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ORIGINAL PAPER

# Economic impact of ticks and tick-borne diseases on cattle production systems around Lake Mburo National Park in South Western Uganda

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**Abstract** A longitudinal economic impact study of Ticks and Tick-Borne Diseases (TTBDs) in cattle around Lake Mburo National Park (LMNP) was done. Impact was valued using Uganda Shilling (Ug. Shs) (exchange rate of 1USD to Ug. Shs 1,420). The costs for controlling TTBDs was constituting 85.6±3.2% (pastoral) and 73.8±4.2% (ranches) to total disease control costs. The main costs were on tick control, constituting 83.1% (ranches) and 87.9% (pastoral). In pastoral herds, the costs were negatively correlated to herd size ($r=-0.99$). The mean annual cost per cattle for controlling TTBDs for ranch and pastoral herds was similar Ug. Shs 5,900±545. The mean annual Economic Cost (EC) of TTBDs per cattle was not significantly different ($p>0.05$) between pastoral (Ug. Shs 6,700±580) and ranch herds (Ug. Shs 7,600± 970). The mean annual EC per cattle was negatively correlated ($r=-0.99$) with herd size in pastoral systems contrary to positive correlation ($r=0.99$) observed among the ranches. The major component of EC of TTBDs of 88.2% (pastoral) and 78.6% (ranches) was due to their control. The other component was owed to mortality, which was positively correlated ($p<0.01$) to the ranch herd size. The total annual EC of TTBDs around LMNP was Ug. Shs 437,754,600 (USD 308,144).

**Keywords** Economic cost · Ticks and tick borne diseases · Pastoral and ranch cattle herds · Lake Mburo Area

**Abbreviations**

| | |
|---|---|
| ARS | Ankole Ranching Scheme |
| BCR | Benefit Cost Ratio |
| DCBR | Dairy Cross Breeding Ranch |
| EC | Economic Cost |
| ECF | East Coast Fever |
| ha | Hectare |
| LMA | Lake Mburo Area |
| LMNP | Lake Mburo National Park |
| TBDs | Tick-Borne Diseases |
| TTBDs | Ticks and Tick-Borne Diseases |

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| | |
|---|---|
| Ug. Shs | Uganda Shilling |
| USA | United States of America |
| USD | United States Dollar |

## Introduction

The study area was done in Lake Mburo Area (LMA) Kiruhura district, Nyabushozi County comprising of Lake Mburo National Park (LMNP) and its surrounding rangeland made up of mainly cattle ranches and pastoral households. LMNP is a small park of about 260 square km. The cattle ranches are made up of 50 ranches of Ankole Ranching Scheme (ARS) and Nshara Dairy Cross Breeding Ranch (DCBR). Each ranch of ARS is about 777 hectares (ha) and Nshara DCBR is 6,475 ha. Nshara DCBR was set up to provide farmers with $F_1$, dairy breed heifer crosses so as to improve the national dairy herd. The main objective of the setting up Ankole ranching scheme was for commercial beef production. There were about 856 pastoral households around LMNP, settled on 39.8 ha of land on average.

Previous work (Ocaido 1995; Ocaido et al. 2006; Mugisha et al. 2005) on disease problems in the study area suggested that Ticks and Tick Borne Diseases (TTBDs) were the major constraint to cattle production. *R. appendiculatus*, the vector of East Coast Fever (ECF), was found to be the most abundant tick species (Ocaido et al. 2006). Likewise, ECF was seen to be the major disease of cattle in the area (Ocaido et al. 1996). Elsewhere in sub-Saharan Africa, TTBDs have been reported to be the major limitation to cattle production systems (Ocaido et al. 2004; Otim et al. 2004; Rubaire-Akiiki et al. 2004; Ocaido et al. 2005; Homewood et al. 2006; Okuthe and Buyu 2006). They cause economic losses to farmers in terms of cattle mortality, loss of body weight, milk loss, costs of control of TTBDs through chemotherapy, infection and treatment methods, and control of ticks by use of acaricides (Kivaria 2006; Homewood et al. 2006).

From what has been observed, it became apparent that economic losses caused by TTBDs needed to be quantified in these two cattle production systems. It was hoped that the output would help the major stakeholders in deciding on the urgency needed in control of these diseases so as to make these cattle production systems economically viable in this geographical location. It was against the above background that this study was designed.

