



ELSEVIER

Livestock Production Science 82 (2003) 211–221

**LIVESTOCK  
PRODUCTION  
SCIENCE**

www.elsevier.com/locate/livprodsci

## Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification

B.O. Bebe<sup>a,b,c</sup>, H.M.J. Udo<sup>b</sup>, G.J. Rowlands<sup>c</sup>, W. Thorpe<sup>c,\*</sup>

<sup>a</sup>*Animal Science Department, Egerton University, Box 536, Njoro, Kenya*

<sup>b</sup>*Animal Production Systems Group, Wageningen Institute of Animal Sciences, Wageningen University and Research Centre, P.O. Box 338, 6700 AH Wageningen, The Netherlands*

<sup>c</sup>*International Livestock Research Institute, P.O. Box 30709, GPO Nairobi 00100, Kenya*

Received 19 March 2002; received in revised form 10 December 2002; accepted 23 December 2002

---

### Abstract

A cross-sectional stratified random sample survey of 1755 households in the Kenya highlands was conducted between June 1996 and April 1998 to quantify cattle population dynamics in smallholder herds. The free-, semi-zero- and zero-grazing systems practised represented increasing levels of intensification of the farms. Additional data were collected in a follow-up survey of 50 households from the main survey sample. In the main survey there were 987 cattle-keeping households, of which 44, 33 and 23% practised zero-, semi-zero- and free-grazing systems, respectively. Compared to free-grazing, zero-grazing farms had a higher proportion of cows in the herd (0.62 vs. 0.51) but lower calving rates (0.52 vs. 0.69), higher losses of potential heifer replacements (0.47 vs. 0.38), fewer heifer replacements as a proportion of cows disposed (0.46 vs. 1.11) and shorter productive life (3.8 vs. 4.8 years). Semi-zero-grazing farms had intermediate performance. They and the zero-grazing farms were unable to maintain their herds without acquiring replacements externally. Animal class mortality rates were high (7–19%) regardless of grazing system practised. Diseases accounted for the largest proportion of animal exits: 85% of heifer-calves, 38% of heifers and 36% of cows. According to farmers' ranking, East Coast fever and Anaplasmosis diseases assumed less importance with a shift from free-grazing to zero-grazing system. A household's needs for cash was the second most frequent reason after disease for animal exits: 33% of heifers and 27% of cows, indicating the importance of cattle as liquid capital assets. The results showed that many zero-grazed herds required external sources of replacement animals to sustain their populations. Solutions to this constraint will include technical and institutional innovations to serve small-scale farms that may result in greater complementarities between the small- and large-scale production components of the dairy sub-sector.

© 2003 Elsevier B.V. All rights reserved.

*Keywords:* Dairy cattle; Intensification; Herd dynamics; Kenya highlands

---

### 1. Introduction

Human demographic growth and changes in economic conditions in developing countries are driving

---

\*Corresponding author. Tel.: +254-2-630-743; fax: +254-2-631-499/632-013.

E-mail address: w.thorpe@cgiar.org (W. Thorpe).

the need for increases in animal production (output) and animal productivity (output per unit input) (Delgado et al., 2001). To increase animal output and productivity, agricultural policies advocate intensification of production, which requires external inputs and services (De Jong, 1996; Devendra, 2001; Bebe et al., 2002). Intensification of ruminant production in developing countries is commonly through smallholder dairying, which is a response by rural and peri-urban households to market demand for milk. Smallholder dairying is the dominant dairy production system in much of sub-Saharan Africa and South Asia. It is generally characterised by the integration of crops and dairy production on holdings usually less than 5 ha, with one to five cattle or buffalo that play important multiple roles (Tulachan et al., 2000; Devendra, 2001; Devendra and Thomas, 2001). Dairying contributes to food production, generates cash income, produces manure to support crop production and is a means to accumulate capital assets for emergency cash needs.

Kenya's dairy development, among developing countries, exemplifies this intensification through smallholder dairying (Bebe et al., 2002). Zero-grazing (stall-feeding) is the common strategy of intensifying dairying. It is widespread in the Kenya highlands where landholdings are continuously declining due to intergenerational subdivision of farms driven by the rapid growth in human population (C.B.S., 2001). Studies of these systems in the Kenya highlands show that growth rates among calves and heifers are less than  $0.25 \text{ kg day}^{-1}$ , mortalities among cows, heifers and calves range from 10 to 30%, age at first calving is about 3 years and calving rate is about 0.60 (Omore, et al., 1996; Lanyasunya et al., 1999). These performances raise concerns about the maintenance of smallholder dairy herds both at individual and community levels. This has implications for the future structure of the dairy sub-sector and its productivity.

In the past, public-owned, large-scale dairy farms produced dairy replacements for smallholders at subsidised costs (Conelly, 1998). These sources are now very limited, because the majority of the large-scale farms have collapsed or have been subdivided for resettlement. In order to better understand the constraints and prospects for maintaining and expanding smallholder dairying, the objective of this

study was to quantify cattle population dynamics in free-, semi-zero- and zero-grazing systems, representing increasing levels of intensification in smallholder farms in the Kenya highlands.

