Situation Analysis of Ticks and Seroprevalence of Theileria Parva in Two Farming Systems in Two Districts of Uganda.

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Abstract

Background: In Uganda, livestock supports the livelihoods of poor people, fulfilling multiple-economic, social, and risk management functions. However, its productivity is constrained by ticks and tick-borne diseases (TTBDs), more importantly, East Cost Fever (ECF) whose epidemiology is not well known and understood in the cattle corridor.

Methodology: A cross-sectional study was carried out in pastoral and mixed crop-livestock farming systems in Nakaseke and Nakasongola districts to understand the; local composition of ticks, the prevalence of *Theileria parva and* management of ECF and ticks. A structured closed-ended questionnaire was administered in (189) pastoral and (197) mixed-crop livestock households which were randomly selected, and a total of 384 calves were sampled. The tick challenge was assessed in situ on one side of the animal body considering different predilection sites. The prevalence of ECF was assessed by collecting whole blood in Ethylene Diamine Tetra acetic Acid (EDTA) tubes following veni-puncture. Thin and thick blood smears were made and serum samples were collected for determination of seroprevalence of ECF, using Enzyme-Linked Immunosorbent Assay (ELISA).

Results/Discussion: From a sample of 384 cattle surveyed, 316 (82.3%) were found to be infested with ticks of different species at their preferential predilection sites. *Rhipicephalus. appendiculatus* was the most abundant tick species (88.2%), followed by *Ambryomma. variegatum* (7.5%) and lastly *Rhipicephalus. evertsi evertsi* (4.3%). 80.7% of respondents believe that there was a tick infestation problem severe and ticks were managed on regular basis mainly by using acaricides (65.3%). In the pastoral farming system, no ticks were found on calves below 6 months old. The seroprevalence of *T. parva* was below 20% percentage positivity (pp)in calves below 4 months old, thereafter rising to 65% at 5 months, and then dropping to 20% from the age of 6 to 9 months. In mixed crop-livestock farming system, all age groups of cattle were exposed to tick challenge. The prevalence of *T. parva* increased from 1-month old calf reaching a peak in 2-3 months old calves but drastically dropped in calves 4 months old. Thereafter, it gradually built up to 70% in animals 7 months old. There was a moderate correlation between the mean number of *R. appendiculatus* ticks and seroprevalence of *T. parva* (r =0.47) and there was no significant difference between age category and percentage positivity of *T. parva* (p = 0.969). However, there was a relationship between mean number of ticks and farming system (p = 0.019) as well as percentage positivity of *T. parva* and farming system (p = 0.007)

Conclusion: ECF was prevalent in the two farming systems albeit frequent application of acaricides on animals as reported by most of the respondents. Further longitudinal studies required to assess seasonal variations of TTBDs, prevalence of other tick-borne diseases and acaricide resistance status.

Introduction

In Uganda, animal husbandry is considered a source of employment and livelihood representing 7.5% of the national gross domestic product (GDP) (NEPAD-CAADP, 2004, UBOS,2005) and most of the livestock

production in the country takes place in the cattle corridor region of the country. However, the productivity of livestock is generally constrained by TTBDs (AfrII, 2010; AfrII, 2011 and Okello-Onen, 1995), that are ranked as a severe threat to livestock productivity and production systems (Mukhebi *et al.*, 1992, Ocaido *et al.*,1996, and Otim, (2000). TTBDs are a major health impediment to the improvement and development of livestock industry in Uganda due to the high economic cost (losses) they impose on farmers and national economies (Okello-Onen *et al.*, 2002). Ticks cause tick worry, blood loss, damage to hides and skins, tick paralysis, reduced weight, and milk production (Bell-sakyil *et al.*, 2004 and Okello-Onen *et al.*, 1999). Tick-borne diseases (TBDs) cause serious debility, morbidity, mortality and production losses in susceptible *Bos* taurine cattle (*Bostaurus* Linnaeus, 1758), their crosses and the indigenous breeds of cattle (*Bos indicus*, Linnaeus, 1758) raised in non- endemic areas (Okello-Onen, 1995 and Walker *et al.*, 2003). They also hinder the introduction of exotic, more productive stock (Okello-Onen *et al.*, 1994). *T. parva*, which causes ECF, is the most pathogenic among *theileria* species affecting cattle (Morrison,2015) and is transmitted by the brown ear tick, *R. appendiculatus.* ECF is the most important widespread tick-borne disease in Uganda (Kabi et al., 2008 and Okello-Onen,1995). Its diverse distribution and prevalence are strongly related to its vector dynamics and entomological inoculation rate, host susceptibility, animal breed and age, livestock production system, and tick control practices (Rubaire-Akiiki *et al*. 2006; Kivaria 2007; Marufu et al. 2010). ECF is caused by obligate intracellular protozoa parasites, *T. parva* that infect the host's lymphoblasts. *Theileria* sporozoites are transmitted to animals through the saliva of the feeding tick and the incubation period for the disease is 8–12 days. Matovelo et al., 2002 report that the pathology of the disease includes fever, enlarged lymph nodes, raised hair, anorexia, laboured breathing, corneal opacity, nasal discharge, diarrhea, anaemia among others. In all affected areas, ECF has considerable epidemiological and economic significance.

Kivaria et al., (2004) report that indigenous cattle are fairly tolerant of TTBDs, and losses are confined to calf crop (10–30%). The animals that recover from tick-borne disease (TBD) infections may suffer from, among others; weight loss, low milk yields, low drought power, reduced fertility and delayed maturity (Latif and Pegram, 1992). In the case of ECF the affected cattle remain carriers and may serve to disseminate the infection (Latif and Walker, 2004, Mugabi et al., 2009 and 2010).

Tick control management practices largely depend on the use of conventional acaricides such as Cypermethrin and Deltamethrin (Latif and Walker, 2004, Thrusfield, 1997). In most farms, where they are used, the intensity of use and frequency of application varies greatly by the number of animals kept on the farm and the system of grazing in use. Common methods of acaricide application include pour-on and hand spraying (Lawrence 1991, Moran 1996 and Rubaire *et al.*, 2004). Other management strategies employed by farmers include bush burning during dry seasons and, to a less extent, use of botanicals to treat infected animals. It also includes the use of breeds of cattle that are genetically resistant to tick infestations (Norval *et al*,1991 and Okello-Onen *et al.*, 2002).

The epidemiological status of ticks and ECF, as well as their management practices in pastoral and mixed crop-livestock farming systems in the cattle corridor districts of Nakaseke and Nakasongola located in the central region of Uganda, was assessed to provide appropriate Provide up to date

knowledge and information that decision-makers need to manage TTBDs risk and inform livestock development decisions thereby influencing policymakers to work toward sustainable livestock production and sustainable livelihoods for pro-poor livestock farmers.

