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Using participatory epidemiology to investigate management options and relative importance of tick-borne diseases amongst transhumant zebu cattle in Karamoja Region, Uganda

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ABSTRACT

A participatory epidemiological (PE) study was conducted with livestock keepers in Moroto and Kotido districts, Karamoja Region, Uganda, between October and December 2013 to determine the management options and relative importance of tick-borne diseases (TBDs) amongst transhumant zebu cattle. Data collection involved 24 focus group discussions (each comprising 8–12 people) in 24 settlement areas (manyattas), key informant interviews (30), direct observation, a review of surveillance data, clinical examination, and laboratory confirmation of cases of TBDs. Methods used in group discussions included semi-structured interviews, simple ranking, pairwise ranking, matrix scoring, proportional piling and participatory mapping. The results of pairwise comparison showed the Ngakarimojong-named diseases, lokit (East Coast fever, ECF), lopid (anaplasmosis), loukoi (contagious bovine pleuropneumonia, CBPP), lokou (heartwater) and lokulam (babesiosis), were considered the most important cattle diseases in Moroto in that order, while ECF, anaplasmosis, trypanosomosis (ediit), CBPP and nonspecific diarrhoea (loleo) were most important in Kotido. Strong agreement between informant groups (Kendall's coefficient of concordance $W = 0.568$ and 0.682; $p < 0.001$) in pairwise ranking indicated that the diseases were a common problem in selected districts. East Coast fever had the highest median score for incidence (18% [range: 2, 33]) in Moroto, followed by anaplasmosis (17.5% [8,32]) and CBPP (9% [1,21]). Most animals that suffered from ECF, anaplasmosis, heartwater and babesiosis died, as the respective median scores for case fatality rates (CFR) were 89.5% (42, 100), 82.8% (63, 100), 66.7% (20, 100) and 85.7% (0, 100). In Kotido, diseases with high incidence scores were ECF (21% [6,32]), anaplasmosis (17% [10,33]) and trypanosomosis (8% [2,18]). The CFRs for ECF and anaplasmosis were 81.7% (44, 100) and 70.7% (48, 100), respectively. Matrix scoring revealed that disease indicators showed strong agreement ($W = 0.382–0.659$, $p < 0.05–p < 0.001$) between informant groups. Inadequate knowledge, poor veterinary services and limited availability of drugs were the main constraints that hindered the control of TBDs. Hand picking of ticks was done by all pastoralists while hand spraying with acaricides was irregular, often determined by availability of drug supplies and money. It was concluded that TBDs, particularly ECF and anaplasmosis were important diseases in this pastoral region. Results from this study may assist in the design of feasible control strategies.

Abbreviations: APUA, Alliance for the Prudent Use of Antibiotics; ATAAS, Agricultural Technology and Agribusiness Advisory Services; CAHW, community-based animal health worker; CBPP, contagious bovine pleuropneumonia; CTTBD, Centre for Ticks and Tick-Borne Diseases; DVO, district veterinary officer; ECF, East Coast fever; GALVmed, Global Alliance for Livestock Veterinary Medicines; IICD, Institute for International Cooperation and Development; ITM, infection-and-treatment method; MAAIF, Ministry of Agriculture, Animal Industry and Fisheries; NARO, National Agricultural Research Organisation; NGO, non-government organisation; PE, participatory epidemiology; REC, Research Ethics Committee; SNV, Netherlands Development Organisation; TBD, tick-borne disease; UBOS, Uganda Bureau of Statistics; UNCST, Uganda National Council for Science and technology.

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1. Introduction

Tick-borne diseases (TBDs) are reported to be the major limitation to cattle production systems in Africa (Malak et al., 2012; Onono et al., 2013). They cause economic losses to farmers through cattle mortality, loss of body weight, milk loss, and control costs through chemotherapy, vaccination, and control of ticks by use of acaricides (Kivaria, 2006; Ocaido et al., 2009a). In Tanzania, the total annual national loss due to TBDs was estimated to be US $364 million (Kivaria, 2006). In Uganda, ticks and TBDs accounted for 75.4% of losses in cattle (Ocaido et al., 2009b), and the costs for control constituted 85% of the total disease control costs in cattle (Ocaido et al., 2009a). Although the effects of TBDs are more pronounced in exotic cattle, they are also a problem in indigenous cattle, especially in situations of endemic instability (Norval et al., 1992).

Pastoralist communities in Africa live in some of the least developed and harshest environments in the world. In these communities, livestock contribute significantly to the social and economic well-being of people (Ocaido et al., 2009a; Onono et al., 2013). In Karamoja Region, the livelihoods of the communities are highly dependent on livestock (IICD, 2010). Cattle in the region are of the short-horned East African zebu breed (*Bos indicus*) and make up a relatively large percentage (19.8%) of Uganda's cattle population (MAAIF, 2011). Grazing is extensive on communal land and there is no supplementary feeding. Due to cycles of drought, transhumance is the livestock management system practiced. In the wet season, enclosures ("kraals") are closer to the permanent settlement zone, taking advantage of temporary pools for watering. In the dry season, pastoralists move their animals to neighbouring districts and countries in search of pastures and water (Anderson and Robinson, 2009). Despite the importance of livestock in the region, there is little information from systematic studies regarding cattle diseases. Local knowledge of pastoralists about the relative importance of cattle diseases, husbandry, and control practices is not fully exploited.

The use of conventional veterinary research and surveillance in pastoral areas is constrained because pastoralists often live in trans-boundary ecosystems and routinely cross national borders to access grazing areas. Furthermore, government veterinary services are poorly funded and the areas are not attractive to veterinarians (Shiferaw et al., 2010). In these areas, insecurity due to cattle raids is common (Chenyambuga et al., 2010), as exemplified by conflicts in South Sudan, Somalia, northern Kenya, eastern Ethiopia and the Karamoja Region of Uganda. As a result, veterinarians have to make best use of local knowledge and experience from the pastoralists, who are valuable sources of disease information (Catley et al., 2012). Participatory epidemiology (PE) is the systematic use of participatory approaches and methods, with the involvement of communities in defining and prioritising veterinary-related problems, and in the development of solutions to service delivery, disease control or surveillance (Catley et al., 2012). In recent years, PE methods have been adapted by epidemiologists to improve understanding of livestock diseases and impact on pastoralists' livelihoods, for example in Ethiopia and South Sudan (Catley et al., 2014; Malak et al., 2012). This approach is a relatively cheap and rapid way to generate information in marginalised resource-poor areas (Catley et al., 2014; Malak et al., 2012). Compared with conventional questionnaires, PE methods create an open and dynamic interaction between the pastoralists and the researchers, who act as facilitators. Within groups, different people offer ideas that are discussed and refined until the group reaches a collective decision (Catley et al., 2002). Moreover, PE methods such as informal interviewing, visualisation and ranking or scoring reduce non-sampling errors (e.g. badly-phrased or insensitive questions), because there is no need for the pastoralists to state the number of animals owned (Catley et al., 2014). Standardisation and repetition of the method allows for some quantification and statistical analysis (Catley et al., 2014). Furthermore, PE uses triangulation to improve the validity of findings by cross-checking information collected through different methods and sources (Catley et al., 2012).

This study was undertaken to determine the relative importance of TBDs as constraints to cattle production amongst livestock keepers in the transhumant system of Karamoja Region, Uganda, using PE methods. Further objectives were to establish current control measures used by livestock owners for ticks and TBDs, and to determine the constraints to the control of ticks and TBDs in the region. This information will assist the design of appropriate animal health programmes, to enhance livestock productivity and improve livelihoods of pastoral communities.

2. Materials and methods

2.1. Study area

This study was conducted in Karamoja Region, north-eastern Uganda. The region covers 27,511 km^2 (about 10% of Uganda) and lies between longitudes 33°30′E to 35°E and latitudes 1°30′ to 4°N. It is bordered by South Sudan to the north and Kenya to the east. The region is divided into seven administrative districts that are, in turn, divided into sub-counties containing a number of parishes and smaller settlement areas or manyattas. The region has a human population of approximately 1,455,200 (UBOS, 2014).

The region is mostly semi-arid. Rainfall is low (average 500–600 mm per year) with peak rainfall in April–May and July–September (Anderson and Robinson, 2009). The temperatures are high, ranging from an average minimum of between 15 °C and 18 °C to an average maximum of between 28 °C and 33 °C. The geographical features include wide savannah plains (1500 m above sea level) covered with seasonal grasses, thorny plants, and occasional small trees (IICD, 2010).

