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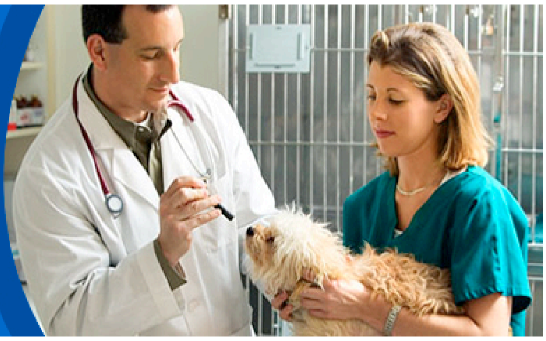

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Prevalence of east coast fever infections based on farmer-observed symptoms in smallholder dairy herds, North rift Kenya

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Abstract
East Coast fever prevalence is variable and causes economic loss to smallholder farmers. A cross-sectional survey involving 1038 cows on 164 farms stratified by agro-ecological zones, production systems and prophylactic strategies conducted. Acaricide use was dominant (79.9%) on sample farms and disease prevalence of cows examined on standard symptoms 18.7%. This did not differ ($p \geq 0.05$) between prophylactic strategies, different grazing systems and the agro-ecological zones. The estimated economic loss due to disease per farm per year on acaricide 1.8 times higher than acaricide and/or vaccine and 48.8 times high than vaccine loss. Disease prevention loss on farms using acaricide and/or vaccine (0.68), acaricide (0.43). Non-veterinary cost on vaccinating farms (0.54) while treatment costed a quarter of the economic loss. Use of any of the three prophylactic strategies hardly expose farmers to risks of disease. Vaccine is cheaper, effective and access to farmers should be beneficial in the smallholder dairy development.

Keywords: Agro-ecological strata, Control strategies, Economic loss, Tick-borne-Diseases, grazing systems

Introduction
East Coast fever (ECF) is a cattle disease caused by a parasitic protozoan, *Theileria parva*, and transmitted by the brown ear tick, *Rhipicephalus appendiculatus*. It is an economically important disease of cattle in Kenya as in other countries of East and Central Africa [1]. Dairy cattle are highly susceptibility to the disease [2].

The dynamics of tick vector may be influenced by the production environment [3] of which important are the agro-ecological zone (AEZ), grazing systems, prophylactic strategies and animal breed. Dairy cattle are reared under different production systems including open grazing, semi-grazing and zero-grazing [4]. These production systems dominate in different agro-climatic zones, classified on a moisture index [5] representing annual rainfall expressed as a percentage of potential evaporation. Areas with an index >50% are designated high potential agriculturally while an index <50% are designated zones low potential agriculturally [4]. Smallholder dairy production dominates in the high agricultural potential areas because of bimodal rainfall that sustains high biomass production and abundant crop residues from crops.

Farmers apply different prophylactic strategies for ECF, using acaricides to control the vector ticks, chemotherapy of sick animals as well as immunization of cattle by the infection and treatment method (ITM) [5, 6]. Acaricide use and chemotherapy are often limited by high costs, development of resistance by the vector ticks, and the parasites as well as environmental impacts [7-9]. On the other hand, vaccination offers a valuable alternative for ECF control [5]; however, its widespread application has faced challenges. These include the requirement of cold chain mode of delivery to remote areas and high cost of the vaccine (up to US$10 per animal), which is unaffordable to most smallholder farmers [10]. Furthermore, vaccination does not completely eliminate the need for acaricide application due to the potential existence of other tick-borne diseases [11].

This study was carried out to estimate of ECF disease prevalence on smallholder farms in using different prophylactic strategies.

2. Materials and methods
2.1 Study site

The selected study sites were Nandi and Uasin Gishu Counties (see map of Kenya) in the North Rift region of Kenya. The two counties covers three agro ecological zones, namely lower highland, upper highland and upper midland zones with bimodal rainfall, but higher in Nandi (1,200 to 2,000 mm per annum) than in Uasin Gishu (900 to1200 mm per annum). In the two counties of the study, smallholder dairying is prominent with long history of using acaricide and growing sales of ECF vaccine [12]. Dairy farming is integrated with tea plantation in Nandi County and with maize in Uasin Gishu County. There are 375,287 dairy animals of which 81,838 are high grade in Uasin Gishu compared to total cattle population of 62,459 in Nandi County [13].

