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Research Article

Morbidity and Productivity Estimates in Smallholder Livestock Farms in Machakos County, Kenya

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Abstract

The study to obtain morbidity and productivity estimates was undertaken using a longitudinal observational data collection method. A total of 14 farms were selected randomly from 7 administrative divisions for monthly data collection for a period of 12 months. The main constraints identified in order of importance were livestock diseases, poor access to livestock and livestock product markets, inadequate veterinary infrastructure and inadequate feed.

Tick infestations and non- specific diarrhoea were the most common causes of morbidity in cattle. ECF and anaplasma were the most important tick-borne diseases of cattle while.

helminthosis and pneumonia were the most commonly diagnosed disease conditions in sheep and goats.

Livestock productivity in the study area was found to be sub-optimal. At a mean daily production of 1.98 litres, milk production in cattle was less than a third of the average daily milk production recorded in the high potential areas of the country while the breeding intervals for goats and sheep was once every 12 months instead of the optimal interval of once every 6 months

The overall mean birth weight for the calves was 27.45kg (range 18-43) while the overall mean birth weight for sheep and goats was 3.73 kg (range 2- 6).

The overall mean weaning age for calves in the study sites was 101.24 days while the mean weaning weight for sheep and goats was 143 days.

It can be concluded from the study that cultural beliefs in keeping livestock as a status symbol played a bigger role in determining offtake than previously thought for both cattle and small ruminants in the study site.

Keywords: Morbidity; Mortality; Offtake; Weaning; Productivity

Introduction

In the sub-humid zones of sub-Saharan Africa, vector-borne diseases limit the expansion of cattle production systems [3]. Disease sharply reduces the productivity of livestock in all agro-ecological zones (AEZs) and production systems with trypanosomiasis as the most important one in sub-Saharan Africa. Tick transmitted and tick associated diseases together with those caused by internal parasites are the next most important group of diseases limiting cattle productivity [4,27]. Past studies in Kenya have enumerated various cattle productivity constraints. Studies in Kiambu District indicated

that the two main constraints lowering milk production in smallholder dairy farms were limited availability of feed [14] and high calf mortality. The high mortality is worsened by slow growth rate due to underfeeding of calves that result in delayed puberty and age at first calving [16].

Studies carried out at the Coast Province of Kenya showed that the major vector-borne disease in smallholder dairy farms that caused substantial losses was East Coast fever [40]. Surveys in Kisii and Homa Bay districts in Kenya documented calf mortality, diseases, poor artificial insemination (AI) services and feed shortages during the dry season as major constraints to dairy cattle development [20]. Other factors that limit cattle productivity in smallholder livestock production systems include poor veterinary services, insufficient marketing channels and lack of farm inputs [25].

Small ruminant production is constrained by biological, technical and social factors. High mortality (40% pre-weaning) leading to low off-take is considered to be an important constraint to this class of ruminants with disease as the most important constraint in Kenya [3]. Apart from diseases, poor management and lack of efficient veterinary clinical and extension services limit productivity of small ruminants [27]. Cross-sectional studies carried out in Machakos [6,26] identified diseases, lack of adequate veterinary services, unavailability of water, high costs of animal concentrate feeds and labour shortages as key constraints to livestock production. However, the studies did not quantify these constraints in terms of economic losses or their impact on the different livestock species kept by the farmers. In the survey by Wesonga [38], Foot and Mouth Disease (FMD), trypanosomosis, Contagious Bovine Pleuropneumonia CBPP) and East Coast fever (ECF) were ranked as the main constraints to livestock production based solely on farmers' perception. The cross-sectional survey undertaken by Abdi Ali [1], lists feed and tick-borne diseases as the main constraints to cattle production in the County. No attempt was made during these studies to determine the prevalence and incidence of these diseases and the associated mortalities. These are key parameters with regard to determining disease risk and in the design of appropriate intervention measures. Measurements of these parameters were the basis of quantification of the risk and economic importance of livestock diseases in the district in the current study.

In this paper, factors affecting livestock productivity in both cattle and small ruminants are assessed.

Materials And Methods

Study site

The study was conducted in the larger Machakos District (now known as Machakos County), one of the districts in the Eastern part of Kenya. The County is subdivided into seven administrative Divisions, namely Athi River, Kangundo, Machakos, Matungulu, Mwala and Yatta (for clarity purposes, one of the divisions at the time when the study was undertaken shares the same name with the study county-Machakos). The County lies between latitudes 0.45'S and1.31'S and longitudes 36.45'E and 37.45'E and covers an area of 6,850 km^2.

The average annual rainfall in the County ranges from 500-1,300 mm. The rains are normally concentrated in two short seasons: end of March to May, and end of October to December. The highest rainfall is received in April. The mean temperature range is 18-25^{0}C.

The farming system in the area is described as Dual-Purpose Cattle Small Scale (DPCSS)/ Sheep and Goats Small Scale (SGSS) [29]. Other livestock kept include donkeys, pigs, poultry, and rabbits. The grazing system is predominantly traditional free ranging system [39] but a few farmers practice zero grazing. The majority of cattle reared are the indigenous zebu cattle but some farmers also keep improved breeds of dairy cattle, especially in Matungulu and Kangundo Divisions.