Materials And Methods

Study area

The study was conducted between July and September 2014 in Nakaseke and Nakasongola, districts located in the center of the cattle corridor within central Uganda (Figure. 1). The cattle corridor is a rangeland area that spans from Northeastern to the Southwestern region of Uganda close to 43% of Uganda's total land area and estimated to be 84,000 km^2 where most of the livestock production (65.5%) takes place in the country (World Bank, 2011). Nakasongola district boarders Nakaseke District to the North and Northeast. According to the Census of 2010, the population of people stood at 178, 000 and 125,297 in Nakasongola and Nakaseke districts respectively with an estimated cattle population of 222185 and 160737 in both districts (UBOS 2014, MAAIF-UBOS, 2008). The region is predominantly constituted by pastoral and mixed crop-livestock farming systems. Livestock production is the lifeblood of this resource-constrained local population keeping indigenous breeds of cattle as the most abundant livestock in the area. The region is sparsely populated and fragile to climate variability experiencing extremes of drought and floods. In dry seasons, it's a common practice for pastoralists to move long distances in search of pasture. In mixed crop-livestock system, both livestock farming and crop production are conducted and there are minimal movements during dry seasons. Crops cultivated include coffee, maize, beans, cassava, sweet potatoes, tomatoes, cabbage, bananas, pineapples, and mangoes. Other activities include fishing in the swamps and lakes. (ticks and tick-borne diseases have been reported to be a major livestock production obstacle among the resource-constrained rural population in this area (AfrII, 2011). The region is dominated by woodland and bushland, swamps, lakes, and rearing of cattle (for meat and milk), goats, and chicken.

Methodology

A sampling of household respondents and cattle population

In the study area, communities were stratified into pastoral-majority areas and areas of mixed crop-livestock producers in each of the two study districts. In each of the two strata in each district, 10 villages representing 25% of the total number of villages were randomly selected, using the registers at the parish local council chairpersons' offices as the sampling frame. In each of the selected villages, 10 households (making a subtotal of 200 households per district and a grand total of 400 households in the two districts). Computer-generated random numbers were used to select household respondents. Only respondents who were above 18 years of age and preferably household heads were selected for the interview after giving their consent.

On an assumption of the prevalence of infection of ECF in cattle being 10%, taking an absolute precision of 5% at the 95% level of confidence, 10% of farms were randomly selected in each village. Using standard epidemiological procedures, the cattle sample size was determined by using a formula given by Thrusfield, 1997 giving a total of 384 local breeds of cattle (*Bos indicus*) for this study. On each farm, all the calves 1–9 months old were sampled.

Data collection and Management

Household surveys and assessment of T and ECF

The instrument used for quantitative data collection was a standard structured interviewer-administered closed-ended questionnaire. The pretested and validated tool was administered to the respondents in both pastoral and mixed crop-livestock farming systems by a trained male and female research assistants in each district who were familiar with the community and language to capture data of high quality easily. Local guides were used to guide research assistants in each of the selected villages. The pretesting exercise was done outside the study area. A household was considered to be a person or group of people who normally cook, eat and live together (for at least 6 of the 12 months preceding the interview) irrespective of whether they are related or unrelated (UNHS, 2016/2017). The questionnaire inquired about tick challenge on cattle, various causes which were believed to result in ECF, distribution, and symptoms of ECF, seasonal fluctuations in the occurrence of ECF, sources of information required for treatment of ECF, and on-farm control and management practices of TTBDs.

Data were managed by availing research assistants with water-proof bags for carrying questionnaires to and from the field to avoid rain and other incidences from destroying the information. While in the field, the data collection process was monitored to ensure that the questionnaires were filled correctly.

Selected households were geo-referenced using a hand-held Global Positioning System (GPS), Germin GPS MAX 60SCx with coordinates taken in the WGS 84 geographical coordinate system in decimal degrees, at a level of accuracy of 3 m. The geographic coordinates were recorded and used for the mapping perceived prevalence of ECF in ArcGIS 10.4 and for ease of tracking households on subsequent visits for on-farm surveys.

The tick challenge and spectrum of species were assessed *in situ* by counting and recording the number of adult ticks (engorged and non-engorged males and females) on one side of each calf examined along the anteroposterior axis. Because ticks are seldom randomly distributed on the animal body but rather confined to a few selected predilection sites of the host where they prefer to feed, total tick count was made on one side of the body of each calf at predilection sites instead of making counts per square meter. This number was later doubled to give total tick count per animal (Thrusfield, 1997 and Morel, 1989). Tick samples were collected from calves by a handpicking method using strong steel forceps with blunt ends and serrated inner surfaces (Walker *et al.*, 2003). The tick samples from each animal were placed and stored separately in universal tubes containing 70% ethanol as a preservative. The tubes were

labelled with field data which included the date of sampling, collection site, calf predilection site, collector's name, calf age among others using lead pencil writing on paper which was placed inside the tube with the ticks. In the laboratory, ticks were identified and categorized by sex, developmental stage, and species, and the identification was done visually during the tick counts, based on the guidelines described by Walker *et al.* (2003).

The prevalence of ECF in livestock was assessed by collecting whole blood samples from each calf in EDTA tubes following jugular venipuncture. The tubes were labelled and correct verifications made before collecting blood from the calves. The animals were examined to assess clinical cases of ECF. EDTA tubes containing blood samples were kept in cool boxes with ice for close to 10 hours in transit to the laboratory. On arrival, the blood samples were centrifuged to obtain sera. Aliquots were then obtained from each sample and stored in a freezer at approximately − 20 °C) for antigen-antibody reaction tests. ECF was determined specifically using indirect Enzyme-Linked Immunosorbent Assay (indirect ELISA) approach as described by Katende et al., 1998, where specific antibodies against *T. parva* were detected. The raw data obtained from the ELISA reader were expressed as Percentage Positivity (PP). PP for test serum was expressed as the percent of the test serum optical density divided by the mean optical density reading derived from the strong positive control standard serum on the linear curve (from a curve of OD against the reciprocal of serial dilutions) (Katende et al. 1998; Katende *et al.*,1990 and Stadman, 1990. For the *T. parva* test conducted, a sample was considered positive if the PP value was 20 or above and hence 20% value was taken as the titer cut-off point.

Statistical analysis

Data collected were entered into Epidata version 3.1, coded cleaned, edited, and exported to MS Excel and Stata version 14 for analysis Data was coded to allow easy analysis. The coding process involved assigning numbers or codes to a response. Values of $p < 0.05$ were considered statistically significant for all tests. Summary of statistics in the form of tables and figures were computed using MS Excel software for data collected at the household level using questionnaires, ticks, and serum samples. Data from serological tests were entered into the Microsoft Excel spreadsheet, 2007. Seroprevalence was determined by expressing positive sera as a percentage of the total number of sera tested. Statistical tests at the bivariate level to establish relationships and variations of research variables (analysis of variance and chi-square test) were carried out at the farm level on ticks and blood sample data collected from cattle. The measure of the degree of association between the mean number of ticks per animal and pp of *T. parva* was computed using Pearson product-moment correlation (r). Data captured in the questionnaire was also used to generate a map on the perceived prevalence of ECF.