## Methodology

This study was carried out in Nshara Dairy Cross Breeding Ranch (DCBR), Ankole Ranching Scheme (ARS) and smallholder sedentary Bahima pastoral communities settled in the ranches and communal grazing areas surrounding Lake Mburo National Park (LMNP), in Mbarara District. The study consisted of both of a survey and longitudinal study.

Initially, reconnaissance survey was done. Here, focus group discussions were held with sedentary pastoralists and ranchers using rapid appraisal methods with aid of a checklist of questions. Later a structured questionnaire survey and longitudinal study was done in Nshara DCBR, 39 ranches of Ankole Ranching Scheme (ARS) and 89 sedentary pastoral households. The sample size was determined at 95% level of confidence using the equation (Dohoo et al. 2003; Thrusfield 2007):-

$$n = \frac{Z^2.P.Q.}{e^2}$$

Where:

| | |
|---|---|
| Q | 1 – P |
| Z | 1.96 |
| e | Confidence level=0.05; |
| P | Prevalence of TBDs about 7% |

$$\text{Adjusted sample size}: {}_{1}n = {}^{nN}/_{n+N}$$

Where n = calculated sample size; N = Total population size

Thirty-nine ranches were randomly selected from 50 ranches of ARS. From each of the ranches, 2–3 of sedentary pastoral households were randomly selected.

The pastoral cattle herds were categorised as small when herd size was below 40 heads, medium between 40–70 and large beyond 70. Meanwhile ranch cattle herds were classified as small when the herd size was below 300 heads and large beyond 300 the herd size was taken as large. Of pastoral households selected, 33 were small, 25 medium and 31 large. For ranches 21 were small herd sized and 18 were large sized.

Later a longitudinal study was done for 18 months. Stock owners were taught on how to keep health and production records under supervision of extension

workers. Health and production data forms were designed for the farmers. Monthly visits were paid to the ranches and households. On each visit, discussions were held with these selected cattle keepers, and a summary of production and health records were entered in standardised data collection sheets. Incidence of TBDs especially ECF was monitored closely by field veterinarians, research assistants and cattle owners. Field veterinarians made tentative diagnosis of the clinical cases and submitted blood and lymph node samples and smears for confirmation. Records of tentative diagnosis and treatment of cattle were kept. Lymph node samples were collected using large bore needles (gauge 16–19). Whole blood samples were dried on Whatman filter paper No.2. Blood and lymph node smears were made using glass slides and cover slips, fixed with methyl alcohol, stained with Giemsa and examined under light microscope.

The economic cost of TTBDs was taken as the sum of costs due to control of TTBDs in the cattle herds and loss caused due to mortality caused by TTBDs. Losses in milk production and weight gain caused by TTBDs were not quantified. Cost of control of TTBDs were taken as sum of costs of treatment of TTBDs and TTBD-related conditions like acaricide poisoning and costs of tick control. Costs of tick control were taken as cost of acaricide and cost of labour spent in spraying (man-hours). Losses caused by mortalities were taken as a sum of herd age specific mortality loss of calves, steers, heifers, adult female cattle and bulls. The total costs of controlling TTBDs were calculated and compared with the total variable costs, total disease control costs and the gross margin.

The cost benefit analysis was done on reduction of costs of tick control over a ten year period. Sensitivity analysis was done on three scenarios of reduction of tick control costs namely: half reduction ($T_1$); third reduction ($T_2$) and quarter reduction ($T_3$).

Economic valuations were done in Ugandan Shilling (Ug. Shs) when the exchange rate with USA dollar was 1USD to Ug. Shs 1,420.

## Results

The cumulative occurrences of common diseases of cattle in herds monitored were as shown in Table 1.

ECF and tick-related diseases constituted 53.1% of the total costs of clinical cases treated in Nshara DCBR (see Table 2). Meanwhile, in other pastoral and ranch cattle herds, ECF was the major clinical problem constituting to about 98.1% and 95.8% of total treatment costs of clinical cases respectively. The treatment of scouring in calves constituted the remaining 1.9% and 4.2% of the total treatment costs in other ranch and pastoral herds respectively.