Selection of the study farms

The study was carried out in seven administrative sub-locations (Kiatineni, Kalandini, Katine, Ndunduni, Kathome, Katani and Ngelani) displayed on the map of Machakos County. Milani sub-location in Ndithini Division was omitted because of inaccessibility during the rainy season. Using a random number table, four farms from each of the three divisions (Kangundo, Matungulu and Athi River) and two from Ndithini Division were randomly selected for the study from a sampling frame consisting of 200 farms (that had participated in an earlier cross-sectional survey).

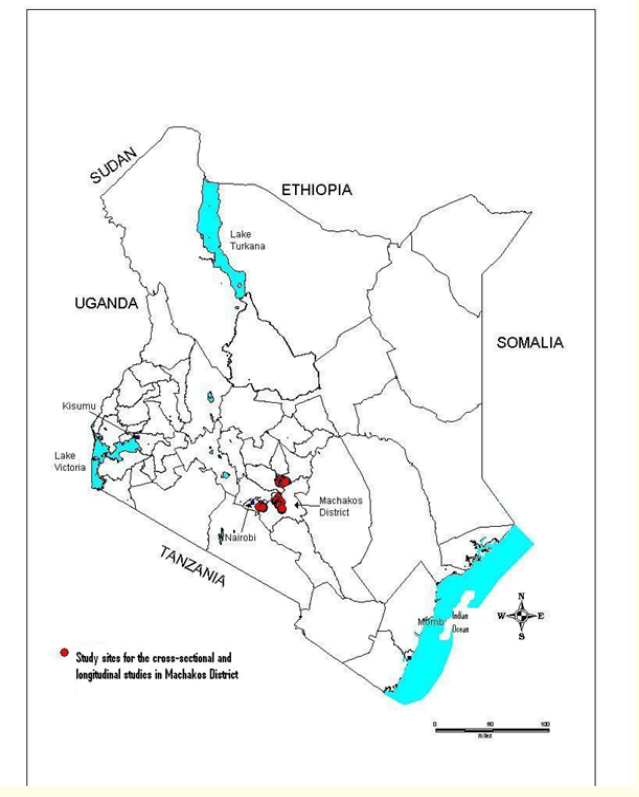

Figure 1: Map of Kenya showing Machakos County and the study site.

Milani sub-location was omitted from the list of selected sub-locations due to concerns about accessibility during the rainy seasons. Thus, fourteen herds were selected for the study.

The selected farms were then followed up for 12 months.

Recruitment of study animals

All young animals (calves, lambs and kids) found on the 14 farms at the time of the first farm visits in were recorded and ear-tagged for ease of identification. Other young animals (calves, kids and lambs) were recruited as they entered the study population mainly through births.

Monitoring of animal health and productivity

Data collection

A notebook was issued to all the study farmers for keeping simple farm records such as livestock births, deaths, sales and milk production. All the farms were followed- up on monthly basis for 12 months. During each of the farm monitoring visits, a short questionnaire to collect both farm and animal level data was administered. The information sought included:

- Birth weights.
- Occurrence of diseases.
- Herd dynamics (births, mortality, culling rates, sales).
- Weaning weights and ages.
- Fertility and breeding female management.
- Milk production of cows calving during the observation period.
- Tick challenge. On every visit all selected animals (cattle, sheep and goats) on the farms were observed for presence of ticks.
- Tick control. Tick control was categorized as follows:

Regular= acaricide (dip, spray or pour- on) applied according to manufacturers 'instructions at 1-2 weeks interval. Irregular= acaricide (dip, spray or pour- on) applied according to manufacturers' instructions only at times of high tick challenge.

None= no tick control measures used.

Other information recorded during the monthly visits were Veterinary interventions and farm management practices undertaken (such as treatments, castrations, dehorning, vaccinations and deworming) between visits. Details of the date(s) when the interventions were undertaken as well as the costs were recorded.

Questionnaires were administered to the designated head of the household or the person in charge of the management of the farm. For each of the administrative sub- locations, the local animal health assistant was recruited as an enumerator to perform the interviews in the local Kikamba language.

Disease diagnosis and reporting

Besides monthly visits by the principal investigator, occurrence of disease on the selected farms was monitored on a daily basis by the livestock owner. Farmers were instructed to report all suspected cases of disease to either the animal health assistant or the principal investigator to enhance data collection and recording. In three of the sub-locations (Katine, Ndithini and Ndunduni), the local animal health assistants were recruited to monitor the occurrence of diseases. Other farms relied on mobile phone communication to notify the chief investigator of disease occurrences who then visited such farms within a period of not more than 24 hours. The animal health assistants were also instructed to notify the principal investigator of disease conditions of which they could not make a diagnosis.

To avoid losing any of the recruited animals particularly calves to Tick Borne Disease (TBDs), t livestock owners were also trained in early recognition of clinical signs of TBDs, namely, East Coast Fever (ECF), anaplasma, cowdriosis (heartwater) and babesiosis. To enhance reporting and confirmation of diseases, all clinical cases of TBDs in cattle on the study farms were treated free of charge throughout the trial period.

