	Ordinal, Likert scale rating by camel herd owners
Herd	Gazing area where the herd is managed	Pastoral herd (0) peri-urban herd (1)	Categorical, dummy
Security	Security situation for keeping camels	0 = not secured, 1 = fairly secured, 2 = secured, 3 = more secured, 4 = highly secured	Categorical
Train	Attendance to trainings/workshops/seminars on camel calf management	No = 1 and 0 otherwise	Categorical, dummy
Labour	Labour used in carrying out camel management activities	Hired = 1 and 0 otherwise	Categorical, dummy
Herd size	Herd size	Mature bulls	The total number of camels for the categories in column 3
		Young bulls	
		Breeding females	
		Heifers	
		Male calves	
		Female calves	
Educ	Level of education	Informal	Likert scale
		Primary	
		Technical after primary	
		Secondary	
		Post secondary	
Supplement	Supplementary feeding/grazing reserves	No = 1 and 0 otherwise	Categorical, dummy

Table 2 Data description for the sample camel population characteristics

Variable	Pastoral herds	Peri-urban herds	Total sample
Herds sampled (*N*)	94	77	171
Breeding females profiled (*N*)	1,214	1,673	2,887
Age of breeding females (mean ± SD) (years)	18.97 ± 4.79	17.81 ± 3.99	18.45 ± 4.48
Herd size (mean ± SD) (*N*)	45.86 ± 30	87.60 ± 50	72.57 ± 48.3
Total calves born (*N*)	3,945	4,800	8,745
Total female calves born (*N*)	1,882	2,516	4,398
Total female calves lost before age at first calving (*N*)	729	1,271	2,000
Estimated proportional heifer loss (mean ± SD)	0.387 ± 0.047	0.505 ± 0.040	0.455

Table 3 Marginal effects of factors influencing loss of replacement heifers before first calving

Variables	Maximum likelihood coefficient	Robust standard error	Z	P > |z|
Herd (0, 1)[a]	0.0857	0.0254	3.37	0.000*
Educ (scale)	−0.0039	0.0109	−0.36	0.719
Train (0, 1)	−0.0104	0.0088	−1.18	0.237
Veterinary services accessed (scale)	−0.0551	0.0173	−3.18	0.001**
Labour[b] (0,1)	0.1059	0.0237	4.47	0.000*
Security (scale)	−0.0627	0.0168	−3.73	0.000*
_cons	0.5387	0.0412	13.08	0.000

Log likelihood = −1,218.1793; number of observations = 1,877; LR chi square (6) = 113.39; Prob > chi square = 0.000; pseudo R^2 = 0.2024. *Significance at 1%; **significance at 5%. [a]A dummy variable indicating pastoral herd (0) and peri-urban herd (1); [b]a dummy variable indicating owner (0) and hired (1) labour.

measurement of variables used in the study is presented in Table 1.

Results

Descriptive analyses of the sample camel population

Table 2 presents a description of the sample camel population from which the proportions of lost heifers were estimated. Of all the female camel calves reported born, 0.455 failed to reach first calving, representing 54.5% of the potential heifer replacements surviving to enter the milking herd. The estimated heifer loss was 11.8% higher in peri-urban herds (0.505 ± 0.040) than in the pastoral herds (0.387 ± 0.047), and herd effect was significant (chi square value 60.55, $P < 0.0001$).

Determinants influencing loss of heifers before first calving

Table 3 presents marginal effects of Tobit model estimates for factors influencing the loss of heifers. The diagnosis of the fitted model found the Tobit regression statistically significant ($P = 0.0000$), indicating that the combination of explanatory variables significantly affect the extent of heifer loss. The pseudo R^2 of 20.24 was above the statistical threshold of 20%, confirming that the loss of heifers could be attributed to covariates fitted. Bivariate correlation analysis indicated that the herd (pastoral and peri-urban) variable had a high correlation coefficient with the distance to the nearest market (0.75) and distance to the watering points (0.60); therefore, variables of distance to market and to watering points were dropped from the model.