The mean disease control cost per head of cattle per annum was Ug. Shs 8,700±1,200 in the ranches

**Table 1** Percentage cumulative prevalence of common diseases in Nshara DCBR, ARS and pastoral herds as revealed by herd monitoring during the longitudinal study

| Disease/condition | Ranch herds | | | Pastoral herds | | |
|---|---|---|---|---|---|---|
| | Nshara | Large | Small | Large | Medium | Small |
| East Coast Fever (ECF) | 25.3 | 11.3 | 10.2 | 10.6 | 4.2 | 8.8 |
| Anaplasmosis | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Acaricide poisoning | 9.2 | 0 | 0 | 0 | 0 | 0 |
| Udder conditions | 3.7 | 0.5 | 0.1 | 0.2 | 0.08 | 0 |
| Abortions | 10.3 | 8.1 | 1.7 | 5.2 | 6.9 | 4.1 |
| Retained placenta | 11.3 | 0 | 0 | 0 | 0 | 0 |
| Dystocia | 1.44 | 0 | 0.5 | 0 | 0 | 0 |
| Metritis | 0.09 | 0 | 0 | 0 | 0 | 0 |
| Ephemeral fever | 1.54 | 0 | 0.5 | 0 | | 0 |
| Scouring | 12.6 | 12 | 15.2 | 9.4 | 13.8 | 24 |
| Hoof conditions | 2.5 | 0 | 0 | 0 | 0 | 0 |
| Kerato conjunctivitis | 1.44 | 0 | 0 | 0 | 0 | 0 |
| Non-specific | 3.3 | 0 | 0.9 | 0 | 0 | 0 |

**Table 2** Chemotherapeutic costs (Ug. Shs '000) and % contribution to total treatment costs of each disease/condition in Nshara DCBR

| Disease treated | Cost (Ug. Shs '000) | % contribution |
|---|---|---|
| ECF | 2,259.6 | 49.4 |
| Anaplasmosis | 19.7 | 0.4 |
| Acaricide poisoning | 457 | 3.3 |
| Scouring | 558.5 | 12.2 |
| Physical injuries | 247.2 | 5.4 |
| Abortion and retained placenta | 284.7 | 6.2 |
| Ephemeral fever | 244.4 | 5.3 |
| Udder conditions | 133.5 | 2.9 |
| Hoof conditions | 112.6 | 2.5 |
| Dystocia | 61.5 | 1.3 |
| Metritis | 47.1 | 1 |
| Keratoconjuctivitis | 39.1 | 0.9 |
| Abscesses | 16.6 | 0.4 |
| None specific conditions | 400.2 | 8.8 |

and Ug. Shs 6,960±870 in pastoral herds. It was shown that the mean percentage contribution of tick control costs to total disease costs were significantly higher ($p<0.05$) in pastoral herds (74.8±5.8%) than in the ranches (61.7±3.4%). Details were as shown in Table 3.

Details of the costs for controlling TTBDs were as shown in Table 4. In Nshara DCBR, the total tick control costs involved the cost of acaricides and costs of monitoring the concentration of the dip wash. One point three percent (Ug. Shs 144,000) of the total tick control costs were incurred monthly for testing the concentration of the dip wash. It was shown that 16.7±1% and 12.1±3.4% of the control costs for TTBDs was due to chemotherapy in the ranches and pastoral herds respectively. While, 83.1% and 87.9% of the total costs of controlling TTBDs were incurred in tick control in the ranches and pastoral herds respectively. The mean proportion of costs for controlling TTBDs used for tick control were not significantly different between pastoral and ranch herds ($p>0.05$). The costs for controlling TTBDs constituted 85.6±3.2% and 73.8±4.2% of the total disease control costs in pastoral herds and ranches respectively. The costs for controlling TTBDs when compared to total disease control costs were significantly different between pastoral and ranch herds. Being higher in pastoral herds than in the ranches ($p<0.05$). In pastoral herds, the total cost of controlling TTBDs was negatively correlated to herd size ($r=-0.99$) and could be predicted using the regression equation: $Y = 7760 - 0.0298X\ (p < 0.05)$.

Where:

Y Cost of controlling TTBDs in Ug. Shs.
X Cattle herd size.

The mean cost per head of cattle for controlling TTBDs in ranch and pastoral herds was similar (Ug. Shs 5,900±545).