Results

Household-level perceptions of ticks, ECF and management of TTBDs

Respondents in both pastoral and mixed crop-livestock farming systems perceived the occurrence of ticks on cattle mainly as a severe challenge (79%), followed by moderate 17%, mild (3%), and others at 1% score. (Fig. 2). ECF was reported as a prevalent livestock disease in both districts at the household level (Fig. 3).

Causes believed by the local population to result in East Coast Fever

About thirty-two percent (31.8%) of communities wrongly perceived the cause of the ECF as being bites by flies, such as Tsetse flies (Table 1). This was followed by ticks as a cause for ECF perceived at 19.7%. ECF was also thought to spread when animals are brought in contact with other animals (12.1%). Lack of pastures in the districts, hence poor feeding of the animals was perceived by 9.1% of respondents as bringing on the disease. A small and insignificant percentage of the respondents thought that the diseases in animals could be due to dirty water, prolonged drought, climate effects, dust, and high temperatures.

Table 1
The various causes believed to result in ECF

Perceived causes of East Coast Fever	Frequency	Percentage (%)
Lack of pasture/ poor feeding	6	9.1
Dirty water	4	6.1
Ticks	13	19.7
Flies like Tsetse flies	21	31.8
High temperature	3	4.5
Contact with other animals	8	12.1
Dust	3	4.5
Prolonged drought	4	6.1
Other reasons	4	6.1
Total	**66**	**100**

Community perspectives on the percentage distribution of ECF symptoms

Both communities, enlisted and a diverse range of symptoms believed to designate ECF and about 20% and 21% of respondents perceived and ranked fever or high temperature and enlarged lymph nodes

respectively as the most important symptoms. These were followed by raised hair (16.0%) and loss of appetite (13.5%) (Table 2).

Table 2
Percentage distribution of East Coast Fever symptoms

Symptoms of East Coast Fever	Frequency	Percentage (%)
Fever/High temperature	108	19.6
Nasal discharge	34	6.2
Diarrhoea	46	8.4
Coughing	36	6.5
Enlarged lymph nodes	115	20.9
Loss of appetite	74	13.5
Loss of appetite/Emaciation	24	4.4
Raised hair	88	16.0
Lameness	10	1.8
Others	15	2.7
Total	**550**	**100**

Source of ECF treatment information

About 34.9% of the respondents reported to have got information on ECF treatment from Veterinary doctors, (25.6%) were advised by relatives, and 23.3% by fellow farmers. The least providers of such information were local political leaders at various local councils (10.5%) and government (4.7%.) (Table 3). Therefore, it implies that there was a paucity of the government's infrastructure on the management of TTBDs.

Table 3
Source of information on the East Coast Fever treatment

The perceived source of treatment information	Frequency	Percentage (%)
Government	4	4.7
Veterinary doctors	30	34.9
Local leaders (such as local council 1,2 or 3)	9	10.5
Fellow farmers	20	23.3
Relatives	22	25.6
Others	1	1.2
Total	**86**	**100**

The occurrence of TTBDs by different seasons

About 58% of respondents reported that ECF was common in both rainy and dry seasons (Fig. 4). However, relatively few respondents believed that this disease was a problem, neither in rainy (20.8%) nor in dry seasons (21.3%).

Management of TTBDs

The largest percentage of cattle keepers (65.3%) bought drugs such as Oxytracycline to treat their animals (Table 4). This was followed by 17.2% who used private veterinary officers, (10.4%) who used government veterinary officers while only 5.6% used local herbs such as *Erythrina abyssinica*

Table 4
Management practices for Ticks and Tick-Borne Diseases

Coping up mechanisms (Prevention methods)	Frequency	Percentage (%)
Use local herbs for treatment	64	5.6
Buy drugs	752	65.3
Call government veterinary officers	120	10.4
Use private veterinary officers	198	17.2
Just look on (no option to do)	6	0.5
Others	11	1.0
Total	**1151**	**100**

On-farm assessment of ticks and seroprevalence of *T. parva* in cattle

Species diversity and the total number of ticks identified

From a sample of 384 cattle examined, 316 (82.3%) animals were found to be infested with ticks of different species at their preferential predilection sites. A total of 3283 Ixodid ticks belonging to different species were collected. Out of this, 2895 (88.2) ticks which were found on the cattle's ears were of the species *R. appendiculatus*, being the most abundant tick species, followed by *A variegatum* species which were found located on the dewlap, axillae, udder, and groin with a total of 247 (7.5%) and lastly *R. evertsi evertsi* species which were picked around the anus with a total of 141(4.3%) ticks (Fig. 5). There was a moderate positive correlation, r = 0.47 (Table 5) between mean number tick per animal and pp of *T. parva*.

Table: 5 correlation (r) between the mean number of ticks per animal and pp of *T. parva*

	ticks	positivity
ticks	1.0000	
% positivity	0.4665*	1.0000
	0.0082	

The farming system was significantly associated with % pp of *T. parva*, p = 0.007 (Table 6), and the mean number of ticks per animal, p = 0.008 (Table 7).

Table 6: Association between Farming system and % positivity of *T.parva*

Analysis of Variance

Source	SS	df	MS	F	Prob >
Between groups	4160.25	1	4160.25	8.18	0.0072
Within groups	17282.5	34	508.308824		
Total	21442.75	35	612.65		

Bartlett's test for equal variances: chi2(1) = 0.2413 Prob>chi2 = 0.623

Table 7: Association between Mean number of ticks per animal and Farming system

Analysis of Variance

Source	SS	df	MS	F	Prob >F
Between groups	478.462779	1	478.462779	11.78	0.0018
Within groups	1177.73077	29	40.6114058		
Total	1656.19355	30	55.2064516		

Bartlett's test for equal variances: chi2(1) = 5.5320 Prob>chi2 = 0.019

The variation of pp of *T. parva* with the age category of cattle was not significant, p = 0.9865

Seroprevalence of T. parva in pastoral farming system

In Nakaseke district, pastoral farming system, the number of *R. appendiculatus* ticks per animal ranged between 0 and 15. No ticks were found on calves below 6 months. The serological tests showed that the prevalence of *T. parva*, expressed as pp was below the cut-off point of 20% within the age groups of calves below 4 months only. However, after 5 months, the prevalence shot up to 65% and drastically dropped at the age of 6 months to the below cut-off point of 20% and this was maintained up to the age of 9 months (Fig. 6).

In Nakasongola district, pastoral farming system, the mean tick number per animal also varied greatly at different age groups of calves ranging from zero to 15. The prevalence of *T. parva* is a mirror image on the tick challenge. The prevalence decreased steadily from newly born calves, up to three months old calves. Thereafter, the prevalence increased steadily reaching a peak in calves six months old. Subsequently, it fluctuated up to the age of nine months (Fig. 6).