Diagnosis and confirmation of common infections

General bacterial infections were confirmed on the basis of response to antibiotic treatment reported by the farmers, three to four days after the treatment.

Mange and mycotic infections were confirmed from the observed lesions and microscopic examination. Areas of thickened skin in obviously itchy animals were very suggestive of mites, particularly if there was no evidence of lice. Skin scrapings were taken from the thickened sections for examination under a microscope in the laboratory.

Helminth infections were confirmed through examination of faecal samples using the quantitative McMaster floatation method [35] for detection of nematode eggs and cestode eggs and coccidian oocysts. A simple sedimentation method was used for detection of trematode eggs. Animals with faecal nematode egg counts of up to 100,000 eggs per gram of faeces (epg) were categorized as suffering from acute nematode infection while those with faecal egg counts of 2,000 or less were considered to be suffering from chronic nematode infection [2,24] Diagnosis of helminthiasis was done in conjunction with clinical signs such as anemia, edema in the mandibular region, weakness, unthriftness and emaciation.

The symptoms on which diagnosis of malnutrition was based included weakness with protrusion of bones of the shoulders, ribs, backbone and hips, sunken eyes and tucked up abdomens. On post-mortem, it was diagnosed based on lack of fat under the skin, very little body fat around the heart, kidneys and other organs and within the bone marrow, reduced muscle mass, and shrunken body organs.

Collection of data on animal productivity and herd dynamics

The farmers were requested to record in the notebooks births, deaths and animals sold or brought into the farm. Farmers with lactating animals were asked to record the daily milk production. In the three sub-locations where AHAs were available, they were asked to make regular visits to the farms to ensure that farmers made the required entries into the notebooks. The live weight of all calves was measured and recorded by the same person (the chief

investigator) using a weight band (Dalton supplies) during the monthly visits. Live weights of kids and lambs were taken using a spring weigh scale (Hanson® Model 21). Farmers were asked to report animal births (and hence date of calving) as soon as possible to enable birth weights to be taken. Records were also taken of when calves, lambs and kids were weaned. Data on cases of infertility in cows and breeding management were also recorded.

Estimating productivity parameters

Productivity rate

The productivity rates and the formula used to derive them are summarized in Table 1. The rates were based on the twelve- month follow up period. Data on female infertility and management were also obtained. Infertility was defined as diminished or lack of capacity to produce viable offspring.

Birth weights, weight at weaning and age at weaning

Birth weights, weight at weaning and age at weaning were obtained for calves, kids and lambs born during the 12-month observation period. The mean birth weights were derived only for the animals whose records were taken within 24 hours of birth.

Estimation of milk production

Farmers kept records of daily milk output from all cows that calved and those that were already lactating during the observation period. Measurements were done in litres using calibrated 1 litre plastic cups, beer bottles (0.5 litres) or soda bottles (0.3 litres). Two milk production parameters; mean daily yield per cow and annual lactation yield were estimated. The production estimates were made for three periods categorised as peak (1 to 90 days), declines (91 to 180 days) and late (181 to 365 days) phases of lactation.

Parameter	Definition
Bull/cow ratio	$\frac{\text{Number of mature bulls}}{\text{Number of cows}}$
Parturition rate	Number of parturitions per female per year
Off-take rate	$\frac{\text{Sales/exits x 100}}{\text{Herd size}}$

Table 1: Definition of productivity parameters estimated during the longitudinal study of smallholder farms in Machakos District.

Meteorological data

The main meteorological station nearest to the longitudinal sites was Katumani, close to Machakos town. Rainfall figures, daily minimum and maximum temperatures for the period of the longitudinal study were derived from records kept at the station. The mean monthly values were then calculated from the daily values.

Data management and analysis

Three separate dataset files for cattle, sheep and goats were designed in Microsoft Access (Microsoft Corporation, USA) to store data on individual animal variables (animal number, age, sex, breed) visit variables (animal number, entries, exits, diseases, tick counts, applied methods of disease control) and farm level variables (division, location, farm code). After screening the files for errors, they were exported to STATA Version 10 (StataCorp, 2007) program for analysis. Risk periods for calculation of incidence rates for various disease events were calculated in Microsoft Excel program (Microsoft Corporation, USA) after exporting the relevant data files from the Access program.

Results

Characteristics of the study farms

The characteristics of the 14 study farms are summarized in Table 2. The average size of the farms was 18.9 acres (range 1.5 to 72). All the farms practiced mixed farming. The average number of cattle was 15.8 (range 4-47). Only 2 (14.2%) of the farms (all in Kangundo Division) had improved (indigenous zebu/ exotic crosses) dairy cattle that were zero-grazed. Cattle on the remaining 12 farms (85.7%) were reared under the free grazing system.

Sheep were the least common species of livestock on the study farms. The average number of sheep on the farms was 6 (range 0-24) while the average number of goats was 12.1 (range 0-50). The breeds of sheep and goats found on the farms were indigenous breeds of sheep (red Maasai) and goats (the small East African goat).