## 2. Materials and methods

### 2.1. Study area and herd management systems

The Kenya highlands comprise areas with elevations  $\geq 1000 \text{ m}$  above sea level, annual mean temperatures of  $10\text{--}18^\circ\text{C}$ , a bimodal rainfall pattern with  $> 800 \text{ mm}$  annually and fertile soils with good potential for biomass production (Jaetzold and Schmidt, 1983). The highlands constitute the most important milk sheds (areas where milk is produced) supplying the Nairobi urban market. The dairy herds comprise Friesian, Ayrshire, Guernsey and Jersey breeds and their crosses with *Bos indicus* cattle (local zebu, Boran and Sahiwal). Grazing systems include free, semi-zero and zero grazing, representing increasing levels of intensification. In the free-grazing systems farmers graze cattle on private or public owned pastures during the day and keep them within the homestead at night. Zero grazing is a cut-and-carry, stall-feeding system in which napier grass and crop residues are the main feeds. Concentrate supplementation is generally restricted to milking cows. Semi-zero grazing is a combination of free grazing and stall feeding, depending on the seasonal availability of feeds and labour.

### 2.2. Survey methodology

A two-phase, cross-sectional characterisation survey of 1755 smallholder households was conducted in nine districts within the major milk sheds of Kenya. The first phase was conducted in Kiambu district during June–July 1996 and the second phase during March–April 1998 in eight districts: Nairobi; Machakos; Kirinyanga; Maragua; Murang'a; Nakuru; Nyandarua and Narok. The sites selected within each district reflected variation, firstly for agro-ecological potential (medium and high) for cropping and dairying as defined by Jaetzold and Schmidt (1983), and secondly for milk market access (low, medium and high). Grouping districts according to human popula-

tion densities, local demand for milk, type of roads (tarmac, passable all weather, seasonally passable) and the availability of milk marketing institutions defined the three categories of market access (Staal et al., 2001).

Five sub-locations (the smallest administrative unit within a district) were selected within each land-use system in a district by a stratified random sampling method. Two pairs of major landmarks (permanent features such as trading centres, schools and churches) in each of the selected sub-locations were randomly selected on a map, and transect lines were drawn between each pair. Sampling was then done as closely as possible following the marked transects. A trained enumerator interviewed each fifth household, first on the right and then on the left. A total of 365 households from 24 sub-locations in Kiambu district and 1390 households from 82 sub-locations in the other eight districts were interviewed. The total sample size in a sub-location represented approximately 1% of the total number of households based on population census figures of 1989 (C.B.S., 1994).

### 2.3. Data collection

Data collection was through household interviews, conducted in the local language by trained enumerators using a pre-tested, structured questionnaire. Information obtained from each household was on farm size, grazing system and total number of animals by class: heifer-calves (pre-weaned females), heifers (post-weaned females until first calving), cows (after first calving), male-calves (pre-weaned), immature males (post-weaned to 3 years old) and bulls (after 3 years old). Information collected included age at first calving and parities and ages of cattle both present and sold or died over the past 12 months. The herd demographic data collected for each animal class included births, purchases, deaths and sales based on the respondents' recall of events over the past 12 months. Farmers ranked, in order of importance (1 = low and 3 = high), named diseases to indicate perceptions about the relative importance of these diseases in their herds.

A follow-up, cross-sectional survey, based on semi-structured interviews of 50 households random-

ly selected from a stratified sample of the main survey sample was carried out to obtain complementary information on the origins of cows and disposal patterns. Stratification was by level of intensification in dairying activities, available household resources and level of market access using a combined method of principal component and cluster analysis applied to the cross-sectional survey sample (Staal et al., 2001).

Information on sources of replacement animals in the main survey was collected on purchases over the past 12 months but ignored replacements originating from within the herd. Complementary information was thus obtained in the follow-up survey on the history of each cow present in the herd: whether born within the herd or purchased from other smallholders or larger-scale farmers. Additional information on cow disposals included parity and physiological status at disposal: lactating/pregnant or dry/open. The 50 respondents also stated the size of herd that they considered manageable within their available resources.

### 2.4. Definitions and calculation of herd demographic rates

Replacement was defined as entry of a female of breeding age into the breeding herd and disposal as exit of a female of breeding age from the herd. Disposal comprised animals that died or were sold over the past 12 months. Reasons for disposal were in eight categories: disease (death from disease); poisoning (death from acaricide poisoning, snake bite and bloat); injury (sale or death due to accidents); sale to meet household needs for cash; sale because of poor performance (low milk yield, slow growth or infertility); sale because of old age; slaughter for meat; and unspecified reasons (death and sale).

Annual demographic rates of calving, mortality, selling and buying were calculated for each grazing system. Calculating these rates from the population as at 12 months preceding the survey would have ignored the purchases and shifts in age classes during the year. Therefore, for each animal class, except for calves, the denominator was the population on the day of survey (which included purchased animals) plus half the number of withdrawals (deaths and

sales) over the past 12 months. Rates describing events for calves were calculated with the total number born over the past 12 months as the denominator.

The number of heifer replacements reaching the breeding age as a proportion of the cows disposed ( $R$ ) was estimated as:

$$R = [(F/C) \cdot (1 - f_m - f_s) \cdot (1 - h_{m1} - h_{s1}) \cdot (1 - h_{m2} - h_{s2})] / (c_m + c_s) \quad (1)$$

where  $F$  is the number of heifer-calves born to  $C$  cows;  $f_m$  and  $f_s$  are their mortality and selling rates to weaning age, respectively;  $h_{m1}$  and  $h_{m2}$  are heifer mortality rates in the first year and in year two to breeding age, respectively;  $h_{s1}$  and  $h_{s2}$  are heifer selling rates in the first year and in year two to breeding age, respectively; and  $c_m$  and  $c_s$  are mortality and selling rates defining disposal rate of cows. The calculation of the rate  $R$  in Eq. (1) uses, in this case, a denominator  $C$  representing the number of cows 12 months previously.