Seroprevalence of T. parva inmixed crop-livestock farming system

In Nakaseke district mixed crop-livestock farming system, the mean number of ticks per animal varied greatly ranging from about 2 to 24. All the age groups of calves were exposed to tick challenge. The prevalence of *T. parva* is a mirror image of the tick population at different age groups. The prevalence increased from 1-month old calf and reached a peak in calves of 2–3 months old, but drastically dropped in calves 4 months old. Thereafter, it gradually built up to the age of 7 months reaching a peak of 70% (Fig. 7).

In Nakasongola district mixed crop-livestock farming system, the mean number of ticks per animal ranged from 14 to 28 and no ticks were found on calves up to 1month old. The prevalence of *T. parva* sharply decreased from newly born calves to calves two months old, reaching a level of 30%, thereafter it increased gradually for some months up to the age of 6 months, reaching a peak of 63% (Fig. 7).

Discussion

Quantitative data collection using questionnaires provided useful insights regarding farmers' perspective on the status quo and incidences of ticks and ECF and how these were routinely managed in the two farming systems. The findings of this study highlight existing challenges, constraints as well as opportunities to exploit concerning livestock production. Perspectives of local farmers were captured on the magnitude of tick challenge on cattle, causes, and symptoms likely to result in ECF, seasonal disease occurrence, sources of information required for treatment of ECF, and on-farm control and management practices of TTBDs. These findings provide baseline data on the status of ticks and ECF pathogens that can inform the development of sustainable and effective livestock health management strategies and as well guide future epidemiological studies even though cross-sectional studies tend to be limiting at determining a cause-effect relationship. Most of the respondents in both farming systems lucidly identified the challenge of infestation of ticks on animals as being a severe and mentioned *theileriosis* as a prevalent TBD in the two districts. This was in tandem with results from on-farm tick collections and serum samples from calves which revealed diversity and infestation of ticks on animals expressed as mean tick number per animal and high pp of *T. parva* respectively in both farming systems in the two districts. The disease was reported to spread mainly in both dry and wet seasons (58% and 67% in the pastoral and mixed crop-livestock farming system respectively). This observation is confirmed by Latif and Walker (2004) findings on the seasonality of ECF. They assert that the activity of many species of tick is adapted to seasonal variations in climate and the tropics, this is usually to overcome the adverse effects of a long dry season. The survival of many species is improved if they have a seasonal cycle which reduces these risks, for example, *R. appendiculatus* has mechanisms, known as diapause, that delay the questing of adults so that their feeding and reproduction starts at the beginning of the single rainy season. This is followed by peak numbers of larvae toward the end of the rainy season when humidity is highest. Regarding farmers' perceptions of various causes believed to result in ECF, a relatively small fraction (19. 7%) of respondents could identify the cause of ECF as ticks. The largest proportion of respondents (31.8%) wrongly identified the cause of the disease as being flies such as tsetse flies and the rest gave other causes which could be the cause of the disease. Therefore, the largest percentage of respondents (80.3%) did not have outstanding knowledge and information regarding the cause of ECF. The cause of trypanosomiasis (tsetse flies) was most perceived to be the cause of ECF. This calls for sensitization of the communities about the actual symptoms of the disease emphasizing that the correct clinical diagnosis of disease symptoms and treatment would help the poor and resource-constrained farmers not to waste their finances while buying wrong drugs as the wrong diagnosis leads to the wrong treatment, besides this could result into fatal consequences on their livestock. Regular control and management of TTBDs largely depended on the use of synthetic acaricides (65.3%). The findings of this study emphasise what Latif and Walker (2004) noted that the threat of serious exposure of cattle herds to ECF has led to substantial use of tick control systems, mostly relying on acaricides. The fact that the majority of the farmers (63.5%) reported that they bought drugs themselves to treat the animals is suggestive of the possibility of inadequate veterinary technical and extension services in the districts. Besides, this could have led to wrong treatments resulting from a mistaken diagnosis. Among

the available sources of information on the treatment of ECF listed, the government was mentioned among the worst performers as far as providing access to such information was concerned, highlights a weakness, risk, and gap in enhancing livestock production and development especially in the cattle corridor where most of the livestock production in the country takes place. This is so because initially the control program for ticks and tick-borne diseases in which technical, advisory services, and extension services where integrated were heavily subsidized by the government as an incentive for the farmers (Okello-Onen and Nsubuga, 1997). This subsidy was valued at USD 10-26m annually. However, due to national economic constraints and economic liberalization policy, the subsidy scheme was withdrawn which in turn led to subsequent general decline technical and extension services explaining the findings obtained under this research. This calls for a rethinking process that will entail designing robust and sustainable livestock health risk management strategies that are applicable to the pro-poor livestock farming systems. On-farm quantitative serological surveys were conducted to determine the seroprevalence of *T. parva* pathogens and the abundance and diversity of ticks infesting cattle in the study area. This survey was key in; validating local perspectives and establishing knowledge gaps in the assessment of the current status of ticks and prevalence of ECF. The study yielded three types of ticks of economic importance in the livestock hotspot production area in Uganda and these were *R. appendiculatus*, *A. variagatum* and *R. evertsi evertsi.* Of these, *R. appendiculatus*, also the brown ear ticks, the vector for *T. parva* haemoparasite which cause ECF was the most prevalent tick species, hence the observed high seroprevalence of *T. parva* in serum samples collected. This was proved statistically by moderately positive correlation coefficient (r) that existed between the mean number of ticks per animal and pp of *T. parva*. These findings were consistent with earlier studies conducted in the country that reported ECF as the most economically important TBD of cattle which is endemic in Uganda (Kabi *et al.*, 2014; Muhanguzi *et al.*, 2014; Ocaido *et al.*, 2009 and Rubaire-Akiiki *et al.*, 2006). Furthermore, Okello-Onen *et al*. (2004) and Mukhebi *et al*. (1992) noted that the disease caused serious debility, morbidity, and mortality with an estimated total direct cost of $ 168 m annually and estimated mortality of 1.1 m cattle. Generally, results indicated that calves of all age-groups were exposed to the tick challenge which translated into infection with *T. parva* (r = 0.47). This was further evidenced by the fact that most of the values were above the cut-off titer value of 20% pp indicative of high infection rates with *T. parva* in the local breeds of cattle. Results indicated that calves of all age groups where exposed to tick infestation challenge at an early stage in life and r value was a moderately positive value. Since local breeds of cattle (*Bos indicus*) such as ankole and zebu cattle are fairly tolerant to ECF (Rubaire-Akiiki *et al.*, 2006) especially in endemic regions like the cattle corridor is suggestive of a pathway to attainment of endemic stability if host-tick and parasite dynamic equilibrium is sustained. Endemic stability refers to a state of a host-tick-pathogen interaction in which there is high level of challenge of calves by infected ticks, absence of clinical disease in calves despite infection, and a high level of immunity in adult cattle with a consequent low incident of clinical disease Young *et a.,l* (1988). Cattle do develop a resistance to infestation with *R. appendiculatus* and other tick species by producing acquired immunity after recovery to tick infestation which varies between individuals and breeds on subsequent exposure to tick infestation challenge (Cheira, et al., 1985; Seifert, 1984). This leads to a reduction in the number and size of ticks that attach to cattle and eventually survival of engorged instars (Cheira et al. 1985). Also, there is