The economic costs caused by TTBDs at farm and ranch level were as shown in Table 5. The mean annual economic cost of TTBDs per head of cattle was not significantly different ($p>0.05$) between pastoral herds (Ug. Shs 6700±580) and the ranches (Ug. Shs 7600±970). In pastoral herds, the economic cost per head of cattle due to TTBDs was very negatively correlated with cattle herd size ($r=0.99$, $p<0.001$), decreasing with the herd size. Whereas in the ranches, the economic cost per head of cattle was positively correlated with the herd size ($r=0.99$, $p<0.001$),

**Table 3** Disease control costs in Ug. Shs ('000)

| Control cost | Ranches | | | Pastoral | | |
|---|---|---|---|---|---|---|
| | Nshara DCBR | Large | Small | Large | Medium | Small |
| Chemotherapy | 4,573.2 | 190 | 144.5 | 90 | 30.1 | 37.7 |
| Tick control | 11,130.8 | 1,086 | 634.2 | 534 | 487 | 178 |
| Vaccinations | 1,872.6 | 200 | 135.6 | 70 | 35 | 26.4 |
| Antihelmintic treatment | 2,520 | 152 | 86.4 | 65 | 12.7 | 20 |
| Trypanosomosis control | 55 | 0 | 0 | 0 | 0 | 0 |
| Total | 20,151.6 | 1,628 | 1,000.7 | 755 | 564 | 262 |
| Cost per head/annum | 10.4 | 6.5 | 7.12 | 6 | 6.2 | 8.7 |

**Table 4** TTBDs control costs in Ug. Shs ('000) and percentage contribution to total disease costs

| Control cost | Ranches | | | Pastoral | | |
|---|---|---|---|---|---|---|
| | Nshara | Large | Small | Large | Medium | Small |
| Treatment of ECF | 2,259.6 | 190 | 141 | 86.2 | 28.8 | 36.1 |
| Treatment of anaplasmosis | 19.7 | 0 | 0 | 0 | 0 | 0 |
| Treatment of acaricide poisoning | 148.6 | 0 | 0 | 0 | 0 | 0 |
| Tick control | 11,130.8 | 1,086 | 634.2 | 534 | 487 | 178 |
| Total cost | 13,558.7 | 1,276 | 776 | 620.2 | 515.8 | 214.1 |
| Cost per head per annum | 7 | 5.2 | 5.6 | 5 | 5.7 | 7.1 |
| % of total disease control costs | 67.2 | 78.4 | 77.5 | 82.2 | 91.5 | 81.7 |

increasing with the herd size. The economic cost per head of cattle due to TTBDs per year based on herd size in pastoral herds and ranches, could be predicted using regression equations: $Y = 8436 - 26.6X\ (p < 0.01)$ and $Y = 6100 + 3.5X\ (p < 0.05)$ respectively.

Where:

Y Annual economic cost per head of cattle due to TTBDs
X Cattle herd size.

The percentage proportion contributed by costs due to mortality caused by TTBDs to total economic cost due to TTBDs was significantly different ($p<0.05$) in pastoral (11.6±1.7%) and ranch (21.5±5%) cattle herds. The proportion caused by cost of mortality due to TTBDs was positively correlated ($p<0.01$) to the ranch herd size and could be predicted using the regression equation:

$$Y = 0.05X + 7.9(p < 0.01)$$

Where:

Y % proportion caused by TTBDs
X Herd size.

Details of total annual economic cost of TTBDs in the ranch and pastoral production systems around Lake Mburo National Park were as shown in Table 6. The estimated total annual economic cost was Ug Shs 437, 754,600 an equivalent of USD 308,144 at an exchange rate of 1 USD to Ug. Shs 1420.

The percentage of the total variable costs and gross margin to the costs incurred in control of TTBDs, taken as a measure of importance of TTBDs to cattle enterprises were as shown in Table 7.

The overall mean percentage of total costs of TTBDs to total variable costs was 33.5±9.4% and 37.7±3% in ranch and pastoral cattle enterprises respectively. Whereas, the overall mean percentage of total costs of control of TTBDs to gross margin was found to be 11.3±2.5% and 17.5±9.4% of the gross margin in ranch and pastoral enterprises respectively. The average overall percentage of total costs of control of TTBDs to gross output was found to be 7.5±3% and 9.8±1.8% of gross output in ranch and pastoral herds respectively.