### 2.5. Statistical analyses

The variables farm size, herd size, stocking rate, age at first calving and age at disposal had skewed distributions; hence they were log transformed for least-squares analyses using the general linear model:

$$Y_{ijk} = \mu + M_i + G_j + (M \times G)_{ij} + e_{ijk} \quad (2)$$

where  $Y_{ijk}$  is the log-transformed value of the relevant variable,  $M_i$  ( $i = 1, 2, 3$ ) is the effect of market access,  $G_j$  ( $j = 1, 2, 3$ ) is the effect of grazing system,  $(M \times G)_{ij}$  is the market access  $\times$  grazing system interaction and  $e_{ijk}$  is the residual error term for household  $k$  within  $(M \times G)_{ij}$ . This model, without the interaction term, was also fitted to logits of the proportions ( $r_{ij}/n_{ij}$ ) of births, deaths, sales and purchases in two-way tables (market access by grazing system) to estimate the annual demographic rates for each grazing system adjusted for market access. Because of evidence of over-dispersion in these models, influences of fixed effects on demographic rates were tested using an  $F$ -test based on the ratio of deviance values (Collett, 1991).

Correlation between farm size, herd size, stocking rate and proportions of animals sold within each

grazing system (ignoring the market access) were determined using the Spearman rank correlation method. The statistical significance of differences between pairs of grazing systems for the relative ranking of diseases of importance was determined using the Mann–Whitney rank sum test.

## 3. Results

### 3.1. Characteristics of dairy production systems

More than three-quarters (1355) of the stratified random sample of 1755 households were engaged in agricultural activities, with 73% (987) practising integrated crop-dairy production. Of the 987 crop-dairy households, 44, 33 and 23% practised zero-, semi-zero- and free-grazing systems, respectively. Most of the crop-dairy farmers (71%) kept one to three cattle. This is consistent with a preference for a herd size of not more than three cattle stated by 68% of the 50 households in the follow-up survey.

The analysis in Tables 1–3 focuses on herd dynamics under the influence of intensification, and consequently results for the effect of market access included in the model are not reported. The average farm size, herd size, number of cows and stocking rate were 1.7 ha, 3.2 cattle, 1.7 cows and 1.2 TLU ha<sup>-1</sup>, respectively, (Table 1). Farm size, herd size and number of cows owned decreased but the proportion of cows in the herd increased with an increase in intensification level, represented by free-, semi-zero- and zero-grazing systems, in that order ( $P < 0.01$ ). The proportion of cows in the herd averaged 0.51 (2.2/4.3) in free-grazing, 0.55 (1.7/3.1) in semi-zero-grazing and 0.62 (1.3/2.1) in zero-grazing farms (Table 1). However, stocking rate was 27% higher in zero-grazing than in free-grazing farms ( $P < 0.01$ ), corroborating correlation analyses showing that small farms kept smaller herds ( $r = 0.34$  to  $0.58$ ;  $P < 0.001$ ), but with higher stocking rates ( $r = -0.60$  to  $-0.74$ ;  $P < 0.001$ ).

Table 2 displays the estimated annual calving rates, ages at first calving, ages and parities of cows kept and ages of cows sold for the three grazing systems in the main cross-sectional survey. On average, annual calving rate was 0.58 and age at first calving 2.7 years. Calving rate was higher in free-

Table 1

Antilogarithms of least-squares means (with 95% confidence intervals) for farm size, herd size, number of cows and stocking rate for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Grazing system	Farms (n)	Farm size (ha)	Herd size (n)	Cows (n)	Stocking rate (TLU ha <sup>-1</sup> )
Free-	227	2.4 <sup>a</sup> (2.0, 2.6)	4.3 <sup>a</sup> (3.9, 4.7)	2.2 <sup>a</sup> (2.0, 2.3)	1.1 <sup>b</sup> (0.9, 1.2)
Semi-zero-	326	1.8 <sup>b</sup> (1.6, 2.0)	3.1 <sup>b</sup> (2.8, 3.4)	1.7 <sup>b</sup> (1.6, 1.8)	1.0 <sup>b</sup> (0.9, 1.1)
Zero-	434	0.9 <sup>c</sup> (0.7, 1.2)	2.1 <sup>c</sup> (1.7, 2.6)	1.3 <sup>c</sup> (1.1, 1.6)	1.4 <sup>a</sup> (1.1, 1.8)
Total	987	1.7	3.2	1.7	1.2

TLU, 1 for bull; 0.7 for cow; 0.5 for heifer and young bull; 0.2 for calves.  
Estimates with different letter superscripts are significantly different at  $P < 0.05$ .