evidence that it reduces the transmission of *T. parva* and other tick-borne pathogens (Norval *et al*,1991 and Young *et al*, 1988). Therefore, these results are suggestive of two practical applications which are based on host resistance to tick infestation that is to select cattle with the ability to produce a high degree of tick resistance or artificially to induce tick resistance. The fact that the tick challenge was evident in the study area with minimal reported calf mortality indicates that in this endemic region for ECF cattle have already been naturally selected for tick resistance as reported by Young, 1981, and Moll et al. 1986). Part of this selection may be due to challenge with *T. parva* since cattle with resistance to ticks will have a lower *T. parva* challenge and survive (Young, 1981; Young *et al.* 1988; Moll et al. 1986). Therefore, one of the promising options for control of TTBDs in this area is breeding for tick resistance for subsequent development of herd immunity. The point of concern to the livestock farmers, in this case, is to ensure that there is a judicious application of the acaricides. If acaricides are used intensively, livestock will not be exposed to disease pathogens and as a result, fail to acquire natural immunity. When this occurs, the livestock have increased susceptibility to disease and a situation of endemic instability arises: disease outbreaks are likely if acaricide use is not maintained. It is often best to achieve a state of endemic stability where there is sufficient exposure to ticks and transmitted pathogens to give high levels of naturally acquired immunity in the population of livestock. Some animals will be lost to tick-borne disease but the cost may be less than the cost of intensive treatment. On the other side, the application must be done in such a way as to reduce the rate at which ticks become resistant to the acaricides. This requires regular monitoring and surveillance of vector-parasite dynamics. Although most of them controlled tick numbers on animals through the use of acaricides as reported, the number of ticks count per animal was high. This was so even in instances where farmers had indicated that they had applied acaricides on the animals a few days before conducting on-farm surveys. Therefore, there is a need to investigate the brands of acaricides used, the frequency of their application, dosage applied, the way the drugs are applied on the animals (Young *et al.*, 1988), to assess local acaricide resistance status.

Conclusion

The study findings provide evidence of the important tick-borne disease pathogens and vectors responsible for ECF, *R. appendiculatus* being the principal tick species infesting cattle in the study areas. The observed tick infestation among cattle in the study areas could be attributed to communal grazing practice that exposes animals to tick-infested areas. The observed tick infestation may increase the risk of occurrence to tick-borne pathogens. One of the limitations of this study is that sampling was carried out in the dry season and this may have influenced tick population dynamics. Also, only one disease pathogen, *T. parva* was tested for in the serum samples as this is what could fit within the available resources. Therefore, further epidemiological studies are required to determine seasonal patterns in diversity, distribution, and abundance. Also, there is a need to assess the prevalence and economic impact of other tick-borne haemoparasites. Besides, strategic tick control during peak periods is necessary to allow ticks to naturally sustain endemic stability of TBDs through a continuous challenge. The abundance of the observed tick species may suggest that humans in the sampled sites are exposed

to the risk of diseases when bitten by infected ticks. Therefore, surveillance of TBDs in humans in the study areas is also recommended.

There was considerable risk to ECF in the cattle herds within the two farming systems posing a threat to livestock development and improvement of livelihoods of local communities whose lifeblood is livestock farming. Tick control was done mainly by spraying acaricides with less technical guidance but rather done on personal perception. There was paucity or no established infrastructure for effective management of ticks and TBD for sustainable livestock production. Therefore, there is an urgent need to create community-based technical and advisory services for livestock health management. Further studies required to enrich these findings and fill in information gaps in the emergence of resistance to acaricides and endemic stability status in the area. This will become even more useful with the introduction of different breeds of cattle in the area for increased milk and meat production. Under such conditions, tick management can be enhanced through the establishment of a robust breeding program for example cattle breeds indigenous to Uganda typically zebu and ankole have a good heritable ability to acquire natural resistance to the feeding of ticks (Latif and Walker, 2004, Okello-Onen *et al.*, 2002). This characteristic can be used in these breeding programmes to produce crosses with more productive exotic cattle of the *Bos taurus* type which can give good resistance to ticks and good production. When tick nymphs feed on resistant calves, these normally turn only half normal weight. Consequently, they molt into small adults with reduced survival and reproductive potential, thus reducing the numbers of the tick population in general (Norval *et al*,1991).

List Of Acronyms

IRB – institution review board

TTBDs – ticks and tick-borne diseases

EDTA- ethylene diamine tetraacetic acid

GDP - gross domestic product

ELISA - enzyme-linked immunosorbent assay

TBDs -tick-borne diseases

ECF- East coast fever

Declarations

Ethics approval and consent to participate

The study was granted permission under the ethical clearance of the Uganda National Council for Science and Technology, UNCST, [Ethical Clearance Reference A456, dated 31st August 2010]. Permission

was also obtained from the District Veterinary Offices of Nakasongola and Nakaseke Districts as well as animal owners. Also, this study was approved by the Faculty of Science (Biology department) of Gulu University, followed by the Institutional Review Board (IRB) at the Faculty of Medicine, Gulu University. No respondent was interviewed as a participant in the survey without prior notice and signature on a written consent form. The questionnaires and households were numbered with serial numbers instead of names to ensure the anonymity of the respondents.

Consent for publication

Not applicable

Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

KS designed the study, collected household, and empirical data, carried out the lab work, analysed and interpreted findings and wrote the manuscript, O-OJ and ONW provided technical guidance, OBS provided necessary logistics to conduct the study. All authors contributed to writing the manuscript. All authors read and approved the final manuscript.