In these high agricultural potential agro-climatic zones, *Theileria parva* infections is endemic, with significant economic impact in dairy cattle production. Farmers protect their dairy herds from ECF disease with acaricide applications, vaccine use or combination of these two strategies.

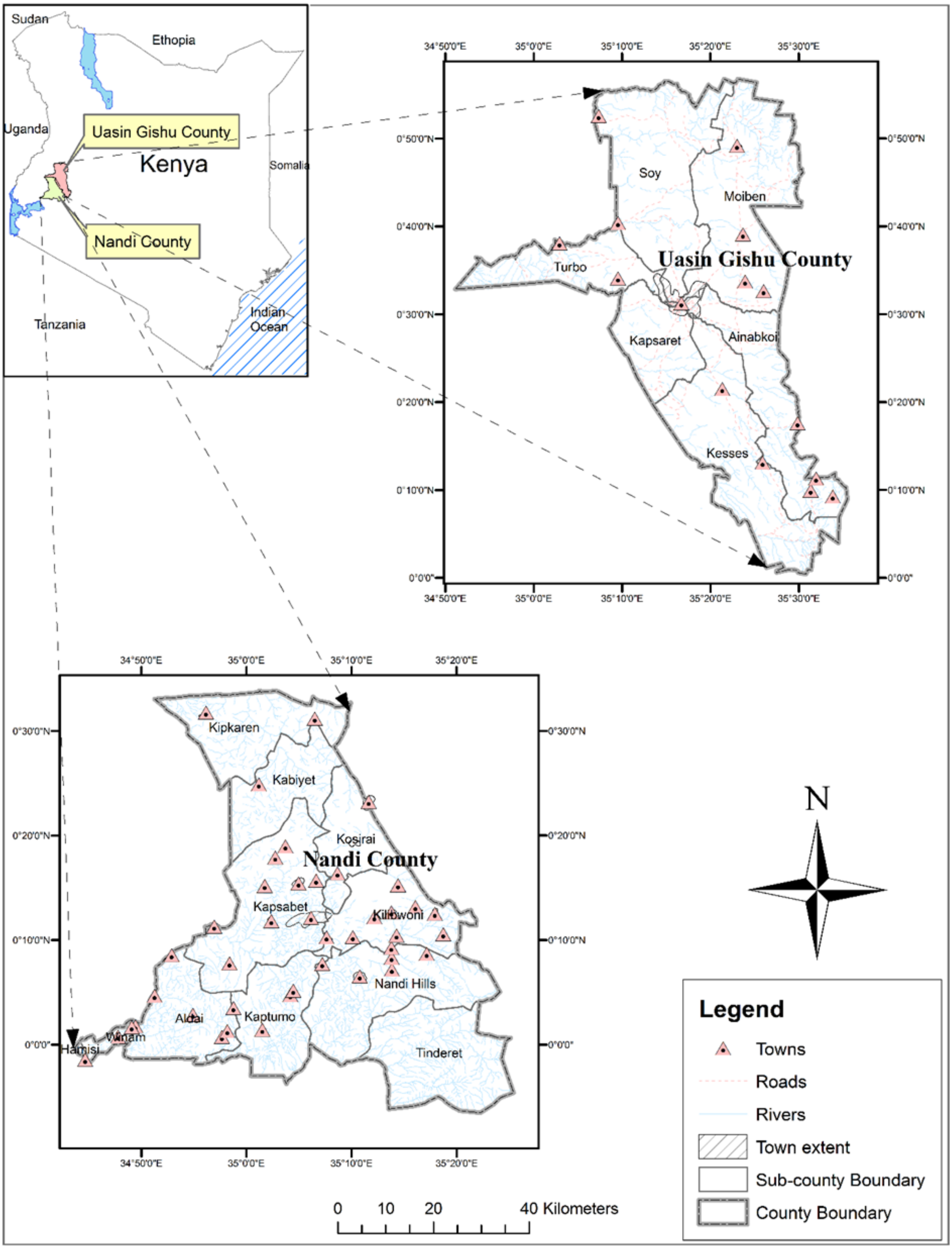

Fig 1: Map of the study sites (Nandi and Uasin Gishu counties)

2.2 Study design and data collection

The minimum sample size (n) was determined using the formula [14] in which n. $=Z^2*p*q/e^2$. where z is desired confidence interval level set at 1.96 for 95% confidence interval p is the proportion of a characteristic of the population to be sampled, which was set at 0.70, prevalence of ECF disease in the Kenya highlands [15], $q = (1- p)$, and e is the error margin allowable for detecting a difference in the sample and was set at 0.05. From this formula, a sample size, (n), of 162 farms was computed. In the actual survey, 164 farms were sampled of which 73 farms were from Uasin Gishu and 91 farms were sampled from Nandi county.