The sensitivity analysis on reduction of tick control costs by half ($T_1$), third ($T_2$) and quarter ($T_3$) on BCR on different categories of pastoral and ranch herds showed that there was an immediate apparent positive

**Table 5** Economic cost in Ug. Shs ('000) of TTBDs at ranch and pastoral herd level

| Cost | | Ranches | | | Pastoral | | |
|---|---|---|---|---|---|---|---|
| | | Nshara | Large | Small | Large | Medium | Small |
| Control of TTBDs | Value | 13,558.7 | 1,276 | 776 | 620.2 | 515.8 | 214.1 |
| | % to total economic cost | 72.5 | 74.4 | 88.6 | 85.5 | 88.1 | 91.5 |
| Loss due to mortality | Value | 5,140 | 440 | 100 | 105 | 70 | 20 |
| | % to total economic cost | 27.5 | 25.6 | 11.4 | 14.5 | 11.9 | 8.5 |
| Total | | 18,698.7 | 1,716 | 876 | 725.2 | 585.8 | 234.1 |
| Annual economic cost per head of cattle | | 9.5 | 7 | 6.3 | 5.8 | 6.5 | 7.8 |

**Table 6** Annual total economic cost (Ug. Shs. '000) of TTBDs in ranch and pastoral cattle production systems around Lake Mburo National Park

| Category | | Total economic cost (Ug. Shs. '000) |
|---|---|---|
| Pastoral Herds | Small | 58,142.3 |
| | Medium | 104,840.9 |
| | Large | 156,050.8 |
| | Subtotal | 319,034 |
| Ranches of ARS | Small | 23,197.4 |
| | Medium | 23,073.8 |
| | Large | 62,910 |
| | Subtotal | 109,181.2 |
| Nshara DCBR | | 9,349.4 |
| Grand total | | 437,564.6 |

shift of the Benefit Cost Ratio (BCR) on reduction of control of TTBDs in pastoral households with small size, but there was no apparent shift of BCR with medium and large pastoral herds; and with all categories of ranches. The variation of BCR for small pastoral herds was as shown in Fig. 1; with large pastoral herds as in Fig. 2. and with small ranch herd size as in Fig. 3.

## Discussion

In ranch and pastoral systems, disease control costs were 44% and 44.2% of the total variable costs respectively. The average annual cost for controlling diseases for both pastoral and ranch herds was Ug. Shs 6,900. Tick control was the major disease control activity followed by chemotherapy and vaccinations (see Table 3). Tick control constituted 61.7% and 74.8% of total disease control costs in pastoral and ranch herds respectively. ECF was the major disease treated in the ranch and pastoral cattle herds. ECF and tick-related problems constituted 53.1% of total disease control costs in Nshara DCBR. Meanwhile, in the ranches of ARS and pastoral herds, the costs of treating ECF and tick related problems constituted 98.1% and 95.8% of the total disease chemotherapeutic costs in the pastoral and ranch herds respectively. The lower percentage of disease control costs attributed to treatment of ECF and tick-related diseases in Nshara DCBR was more of costs incurred in treatment of scouring and dystocia.

The losses of TTBDs to livestock production around LMNP were incurred through control of TTBDs, mortality and morbidity. Control of TTBDs involved tick control (dipping and spraying) and chemotherapy. The major method of tick control was acaricide application by spraying. All pastoralists adopted spraying as a method of tick control. Only Nshara and 15% of the ranches of ARS controlled ticks by acaricide dipping. This observation supported what was reported by Okello-Onen et al. (1997), McDermott et al. (1999), Otim et al. (2004), Ocaido et al. (2005) and Mugisha et al. (2008) that small scale cattle keepers were moving away from use of dips because they were expensive to run and preferred spraying, which could easily be managed by an individual. The control of TTBDs amounted to 85.6% and 73.8% of the total disease costs in the pastoral herds and ranches respectively. Most of TTBDs costs were due to tick control which contributed to 87.9% and 83.1% of total costs of controlling TTBDs in pastoral and ranch herds respectively. Only 12.1% and 16.7% of costs due TTBDs were due to chemotherapy. The average annual costs for controlling TTBDs per head of cattle around LMNP was Ug. Shs 5,900 among ranches of ARS and pastoral herds. Nshara DCBR had a higher cost of Ug Shs. 7,000 per head of cattle. This could be due to the fact that more revenue was spent on treatment of sick animals, which were calves or sub-adult crosses. However, these interventions seemed to be effective because