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Figures

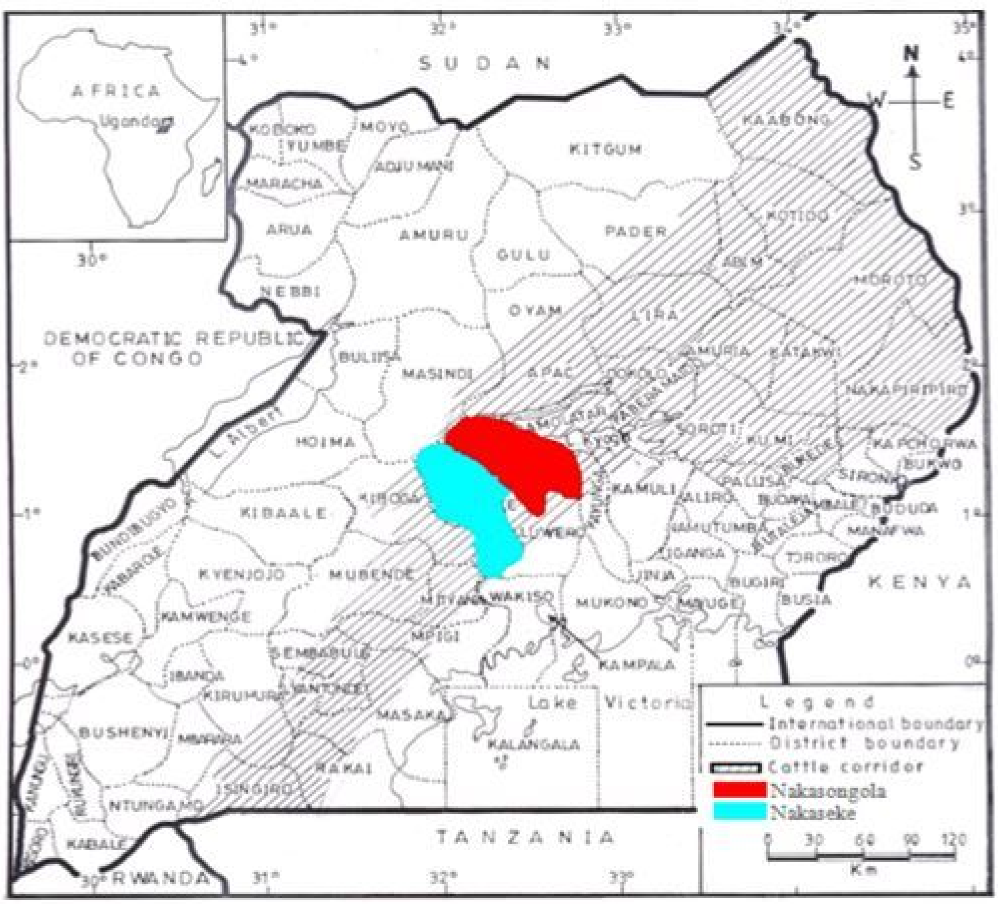

Figure 1

Location of Nakaseke and Nakasongola Districts.