2.2. Selection of study locations

Two districts, Moroto and Kotido, were purposively selected representing pastoral and agro-pastoral livelihood zones, respectively (Anderson and Robinson, 2009). In each district, two sub-counties were randomly selected, using tabulated random numbers, from a sampling frame drawn up with the help of local leaders. The sampling units were manyattas, which are settlement areas occupied by clusters of families. Six manyattas were selected from each sub-county. From each manyatta, one informant group was mobilised for the interviews. Therefore, a total of 24 manyattas, comprising 24 informant groups (12 from each district) were selected. The manyattas and informants were purposively identified in a participatory manner together with community leaders and community-based animal health workers (CAHWs). Study locations are shown in Fig. 1. The informant groups comprised herd owners and cattle herders.

2.3. Data collection

2.3.1. Clearance, training and administration for the study

Ethical clearance for the study was obtained from the Research Ethics Committees (REC) of the National Agricultural Research Organisation (NARO), Uganda (no. 1416), and the Faculty of Humanities, University of Pretoria (no. GW20150211). The RECs of NARO are accredited by the Accreditation Committee of Uganda National Council for Science and Technology (UNCST), and they review and approve research projects, with the aim of protecting rights and welfare of human research participants. The Agricultural Technology and Agribusiness Advisory Services (ATAAS) project,

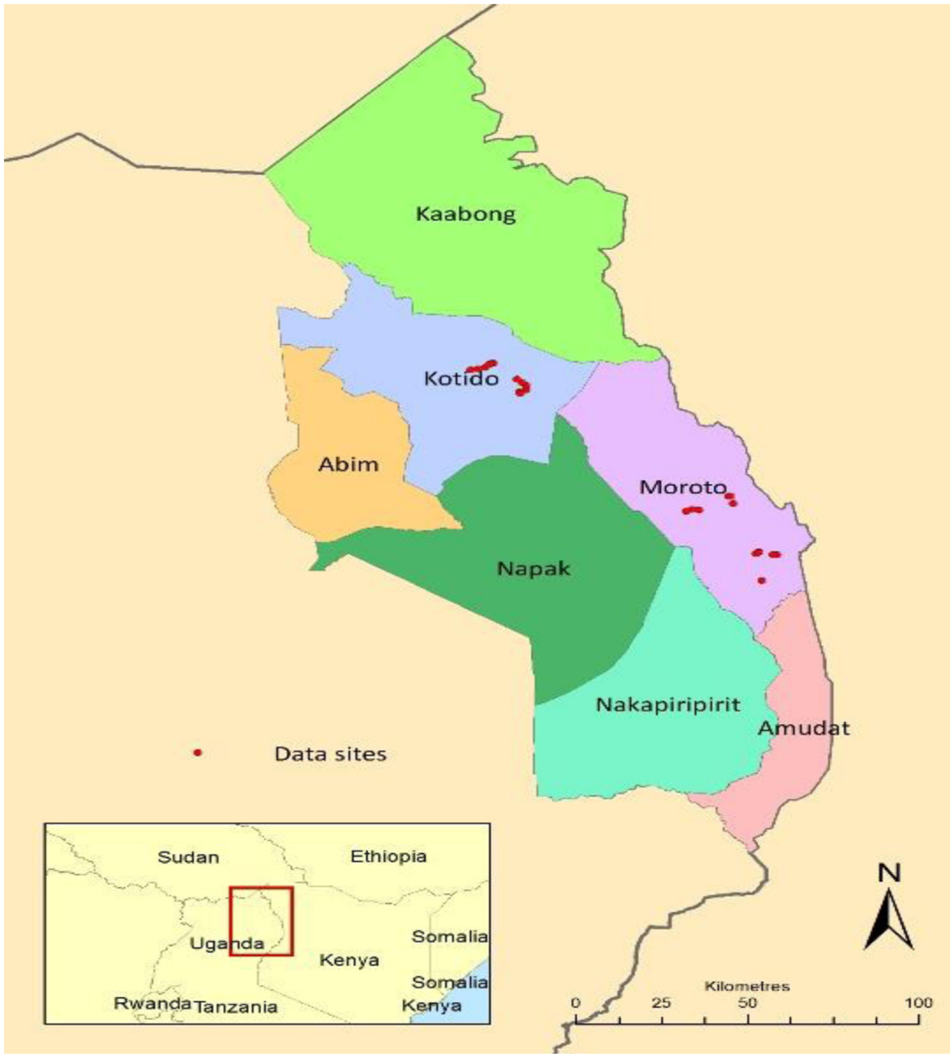

Fig. 1. Map of Karamoja Region showing the study sites in the districts of Moroto and Kotido. The region is sub-divided into seven districts. The study was conducted in 4 sub-counties, two in each district. Inset is the map of Uganda and neigbouring countries, highlighting the location of the study area.

under which this study falls, was approved by UNCST. Data collection progressed only after consent was given by the participants. To avoid bias during mobilisation, we introduced the general topic of the study as cattle health and management, rather than specifically TBDs. Methodological training that consisted of PE techniques, interviewing skills, and in-class practice of selected PE techniques (Catley, 2005) was conducted for the team members.

Data were collected between October and December 2013 using PE techniques described by Catley et al. (2012). Data collection tools consisted of focus group discussions, key informant interviews, review of surveillance data and researcher observations. Discussions with the participants were conducted in the local language (Ngakarimojong), by two teams of 4 members: a team leader who asked most of the questions and facilitated the discussion, a community mobiliser, a recorder and a translator. In each team, there was one veterinarian and two assistant veterinarians. The checklist of topics and PE techniques were pre-tested and adjusted in one location in Moroto district, which was not included in the final study. Each team conducted one or two discussions per day, normally in the mid-morning, with discussions taking an average of 90 min. Within each method, cross-checking and probing were done to verify internal consistency of information, make sure that the informants understood the different items to be scored or ranked, and to gather more detailed information on a particular subject. Efforts were made to ensure all members of the discussion group expressed their opinions, and that discussion was open and not dominated by one or a few individuals. The informants were given time to discuss and reach consensus. Ranking, scoring and other visualisation activities were done on flip charts that were laid on the ground. The PE activities were repeated with all 24 informant groups (12 in Moroto, 12 in Kotido) representing 24 manyattas. In the afternoon, interview teams met and reviewed the records of the discussions to ensure these were accurate.

2.3.2. *Participatory epidemiology tools*

2.3.2.1. Semi-structured interviews and participatory mapping for groups. Semi-structured interviews were used to gather qualitative data by guided conversation on pre-determined topics, using open-ended questions. The topics included husbandry and grazing systems, description of major diseases affecting cattle, control options for ticks and TBDs, and timing and frequency of tick control. Other topics were veterinary services, use and source of veterinary drugs, and constraints to the control of ticks and TBDs. The informants listed the diseases that affected cattle by their own description and local names. The researchers and district veterinarians knew the local disease names, and the description by the informants was collated with confirmation from previous clinical and post-mortem findings, and laboratory diagnosis (field veterinarians, personal communication), and then available literature.

Participants drew a map of their area using coloured pens. The map showed the location of roads, wet and dry season grazing areas, watering points (including rivers, ponds and dams), veterinary services and drug sources, and physical features like hills and settlements. Participants highlighted areas associated with high intensity of ticks, wildlife habitats, and distribution of haematophagous insects. Following the map, semi-structured questions were asked to obtain specific information about the epidemiology of TBDs.

2.3.2.2. Simple ranking for tick control options and drugs used. Cards were used to represent tick control options and drugs. A symbol that depicted the item to be ranked, as suggested by the participants, was drawn on a card. Informants then arranged items vertically in an order based on defined criteria: effectiveness, cost, frequency and simplicity of use. The cards were arranged on the ground against one criterion at a time. The first and last cards in the sequence were given the highest and lowest scores, respectively. The item with the highest score was then ranked number one.

2.3.2.3. Pairwise ranking and comparison for cattle diseases and constraints to control of TBDs. Pairwise ranking was done by comparing each item individually with all the other items one-by-one. The informants were asked to list and discuss the five most important cattle diseases with respect to cattle productivity and impact on their livelihoods. The recorder sketched a 5×5 grid. Two cards that represented two diseases were then randomly picked, and the informants were asked to compare the two diseases and mention the reasons why one disease was more important than the other. The recorder documented the disease that was indicated as more important in the corresponding box. The total score (0–5) for each disease in a group was noted. The median scores for each disease in the 24 groups were then used to establish an overall ranking. The exercise was repeated for constraints to the control of ticks and TBDs, and the participants discussed ways of improving TBD control. The process of pairwise ranking for diseases was used to generate indicators for disease matrix scoring (see next section).