The housing for calves, goats and sheep consisted of simple grass thatched or galvanised sheets roofs supported by gum or eucalyptus poles. The walls consisted of widely spaced eucalyptus poles designed to keep the animals confined and keep predators away.

Division	Farm size (acres)	No of cattle	No of sheep	No of goats
Athi River	25	20	5	0
	15	14	0	12
	70	47	24	43
	72	40	15	50
Kangundo	9	5	3	0
	1.5	5	0	2
	10	20	0	26
	2	4	0	2
Matungulu	20	30	15	10
	4	12	6	0
	7	4	12	2
	8	4	4	3
Ndithini	18	8	0	20
	3	8	0	0
Total	264.5	221	84	170
Average	18.9	15.8	6	12.1

Table 2: Farm characteristics of the 14 farms that participated in the longitudinal study in Machakos District.

Cohort dynamics

Cattle cohort dynamics

Initially, 17 calves and 7 yearlings with birth and disease history records were recruited (Table 3). These calves and yearlings were found on 13 of the farms. Calf entries resulted mainly from births within the study farms. Out of a total of 65 new entries observed, 56 (86.2%) were from births with male calves contributing 29 (51.7%) of the births. No calving took place in one of the farms throughout the study period. Six calves and 3 yearlings entered the farms from other farms as gifts or entrustments. Of the 9 calves and yearlings that were transferred into the selected farms during the study, 6 were female and 3 were male. Sixty (92.3%) of the new entries were indigenous (zebu) while 5 five (7.7%) were exotic. A total of 26 calves that contributed to the follow–ups exited from the study cohort before the end of the study due to deaths, sales, theft or transfer out of farms as gifts or entrustments. Of the exits, 16 (61.5%) were female and the other 10 were male. Twenty-three (88.4%) of the exits were calves or yearlings of indigenous (Zebu) breed. Fourteen (53.8%) of the exits came from Athi River, Kangundo 5 (19.2%), Ndithini 2 (7.7%) and 5 (19.2) from Matungulu Division.

No adult cattle were brought into the any of the recruited farms during the study period. However, five animals, all cows exited during the study period. Three cows died during the observational period while 1 cow each was given out as a present or sold. No cow or breeding bull was culled during the study period.

Dynamics of kids and lambs

Twenty-eight lambs/kids and 7 weaners were originally recruited into the study (Table 4). The kids and lambs were recruited from each of the selected farms while the weaners were found on 5 (35.7%) of the farms. The 12 monitoring visits resulted into 632 individual observations for goats and sheep. New entries resulted mainly from births within the farms. Of the 43 new entries, 34 (79.0%) were from births. Female kids/ lambs contributed 24 (70.5 %) of the new births.

Entries since precious visit				Withdrawals since previous visit					
Visit Number	Births	Transfers	Total	Deaths	Sales	Transfers	Theft	Total	No. calves/yearlings observed
Initial				N/A	N/A	N/A	N/A	N/A	24
1	6		6	0	0	0	0	0	30
2	6	1	7	2	0	0	0	2	35
3	7	5	12	1	0	3	1	5	42
4	2	1	3	2	2	0	1	5	40
5	3		3	1	2	0	0	3	40
6	2		2	0	0	1	0	1	41
7	4		4	1	0	2	1	4	41
8	7		7	0	0	0	0	0	48
9	3	2	5	1	0	0	0	1	52
10	6		6	1	2	0	0	3	55
11	5		5	0	1	1	0	2	58
12	5		5	0	0	0	0	0	63
Total	56	9*	65	9	7	7	3	26	

Table 3: A cohort of calves/yearlings monitored for 12 months and reasons for exit from the study.

*Three of the transfers into the study farms were yearlings.

Eight goats and sheep (4 weaners and 4 adults) were bought and brought into the farms during the study. One goat (a male adult) entered one of the farms as a gift. Of the new entries that entered the farms through purchasing or as gifts, 5 were male while 4 were female.

Twenty one (48.8%) of the new entries were recorded in Athi River Division. Five (11.6%) new entries were recorded in Kangundo Division. Ndithini had 6 (14.0%) while Matungulu Divisions had 11 (25.6%) new entries.

A total of 14 exits were recorded during the study due to deaths, sales, theft or transfer out of the farms as gifts or entrustments (Table 4). Five of the exits were a result of death from disease, 4 animals were sold, another 4 were transferred to other farms while 1 animal was stolen from one of the farms.

Entries since precious visit					Withdrawals since previous visit					
Visit Number	Births	Purchase	Transfers	Total	Deaths	Sales	Transfers	Theft	Total	No. kids/lambs observed
Initial	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28
1	2	0	0	2	0	0	2	0	2	28
2	2	1	0	3	0	0	0	0	0	31
3	1	0	0	1	1	0	0	0	1	31
4	4	0	0	4	1	0	0	0	1	34
5	1	0	0	1	1	1	0	1	3	32
6	2	4	1	7	0	0	1	0	1	38
7	6	1	0	7	1	0	0	0	1	44
8	5	0	0	5	0	0	1	0	1	48
9	4	0	0	4	0	0	0	0	0	52
10	2	2	0	4	0	0	0	0	0	56
11	1	0	0	1	1	2	0	0	3	54
12	4	0	0	4	0	1	0	0	1	57
Total	34	8	1	43	5	4	4	1	14	

Table 4: A cohort of goats and sheep followed up for 12 months in Machakos District, reasons for exit from the study.