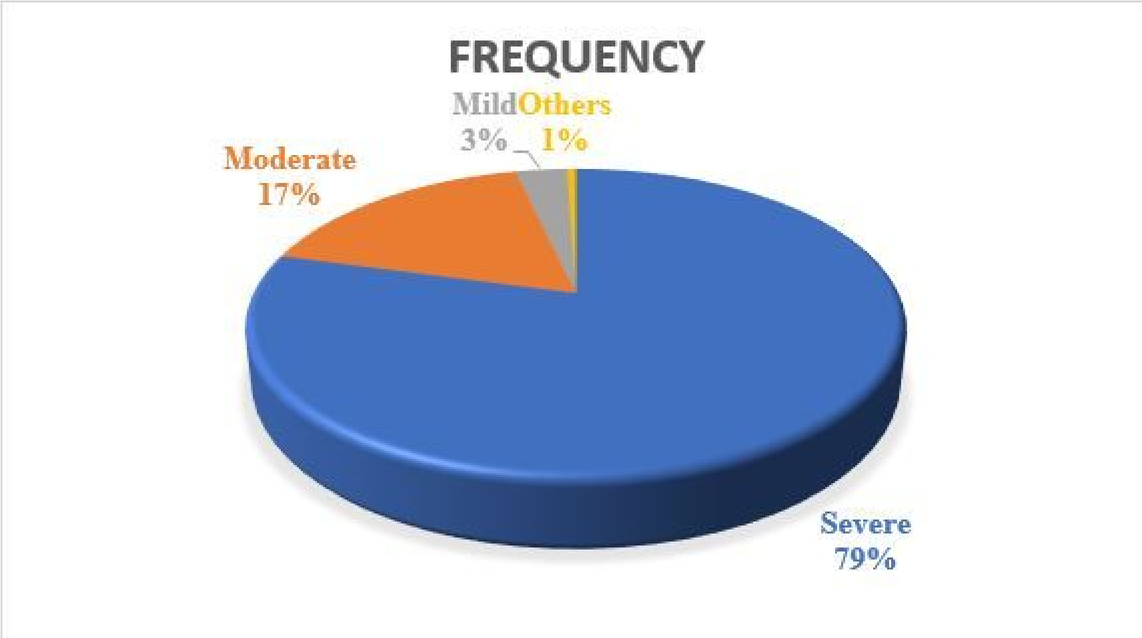

Figure 2

Tick infestation in cattle

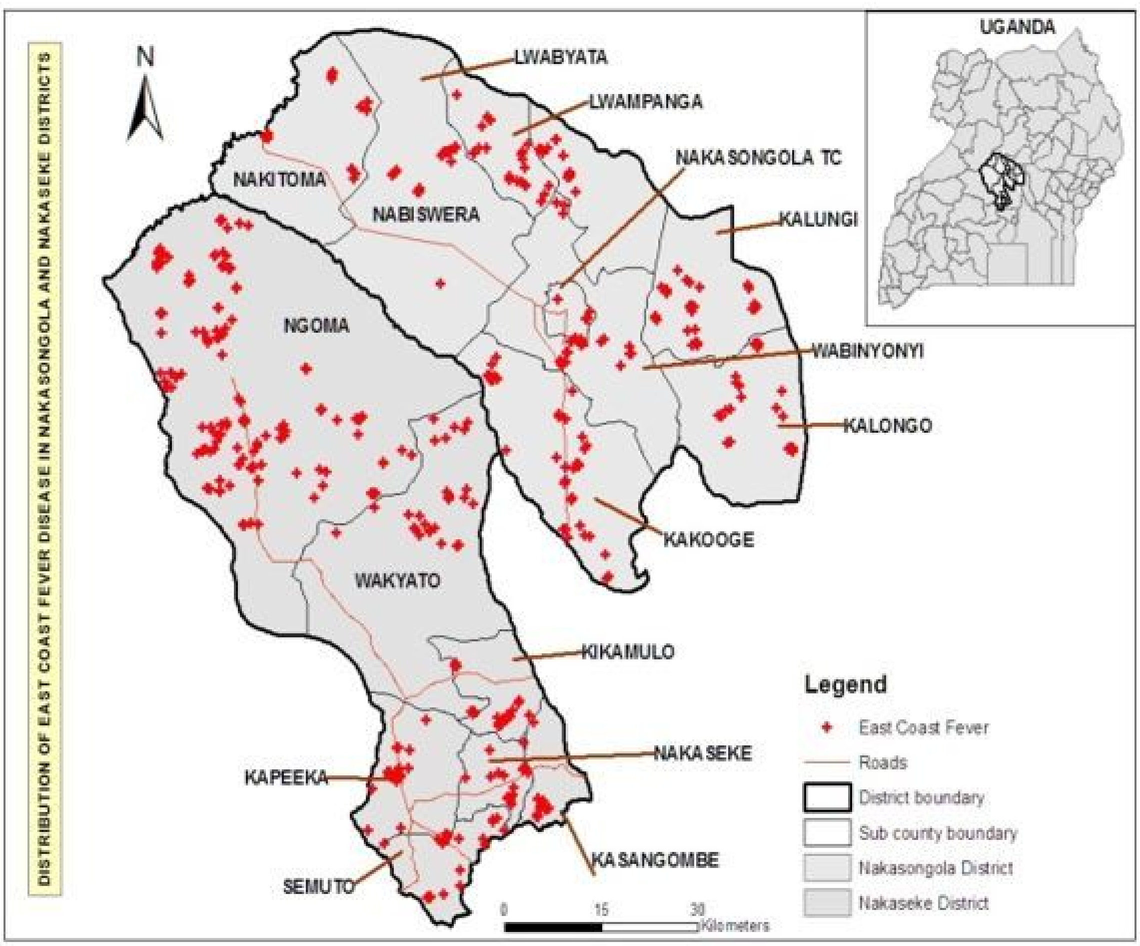

Figure 3

Perceived prevalence of ECF (Questionnaire)