2.3.2.4. Matrix scoring for cattle diseases. The matrix scoring for the diseases was conducted as described by Catley and Mohammed (1996). In each district, the five top-ranked cattle diseases, based on the pairwise ranking, were scored against clinical and production-related indicators mentioned during the pairwise comparisons. The diseases were represented using cards, which were placed along the top *x*-axis of the matrix and the indicators were illustrated on cards placed along the *y*-axis. Other diseases outside the top five were categorized as 'others'. An indicator (e.g. mortality rate) was picked at random to score. The informant group was given 30 stones to divide among the disease cards, the stones indicating that the disease was associated with the indicator being scored. The number of stones was chosen because five stones per disease should be sufficient to show differences between diseases but not so large as to be difficult to handle or divide (Catley and Mohammed, 1996). The number of stones allocated to each disease was then counted and recorded. The scoring procedure was repeated until all the indicators had been scored against each disease.

2.3.2.5. Proportional piling for disease incidence. Proportional piling was used to estimate the incidence, mortality and case fatality rate of the five most important cattle diseases, using the method described by Catley et al. (2014). Each informant group was provided with a pile of 100 stones that represented the number of cattle in a herd. First, the informant group was asked to divide the stones into two, a pile representing the proportion of the herd that got sick and those that remained healthy during the past one year. The pile representing the proportion of animals that became ill was further sub-divided into 6 piles corresponding to the proportion of animals that got each of the five diseases and a sixth group representing 'other diseases' during the past one year. This activity provided estimates of the annual incidences of the diseases. Subsequently, each group was asked to remove some of the already-allocated stones representing the sick, to indicate the proportion of dead animals for each of the five prioritised diseases and the group of 'other diseases' during the past one year. We cross-checked the pattern of surviving in relation to dead, and asked about the proportion of survivors treated, the type of treatment used, and proportion of survivors still in the herd. We also asked for the durations of illness within the pile that represented the dead animals. This provided estimates of the mortalities and case fatality rates due to the diseases. The group of 'other diseases' was not included in the estimation of case fatality rates.

2.3.2.6. Key informant interviews, review of surveillance data, direct observation, clinical examination, and collection of ticks. Key informant interviews ($n = 30$) were held independently before or after the group sessions, with district veterinary officers (DVOs) and CAHWs. The interviews followed a checklist of important topics to guide the discussion, including husbandry and grazing systems, major cattle diseases, control options for ticks and TBDs, acaricides and chemotherapeutic drugs sources and use, and constraints to the control of ticks and TBDs. Information from the veterinarians on diseases was based on clinical examination, postmortem findings, and surveillance data provided to the DVOs from the Institute for International Cooperation and Development (IICD). The IICD is an Italian non-profit organisation with objectives that include improving livestock production and productivity in Karamoja Region, and has a Veterinary Diagnostic Laboratory. The DVOs regularly (between 3 months and one year) request the IICD to provide or conduct disease surveillance. The informants also estimated distances between key features, which had been mentioned in group discussions.

To seek confirmation of information gathered during the PE study, we assessed a published surveillance report (IICD, 2010) and other literature (Jost et al., 1998). We also observed pastoralists' activities regarding tick and TBD control in some herds, and analysed the surrounding environment as we walked through the villages. In 18 of the 24 manyattas visited, we found sick animals (including calves) that had not been driven out for grazing ($n = 82$). We took case histories, conducted clinical examinations of the animals, and provided treatment and/or gave advice. To avoid bias, treatment of cases was only done after group discussions in a sub-location were complete. We examined blood samples from eight clinical cases of TBDs at University of Pretoria (Onderstepoort, South Africa) by reverse line blot hybridization assay (Byaruhanga et al., unpublished data). Ticks were also collected on whole body of 161 cattle in separate visits to 20 herds, to estimate potential risk of transmission of TBDs.

2.4. Statistical analysis

Non-parametric tests and descriptive statistical procedures (frequencies, median and range) were used to analyse the PE data, using Statistical Package for the Social Sciences (SPSS) version 20.0 (IBM SPSS, 2011). The level of agreement between informant groups was assessed using Kendall's coefficient of concordance (W). A p-value was assigned to W. Evidence of agreement between informant groups was categorised as 'weak' ($W < 0.26$, $p > 0.05$), 'moderate' ($W = 0.26–0.38$, $p < 0.05$) and 'strong' ($W > 0.38$, $p < 0.01$) as previously described by Catley (2006).

Table 1
Pairwise ranking: overall ranking of cattle diseases amongst groups of livestock keepers in Karamoja Region, Uganda, October to December 2013.

Disease	Moroto			Kotido		
	n	Median score	Rank	*n*	Median score	Rank
East Coast fever	12	4.0	1	12	3.0	2
Anaplasmosis	12	3.0	2	12	3.0	2
Trypanosomosis	0	–	–	12	1.5	3
CBPP	12	2.0	3	12	1.0	4
Nonspecific diarrhoea	2	0	8	7	0.5	5
Heartwater	9	0	4	1	0	7
Blackquarter	4	0	6	3	0	6
Mange	3	0	7	1	0	8
Babesiosis	5	0	5	0	–	–
Overgrown hooves/foot rot	2	0	9	0	–	–
Anthrax	1	0	10	1	0	9

n—number of informant groups.

3. Results

3.1. Composition of the groups

The number of informants in the focus groups ranged from 8 to 12, and they were all male. The social setting of the communities in Karamoja Region makes it difficult to interview women, reportedly due to high domestic workload for women, but also due to cultural norms. By our observation, women were preoccupied with activities including construction and repair of houses and fences around the manyattas. It was also the role of women to avail food in the homes. Nearly all the informants were illiterate. No group declined to participate in the study, and all informants readily participated in the interviews.

3.2. Grazing systems and water sources

Participatory mapping revealed that animals graze close to the settlement areas (within 5 km) during the wet season. During the dry season, animals migrate and share grazing and watering points with communities from neigbouring districts and countries (mainly with Turkana from Kenya). The participants indicated that it would take them up to two days to reach the dry season grazing areas. The informants mentioned that tick infestations and the risk of TBDs were higher in the wet season and communal grazing areas. Haematophagous insects, which may transmit some TBDs, were prevalent in the grazing areas. Wild animals (e.g. buffaloes and small antelopes) shared grazing with livestock, mostly in dry season grazing areas. In Kotido, dry grazing areas were in proximity to Kidepo Valley National Park.

3.3. Cattle diseases

3.3.1. Description of cattle diseases

The semi-structured interviews showed that the informants understood and demonstrated good knowledge of clinical signs, post mortem findings and epidemiological features of cattle diseases which conform to the literature (e.g. Radostitis et al., 1994). This knowledge is orally passed on from one generation to the next. The common cattle diseases were given literal meanings in the local language which correspond to specific disease entities. Anaplasmosis and babesiosis were recognised by all Karamojong livestock keepers as lopid (bile disease) and lokulam (urinary bladder disease), respectively. The participants mentioned that anaplasmosis was characterised by 'enlarged gall bladder', 'hard dry dung', 'yellowish discoloration of the outer membranes and internal organs'. Through the years, the livestock keepers have learnt to associate particular lesions in internal organs or tissues of dead animals with specific diseases. ECF was known by the cattle keepers as lokit (ear disease), an association with the enlargement of the parotid lymphnodes, which are found behind the ears, in the early stages of the disease. Heartwater is recognised as lokou (head disease), characterised mainly by animals moving in circles. The participants emphasised that ECF was associated with grazing animals on pasture where they pick up the ticks that transmit the disease; however, the informants were uncertain about the causes of anaplasmosis, heartwater and babesiosis. Nonspecific diarrhoea was known locally as loleo which literally means 'severe diarrhoea'. It refers to a condition where sick animals have profuse diarrhoea, lose weight and have dry skin. The problem of overgrown hooves (emara) led to lameness in animals which eventually led to wounds and foot rot. Blackquarter is called ekicumet in Moroto and lokicumet in Kotido. Both names mean 'speared/pierced from one side'. The disease emitina (mange), meaning 'itching spots', was reportedly more common in calves, characterised by hairless areas around body parts. Ediit (trypanosomosis), literally 'tsetse fly', was associated with bites from tsetse flies, the principal vectors of the disease. Contagious bovine pleuropneumonia (CBPP) was recognized as loukoi (lung disease), characterised by 'laboured, fast breathing and cough', and at slaughter, 'lungs are attached to the thoracic cavity' and 'fluids and pus accumulate in the lungs'. A disease referred to by the cattle keepers as lotidae, which reportedly affected humans, and led to skin lesions after contact with blood from affected animals, often leading to death, was later defined by the DVOs as anthrax. Clinical manifestations of mixed infections were described by the observation of concurrent clinical signs and/or postmortem features of the respective diseases. We did not encounter conflicting information amongst informant groups and individuals regarding the perception and knowledge of livestock diseases in the two districts.