Mortality rates

Eleven cattle died during the follow-up period converting to an overall crude mortality rate of 11.6% per cow-year. Of the 11 that died, 8 were calves and 3 were adults.

Three calves died of East Coast Fever (ECF), 4 calves died suddenly of a disease condition that could not be established and 1 calf died of diarrhoea.

The cause specific annual mortality rates for ECF, non-specific disease condition and diarrhoea were 6.56%, 8.74% and 2.19% respectively per cow year. One cow each died of milk fever, malnutrition and injuries as a result of falling into a deep pit. This converted to a cause specific annual mortality rate of 3.27% per cow year

Morbidity in sheep and goats

A variety of diseases/conditions were observed in both sheep and goats during the follow-up period. The cases were too few to enable the computation of true rates as was done for cattle diseases. However, helminthosis had the highest number of cases (8) detected in both species followed by 7 suspected cases of Contagious Caprine Pleuropneumonia (CCPP) (Table 5). The helminths identified were *Trichostrongylus colubriformis*. Pneumonia, diarrhoea due to bacterial infections, severe flea infestations and mange were the other diseases detected in small ruminants. The 7-suspected cases of CCPP were reported in Ngelani sub-location of Athi River Division. All the goats died despite attempts by the farmer to treat with antibiotics. Confirmation of diagnosis was not done as the farmers did not report the outbreak immediately it occurred. The source of the CCPP outbreak was goats reportedly sourced from North Eastern Kenya.

Estimates of productivity parameter

Mean daily milk yield

A total of 44 lactating cows were monitored (Table 6). The mean daily milk yield was significantly ($p<0.05$) higher for the exotic breeds (6.22 litres) than for the indigenous (1.86 litres) zebu breeds.

Species	Disease/ Condition							
	Helminthosis	Pneumonia	Fleas	Mange	Diarrhea	CCPP (suspected)	Injuries	Non-specific diagnosis
Sheep	3	1	0	0	1	0	1	2
Goats	5	3	3	1	3	7	1	1
Total	8	4	3	1	4	7	2	3

Table 5: Distribution of cases of disease/conditions in sheep and goats during a one-year follow-up period in Machakos District.

Breed	No. of lactating cows	Mean milk yield (litres)	95% CI	
			Lower	Upper
Exotic crosses	7	6.22	6.17	6.27
Indigenous breed	37	1.86	1.85	1.87
Overall	44	1.97	1.98	1.96

Table 6: Comparison of the mean daily milk yield between exotic crosses and indigenous breeds of cattle, in Machakos District.

The annual lactation curves

The decline of milk yield was more pronounced for exotic breeds but was more gradual for indigenous cattle (Figure 2). The milk yield for the exotic breeds was higher than for the indigenous breeds for the entire follow-up period. A sharp fall in milk yield was observed for exotic crosses between the first and sixth month of lactation that coincided with the onset of a prolonged dry period.

Birth weights and age at weaning

A total of 51 calves and a combined total of 34 lambs and kids were recorded within 24 hours of birth (Tables 7,8). The overall mean birth weight for the calves was 27.45kg (range 18-43). However, the birth weights were higher for exotic cross calves (37 kg) than for the indigenous calves (26kg) and female calves (29 kg) on average weighed more than male calves (26 kg) (Table 8). The high-

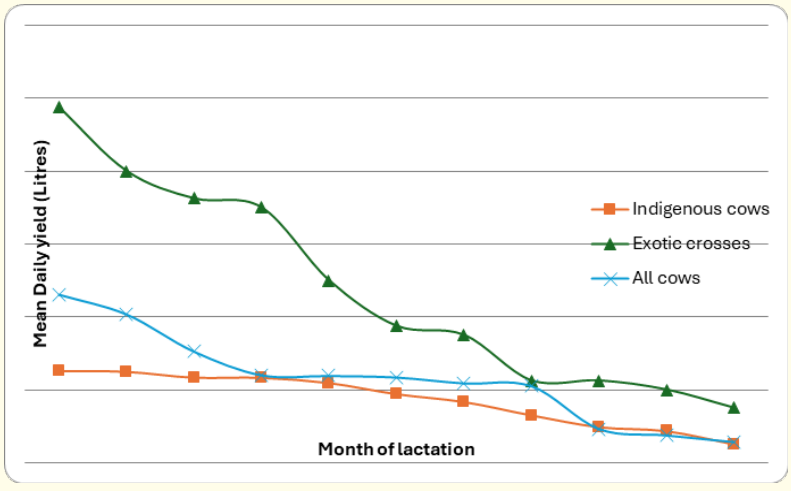

Figure 2: Comparative annual lactation curves for exotic cross breeds, indigenous zebu and all cows (combined) monitored in the four divisions of Machakos County.