**Table 7** Percentage of costs incurred in control of TTBDs to total variable costs and Gross Margin in cattle in Nshara DCBR, ranches of ARS and pastoral herds

| Indicators | Ranches | | | Pastoral | | |
|---|---|---|---|---|---|---|
| | Nshara | Medium | Small | Large | Medium | Small |
| % of total variable costs | 14.8 | 40.7 | 45 | 42.6 | 42.9 | 27.6 |
| % of gross Margin | 12.8 | 14.3 | 6.3 | 7.3 | 9 | 36.2 |
| % of gross output | 6.9 | 10.6 | 4.5 | 6.3 | 7.5 | 15.5 |

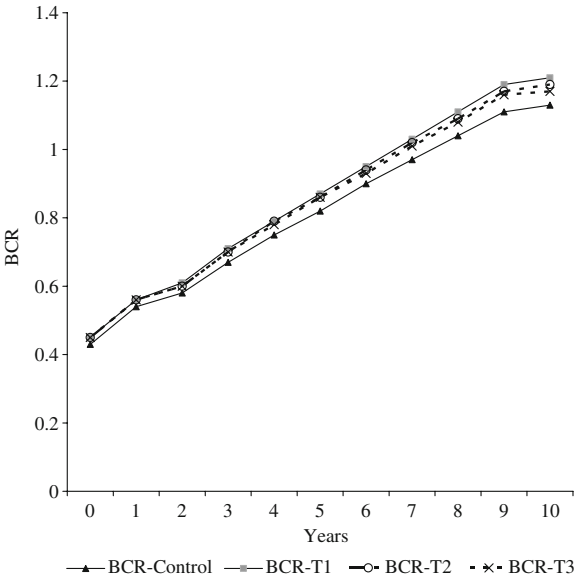


**Fig. 1** Sensitivity analysis of reduction of cost of control of TTBDs under different scenarios of levels of reduction on BCR of small sized pastoral cattle herds

Nshara DCBR recorded the lowest crude mortality rate of calves (2.9%) as compared to average crude mortality rate of 3.7% recorded in ARS and pastoral herds (Ocaido et al. 2008). Similarly, there was a high annual economic cost per head of cattle due to TTBDs in Nshara DCBR of Ug Shs. 9,500 compared to Ug. Shs 6,700 and 7,600 for pastoral and ranch

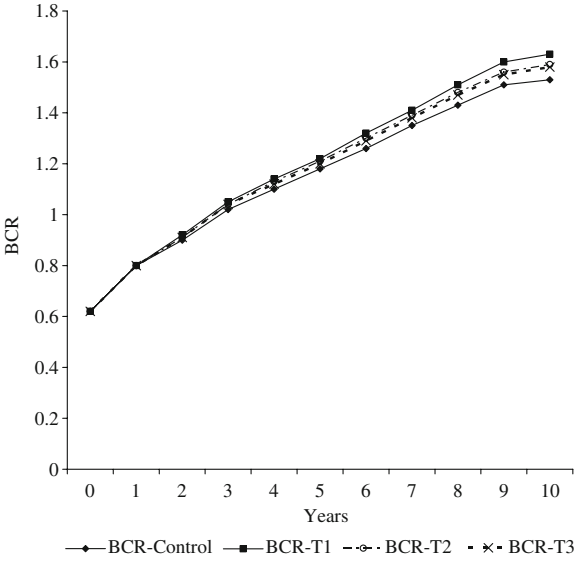


**Fig. 2** Sensitivity analysis of reduction of cost of control of TTBDs under different scenarios of levels of reduction on BCR of large sized pastoral cattle herds

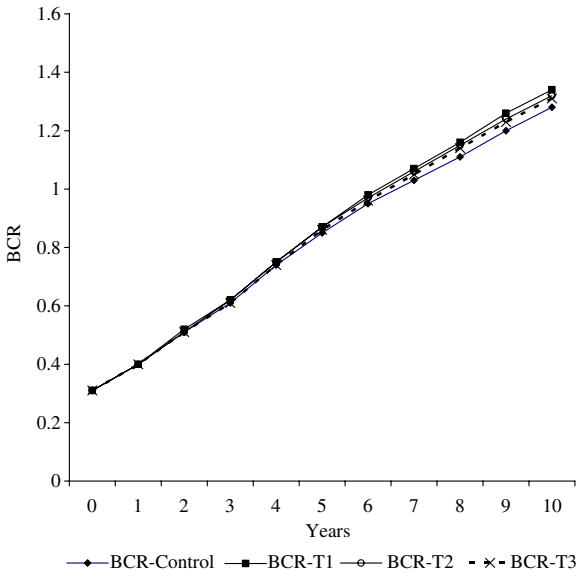


**Fig. 3** Sensitivity analysis of reduction of cost of control of TTBDs under different scenarios of levels of reduction on BCR of small herd sized ranch cattle herds