3.3.2. Most important cattle diseases as determined from pairwise ranking

As shown in Table 1, informants in Moroto ranked the five most important cattle diseases as ECF, anaplasmosis, CBPP, heartwater and babesiosis in that order. The most important diseases in Kotido were ECF and anaplasmosis (tied), trypanosomosis, CBPP and nonspecific diarrhea in that order. Prioritisation and ranking of disease pairs by the cattle keepers were based on morbidity and mortality rates, rates of transmission, treatment costs, difficulty in accessing the correct treatment, difficulty of control, rapid fatality, and lack of knowledge to manage the disease. East Coast fever, anaplasmosis, and CBPP were listed in the pairwise ranking activity in every informant group in both districts. Kendall's coefficient of concordance (W) for informant groups for the diseases indicated strong agreement in Moroto ($W = 0.682$, $p < 0.001$, $n = 12$) and Kotido ($W = 0.568$, $p < 0.001$, $n = 12$).

3.3.3. Matrix scoring for cattle diseases

The results of matrix scoring for the five most important diseases and a group of 'other' diseases by informants' criteria in Moroto and Kotido are summarised in Tables 2 and 3, respectively. Disease indicators were identical between districts. In both districts, there was strong agreement between informant groups for the 8 disease indicators ($W = 0.38–0.66$, $p < 0.05$ to $p < 0.001$). ECF and anaplasmosis had the highest scores for all the indicators.

3.3.4. Incidence of cattle diseases

The overall median proportion of cattle that became ill during the past one year, with the range, was 65.5% (range: 39, 93). Overall median deaths from all diseases in Moroto and Kotido were 44% (39, 93) and 53% (45, 84), respectively. The overall median scores for annual incidence, mortality and case fatality rates of cattle estimated by Karamojong cattle keepers and attributed to the five top ranked and 'other diseases' in Moroto and Kotido, during proportional piling, are illustrated in Tables 4a and b, respectively. East Coast fever had the highest estimated incidence score in Moroto (18% [2,33]) and Kotido (21% [6,32]), followed by anaplasmosis (17.5% [8,32] and 17% [10,33], respectively). Tick-borne diseases (ECF, anaplasmosis, heartwater and babesiosis) were responsible for 69.7% and 79.3% of the overall illness and deaths, respectively, in Moroto. Of the total illnesses and deaths reported in Kotido, 56.1% and 60.7%, respectively, were due to ECF and anaplasmosis. Most animals that suffered from TBDs in the study area died, as the median scores for case fatality rates were at least 66% for each disease.

3.4. Control of ticks and tick-borne diseases

3.4.1. Tick control practices

The conventional methods for controlling ticks were hand spraying and pour-on acaricides. Other methods included picking off ticks by hand, bush burning and the use of plants. For all 24 informant groups, daily picking of ticks by hand and irregular hand spraying with acaricides were the most common tick control practices. Hand picking was a common practice because there is no monetary cost, it does not require special skills or knowledge, and can be done at any time. Ticks were killed by throwing them into a fire or crushing them between stones.

The purchase of acaricides was determined by availability of supplies and money. Quantities of acaricides bought were often insufficient, leading to spraying at irregular and infrequent intervals. Spraying was done with hand sprays. Only 2 groups (19 participants) used spray pumps. Some cattle keepers indicated that they applied acaricides by swabbing the body of the animals with fibres of shrubs soaked in acaricides. About two-thirds of herders did the dilution using uncalibrated materials. They described the quantities of acaricide used in terms of bottle lids. From our observation and information from the key informants, cattle keepers used insufficient acaricide wash (about one litre per animal). However, apart from one group in Kotido, the informants noted that the efficacy of the acaricides was good to control ticks.

The most common acaricides were amitraz group formulations (mainly Amitix®), indicated by 215 informants in 23 groups. Ivermectin, flumethrin, pye-grease and Supona Extra® (chlorfenvinphos pour-on) were used by few participants (31, 65, 31 and 37 individuals in 3, 7, 3 and 4 manyattas, respectively). Livestock keepers preferred amitraz acaricides to other groups, as amitraz drugs were cheaper. One group (9 informants) in Moroto used deltamethrin (Decatix®).

The frequency of spraying ranged from twice a week to once a year. Half (12) of the informant groups ($n = 117$ individuals) applied acaricide weekly in wet and dry seasons (if acaricides were available). Acaricides were applied to only those animals with high tick infestations. Spraying was generally more frequent in the wet than dry season, with some informants indicating that they sprayed twice a week in the wet season. The pastoralists noted that ticks survived and multiplied better in the wet season, leading to higher intensity which required higher frequency of spraying. Furthermore, there was a perception that acaricides were washed off in the rain and this prompted them to spray their animals again. Tick control in calves commenced when ticks were seen on the animals, about two weeks after birth.

Bush burning in the dry season as a method to control ticks was mentioned by 17 ($n = 162$) of the 24 groups, with the aim to destroy ticks and their habitats (grass). However, the informants believed the method was less effective since the ticks burrowed underground or climbed trees to escape the fire. Traditional medicine including the use of plants is practiced (68 pastoralists in 7 groups) to control ticks; however, the informants said the method was less effective, and that plants were used in desperation to control ticks when conventional acaricides were not available.

3.4.2. Drugs and drug use practices in treating TBDs

All group participants admitted that they were treating cases of TBDs. Oxytetracycline was the drug most commonly used and it was used indiscriminately for various diseases. All the participants in the 24 manyattas indicated they used a 10% concentration of oxytetracycline and 5 groups ($n = 51$) also used a 20% concentration. From our observation, oxytetracyclines are more available and cheaper than alternatives, and are perceived by cattle keepers to have a broad spectrum of activity against a number of diseases.

Some participants occasionally used other drugs including parvaquone (e.g. Parvexon®) and buparvaquone (e.g. Butalex®) for ECF (9 groups, $n = 89$), Imizol® for anaplasmosis (3 groups, $n = 33$), diminazene aceturate (4 groups, $n = 42$) and penicillin-streptomycin formulations (7 groups, $n = 67$). The participants could distinguish the different brands and concentrations of commonly-used drugs only by their prices and packaging. Identity of the drugs was obtained through probing, combined with the experiences of CAHWs and community mobilisers. At times, the informants showed the drugs that were kept for use or empty bottles which previously contained the drugs. The cattle keepers did not necessarily take into account the weights of the animals and dose regimens were not properly followed.

Traditional herbs were also reported as a treatment for TBDs. These included *Aloe vera*, tobacco and red pepper for ECF. Burning of lymphnodes with hot iron was mentioned by three informant groups ($n = 29$) as a treatment for ECF. All informants indicated that treatment against TBDs was not very effective leading to low recovery rates, probably due to under dosing and the use of incorrect drugs.

3.4.3. Constraints to the control of ticks and TBDs

The informants ranked the major constraints that hindered the control of ticks and TBDs as inadequate knowledge, inadequate veterinary services, limited availability of drugs, and shortage of money in that order. Other constraints in order of importance were high costs of drugs, lack of equipment, lack of cattle crushes, and insecurity from cattle raids.

Inadequate veterinary services were blamed on the small number of local veterinarians (one or two per district) who could seldom reach the communities. Non-government organisations (NGOs) and CAHWs complement the local veterinary services; however, they had limited inputs for animal health care, and in some cases CAHWs were not residents of the respective communities. In the absence of CAHWs, the cattle keepers bought drugs and treated their animals. The informants indicated that due to inadequate veterinary services, they lacked enough information to determine proper dosage and correct treatment for diseases.

Table 2
Summarised matrix scoring of cattle diseases by pastoralists' criteria in Moroto district, Uganda.