Variable Level	No of calves	Mean birth weight in Kg (range)
Division Athi River	28	27.50 (20-38)
Kangundo	9	32.78 (24-43)
Matungulu	8	21.75 (18-28)
Ndithini	6	26.83 (21-32)
Sex Male	24	25.67 (18-35)
Female	27	29.03 (20-43)
Breed Indigenous	46	26.41 (18-38)
Exotic	5	37.0 (34-43)
Overall		27.5 (18-43)

Table 7: Distribution of calf birth weights by division, sex and breed in Machakos County.

Variable Level	No of sheep and goats	Mean birth weight in kg	(range)
Division			
Athi River	18	3.61	2-6
Kangundo	4	4.25	3-6
Matungulu	10	3.91	2-6
Ndithini	2	3.54	2-6
Sex Male	10	3.97	2-6
Female	24	3.54	2-6
Overall		3.73	2-6

Table 8: Distribution of kid and lamb birth weights by division and sex in Machakos District.

est birth weights were recorded for calves in Kangundo Division (32.8kg) and the least in Matungulu Division (21.8kg). The overall mean birth weight for sheep and goats was 3.73kg (range 2- 6). Male goats and sheep (3.97kg) on average weighed more than female goats and sheep (3.54 kg). The highest birth weights were recorded in Kangundo Division (4.25 kg) and least in Ndithini (2.00kg).

Weaning age

The overall mean weaning age for calves in the study sites was 101.24 days (Table 9). Athi River Division had the lowest mean weaning age (76.2 days) while Kangundo had the highest mean weaning age (140 days). Male calves were weaned at a significantly ($p < 0.05$) earlier age than the female calves. There was no significant difference in the mean weaning age between the indigenous and exotic crossbreeds of cattle. Calves in Ndithini Division had the highest mean weaning weight (89.2kg). The average mean weaning weight for the indigenous calves was higher than that of the exotic cross calves.

The average weaning age for goats and sheep was 143 days (Table 10). The lowest weaning age for the small ruminants was

Variable	Level	Mean age (days) at weaning	Mean weight in kg (range)
Division	Athi River	76.15 (3-361)	67.57 (23-134)
	Kangundo	140.00 (11-328)	79.63 (24-154)
	Matungulu	116.93 (4-537)	58.46 (18-143)
	*Ndithini	-	-
Sex	Male	83.42 (3-361)	70.52 (18-23)
	Female	117.69 (7-537)	72.33 (23-143)
Breed	Exotic Cross	102.40 (11-283)	67.14 (34-143)
	Indigenous	100.95 (3-537)	70.95 (18-154)
Overall		101.24 (3-537	70.52 (18-154)

Table 9: Distribution of weaning age and weight by division, sex and breed in Machakos District.
*Only one calf was weaned on the selected farms during the study period.

Variable	Level	Mean age (days) at weaning (range)	Mean weight (kg) at weaning (range)
Division	Athi River	138.42 (28-248)	12.34 (3-20)
	Kangundo	163.06 (30-248)	11.97 (3-16)
	Matungulu	122.00 (28-235)	11.09 (2-19)
	Ndithini	160.33 (128-218)	16.00 (13-16)
Sex	Male	136.75 (28-248)	11.71 (3-20)
	Female	154.54 (30-248)	13.34 (2-20)
Overall		143.23 (28-248)	12.25 (2-20)

Table 10: Goat and sheep weaning age and weight in the four divisions of Machakos District during the observational study.

recorded in Matungulu Division (122 days) and the highest in Kangundo Division (163 days). Male goats and sheep were weaned at a lower mean age (137 days) than the female goats and sheep (155 days).

Goats and sheep were weaned at a mean weight of 12.25kg. The lowest mean weaning weight was recorded in Matungulu Division (11.09kg) and the highest in Ndithini (16.00kg). Female goats and sheep were weaned at a higher mean weight 13.34kg compared to the male animals (11.71kg).

Bull/cow ratio

The number of mature bulls and breeding females was 47 and 70, respectively, equivalent to a bull/cow ratio of 1:1.5. However, approximately 50% of the bulls were castrated and thus the breeding bull/cow ratio was 1:3.0. The two farms that kept exotic crosses relied on artificial insemination services for breeding. Most of the farms that reared indigenous cows shared one bull that they considered to be of "superior genetic" make up. The choice of the suitable breeding bull was based on physical characteristics such as body size, hump size or "skin" colour.

Female fertility and management

Four cases of infertility were reported during the study period, two in Kathome sub-location and 1 case each in Kalandini and Ndunduni sub-locations. The common practice was to serve cows 4-5 months after calving. Calves were allowed to suckle up to 2-3 months before cows calved. Goats and sheep on average kidded/lambed once a year.

Livestock off-takes

Livestock off-take was defined as the proportion of animals annually leaving the total herd/flock due to slaughters, sales or other transactions such as exchanges, gifts and loans. Death was excluded from the definition.