The coefficient for herd variable has a positive marginal value (0.0857) and is significant ($P = 0.000$), indicating that loss of heifers was 8.6% higher in peri-urban than in the pastoral camel herds. The coefficient veterinary services has a negative marginal value (−0.0551) and is significant ($P = 0.000$), indicating that loss of heifers was lower for camel herds that were accessing veterinary services. Therefore, access to veterinary services is essential to managing heifer loss, which in this study is associated with reduced heifer loss by 5.5%.

Labour used for carrying out camel management activities has a positive marginal effect (0.1059) and significantly influenced heifer loss ($P = 0.000$). Comparatively, hired labour increases heifer loss by 10.59% in camel herds. The coefficient of security threat situation for camels has a negative marginal effect (−0.062) and is significant ($P = 0.000$), indicating that heifer loss was higher in unsecured camel herds. The findings imply that ensuring security situation from theft/rustling would decrease heifer loss by 6.2% in camel herds.

Discussion

Peri-urban herds are restricted to grazing near settled areas which could lead to over utilization of forage and feed resources. This could result in feed pressure and subsequently impact on survival of heifers. Restricted grazing of camel herds closer to urban market outlets can be associated with decreased mobility of pastoralists and reduced access to grazing reserves for dry seasons (Seré et al. 2008). This would imply that peri-urban herds were exposed to inadequate quantity and quality of year-round feeding necessary to support lactating camels concentrated around Isiolo town (Noor et al. 2012). The feeding pressure is likely to impact on calf nutrition in the absence of supplementary feeding; this could lead to increased susceptibility to disease incidences and malnutrition. Low quality and quantity feeding has been associated with high calf losses in cow dairy herds (Ombura et al. 2007).

Markets drive the demand for camel milk in the peri-urban herds (Guliye et al. 2007), and this intensifies the competition for milk between humans and calves, as more milk is supplied to markets. This leads to poor calf health in the absence of commercial feed supplementation. Malnutrition was reported as a major cause of camel loss resulting from increased competition between human beings and calves in earlier studies (Schwartz et al. 1983; Baumann and Zessin 1992). The marginal effect of access to veterinary services on the proportional loss implies that reduced heifer loss is associated with more frequent access to veterinary services. Often, the veterinarians are inadequately trained in camel health, husbandry and management, which could impact on the effectiveness and delivery of veterinary services. Consequently, camel herd owners often use ethno-veterinary alternatives for animal health cases.

Diseases cause the loss of heifers and were reported to generate additional costs through veterinary care and changes in management practices (Chilonda and Van

Huylenbroeck 2001). However, wealth also influences access to veterinary services because of the ability to pay for private services (Ahuja et al. 2003). Veterinary intervention packages and improved veterinary care were reported to reduce camel calves' mortality (Simpkin 1985; Njanja and Gathuma 2007).

The marginal effect of security on the loss of a heifer implies that unsecured camel herds lost more breeding stock, which can be attributed to rustling/theft. Consequently, camel herds are forced to migrate to areas with limited access to pasture, water, markets and veterinary services. Insecurity is a cause of forced sale of stock at lower prices and unplanned dowry payment (Kaimba et al. 2011; Kinyua et al. 2011). Insecurity situations sometimes spill into urban centres too, from the rural conflicts over pastures and water (Fratkin and Roth 2005). Camel owners respond to insecurity by hiring armed home guards, which increases their cost of production.

The marginal effect of labour is that use of hired labour to carry out camel management activities increased the loss of heifers. On average, 77% of camel herds in the peri-urban reported using hired labour. Herd owners have less direct involvement with the routine management activities of their herds. Other studies reported that pastoralists reduce their mobility in order to access markets and social amenities (Fratkin and Roth 2005; Tura 2008). Consequently, indigenous knowledge of livestock husbandry is eroding, due to separation of the herd owners from carrying out herding activities.

Conclusions

Results from the study indicate that, on average, peri-urban camel herds lose 11.8% more of heifers, compared to pastoral herds, and this loss could be significantly reduced with improved access to veterinary services, herd owners actively engaging in herding and daily management and lastly improved security situation in the grazing pastures. The frequent cause of loss of heifers in peri-urban herds differs from the frequency in pastoral herds, reflecting differences in management practices.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors participated in concept development, data collecting, analysis and interpretation. MGS produced this work from her Master's degree thesis under the supervision of GO and BOB, who also reviewed the manuscript for scientific publication. All authors read and approved the manuscript.

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