Table 2

Estimates of average annual calving rates, ages at first calving, ages and parities of cows kept and ages of cows sold for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Variable	Grazing system	n	Average estimate	95% CI
Annual calving rate <sup>ML</sup>	Free-	697	0.69 ± 0.04 <sup>a</sup>	
	Semi-zero-	678	0.51 ± 0.04 <sup>b</sup>	
	Zero-	642	0.52 ± 0.05 <sup>b</sup>	
	Total	2017	0.58	
Age at first calving (years) <sup>ALS</sup>	Free-	116	2.8 <sup>a</sup>	2.6, 2.9
	Semi-zero-	198	2.7 <sup>a</sup>	2.6, 2.8
	Zero-	295	2.5 <sup>b</sup>	2.3, 2.6
	Total	609	2.7	
Age of cows kept (years) <sup>ALS</sup>	Free-	171	6.4 <sup>a</sup>	6.0, 6.6
	Semi-zero-	309	5.8 <sup>ab</sup>	5.5, 6.1
	Zero-	349	5.0 <sup>b</sup>	4.5, 5.6
	Total	829	5.7	
Parity of cows kept (number) <sup>ALS</sup>	Free-	171	2.6	2.3, 3.0
	Semi-zero-	314	2.5	2.0, 3.1
	Zero-	365	2.4	2.2, 2.6
	Total	850	2.5	
Age of cows sold (years) <sup>ALS</sup>	Free-	38	6.6	5.5, 7.9
	Semi-zero-	65	6.1	5.1, 7.3
	Zero-	57	6.0	4.1, 8.9
	Total	160	6.2	

ML, maximum likelihood estimates from logistic regression; ALS, antilogarithms of least-squares mean estimates.  
Estimates with different letter superscripts are significantly different at  $P < 0.05$ .

grazing farms (0.69) than in semi-zero-grazing (0.51) and zero-grazing farms (0.52), whereas age at first calving was earlier in zero-grazing (2.5 years) than in semi-zero-grazing (2.7 years) and free-grazing farms (2.8 years) ( $P < 0.05$ ). Cows were on average 5.7 years old with 2.5 parities and were sold when 6.2 years old. Parities and ages of cows kept and sold indicated that cows kept were on average generally younger as farmers intensified their dairy-

ing, as represented by free-, semi-zero- and zero-grazing systems, in that order.

### 3.2. Disposal and replacement patterns

Table 3 shows the predicted maximum likelihood estimates of annual demographic rates for the three grazing systems in the main cross-sectional survey. Mortality rates were high, ranging from 7 to 19%,

Table 3

Estimates from logistic regression of annual rates of mortality, selling and buying for each animal class for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Animal class	Grazing system	<i>n</i>	Mortality rate	Selling rate	Buying rate
Heifer-calves	Free-	264	0.15±0.03	0.01±0.01	0
	Semi-zero-	191	0.13±0.03	0.03±0.01	0
	Zero-	147	0.15±0.05	0.01±0.01	0.01±0.004
	Total	602	0.14	0.01	0
Heifers	Free-	386	0.08±0.02	0.07±0.02	0.05±0.01 <sup>b</sup>
	Semi-zero	326	0.12±0.02	0.09±0.02	0.07±0.02 <sup>ab</sup>
	Zero	308	0.07±0.02	0.15±0.03	0.12±0.02 <sup>a</sup>
	Total	1020	0.09	0.10	0.08
Cows	Free-	697	0.13±0.02	0.08±0.01	0.02±0.01 <sup>b</sup>
	Semi-zero	678	0.14±0.02	0.11±0.02	0.04±0.01 <sup>ab</sup>
	Zero-	642	0.12±0.02	0.14±0.02	0.09±0.02 <sup>a</sup>
	Total	2017	0.13	0.11	0.05
Male-calves	Free-	238	0.21±0.04	0.01±0.01	0
	Semi-zero-	164	0.19±0.04	0.02±0.01	0
	Zero-	164	0.14±0.04	0.03±0.01	0
	Total	566	0.18	0.02	0
Immature-males	Free-	143	0.16±0.04	0.14±0.06	0.03±0.01
	Semi-zero-	164	0.16±0.04	0.31±0.07	0.05±0.01
	Zero-	170	0.11±0.03	0.32±0.08	0.05±0.01
	Total	476	0.14	0.27	0.05
Mature bulls	Free-	235	0.13±0.03	0.34±0.08	0.07±0.02
	Semi-zero-	98	0.10±0.04	0.41±0.12	0.13±0.04
	Zero-	140	0.13±0.04	0.46±0.11	0.07±0.03
	Total	472	0.12	0.39	0.08

Estimates with different letter superscripts are significantly different at  $P < 0.05$ .

depending on animal class, but not significantly different across the grazing systems for any of the animal classes.

Selling rate of heifers and cows tended to be higher in zero- than in semi-zero- and free-grazing farms. This corroborated the correlation analyses, which indicated that small herds sold larger proportions of the total herd ( $r = -0.74$  to  $-0.86$ ;  $P < 0.001$ ). When averaged over all age classes, animal sales were highest (17%) in zero-grazing, intermediate (12%) in semi-zero-grazing and lowest (9%) in free-grazing farms (not shown in the table), suggesting an increased animal turnover as farmers intensified their dairying ( $P < 0.05$ ). Farmers practising zero grazing reported higher buying rates for heifers (0.12) and cows (0.09) than those practising semi-zero or free grazing, where the corresponding rates ranged from 0.02 to 0.07 ( $P < 0.05$ ).