Indicator	Disease					
	ECF	Anaplasmosis	CBPP	Heartwater	Babesiosis	Others
	Lokit	Lopid	Loukoi	Lokou	Lokulam	
High morbidity (W = 0.61***)	10.5 (3, 15)	8 (7, 15)	3.5 (1, 11)	2 (0, 4)	0 (0, 4)	2 (0, 13)
High mortality (W = 0.52***)	10 (0, 30)	8 (0, 14)	3 (0, 6)	2 (0, 8)	0 (0, 5)	2.5 (0, 16)
Rapid fatality (W = 0.50***)	8 (1, 17)	8 (1, 13)	4 (1, 8)	2 (0, 6)	0 (0, 4)	3 (0, 20)
High treatment cost (W = 0.62***)	11 (1, 16)	9 (5, 18)	3 (1, 11)	2 (0, 4)	0 (0, 3)	3 (0, 11)
Difficult to treat (W = 0.66**)	12 (1, 14)	9.5 (7, 19)	2 (0, 8)	2.5 (1, 5)	0 (0, 5)	1.5 (0, 7)
Difficult to access correct drug (W = 0.47**)	8 (0, 13)	9.5 (0, 16)	3.5 (2, 30)	3 (0, 9)	0 (0, 1)	1.5 (0, 13)
Inadequate knowledge for effective treatment (W = 0.54***)	9 (2, 11)	9 (2, 14)	3 (1, 6)	2 (0, 9)	0 (0, 6)	4 (2, 12)
Rate of transmission[a] (W = 0.46*)	8.5 (0, 14)	8 (1, 13)	8 (2, 18)	0.5 (0, 3)	0 (0, 5)	2 (0, 6)

Number of informant groups = 12. W = Kendall's coefficient of concordance (*p < 0.05; **p < 0.01;***p < 0.001). W values vary from 0 to 1; the higher the value, the higher the level of agreement between the informant groups.
Median scores (number of stones that were assigned) are shown in each cell. Minimum and maximum values are shown in parentheses. More counters represent a stronger positive association.
[a] Rate of transmission was the rate at which other animals in the herd acquired a particular disease from the time the first case(s) was detected.

Table 3
Summarised matrix scoring of cattle diseases by pastoralists' criteria in Kotido district, Uganda.

Indicator	Disease					
	ECF	Anaplasmosis	Trypanosomosis	CBPP	Non-specific diarrhoea	Others
	Lokit	Lopid	Ediit	Loukoi	Loleo	
High morbidity (W = 0.55***)	8 (6, 13)	7 (4, 14)	3 (2, 11)	4 (2, 6)	2 (0, 8)	3 (0, 8)
High mortality (W = 0.46***)	8 (4, 15)	11 (5, 17)	2.5 (1, 7)	2.5 (1, 6)	1.5 (0, 9)	3 (0, 7)
Rapid fatality (W = 0.55***)	8 (5, 13)	8 (5, 12)	2 (1, 8)	3 (1, 5)	2 (0, 7)	3 (1, 14)
High treatment cost (W = 0.65***)	8 (6, 18)	7.5 (4, 12)	2.5 (1, 5)	3.5 (1, 7)	2.5 (0, 5)	4 (0, 6)
Difficult to treat (W = 0.61***)	8 (5, 14)	10 (7, 13)	2 (1, 4)	2 (1, 5)	1 (0, 8)	4 (0, 9)
Difficult to access correct drug (W = 0.61**)	8 (5, 12)	10 (5, 14)	3 (1, 5)	4 (1, 5)	1 (0, 5)	5 (1, 9)
Inadequate knowledge for effective treatment (W = 0.42*)	7 (6, 15)	8.5 (1, 14)	3.5 (1, 7)	4 (1, 8)	2.5 (0, 4)	2.5 (0, 6)
Rate of transmission[a] (W = 0.38**)	7.5 (3, 11)	6.5 (2, 11)	3 (2, 5)	5 (3, 7)	4 (0, 8)	3 (1, 11)

Number of informant groups = 12. W = Kendall's Coefficient of Concordance (*p < 0.05; **p < 0.01;***p < 0.001). W values vary from 0 to 1; the higher the value, the higher the level of agreement between the informant groups.
Median scores (number of stones that were assigned) are shown in each cell. The minimum and maximum values are shown in parentheses. More counters represent a stronger positive association.
[a] Rate of transmission was the rate at which other animals in the herd acquired a particular disease from the time the first case(s) was detected.

Table 4a
Median standardised scores of annual incidence, mortality and case fatality estimates for the five top ranked and other cattle diseases in Moroto district of Karamoja pastoral Region, Uganda.

	Median scores for diseases (%)					
	ECF	Anaplasmosis	CBPP	Heartwater	Babesiosis	Others
Sick	18 (2, 33)	17.5 (8, 32)	9 (1, 21)	5 (1, 10)	4 (1, 13)	7 (1, 23)
Dead	14 (1, 30)	17.5 (6, 32)	3.5 (1, 17)	2 (1, 19)	4 (0, 6)	2.5 (0, 23)
CFR	89.5 (42, 100)	82.8 (63, 100)	41 (19, 100)	66.7 (20, 100)	85.7 (0, 100)	

Results obtained by incidence scoring technique (number of informant groups = 12).
Other diseases: mange, blackquarter, anthrax, foot rot/overgrown hooves, nonspecific diarrhoea and lumpy skin disease.
CFR—case fatality rate; Numbers in brackets are minimum and maximum values.

Table 4b
Median standardised scores of annual incidence, mortality and case fatality estimates for the five top ranked and other cattle diseases in Kotido district of Karamoja pastoral Region, Uganda.

	Median scores for diseases (%)					
	ECF	Anaplasmosis	Trypanosomosis	CBPP	Nonspecific diarrhoea	Others
Sick	21 (6, 32)	17 (10, 33)	8 (2, 18)	6.5 (4, 18)	12 (4, 17)	5.5 (3, 10)
Dead	16.5 (4, 28)	10 (7, 30)	2 (0, 17)	2.5 (1, 13)	11 (2, 17)	2.5 (0, 7)
CFR	81.7 (44, 100)	70.7 (48, 100)	41.7 (14, 100)	38.9 (22, 100)	86.7 (40, 100)	

Results obtained by incidence scoring technique (number of informant groups = 12).
Other diseases: heartwater, mange, blackquarter, anthrax and lumpy skin disease.
CFR—case fatality rate; Numbers in brackets are minimum and maximum values.

Drug outlets were often lacking among communities; therefore, livestock keepers walked up to 45 km (distance estimated by key informants) in search of drugs. As a result, the cattle keepers could not control diseases in time, resulting in high morbidity and case fatality rates. Shortage of money, as expressed by two-thirds of the informant groups, meant that the cattle keepers had difficulty to buy drugs and equipment, and pay for the services of CAHWs. From our observation, the practice of selling animals for profit does not seem to apply in this region. Livestock keepers only sell animals when they need cash for basic needs such as food and medicines. One group in Moroto (11 participants) said that inaccessibility to diagnostic facilities hampered the effective treatment of diseases. There was strong agreement from pairwise ranking between informant groups for constraints to the control of TBDs [(Moroto, $W = 0.47$, $p < 0.001$), (Kotido $W = 0.35$, $p < 0.001$)].

3.5. Key informant interviews, review of surveillance data, direct observation, clinical examination of animals, and collection of ticks

Data collected showed agreement between key informants and cattle herders, regarding control of ticks and TBDs in the area. There was also agreement from the key informants about the most important cattle diseases. A review of surveillance data for cattle in Moroto and Kotido districts from 2009, revealed prevalences of 17–28% (anaplasmosis), 13–18% (babesiosis), 38–41% (ECF) by microscopic examination of blood and lymphnode smears (DVOs, personal communication; IICD, 2010). On clinical examination of the sick animals that we found in 18 of the 24 manyattas, we observed cases of TBDs: on average two cases of anaplasmosis and one of ECF per manyatta, and one case of heartwater in each of two manyattas in Moroto district. Reverse line blot hybridization assay confirmed the presence of *Anaplasma marginale* (5 anaplasmosis cases), *Theileria parva* and *A. marginale* (one ECF case), and *T. parva* (two ECF cases) in blood samples from clinical cases. From the 161 cattle examined for ticks, the number of ticks was 5947 for *Rhipicephalus appendiculatus*, 1929 for *Rhipicephalus* (*Boophilus*) *decoloratus*, and 1313 for *Amblyomma variegatum*. A high proportion of the cattle were infested: 77% (*R. appendiculatus*), 53.4% (*R.* [*Boophilus*] *decoloratus*), and 49% (*A. variegatum*).

Although Moroto and Kotido districts were previously categorised as pastoral and agro-pastoral zones (Anderson and Robinson, 2009), from our observation, and information from key informants and livestock keepers, livestock herding was the main livelihood activity in both districts. The degree of dependence on livestock (social, cultural and economic), and livestock migration was similar in the two districts.