The total numbers of cattle, sheep and goats on each of the study farms are shown in Table 2. The number of cattle that exited the study farms in Athi River, Kangundo, Ndithini and Matungulu Divisions was 7, 4, 2 and 3 respectively. This converted into off-take rates of 5.79%, 11.76%, 12.50% and 6.00% respectively.

The corresponding number of sheep and goats that exited the study farms in the four divisions was 3, 3, 0 and 2 respectively. This converted into off-take rates of 2.01%, 9.10%, 0 and 3.85% respectively.

Discussion and Conclusion

There was a consistently higher entry rate to the study herd compared to the exit rate resulting into an increase of the originally recruited (calf, kid and lamb) cohorts. Births contributed the majority of the entries. These results were similar to observations made by Muraguri [22] in Kwale and Kilifi Districts in the Coast Province. Majority of the surveyed farmers had high regard for calves, lambs and kids as they regarded them as future replacement stock. Generally, good care was taken of the young animals. For instance in Ndithini and Ngelani sub-locations, the young of all species were housed in specially constructed units to protect them from predators.

Although farmers often sold adult small ruminants to meet their immediate financial needs, cattle were rarely sold even during severe dry spells as was the case during the second half of the study. Cattle were used for long-term investment options. Similar observations were made by [4] in a study of livestock farming systems in Sub-Sahara Africa, Onono [27] in northern Kenya and southern Ethiopia, and Maichomo [15] in the pastoral Masaai community of Kajiado District. Small stocks were useful in cushioning against the effects of drought due to their fast multiplication compared to cattle. The reluctance to sell cattle even when pastures were inadequate resulted in severe malnutrition and starvation to death of animals on some farms. The rearing of livestock in the study area is not entirely a commercial enterprise as may be expected but a combination of source of livelihood and a status symbol. A similar observation was made by Maichomo [15] in a study carried out in Kajiado District. This is an issue that needs to be addressed if livestock production is to be improved in Machakos County.

Concurrent rearing of cattle, sheep and goats can be used to diversify risks associated with the different species [12]. This becomes important especially during prolonged dry spells because it is known that different livestock species adapt differently to

drought [3,18]. For instance, small ruminants survive on poor quality forbs and browse, which is the only available foliage during severe droughts.

The rate of multiplication for small ruminants is also faster than that of cattle. Thus, a herd of small ruminants recovers from losses incurred during droughts faster than for cattle. The resilience of small stock in the face of drought has been reported by several authors including [31]. Small ruminants are more easily sold compared to cattle during drought events enabling farmers to liquidate their herds to avoid further losses.

Misdiagnosis or unconfirmed cases of disease can lead to biased estimates of disease risk. The current study combined clinical signs and microscopic examination of biopsy smears as the basis for diagnosis of Tick-Borne Diseases (TBDS). The approach is most suitable for confirmation of current infections and it may have helped to minimise the incidences of misdiagnosis often associated with the diagnosis of TBDs [13].

Non-specific diarrhea and tick infestations were the most common causes of morbidity in cattle. This finding was similar to that of a study carried out by Phiri [30] in Zambia. Sheep and goat diseases diagnosed most commonly included helminthosis and pneumonia. Pneumonia was particularly a problem in goats. Although only 4 cases were diagnosed on the study farms during the observation period, farmers insisted pneumonia was the commonest disease problem in small ruminants particularly during the cold period of the year (May to August). Indeed, all the cases during the observation period were diagnosed during this period. This may perhaps be due to the poor design of housing for the small stock leading to exposure to cold conditions during the night. The houses were designed to keep away predators or prevent thefts.

Fleas were a serious problem particularly in Kathome sub-location where farmers complained of their persistence despite application of acaricides regularly. They applied amitraz, pyrethroid or organophosphate compounds for fleas' control but all were apparently ineffective. Control of fleas appears to be a problem in the country as reported in a survey conducted in Kajiado District [5]. A plan of action on the control of fleas in the country needs to be drawn up by the Department of Veterinary Services to enable farmers deal with the growing menace. Extension messages in the country on the control of ectoparasites mainly focus on ticks and largely ignore other ectoparasites some of which are of public health importance. Livestock harbour fleas which cause dermatitis, allergies or jiggers in human beings. Some species of bovine fungal and mite infestations can also infect human beings. Thus, the control of livestock ectoparasites needs to be comprehensive in the interest of public health and should not be primarily directed at the control of TBDs.

Contagious Caprine Pleuropneumonia is not known to be endemic in the study area. However, the outbreak of suspected cases of the disease underlies the problem of uncontrolled livestock movements between different parts of the country. Although there is a shortage of veterinary personnel who are tasked with monitoring livestock movement in the study area, the fact that the animals were transported more than 300 kilometres from the North Eastern region of the country into the County without any valid documentation exposes serious weakness with regard to enforcement of laws governing livestock movement in the country. If the country is to successfully establish the proposed disease-free zone [7], which will enable the country to access the lucrative European Union market under vision 2030, then the act (Act 354) governing livestock movement needs to be strictly enforced. Successful implementation of the disease-free zones is expected to have a spin-off effect that will spur livestock development especially in the marginal areas such as the study area.