Based on the demographic rates obtained in Table 2 (calving rates) and in Table 3 (mortality and selling

rates), Table 4 gives the estimated proportions of cows disposed, proportion of females born, proportion of females that died or were sold before breeding age and, by applying Eq. (1), the number of heifers available for replacement per cow disposed for the three grazing systems in the main cross-sectional survey. The annual average cow disposal rate was 0.21, 0.25 and 0.26 in free-, semi-zero- and zero-grazing systems, respectively. The reciprocal of the disposal rate yields the length of productive life, corresponding to 4.8, 4.0 and 3.8 years for the free-, semi-zero- and zero-grazing systems, respectively. The estimates indicate a tendency towards shorter productive life in those herds under increasing intensification management.

On average 0.43 of heifer-calves born were removed before reaching breeding age (see Table 4). Deaths (0.28) accounted for about two-thirds of the removals and the remaining third was due to sales (0.15). Sale of heifers before the breeding age

Table 4

Estimated proportions of cows disposed, proportion of females born, proportion of females that died or were sold before breeding age for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Variables	Grazing system			Total
	Free	Semi-zero	Zero	
Proportion of cows disposed	0.21	0.25	0.26	0.24
Proportion of females born	0.38	0.28	0.23	0.30
<i>Proportion of females born that:</i>				
died before reaching breeding age <sup>a</sup>	0.27	0.31	0.25	0.28
were sold before reaching breeding age <sup>a</sup>	0.11	0.15	0.22	0.15
reached breeding age	0.62	0.54	0.53	0.57
Number of females reaching breeding age as a ratio of cows disposed	1.11	0.61	0.46	0.71

<sup>a</sup> Cumulative proportions from birth to breeding age.

increased from a proportion of 0.11 to 0.22 with shift from free- to zero-grazing systems. Removal of heifers was such that those reaching breeding age each year as a proportion of cows disposed were 1.11 in free-, 0.61 in semi-zero- and 0.46 in zero-grazing farms. The estimates imply that, on average, semi-zero- and zero-grazing farms maintained insufficient number of heifers to replace the cows leaving the herd, whereas free-grazing farms had an annual surplus of 11%.

### 3.3. Exit reasons and farmers' perception of the relative importance of diseases

Diseases accounted for the largest proportion of female exits: 85% among heifer-calves, 38% among

heifers and 36% among cows (Table 5). The needs of households for cash were the second most frequent reason for female exits, accounting for over a quarter (27%) of the cow exits and a third (33%) of the heifer exits. Exits due to diseases or cash needs were each three to five times greater than those attributed to poor performance, which accounted for 10% of the cow exits and 5% of the heifer exits. On average, cows left the herd for poor performance at 7.2 years of age and for old age at 12.6 years of age. The follow-up survey data showed that a large majority (76%) of cows left a herd when lactating or pregnant, mainly in their second and third parities (Fig. 1). When asked to whom they sold their animals, farmers in most cases said that sales were within the local community.

Table 5

Frequency of reasons for exits of heifer-calves, heifers and cows in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Reason for disposal	Heifer-calves ( <i>n</i> = 79)	Heifers ( <i>n</i> = 167)	Cows ( <i>n</i> = 434)
<i>Involuntary reasons (%)</i>			
Diseases	85	38	36
Unspecified reasons	7	12	9
Injury	3	9	7
Poisoning	0	2	3
<i>Total involuntary</i>	<i>95</i>	<i>61</i>	<i>55</i>
<i>Voluntary reasons (%)</i>			
Cash needs	5	33	27
Poor performance	0	5	10
Old age	–	–	6
Slaughter for meat	0	1	2
<i>Total voluntary</i>	<i>5</i>	<i>39</i>	<i>45</i>

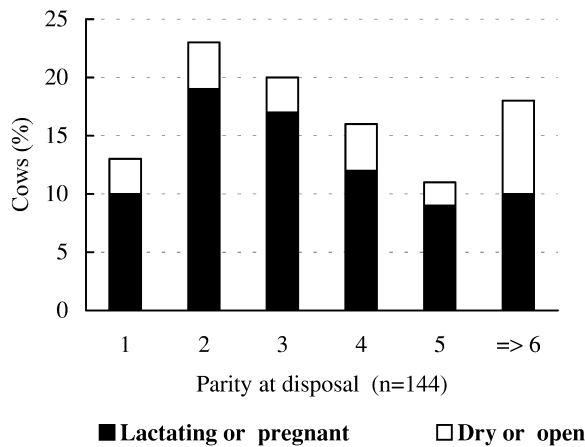


Fig. 1. Frequency (%) of cow disposals by parity and physiological status (lactating/pregnant or dry/open) in a follow-up survey of 50 smallholder farms in the Kenya highlands.