4. Discussion

We used PE methods to define and prioritise cattle diseases, evaluate current control activities for TBDs, and identify constraints to control of TBDs. Participants also proposed solutions to service delivery, disease control and surveillance. Most pastoral areas of Africa, including Karamoja, are physically remote and characterised by mobility of herds. When combined with apparent reluctance of herders to provide accurate information on herd size to outsiders, disease estimates (e.g. mortality) determined by conventional research methods may be questionable due to invalid denominators (Catley et al., 2014). For individual interviews with conventional questionnaires, local people answer questions posed by outsiders, which may be of limited interest to them. In contrast, PE methods seem to offer lower risk of informants consciously offering incorrect or misleading information because the topic under discussion is often a local priority (Catley et al., 2012). Karamoja communities are clustered in manyattas where groups of cattle keepers have similar social, economic and political objectives, and manage and share resources (including animals, water and grazing) together. In such settings, any discussion on livestock is a concern for groups of cattle keepers, with consent of the manyatta leader, rather than individuals. For these reasons, we believe that PE methods have significant advantages over conventional household surveys in this setting.

Our PE results indicated that Karamoja cattle keepers regard TBDs, especially ECF and anaplasmosis, as a major constraint to cattle keeping in the area. This perception relates to the high incidence rate, high case fatality rates, and treatment costs associated with the diseases. The estimated incidence scores for TBDs were similar in the two districts, indicating that the diseases are widespread amongst cattle in Karamoja Region. Our findings are consistent with previous studies in Tanga Region, Tanzania (Swai et al., 2009), Machakos District, Kenya (Wesonga et al., 2010) and Kiruhura, Kayunga and Soroti districts of Uganda (Ocaido et al., 2009b) where ECF and anaplasmosis were the two top ranked diseases. Our findings are also consistent with those of Kasozi et al. (2014) who reported widespread occurrence of *T. parva* (47.4%) and *Anaplasma* spp. (14.4%) amongst cattle in 15 districts of western and central Uganda. In another study, Jost et al. (1998) demonstrated that anaplasmosis and ECF were the second and fourth most important diseases, respectively, in Karamoja Region. In this study, the overall mortality estimates (44–53%) in cattle from all diseases are similar to that reported among livestock keepers in South Sudan (39%; Malak et al., 2012), but differ from those in Ethiopia (6–18% in Catley et al., 2014; 8% in Shiferaw et al., 2010). The variations in the mortality may be due to differences in local epidemiologic conditions as well as control strategies and veterinary services. Our values for mortality are consistent with the Global Alliance for Livestock Veterinary Medicines (GALVmed) estimates that indicated that 60% of Karamojong pastoralists' calves die of ECF (GALVmed, 2014). In other reports from Karamoja, it was estimated that on average 100 cattle (out of about 3000) die per month in communal camps, mostly due to disease (equating to 40% annual mortality; Anderson and Robinson, 2009), and the average herd sizes have markedly reduced in the last decade (field veterinarians, personal communication; IICD, 2010) from around 100 to around 40 (field veterinarians, personal communication). However, although there has been reduction in herd sizes, the number of herds has increased, corresponding to the increase in the human population. This has maintained and/or increased the overall cattle population in the region (Anderson and Robinson, 2009; UBOS, 2014), despite the high rate of losses to disease.

A low carrier state of *T. parva* (18%) in cattle was reported in some parts of Karamoja Region using nested PCR (Kabi et al., 2014), which may reduce the likelihood of the development of acquired immunity, and therefore result in outbreaks of ECF. In other parts of Uganda, *T. parva* prevalence was up to 21% in a crop-livestock system of Tororo district (Muhanguzi et al., 2014a,b). Although indigenous zebu cattle usually show endemic stability to anaplasmosis in areas with little tick control (Perry and Young, 1995), clinical cases were observed and a high incidence reported by the informants. In endemic areas where many different *A. marginale* strains are present, persistent infections occur in cattle due to superinfection with *A. marginale* antigenic variants. The variants evade the immune response to the primary strain or infect the truly naïve animals which results in acute bacteraemia (Palmer and Brayton, 2013). The other TBDs, babesiosis and heartwater, are also responsible for economic losses in eastern Africa (Kivaria, 2006; Ocaido et al., 2009b).

Within-method and across-method triangulation were used, demonstrating consistency in the findings. The information from cattle keepers was supported by researchers' observations, review of published surveillance reports (IICD, 2010; Jost et al., 1998), information from key informants, laboratory diagnosis and tick infestation. A high proportion of sampled cattle were infested with ticks that included the vectors of ECF, anaplasmosis, babesiosis and heartwater, indicating a high potential for transmission of TBDs (Magona et al., 2011).

This study showed that wildlife share common grazing land with cattle. Wildlife especially Cape buffalo (*Syncerus caffer*) act as a reservoir for many of the important tick borne pathogens of cattle (Oura et al., 2011), indicating a potential to spread and increase parasite burdens in cattle.

The pastoralists applied under-strength acaricide, often at irregular intervals, and used very little or no acaricide wash, which is consistent with other studies amongst pastoralists in East Africa (Mbassa et al., 2009; Mugisha et al., 2005; Swai et al., 2009; Wesonga et al., 2010). The correct frequency for acaricide application depends on the acaricidal agent, tick species involved, breed of cattle, season, and level of tick infestation, but is on average twice per week (Mbassa et al., 2009; Mugisha et al., 2005). In the present study, tick control on calves commenced about two weeks after birth, when ticks were seen on the animals, a practice that reduces exposure to infection when animals are still protected by maternal antibodies, and may therefore leave animals susceptible to infection at a later stage. There was widespread use of oxytetracyclines to treat TBDs in Karamoja Region, which is consistent with previous reports among pastoralists in East Africa (Chenyambuga et al., 2010; Kairu-Wanyoike et al., 2014; Kasozi et al., 2014). These inappropriate practices lead to increased haemoparasite burdens and animal losses, due to endemic instability (Mbassa et al., 2009), drug resistance and maintenance of chronic carriers (APUA, 2010; Kasozi et al., 2014).

Like other pastoral areas in East Africa (Kasozi et al., 2014; Onono et al., 2013; Wesonga et al., 2010), the constraints to control of TBDs were inadequate extension services, inadequate knowledge to give the right treatment and limited availability of drugs. Due to insufficient/poor amenities, the region is not attractive to veterinarians, consistent with other rural pastoral areas in Africa (Shiferaw et al., 2010). The local government veterinary offices lacked basic diagnostic and sampling facilities, and power supply for a cold chain was unreliable or lacking. Resources for transport were lacking or inappropriate with regard to expected workload. The diagnostic facility at IICD was inadequate for the entire region. These constraints limited the effective and timely diagnosis and control of diseases, and may have led to the high disease-related mortality.

From our findings, together with those of previous studies, we are able to gain insight into future strategies for controlling TBDs and improving livestock productivity in marginal pastoral areas. The Karamojong livestock keepers identified locally appropriate veterinary service delivery systems, disease surveillance, and control options as being essential to achieving relevant and sustained benefits. The informants suggested that veterinary service delivery can be improved if government provides incentives to attract more veterinarians. Veterinary services are necessary to assist livestock keepers on the right choice of acaricides, correct dilution, effective spraying techniques, and frequency of application. Furthermore, the capacity and effectiveness of CAHWs, whose services have become a common component of tropical veterinary programmes in pastoral communities (Jost et al., 1998; Swai et al., 2014), can be enhanced by continuous training, and subsidising and improving on the supply of drugs, vaccines and equipment. CAHWs can play a significant role, but appropriate policies must be in place to strengthen their activities (Swai et al., 2014). Government-community partnership is essential for establishment and maintenance of dip tanks. The pastoralists also emphasised the need to rationalise and improve water supply to match preferred animal movements.

In pastoral systems of East Africa, including Karamoja, dipping facilities are frequently not operational because of lack of finances for refurbishment of dip tanks and provision of acaricides. In the past, the dip tanks in Karamoja Region have been destroyed or vandalised. Water supply is also a challenge. Dipping in the East African region is not compulsory, and is consequently inconsistent (Kivaria, 2006; Mbassa et al., 2009; Mugisha et al., 2005). However, a study in eastern Tanzania demonstrated an improvement in the organisational skills of farmers, through cooperative societies, which addressed the problem of funding; thus providing a sustainable community-based model using cattle dips to reduce losses due to ticks and TBDs and increase cattle productivity (Mbassa et al., 2009).