A cross-sectional survey stratified the farms in representative villages in each county stratified by agro ecological zones and production systems (pasture, semi zero, zero-grazing). The local extension officers together with the Agro-vet dealers selling the acaricides and ECF vaccine assisted in identification of the farms. A list of farms was constructed from names given by extension officers and Agro-vet dealers to which simple sampling procedure was performed to select the farms to visit for data collection.

The ECF disease and other tick-borne disease were identified by their standard symptoms with the help of a veterinarian/vet assistants. Data by interviewing household heads with a pre-tested questionnaire specifically designed for the study. This was on the basis of farmers' recall from current and with the reference period of one year. Data were collected on herd structure, ECF prophylactic strategy, AEZs, production system, TBDs symptoms, frequency of ECF infections and the number of animals with the symptom that recovered or died.

2.3 Data analysis

Data were analyzed using SPSS statistical package (version 23). The data on 1038 cows from 164 farms were cross tabulated in *Chi* square test statistic to estimate ECF disease prevalence rates by prophylactic strategies, grazing systems and agro-ecological zones. The economic losses directly and indirectly related to ECF infections were computed from the summation of costs in monetary values categorized into model components defined by [16] in the form of equation

$$C = (L + R) + (T + P) \qquad \text{(i)}$$

where: C = Economic cost of disease, L = the cost of disease in terms of the loss in expected output due to ECF, R = Increase in expenditure on non-veterinary resources due to ECF, T = the cost of inputs used to treat ECF, P = the cost of disease prevention measures (acaricide, vaccine and both acaricide/vaccine). The difference in mean economic loss between the three prophylactic strategies was determined on percentage differences.

3. Results

3.1 Use of ECF prophylactic strategies

Table 1 shows the distribution of farms using ECF prophylactic strategies by different tick-borne diseases, county and grazing systems. Among the sample farms (n=164) examined, the dominant prophylactic strategy was acaricide (0.799) with only few using combined acaricide with vaccine (0.165) or vaccine alone (0.037). The Use of acaricide dominated regardless of grazing systems (χ^2 (6) = 14.488; p = 0.025) and tick-borne disease (χ^2 (8) = 58.334; p= 0.001) but not between the two counties (χ^2 (2) = 1.663; p= 0.435).

Table 1: The distribution of farms for use of ECF prophylactic strategies by different tick-borne diseases, county and grazing systems

Factors	Level	Proportion of farms using			*Chi* square test
		Acaricide	Vaccine	Acaricide + vaccine	
Tick-borne disease					**
	ECF (n=75)	0.920	0.027	0.053	
	Anaplasmosis (n=54)	0.833	0.037	0.130	
	Babesiosis (n=10)	1.000	0.000	0.000	
	Heart water (n=20)	0.200	0.100	0.700	
	Piroplasmosis (n=5)	0.600	0.000	0.400	
County					NS
	Nandi (n=91)	0.769	0.033	0.198	
	Uasin Gishu (n=73)	0.836	0.041	0.123	
Grazing system					*
	Only grazing (n=63)	0.841	0.048	0.111	
	Mostly grazing with some stall feeding (n=77)	0.831	0.026	0.143	
	Stall feeding with some grazing (n=19)	0.632	0.000	0.368	
	Zero grazing (n=5)	0.400	0.200	0.400	
Overall	Overall (n=164)	0.799	0.037	0.165	

Significance levels *p<0.05, **p<0.001, NS is not significant (p≥0.05)

Table 2 presents ECF disease prevalence rates among 1038 cows sampled under different prophylactic strategies, grazing systems and agro-ecological zones. The ECF disease prevalence was 0.187 but this did not differ (p≥0.05) between prophylactic strategies (0.184 with vaccine, 0.180 with acaricide and 0.229 with combined acaricide and vaccine); between different grazing systems (18.9% when only grazing, 17.6% when semi-grazing and 21.8% when stall feeding) and between the agro-ecological zones (17.5% in lower highland and 20.7% in the upper highland).