Table 6 displays farmers' ranking of diseases of importance in the three grazing systems from the main cross-sectional survey sample. We present only those diseases that farmers ranked differently ( $P < 0.01$ ). These were East Coast fever, Anaplasmosis and intestinal worm infestations, in that order. Farmers' ranking corroborated with the reported death cases. Suspected and/or confirmed cases of East Coast fever were 296 of which 51% died, and corresponding cases of anaplasmosis were 135 of which 24% died. East Coast fever and anaplasmosis were rated more important in free-grazing and in semi-zero-grazing than in zero-grazing farms. Dis-

Table 6  
Farmers' average ranking (with standard errors) of diseases of importance (1=low and 3=high) affecting dairy production in free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Grazing system	n	Disease		
		East Coast fever	Anaplasmosis	Intestinal worms
Free	227	2.5±0.02 <sup>a</sup>	1.8±0.02 <sup>a</sup>	1.2±0.11 <sup>c</sup>
Semi-zero	326	2.0±0.01	1.7±0.02 <sup>b</sup>	1.5±0.13 <sup>c</sup>
Zero	434	1.8±0.01 <sup>a</sup>	1.4±0.01 <sup>a,b</sup>	1.4±0.08
Total	987	2.1±0.01	1.7±0.02	1.4±0.06

Significant difference (Mann–Whitney test,  $P < 0.01$ ): <sup>a</sup>between free and zero grazing; <sup>b</sup>between semi zero and zero grazing; and <sup>c</sup>between free and semi-zero grazing.

eases that farmers did not rank differently across systems were abortion, pneumonia, mastitis, milk fever, foot problems and poisoning.

### 3.4. Sources of breeding stock

The households in the cross-sectional survey reported purchasing more cows (102) than heifers (78) as replacement animals over the previous 12 months. By origin, 90% of the cows and 94% of heifers were purchased from other smallholdings, whereas 10% of cows and 6% of heifers were from large-scale farms. Households in the follow-up survey owned 149 cows, of which 68% were born within the herd, 25% had been purchased from other smallholdings and 7% were purchased from large-scale farms. When cows and heifers were purchased they were mostly, in both surveys, from within the local community. Thus, the majority of dairy replacement animals were either reared in the herd in which they were producing or were purchased from another smallholding.

## 4. Discussion

### 4.1. Dairy production system

For a large majority of smallholders (73%) dairying is an integral part of mixed farming on holdings, which, on average, are less than two hectares. They integrate crops (for food and cash) and dairy production to diversify risks from dependency on a single crop or livestock enterprise. Mixed farming derives complementarities in resource use: crop residues and by-products from crop production constitute feeds for cattle, which return manure to maintain soil fertility and crop production (De Haan et al., 1997).

Zero-grazing is an important strategy through which smallholders in the densely populated highlands intensify their farming systems, particularly as farm sizes decrease. This is a consequence of high human population growth rate (3% annually) in the Kenya highlands (C.B.S., 2001) where inter-generation inheritance results in subdivision and fragmentation of farms. Consequently, the number of holdings increases, and they get smaller with smaller

herds. Where dairying is an integral part of the farming system, the increased number of individual holdings has increased the overall cattle population, putting pressure on feed resources. Indeed, Zemmeling et al. (1999) estimated that the actual herd size (211 000 Tropical Livestock Units (TLU)) in parts of the Kenya highlands was far in excess of the optimum herd size (130 000 TLU) to be supported by the available feed resources. This pressure on feed resources explains why the majority (70%) of the smallholders either keeps or prefers a herd of no more than three cattle.

Associated with intensification through the change from free to zero grazing are changes in herd structure with more emphasis on milk production and increased stocking rates. Higher stocking rates are maintained through cut-and-carry feeding of napier fodder and crop residues, fodder purchased from neighbours, forages collected from common properties (road and reserves, forests, schools) and purchased concentrate feeds (Reynolds et al., 1996; Lekasi et al., 1998; Utiger et al., 2000). The findings highlight the need for adequate access by smallholders to external feed resources if farmers are to sustain the intensification of their dairying.

#### 4.2. Cattle population dynamics

Diseases were the major cause of involuntary animal losses. Vector-borne and infectious diseases are locally important but often their incidence decreases with change from free- to zero-grazing systems, because of lowered exposure to ticks (Gitau et al., 1997; Siamba et al., 1999). Cattle in semi-zero- and free-grazing farms are commonly tick infested throughout the year, but those in zero-grazing farms experience increased tick infestation only during periods of drought when feeds are imported from common properties (Siamba et al., 1999). Farmers practising zero-grazing therefore attached less importance to the risk of East Coast fever and anaplasmosis than those who practise semi-zero and free grazing.

Nevertheless, mortality rates in all animal classes, which were generally high (7–19%), did not vary with grazing system. Losses due to animal diseases and their interaction with nutritional level are therefore a major constraint to smallholder dairying

irrespective of grazing system. Current policies in Kenya promote private sector participation in the delivery of livestock health inputs and services, including advice on dairy production (Owango et al., 1998). Efficient delivery of these private goods will be critical in enhancing the competitiveness of intensive smallholder dairying. This will require government support, because the efficiency of the private market is contingent upon the ability of the state in providing the public goods of infrastructure (e.g., rural access roads) and institutional support.

Whereas calving rate declined as smallholders intensified their dairying, age at first calving improved. Earlier age at first calving in zero-grazing farms may be attributed to the dominance of *Bos taurus* dairy breeds in these farms (Bebe et al., 2003) and also farmers' management strategy of retaining fewer heifers, possibly only when the need for a replacement was anticipated or when there were sufficient feed resources (Table 3). On the other hand, lower calving rates in the most intensive systems may have resulted partly from under-nutrition and partly from a management strategy of delaying service of cows after calving in order to maintain milk supply for the household (Odima et al., 1994).