Immunisation can be a viable option for control of common TBDs in cattle. Currently in eastern Africa, immunisation is done only against ECF, using the Muguga cocktail infection-and-treatment method (ITM), coordinated by the GALVmed (Di Giulio et al., 2009). In Uganda, ITM has been used in 43 districts, but mostly on exotic breeds of cattle and their crosses, conferring immunity in about 85% of vaccinated animals (SNV, 2013). Widespread use of ITM in Africa has been affected by the high costs and poor access to the vaccine and liquid nitrogen, poor access to infrastructure, inadequate expertise for ITM in pastoral areas, and *T. parva* diversity (Di Giulio et al., 2009; GALVmed, 2015; Oura et al., 2011). However, there is prospect for ITM in pastoral areas. Livestock keepers are willing to adopt and commit themselves to a product that works and demonstrates a future in livestock production (Lynen et al., 2006). In northern Tanzania, ITM was effectively adopted by cross-border pastoral communities, reducing ECF incidence, mortality, and improving weight gain and quality of animals (Lynen et al., 2006). The ITM also resulted in reduced acaricide use, without compromising survival in the face of other TBDs (Lynen et al., 2012). Currently, the Centre for Ticks and Tick Borne Diseases (CTTBD) in Malawi is producing the ECF vaccine, and GALVmed is providing support to reduce the time it takes to manufacture the vaccine, eliminate the need for liquid nitrogen, and promote collaboration between governments, scientific think-tanks and private business innovators (GALVmed, 2015). Elsewhere in the world, vaccines against anaplasmosis have been used, but the vaccines do not prevent cattle from becoming persistently infected with *A. marginale* or becoming reservoirs of infections. Moreover, the increasing numbers of *A. marginale* field strains in a given geographical area complicates effective vaccination (Aubry and Geale, 2011).

In this study we could not interview women regarding the study objectives. Although women do not own livestock in Karamoja (Anderson and Robinson, 2009), they do participate in some livestock-related activities including construction and cleaning of sheds for small ruminants and calves, hand picking and burning of ticks, milking cows, and processing traditional medicines. This may indicate that women can contribute to the improvement of livestock health and production in pastoral areas. It is therefore important that future livestock development programmes should consider both genders, so as to ensure equity and empower women, thus reducing their vulnerability and improving their livelihoods.

Although animal milk is an important component in children's diets in Karamoja (Stites and Mitchard, 2011), the effect of TBDs on milk production was not mentioned as an indicator in the matrix scoring exercises. A possible explanation is that men may place less emphasis to this aspect of production because milking of cows is predominantly women's business (field veterinarians, personal communication) and the participants were all men. Alternative explanations for the omission of effects of milk production (other than gender bias) may be: households rely more on purchased milk as a source for children (Stites and Mitchard, 2011), and livestock keepers may have difficulty in quantifying relative decreases in milk production due to different diseases (given the small quantity of milk already produced). Therefore, in developing PE methods, researchers may include additional indicators of disease impacts (such as milk production in this case), which are not mentioned by informants. However, this may reduce the primary advantage of participatory approaches over more structured surveys; namely, that the impacts of disease and the problems associated with their control are identified by livestock keepers themselves.

The approaches used in this study are limited by the possibility of mixed parasite infections in cattle in endemic areas that result in the combined or simultaneous effects of different parasites, and which may present difficulties during scoring. In all groups visited, the informants described the possibility of mixed infections, due to concurrent clinical signs of TBDs, especially of anaplasmosis and ECF. In cases of mixed diseases, cases were allocated to the disease whose manifestation was more pronounced. This may result in underestimation of the burden of those diseases which, when present as a mixed infection, tend to be masked by a more severe concurrent infection. Teasing apart the relative contribution of co-infections would however require extensive confirmatory laboratory testing, a costly exercise that would negate many of the advantages of the participatory approach employed in our study.

Our findings, together with previous studies suggest that TBDs impact on the livelihoods of pastoralists in East Africa. There is urgent need for an integrated approach for control of ticks and TBDs, including further work on vaccines for cattle and improved policy. There is also need to improve drug usage and extension services. Research should also target the contribution of multiple host species, including wildlife, multiple strains of tick-borne pathogens, and acaricide resistance. Research in anti-tick vaccines offers the advantage of controlling both tick numbers and disrupting the tick vector-pathogen interface.

5. Conclusions

We investigated the management practices and relative importance of TBDs amongst transhumant zebu cattle in Karamoja Region, Uganda. Tick-borne diseases, in particular ECF and anaplasmosis, were regarded as the most important due to high morbidity, mortality and treatment costs. Control of ticks was done mostly by daily hand picking of ticks and irregular hand spraying with acaricides. The main constraints to control activities were inadequate knowledge to manage the diseases, inadequate veterinary services, and limited availability of drugs.

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References

Anderson, I.M., Robinson, W.I., 2009. Tenth EDF Karamoja Livelihoods Programme (KALIP), working paper 2, agriculture and livestock. In: European Union Delegation to the Republic of Uganda, The Republic of Uganda, and Food and Agriculture Organisation of the United Nations, Marketbrands Solutions Ltd, Kampala, Uganda, p. 76.

APUA, 2010. Antibiotics in Food Animal Production: A Forty Year Debate, 28. Alliance for the Prudent Use of Antibiotics Newsletter, Boston, MA, pp. 27 (2) (accessed 24.03.15.) www.tufts.edu/med/apua/news/newsletter_33_3555326098.pdf.

Aubry, P., Geale, D.W., 2011. A review of bovine anaplasmosis. Transbound. Emerg. Dis. 58, 1–30.

Catley, A., 2005. Participatory Epidemiology: A Guide for Trainers. African Union/Interafrican Bureau for Animal Resources, Nairobi, pp. 52.

Catley, A., 2006. Use of participatory epidemiology to compare the clinical veterinary knowledge of pastoralists and veterinarians in East Africa. Trop. Anim. Health Prod. 38, 171–184.

Catley, A., Admassu, B., Bekele, G., Abebe, D., 2014. Livestock mortality in pastoralist herds in Ethiopia and implications for drought response. Disasters 38, 500–516.

Catley, A., Alders, R.G., Wood, J.L., 2012. Participatory epidemiology: approaches, methods, experiences. Vet. J. 191, 151–160.

Catley, A.P., Mohammed, A.A., 1996. The use of livestock-disease scoring by a primary animal-health project in Somaliland. Prev. Vet. Med. 28, 175–186.

Catley, A., Osman, J., Mawien, C., Jones, B.A., Leyland, T.J., 2002. Participatory analysis of seasonal incidences of diseases of cattle, disease vectors and rainfall in southern Sudan. Prev. Vet. Med. 53, 275–284.

Chenyambuga, S.W., Waiswa, C., Saimo, M., Ngumi, P., Gwakisa, P.S., 2010. Knowledge and perceptions of traditional livestock keepers on tick-borne diseases and sero-prevalence of *Theileria parva* around Lake Victoria Basin. Livest. Res. Rural Dev. 22 (7), Article #135.

Di Giulio, D., Lynen, G., Morzaria, S., Oura, C., Bishop, R., 2009. Live immunization against East Coast fever-current status. Trends Parasitol. 25, 85–92.

GALVmed, 2014. Uganda's ECF Progress. GALVmed Newsletter, Global Alliance for Livestock Veterinary Medicines, Pentlands SciencePark, Bush Loan, Edinburgh EH26 OPZ, UK, pp. 4. www.galvmed.org/wp-content/uploads/2014/03/GALVmed-Newsletter-March-2014.pdf (accessed 05.12.14.).

GALVmed, 2015. The CTTBD ECF Vaccine: Greater opportunity to control East Coast fever and other tick-borne diseases in Africa. Global Alliance for Livestock Veterinary Medicines, Pentlands SciencePark, Bush Loan, Edinburgh EH26 OPZ, UK. http://www.galvmed.org/2014/12/the-cttbd-ecf-vaccinegreater-opportunity-to-control-east-coast-fever-and-other-tick-borne-diseases-in-africa/ (accessed 10.10.15.).

IBM SPSS, 2011. IBM SPSS Statistics for Windows, Version 20.0. IBM Corp., Armonk, NY.

IICD, 2010. Livestock disease surveillance in Karamoja. In: Ruspantini, C. (Ed.), The Importance of Early Detection of Diseases and Epidemics for Livestock Dependent Communities. European Commission, Government of Uganda and Institute for International Co-operation and Development (IICD), Uganda, p. 67 (accessed 24.03.15.) www.disasterriskreduction.net/fileadmin/user_upload/drought/docs/C&DPublicationLivestockDiseaseSurveillance2.pdf.