Table 2: ECF disease prevalence rates among 1038 cows sampled under different prophylactic strategies, grazing systems and agro-ecological zones

Variable	Observation (n)	ECF infections		Chi square test
		Positive	Negative	
Prophylactic strategy				NS
Acaricide	845	0.180	0.820	
Vaccine	49	0.184	0.816	
Acaricide + Vaccine	144	0.229	0.771	
Grazing system				NS
Only grazing	380	0.189	0.811	
Semi-grazing	511	0.176	0.824	
Stall feeding	147	0.218	0.782	
Agro-ecological zone				
Lower highland	623	0.175	0827	NS
Upper highland	415	0.207	0.793	
Overall	1038	0.187	0.813	

Significance level: NS is not significant ($p \geq 0.05$)

The economic loss associated with ECF disease per farm per year was estimated and are presented in Table 3. The estimated economic loss on farms using acaricide (KES 10978.40) was 1.8 times higher than on the farms using a combined acaricide and vaccine (KES 6127.10) and 48.4 times higher than on the farms using vaccine (KES 226.80). Accounting for the largest economic loss was disease prevention on farms using combined acaricide and vaccine (0.68) and also on using acaricide (0.43) but non-veterinary cost accounted for the largest economic loss on farms using vaccine (0.54). Disease treatment accounted for about a quarter of the economic loss regardless of the prophylactic strategy a farm used.

Table 3: Economic loss estimates in KES/farm/year and contribution of various sources (percent contribution) by prophylactic strategies practiced in sample farms

Economic loss	Acaricide	Vaccine	Acaricide & Vaccine
$Production loss	947.70 (0.09)	9.10 (0.04)	401.20 (0.06)
Disease prevention	4754.20 (0.43)	48.80 (0.22)	4146.30 (0.68)
Disease treatment	2713.40 (0.25)	45.70 (0.20)	1286.20 (0.21)
Non-veterinary costs	2563.10 (0.23)	123.20 (0.54)	293.40 (0.05)
Total loss	10978.40	226.80	6127.10

$Production loss = reduced milk yield

4. Discussion

The sample farms predominantly used acaricide strategy to control tick vectors of the *Theileria parva* infections. Tick control is one of the most important factors influencing the epidemiology of ECF infection. This has been achieved mainly by application of acaricides to kill ticks in both free living as well as parasitic stages [17]. Use of the acaricide has long history which has ensured wider uptake among dairy farmers [12]. The pharmaceutical firms have penetrated farming communities with acaricide in the absence of an alternative prophylactics strategy, until recently when vaccine development became successful and commercially viable. Tick free or acaricide treated cattle have better productivity as compared to tick infested cattle [18, 19]. Confirmed that farmers apply the acaricides control strategy on weekly basis or twice a week based on tick vector infestations. Dipping is usually compulsory at stated intervals to achieve more effective and widespread control, is considered the most effective method for acaricide application [17]. Despite its effectiveness, acaricide use is very expensive, and is applied inconsistently due to poor rehabilitation of dip tanks, provisions of acaricides and water, which require resources [20]. Use of acaricide against ECF infection also many limitations including; shortages of water- for public dips, the development of resistance to acaricide by tick populations, uncontrolled cattle movements, civil unrest, contamination of the environment or food with toxic residues of acaricides and the existence of alternative hosts for ticks (mainly wild ungulates) in proximity to cattle [34] This necessitates search for cost-effective and integrated control strategies, vaccine; that allows considerable relaxation of acaricide use and hence, reduce morbidity, mortality, increase milk production and net income to farmers [19].

Based on farmer-observed disease symptoms, ECF disease was the most prevalent TBD on the sample farms, pointing to the disease being a major challenge and threat to dairy development in the study region. As high as 20% of cows had been observed with ECF disease symptoms, which represent high morbidity that warrant an effective prophylactics strategy for the disease on smallholder farms. Many authors have emphasized that ECF is the most important disease impeding dairy production more than another tick borne disease, anaplasmosis, heart water and babesiosis [21-25]. Estimates of deaths can be as high 40% to 80% [26] especially among calves. ECF prevalence reported in Kenya on smallholder farms is very variable, reflecting differences in ecological conditions and management practices. Practicing regular dipping/spraying with acaricide does effectively control ticks, and is associated with lower *Theileria parva* prevalence if good acaricide use practices are adhered to by farmers. Compared to present prevalence estimates, [27] reported lower *Theileria parva* prevalence (14.2%) but other reported higher prevalence: [28] study estimates (27.7%) in the in the Lake region, [21] study estimates (19.7%) in northern part of Tanzania, and [20] study estimates (8.1%) in the eastern part of Tanzania. The additional factors likely to explain these observed differences could be animal genetics, prophylactic practice, virulence of the pathogens, and infection rate of ticks in the different regions [29, 11, 24, 22].