The high mortality and low reproductive rates, considered together, resulted in high reproductive wastage in these smallholder herds, irrespective of the level of intensification. Reproductive wastage in smallholder dairying in the Tanzania highlands (Kanuya et al., 2000) and in Asia (Hermans et al., 1989; De Jong, 1996) has been associated with inadequate quantity and quality of feeds, lack of bulls, inefficient delivery of artificial insemination (AI), poor access to veterinary services and difficulties in oestrus detection. These also apply to smallholder dairying in the Kenya highlands (Odima et al., 1994; Omore et al., 1996; Owango et al., 1998; Lanyasunya et al., 1999). To overcome these constraints improved access to effective input services will be required. The strengthening of farmer co-operatives is one way to achieve this. For instance, a recent study in Kenya highlands showed that smallholder farmers were willing to invest in supplementary feeds, mainly milling by-products, when given credit (Romney et al., 2000).

A high proportion of voluntary exits of female

cattle (60% of cows and 85% of heifers) was due to a household's need for cash, and not poor performance (22% of cows and 13% of heifers), demonstrating the importance of dairy cattle as a means of accumulating fluid capital assets for the household. Cattle were frequently sold to generate cash for financing school fees, hospital bills and household investments, which required larger amounts of money than were available from daily sales of milk. Meeting these cash needs was of high priority to the household regardless of the herd size (small herds sold a larger proportions of the total herd) or reproductive status of the individual animals (a large proportion of the exits in the follow-up survey were lactating or pregnant cows before their fourth parity). This resulted in a large turnover of animals, which was particularly high in the zero-grazing farms, explaining why cows were younger and of shorter productive life as intensification progressed.

The high reproductive wastage and the high turnover of females were such that herds in zero- and semi-zero-grazing farms were often unable to maintain a sufficient number of heifers for replacement of cows leaving the herd (Table 4). This implies that these systems are unable to maintain their herds without an external supply of replacement animals. Consequently, farmers practising semi-zero- and zero-grazing systems purchased more replacement animals than those practising free-grazing systems. Purchased replacement animals comprised more cows (57%) than heifers (43%), possibly due to inadequate feed resources to raise heifers.

Sourcing of replacement animals was generally from within the local community, which allowed smallholders to more confidently verify the fertility and milk yield of the animal being purchased. Replacement animals from large-scale farms are generally expensive for the majority of smallholder farmers, who perceive them to be less adaptable to their feeding systems. The surplus replacement animals available in free-grazing farms thus served as replacement or foundation stocks for the existing or new farmers in the area. The change from free- to zero-grazing systems, however, can be expected to continue, given the continued subdivision of land through family inheritance. Therefore, the primary concern with this anticipated change in smallholder dairy production systems will be how to maintain a

continuous supply of replacement animals for the zero-grazing systems.

## 5. Conclusion

Increasing intensification influenced herd dynamics such that farmers practising semi-zero- and zero-grazing systems were unable to maintain sufficient heifers to replace the cows leaving the herd. Constraints to rearing replacement animals included high losses from animal diseases and inadequate access to feed resources, breeding services and credit. Sustained intensification of smallholder dairying in the Kenya highlands will depend upon finding solutions to these constraints. These solutions will include technical and institutional innovations to serve small-scale farms that may result in more stratification of the dairy sub-sector.

## Acknowledgements

The first author was supported by a research grant from The Netherlands Foundation for the Advancement of Tropical Research-WOTRO. The authors acknowledge the support of the Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) for this study. SDP was funded by the UK Department for International Development (DFID) for the benefit of developing countries.

## References

- Bebe, B.O., Udo, H.M.J., Thorpe, W., 2002. Development of smallholder dairy systems in the Kenya highlands. *Outlook Agric.* 31, 113–120.
- Bebe, B.O., Udo, H.M.J., Rowlands, G.J., Thorpe, W., 2003. Smallholder dairy systems in the Kenya highlands: breed preferences and breeding practices. *Livest. Prod. Sci.* doi:S0301-6226(03)00029-0.
- C.B.S., 1994. Kenya Population Census 1989. Office of the vice president and ministry of planning and national development, Vol. I, Central Bureau of Statistics, Nairobi, Kenya.
- C.B.S., 2001. The 1999 population and housing census, Vol. I.