Jost, C., Stem, C., Ramushwa, M., Twinamasiko, E., Mariner, J., 1998. Comparative ethnoveterinary and serological evaluation of the Karimojong Community Animal Health Worker Program in Uganda. Ann. N.Y. Acad. Sci. 849, 327–337.

Kabi, F., Masembe, C., Muwanika, V., Kirunda, H., Negrini, R., 2014. Geographic distribution of non-clinical *Theileria parva* infection among indigenous cattle populations in contrasting agro-ecological zones of Uganda: implications for control strategies. Parasites Vectors 7, 414.

Kairu-Wanyoike, S.W., Kiara, H., Heffernan, C., Kaitibie, S., Gitau, G.K., McKeever, D., Taylor, N.M., 2014. Control of contagious bovine pleuropneumonia: knowledge, attitudes, perceptions and practices in Narok district of Kenya. Prev. Vet. Med. 115, 143–156.

Kasozi, K.I., Matovu, E., Tayebwa, D.S., Natuhwera, J., Mugezi, I., Mahero, M., 2014. Epidemiology of increasing hemo-parasite burden in Ugandan cattle. Open J. Vet. Med. 4, 220–231.

Kivaria, F.M., 2006. Estimated direct economic costs associated with tick-borne diseases on cattle in Tanzania. Trop. Anim. Health Prod. 38, 291–299.

Lynen, G., Giulio, G., di Homewood, K., Reid, R., Mwilawa, A., 2006. Deployment of a live ECF vaccine in pastoral areas: lessons learned from Tanzania. In: Rege, J.E.O, Nyamu, A.M., Sendalo, D. (Eds.), The Role of Biotechnology in Animal Agriculture to Address Poverty in Africa: Opportunities and Challenges. Proceedings of the 4th All African Conference on Animal Agriculture and the 31st Annual Meeting of the Tanzania Society for Animal Production (TSAP), Arusha, Tanzania, 20–24 September, 2005. All Africa Society for Animal Production (AASAP), Nairobi, Kenya, pp. 193–201.

Lynen, G., Yrjö-Koskinen, A.E., Bakuname, C., Giulio, G., Mlinga, N., Khama, I., Hanks, J., Taylor, N.M., James, A.D., McKeever, D., Peters, A.R., Rushton, J., 2012. East Coast fever immunisation field trial in crossbred dairy cattle in Hanang and Handeni districts in northern Tanzania. Trop. Anim. Health Prod. 44, 567–572.

MAAIF, 2011. Statistical Abstract. Agricultural Planning Department, Ministry of Agriculture, Animal Industry and Fisheries (accessed 07.06.13.) www.agriculture.go.ug/userfiles/StatisticalAbstract.2011.pdf.

Magona, J.W., Walubengo, J., Olaho-Mukani, W., Jonsson, N.N., Welburn, S.W., Eisler, M.C., 2011. Spatial variation of tick abundance and seroconversion rates of indigenous cattle to *Anaplasma marginale*, *Babesia bigemina* and *Theileria parva* infections in Uganda. Exp. Appl. Acarol. 55, 203–213.

Malak, A.K., Mpoke, L., Banak, J., Muriuki, S., Skilton, R.A., Odongo, D., Sunter, J., Kiara, H., 2012. Prevalence of livestock diseases and their impact on livelihoods in Central Equatoria State, southern Sudan. Prev. Vet. Med. 104, 216–223.

Mbassa, G.K., Mgongo, F.O.K., Melau, L.S.B., Mlangwa, J.E.D., Silayo, R.S., Bimbita, E.N., Hayghaimo, A.A., Mbiha, E.R., 2009. A financing system for the control of tick-borne diseases in pastoral herds: the Kambala (Tanzania) model. Livest. Res. Rural Dev. 21 (3), Article #44.

Mugisha, A., McLeod, A., Percy, R., Kyewalabye, E., 2005. Strategies, effectiveness and rationale of vector-borne disease control in the pastoralist system of south-western Uganda. Trop. Anim. Health Prod. 37, 479–489.

Muhanguzi, D., Picozzi, K., Hatendorf, J., Thrusfield, M., Welburn, S.C., Kabasa, J.D., Waiswa, C., 2014a. Prevalence and spatial distribution of *Theileria parva* in cattle under crop-livestock farming systems in Tororo District, Eastern Uganda. Parasites Vectors 7, 91.

Muhanguzi, D., Picozzi, K., Hatendorf, J., Thrusfield, M., Welburn, S.C., Kabasa, J.D., Waiswa, C., 2014b. Collateral benefits of restricted insecticide application for

control of African trypanosomiasis on *Theileria parva* in cattle: a randomised controlled trail. Parasites Vectors 7, 432.
Norval, R.A.I., Perry, B.D., Young, A.S., Lawrence, J.A., Mukhebi, A.W., Bishop, R., McKeever, D., 1992. The Epidemiology of Theileriosis in Africa. Academic press, London, UK, pp. 13–481.
Ocaido, M., Muwazi, R.T., Opuda, J.A., 2009a. Economic impact of ticks and tick-borne disease on cattle production systems around Lake Mburo National Park in South Western Uganda. Trop. Anim. Health Prod. 41, 731–739.
Ocaido, M., Otim, C.P., Kakaire, D., 2009b. Impact of major diseases and vectors in smallholder cattle production systems in different agro-ecological zones and farming systems in Uganda. Livest. Res. Rural Dev. 21 (9), Article #155.
Onono, J.O., Wieland, B., Rushton, J., 2013. Constraints to cattle production in a semiarid pastoral system in Kenya. Trop. Anim. Health Prod. 45, 1415–1422.
Oura, C.A.L., Tait, A., Asiimwe, B., Lubega, G.W., Weir, W., 2011. *Theileria parva* genetic diversity and haemoparasite prevalence in cattle and wildlife in and around Lake Mburo National Park in Uganda. Parasitol. Res. 108, 1365–1374.
Palmer, G.H., Brayton, K.A., 2013. Antigenic variation and transmission fitness as drivers of bacterial strain structure. Cell. Microbiol. 15, 1969–1975.
Perry, B.D., Young, A.S., 1995. The past and future roles of epidemiology and economics in the control of tick-borne diseases of livestock in Africa: the case of theileriosis. Prev. Vet. Med. 25, 107–120.
Radostitis, O.M., Blood, D.C., Gay, C.C., 1994. Veterinary Medicine, eighth ed. Bailliere Tindall, London.
Shiferaw, T.J., Moses, K., Manyahilishal, K.E., 2010. Participatory appraisal of foot and mouth disease in the Afar pastoral area, northeast Ethiopia: implications for understanding disease ecology and control strategy. Trop. Anim. Health Prod. 42, 193–201.
SNV, 2013. Diary Platform Policy brief 01: management of ticks and East Coast fever, pp. 6. www.snvworld.org/download/publications/ecf_brief_1.pdf (accessed 25.03.15.).
Stites, E., Mitchard, E., 2011. Milk Matters in Karamoja: Milk in Children's Diets and Household Livelihoods. Feinstein International Center, Tufts University, 200 Boston Ave., Suite 4800, Medford, MA 02155, USA, 35 pp. http://www.fao.org/fileadmin/user_upload/drought/docs/MM-Karamoja.pdf (accessed 10.10.15.).
Swai, E.S., Karimuribo, E.D., Kambarage, D.M., Moshy, W.E., 2009. A longitudinal study on morbidity and mortality in youngstock smallholder dairy cattle with special reference to tick borne infections in Tanga region, Tanzania. Vet. Parasitol. 160, 34–42.
Swai, E.S., Masaaza, S., Daborn, C.J., 2014. Evaluation of community animal health delivery systems in Simanjiro, Tanzania. Livest. Res. Rural Dev. 26 (8), Article #138.
UBOS, 2014. Statistical Abstract, Uganda Bureau of Statistics. www.ubos.org/onlinefiles/uploads/ubos/statistical_abstracts/Statistical_Abstract_2014.pdf (accessed 20.12.14.).
Wesonga, F.D., Kitala, P.M., Gathuma, J.M., Njenga, M.J., Ngumi, P.N., 2010. An assessment of tick-borne diseases constraints to livesctock production in a smallholder livestock production system in Machakos District, Kenya. Livest. Res. Rural Dev. 22 (6), Article #111.