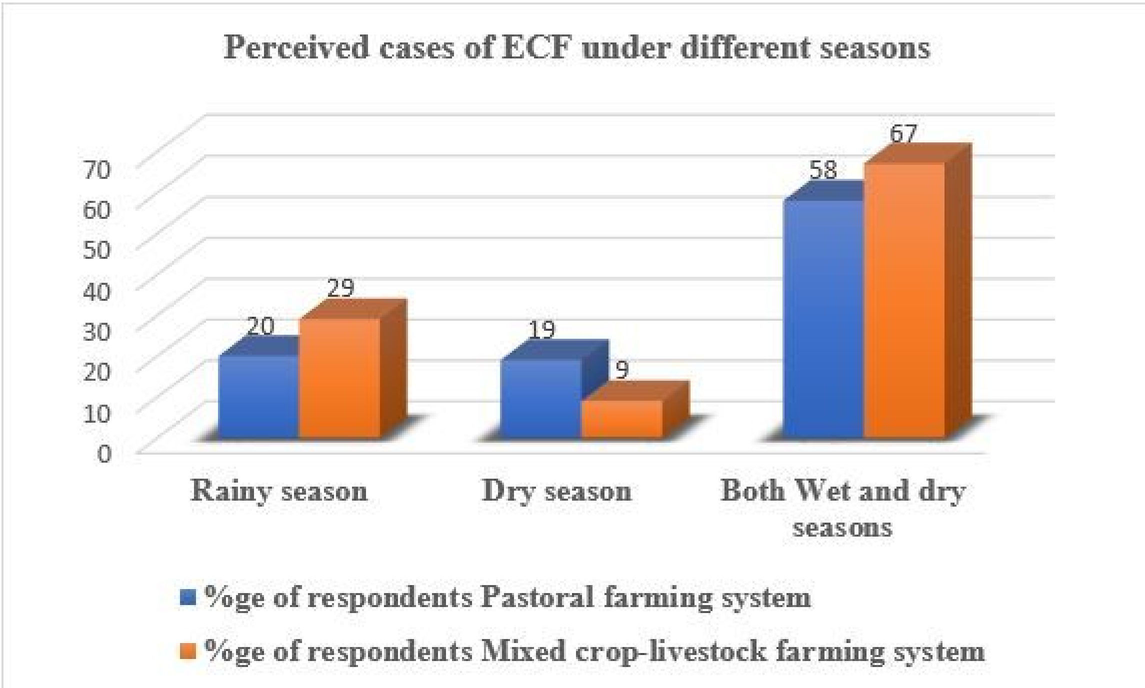

Figure 4

Occurrence of ticks in different seasons

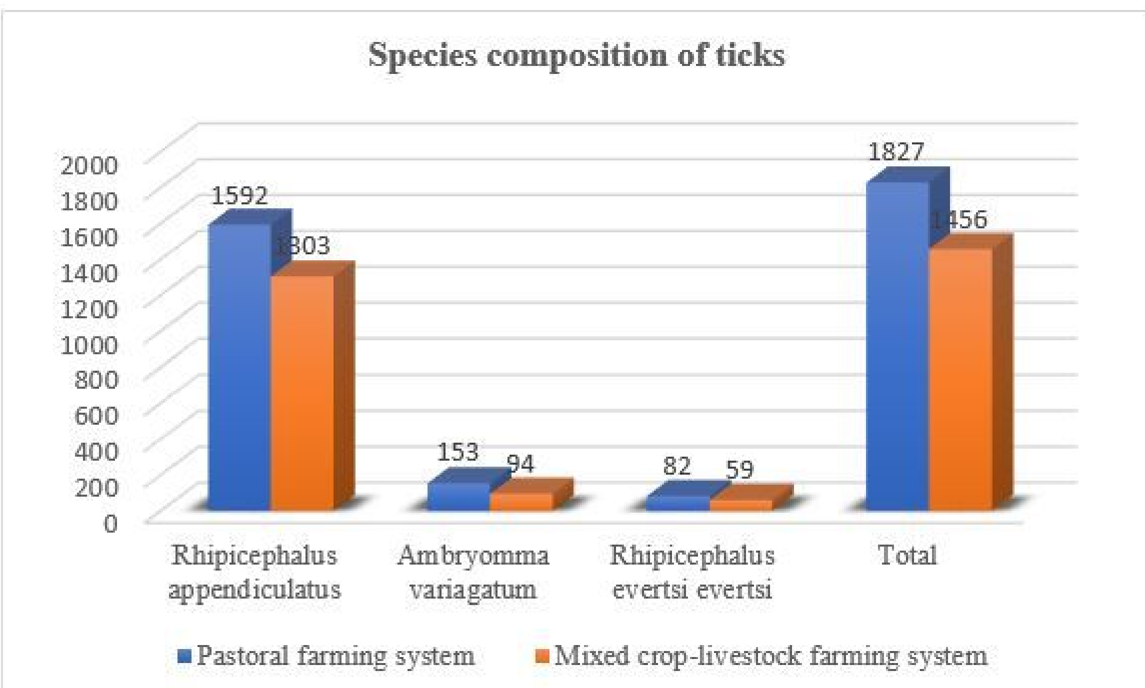

Figure 5

Various types of ticks found on cattle

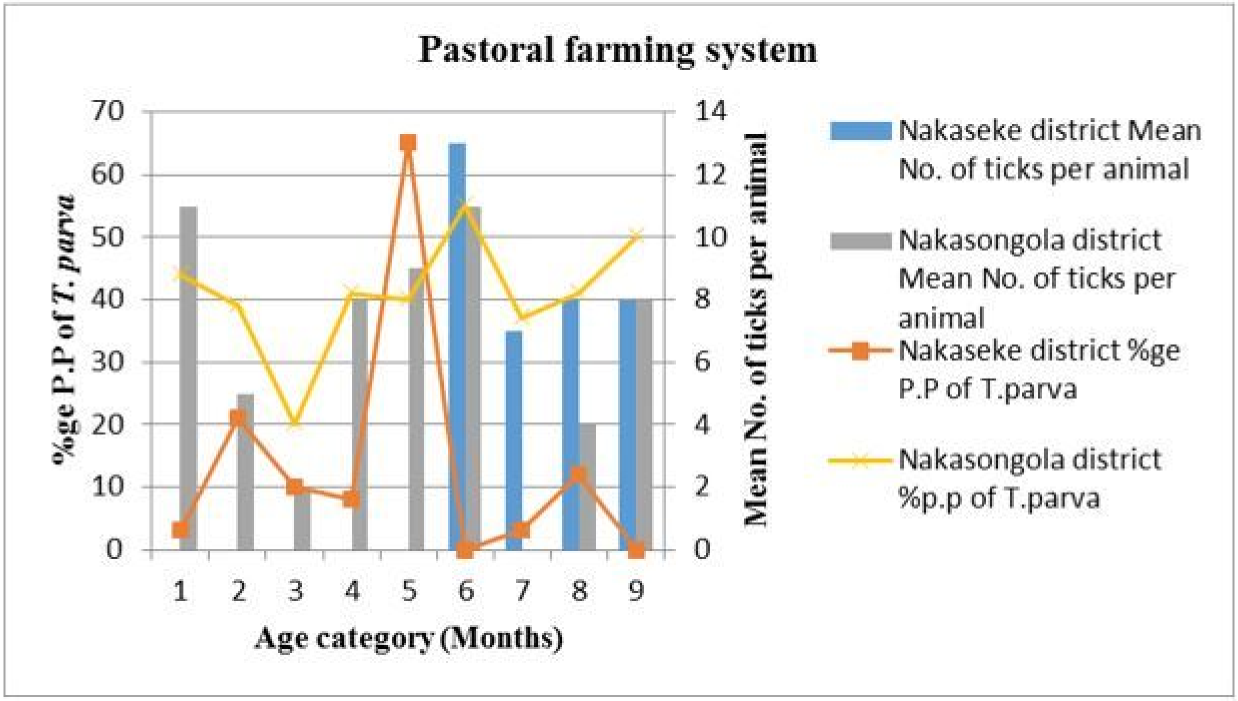

Figure 6

Variations of mean number of ticks per animal and pp of T. parva with age of calf in the pastoral farming system

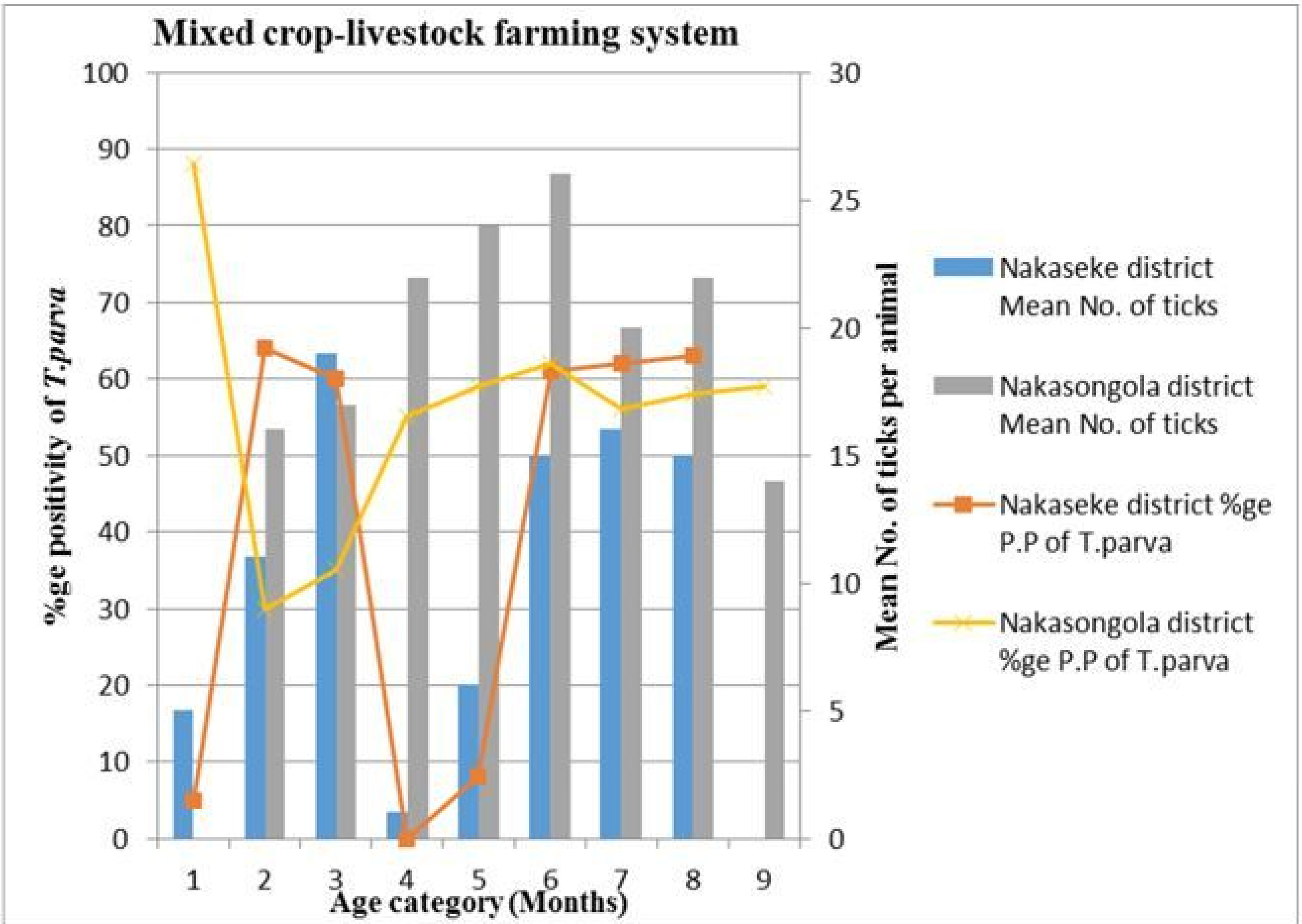

Figure 7

Variations of mean number of ticks and pp of T. parva with age of calf in the mixed crop-livestock farming system