- Population distribution by administrative area and urban centres. Central Bureau of Statistics, Ministry of Finance and Planning, Nairobi, Kenya.
- Collett, D., 1991. In: *Modelling Binary Data*. Chapman and Hall, London, p. 369.
- Conelly, W.T., 1998. Colonial Era Livestock Development Policy: Introduction of improved dairy cattle in high potential farming areas of Kenya. *World Dev.* 26, 1733–1748.
- De Haan, C., Steinfield, H., Blackburn, H., 1997. Livestock and the environment. finding a balance. FAO/USAID/The World Bank. WRENmedia, Eye, Suffolk, UK.
- De Jong, R., 1996. Dairy stock development and milk production with smallholders. PhD Thesis, Department of Animal Production Systems, Wageningen Agricultural University, The Netherlands, 303 pp.
- Delgado, C.L., Rosengrant M.W., Meyer, S., 2001. Livestock to 2020: The revolution continues. Paper presented to the International Agricultural Trade Research Consortium, Auckland, New Zealand, January, 2001.
- Devendra, C., 2001. Smallholder dairy production systems in developing countries: characteristics, potential and opportunities for improvement. A review. *Asian–Aust. J. Anim. Sci.* 14, 104–113.
- Devendra, C., Thomas, D., 2001. Smallholder farming systems in Asia. *Agric. Syst.* 71, 17–25.
- Gitau, G.K., Perry, B.D., Katende, J.M., McDermott, J.J., Morzaria, S.P., Young, A.S., 1997. The prevalence of serum antibodies to tick-borne infections in cattle in smallholder dairy farms in Murang'a district, Kenya: a cross-sectional study. *Prev. Vet. Med.* 30, 95–107.
- Hermans, C., Udo, H.M.J., Dawood, F., 1989. Cattle dynamics and their implications in Pabna District, Bangladesh. *Agric. Syst.* 29, 371–384.
- Jaetzold, R., Schmidt, H., 1983. In: *Farm Management Handbook of Kenya*, Vol. II. Part B, Central Kenya. Ministry of Agriculture, Nairobi, Kenya, pp. 510–620.
- Kanuya, N.L., Kessy, B.M., Bittegeko, S.B.P., Mdoe, N.S.Y., Aboud, A.A.O., 2000. Suboptimal reproductive performance of dairy cattle in smallholder herds in a rural highland area of northern Tanzania. *Prev. Vet. Med.* 45, 183–192.
- Lanyasunya, T.P., Wekesa, F.W., de Jong, R., Udo, H., Mukisira, E.A., Ole Sinkeet, N.S., 1999. Effects of a calf rearing package introduced to smallholder dairy farms in Bahati division, Nakuru district, Kenya. In: Proc. 6th Biennial KARI Scientific Conf. held on 9–13 November, 1998, Nairobi, Kenya, pp. 450–457.
- Lekasi, J.K., Tanner, J.C., Kimani, S.K., Harris, P.J.C., 1998. In: *Manure Management in the Kenya Highlands: Practices and Potential*. HDRA Publications, Coventry, UK, p. 24.
- Odima, P.A., McDermott, J.J., Mutiga, E.R., 1994. Reproductive performance of dairy cows on smallholder farms in Kiambu district, Kenya. *Kenya Vet.* 18, 366.
- Omoro, A.O., McDermott, J.J., Gitau, G.K., 1996. In: Proc. 5th Scientific Conf. of the Kenya Agricultural Research Institute, October 14–16, 1996, Nairobi, Kenya. Factors influencing production on smallholder dairy farms in Central Kenya, pp. 370–379.
- Owango, M., Lukuyu, B., Staal, S.J., Kenyanjui, M., Njumbi, D., Thorpe, W., 1998. Dairy co-operatives and policy reforms in Kenya: effects of livestock service and milk market liberalisation. *Food Policy* 23, 173–185.
- Reynolds, L., Metz, T., Kiptarus, J., 1996. Smallholder dairy production in Kenya. *World Anim. Rev.* 87 (2), 66–72.
- Romney, D., Kaitho, R., Biwott, J., Wambugu, M., Chege, L., Omoro, A., Staal, S., Wanjohi, P., Thorpe, W., 2000. In: Proc. 3rd All Africa Conf. on Animal Agriculture and 11th Conf. of the Egyptian Soc. Anim. Prod., Alexandria, Egypt from 6th–9th November 2000. Technology development and field testing: access to credit to allow smallholder dairy farmers in Central Kenya to reallocate concentrates during lactation, p. 18.
- Siamba, D.N., Lokwaleput, I., Onyango, T.A., Nampaso, J., Nyakira, B.S., 1999. In: Proc. 6th Biennial KARI Scientific Conf. held on 9–13 November, 1998, Nairobi, Kenya. Ticks and tick-borne diseases: Epidemiology, control practices and prospects for integrated ticks and tick-borne disease management in Bahati, Nakuru, pp. 34–46.
- Staal, S.J., Owango, M., Muriuki, H., Kenyanjui, M., Lukuyu, B., Njoroge, L., Njubi, D., Baltenweck, I., Musembi, F., Bwana, O., Muriuki, K., Gichungu, G., Omoro A., Thorpe, W., 2001. Dairy Systems Characterisation of Greater Nairobi Milk Shed. SDP (Smallholder Dairy (R&D) Project) Research Report, Ministry of Agriculture, Kenya Agricultural Research Institute and International Livestock Research Institute, Nairobi, Kenya, 73 pp.
- Tulachan, M.P., Partap, T., Maki-Hokkonen, J., 2000. Livestock in the mountains and highlands of Asia, Africa and South America: an overview of research and development issues and challenges. In: Tulachan, P.M., Saleem, M.A.A., Maki-Hokkonen, J., Partap, T. (Eds.), *Contribution of Livestock To Mountain Livelihoods: Research and Development Issues*. International Centre for Integrated Mountain Development (ICIMOD), pp. 3–31.
- Utiger, C., Romney, D., Njoroge, L., Staal, S., Lukuyu, B., Chege, L., 2000. In: Proc. 3rd All Africa Conf. on Animal Agriculture and 11th Conf. of the Egyptian Soc. Anim. Prod., Alexandria, Egypt from 6th–9th November 2000. Nutrient flows and balances in intensive crop-dairy production systems in the Kenya highlands, p. 137.
- Zemmelink, G., Romney, D.L., Kaitho, R.J., 1999. In: *Outcome and Perspective of Collaborative Research*, 11th International Symposium on Tropical Animal Health and Production. Utrecht University, Faculty of Veterinary Medicine, The Netherlands, 5th November 1999. Dairy farming in Kenya: Resources and nitrogen flows, pp. 46–50.