There are also observed differences in the ECF prevalence related to the prophylactic strategy in use. Prevalence is lower on farms neighboring game reserves, as observed in Tanzanian Serengeti (38.3%) when using acaricide [28] than when using vaccine (50%) on Maasai cattle [21]. These corroborates the observations elsewhere in East Africa, for instance prevalence estimates (25.3% to (27.1%) in Rwanda between 1998 and 2003, based on p104 *Theileria parva* specific gene and 18S assays [30]. In Rwanda, dairy cows are mostly confined in zero grazing units under the one cow programme, which would explain comparable ECF prevalence to Kenya where smallholders predominantly practice zero grazing as well [31]. In this study, the ECF infection prevalence among the sample animals did not differ ($p \geq 0.05$) between the three prophylactic strategies, different grazing systems and between the agro-ecological zones. This implies that use of any of the three strategies would not disadvantage farmers in risks of ECF infection and cattle losses. The difference is in the cost involved in use of the strategy, which showed marked differences. Use of vaccine had the lowest cost therefore would save farmers resources in ECF disease control.

The estimated economic loss associated with ECF infections per farm per year was highest when using acaricide (KES 10978.40) about 1.8 times higher than when using a combination of acaricide and vaccine (KES 6127.10) and 48.4 times higher when using vaccine alone (KES 226.80). This shows that use of vaccine, immunization is presently a cheaper strategy to control ECF in smallholder farms. Vaccine is life long and confers immunity to subsequent infections that challenge the immunized animal [32]. Further, vaccine reduces cost and relaxes use of acaricides in control of ECF [33].

The larger loss in acaricide strategy could be attributed to cost of acaricide use which is the primary means of tick control estimated to range between US$6 and US$36 per adult animal in Kenya, Tanzania and Uganda [2]. Depending on the frequency of applications, annual costs of acaricide to farmers can be substantial [34-37]. In areas of heavy tick infestation, cattle are dipped or sprayed with acaricides twice a week [19]. Further increasing the cost.

The effective treatment of ECF infection requires disease identification through surveillance and diagnosis preceded by treatment of infected animals with drugs. In the study area, this service is provided by government and or private practitioners, on charges that vary, through veterinary investigation laboratories and the veterinary extension service [38]. Farmers who pay for the service can spend as much as US$ 10 to 20 per animal per treatment but depends on professional cadre [38]. The relatively high cost of treatment coupled with the limited veterinary services available to smallholder farmers imply that only a small proportion of infected animals have access to treatment.

The costs associated with ECF infection treatment (non-veterinary costs) could have led to economic loss variation in each prophylactic strategy. Farmers incur costs that were no longer considered in disease costing and spend money annually on reporting the disease to an animal health service provider, drug purchase and labor costs [38]. This confers with the results in a study [39] in which such costs were treated as fixed (in this study non-veterinary costs) since they were charged uniformly, irrespective of the number of animals on the farm contributed up to (53%).

Control of tick vectors which cause ECF infections is managed by use of acaricide. This inflict substantial economic loss to farmers and resource use [19]. The consequences of the control of ECF by this method is therefore grim; extension staff generally do not have transport, most public dips are poorly managed and non-functional. The few operational ones are often dilute in acaricides concentration, drugs are not readily available to government veterinarians, and if they are available in local markets, they are too expensive for most smallholder farmers [19].

ECF management by chemotherapy is readily available but successful application requires diagnosis of the disease at its early stage of development. This specialization is beyond the capacity of many smallholder farmers because of the poor state of the animal health service infrastructure [40]. This factor, coupled with the high cost of drugs, implies that only a small proportion of animals which become infected with the disease receive treatment [19]. The application of acaricides on vector ticks through dipping, spraying or hand-washing animals contributes to the pollution of the environment and may endanger human health. This arises from direct contact, spilled or misused acaricides and also from consumption of products derived from animals treated with acaricides [41, 35].

Conclusion

These results imply that use of any of the three prophylactic strategies would not expose farmers to varying risks of ECF disease in their dairy herds. However, acaricide is very expensive and vaccine is cheaper and effective. Therefore strengthening vaccine delivery to increase access to farmers should be beneficial in the smallholder dairy development.

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