A spell of drought was experienced during the study period. Though much of the district can be described as being semi-arid, the amount of rainfall received was far below the annual average. In arid and semi-arid lands of Kenya, drought is the most important hazard encountered by households [3,9]. Indeed, drought has been increasing in frequency, especially in Northern Kenya from once every 10 years in 1970 to currently once in every 2-3 years in [8]. Prolonged droughts can lead to gradual changes in rangelands vegetation from palatable to non-palatable species with the overall effect of diminishing pasture quantity and quality [17]. The drought weather spell that was experienced during the study period was

the cause of malnutrition observed on some of the farms.

The average daily milk production was low compared to that reported for high potential areas in the central region of the country. Although the drought weather conditions adversely affected milk production especially among the exotic crossbreed of cows, the overall average daily milk production (1.98 litres) was less than a third of the average daily milk production of 7.2 litres recorded in the central highlands of Kenya [10,34]. The low milk production can be attributed to the predominantly poor breeds of indigenous cattle kept in district, which are not suitable for a dairy cattle enterprise [37].

Previous studies in the neighbouring Kiambu County on factors influencing milk production reported inadequate feeds and poor reproduction management as the key factor [26]. Lack of adequate feed was one of the constraints to livestock production that was ranked highly by the farmers during a rapid appraisal study undertaken earlier on. This was further aggravated by the drought conditions experienced during the last three months of the study.

Farmers with exotic crosses of cattle had very limited access to artificial insemination services and relied on "shared" bulls, often of low genetic potential. The resulting offspring were often of lower genetic potential than the dams. This may have contributed to the lower than expected milk production on the farms that kept the exotic crosses. Crossbreeding between suitable *Bos Taurus* breeds and local breeds can be used to improve the genetic potential of the local breeds in the study area.

Although the average weaning age for calves was within the recommended range of 3 to 7 months, calves on some farms were allowed to suckle up to 2 months prior to calving. Studies have shown that cows not being suckled have increased fertility [33]. When artificial insemination is used, the pregnancy rate increases by 63% in cows that are weaned at 80 days compared to 54% in cows weaned at 215 days [33]. In addition, cows with calves that had been weaned early conceived on average 7 days earlier than those cows with calves that were not weaned early. In small ruminants early weaning enables breeding ewes and does to regain condition faster resulting in higher conception rates [26]. Early weaning can also help improve the throughput (rate of giving birth) of calves, lambs and kids and therefore further improving livestock productivity. It is also advantageous during drought to avoid rapid deterioration of the body condition of female animals. Livestock productivity in the study area was found to be unsatisfactory but can substantially be improved by adoption of good breeding management and animal husbandry practices.

Although the birth weights of calves seemed not to be adversely affected by the sub-optimal genetic potential of the cattle breeds in the study region, the growth performance as at the time of weaning was low compared to the performances recorded for dairy, beef and dual-purpose cattle [19]. Despite the birth weight of the exotic crosses (37kg) being higher than the 23.7 kg recorded by Muraguri [22] in the Coastal lowlands and Omore., *et al*. (1994) in Kiambu District, the weaning weights for calves weaned at 8 months (143-154kg) were less than average weight of 170 kg those recorded by Trail and Gregory [36] and [33] for Boran and Sahiwal (breeds) calves of similar age. Factors that are associated with daily weight again of calves include pasture condition, season, distance to the pastures, watering frequency, initial body weight and infection with TBDs [11]. The drier climatic conditions in the study area could have been responsible for the relatively lower average weight attained by the calves at the time of weaning compared to those recorded in higher potential areas of the country.

Productivity of the small ruminants in the study area was sub-optimal. Under good breeding management, goats and sheep are expected to give birth on average twice a year. None of the breeding ewes or does gave birth more than once during the study period. On all farms, goats and sheep were allowed to mate naturally and this could have been the main cause of the relatively long inter kidding or lambing intervals. However, the birth weights for lambs and kids were comparable to those of other studies [19].

Livestock off-take rates were low in all the four study divisions. The off-take rates for cattle were similar to those recorded by Odero-Waitituh, [20] in Turkana County, Kenya (1.30% -12.00%) while the off-take rates for small ruminants were much lower than the 25% recorded in the same study. The off-take rates were also much lower than those recorded by Odero-Waitituh [26] on commer-

cial ranches in Machakos County (28.7% for cattle and 15.3% for small ruminants) and the average off-take rate of 25% for cattle and small ruminants in the commercial sector in Africa [4]. The off-take rates for small ruminants in the four divisions were not consistent with those of the socio-economic study undertaken on the same farms, whereby farmers indicated that sheep and goats were frequently sold to cater for short falls in the family incomes. Indeed, the off-take rates were less than those recorded for cattle. This was probably due to drought conditions experienced at the time of the survey. The farmers were apparently aware of the fact that small ruminants had a better chance of survival compared to cattle under such conditions and hence were reluctant to sell or dispose off the animals.

No culling of livestock that were either infertile or past their peak performance with regard to milk production took place during the study period. *Despite the fact that reproduction is not a highly heritable trait, it is important to remove genetic material (infertile animals) from the herd so as not to proliferate females that are difficult to breed.*

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