herds respectively. There was also a decrease of annual economic cost per head of cattle due to TTBDs as the herd sizes increased among pastoral households (Table 5). This could be due to economies of scale enjoyed by large herd sizes among pastoralists. A similar observation was made among dairy farmers in Mukono (Laker 1999). In the ranches of ARS, the opposite was true, as the economic cost due to TTBDs was increasing with the herd size. This observed difference, is brought about by difference in losses associated with mortalities caused by ECF. This explanation is further supported by a highly significant correlation observed between the increasing economic costs of TTBDs due to mortality of cattle with increasing ranch cattle herd size. This is so, because of the tendency of the ranchers to improve their local indigenous Ankole cattle with exotic TBD' susceptible breeds (especially the dairy Friesian breed) when they become wealthier. This further, explains the high economic cost of TTBDs observed in Nshara DCBR.

The major component of economic cost of TTBDs was the cost of their control, which constituted 88.2% and 78.6% of total economic cost of TTBDs in pastoral and ranch herds respectively. Meanwhile, mortality due to ECF was only 11.6% and 21.4% of the total economic cost due to TTBDs in pastoral and ranch herds respectively. This was contrary to what

was reported by Kivaria (2006) in Tanzania in which more losses due to TTBDs were due to mortality of cattle. The current estimated economic cost caused by TTBDs could be slightly higher, because the costs caused by weight loss due to tick worry and morbidity due to TTBDs were not quantified. However, studies done by Norval et al. (1986), Okello-Onen (1995) and Pegram et al. (1996) showed that the losses caused by ticks on Ankole Sanga cattle were insignificant. It was observed that the weight lost by indigenous cattle in Zimbabwe (Pegram et al. 1996) and in South Africa (Muchenje et al. 2008) during periods of high tick activity was recovered during those periods of the year when the tick activity was low.

When the cost of control of TTBDs was compared to total variable costs, it contributed substantially to total variable costs both in pastoral (37.7%) and ranch herds (33.5%). In Nshara DCBR, the percentage cost of control of TTBDs to total variable costs was small, only 14.9%. Also, when the cost of control of TTBDs was compared to gross margin, it was only 17.5% and 11.3% of the gross margins in pastoral and ranch herds respectively. Furthermore, the cost of controlling TTBDs was only 9.8% and 7.3% of the total gross output from pastoral and ranch herds respectively. These findings showed that control of TTBDs did not erode significantly the gross output of the cattle enterprises. Therefore cattle enterprises still made good margins despite the presence of TTBDs.

The total annual economic cost due to TTBDs around LMNP was estimated as an equivalent of USD 308,144. The economic loss caused by mortality due to drought was 9.2 times more than the losses caused by TTBDs in pastoral herds around LMNP (Ocaido et al. 2008). But in the ranches, the loss caused by drought was only 59% of that caused by TTBDs. TTBDs caused more economic losses in ranch herds than drought. Whereas drought caused more economic losses in pastoral herds than TTBDs. Similar observations were made by Hopcraft (1985) in Machakos district, Kenya, where drought killed 61% of pastoral cattle.

The reduction of costs of controlling TTBDs did not significantly affect the BCR during the first 4 years in pastoral herds except those with small herds (see Fig. 1). This showed that, the current the cost of controlling TTBDs did not severely affect the profitability of livestock production in medium and large pastoral herds; and the ranch herds. The only observed difference in small pastoral herds, was due to the fact that, the costs of controlling TTBDs per head of cattle was inversely proportional to the herd size, being higher in small herd sized herds. This implies that the smaller the herd size, the more the effect of reduction of cost of tick control could make economic sense. This was because the large cattle herds were enjoying economies of scale when controlling TTBDs, agreeing with what was earlier reported by Laker (1999) among dairy cattle farmers in controlling trypanasomosis in Mukono, Uganda.

In conclusion, TTBDs made a sizeable economic impact but did not significantly affect the overall profitability of cattle keeping enterprises. A major portion of economic cost was incurred in tick control. Economic cost of TTBDs was increasing with increasing herd size of the ranches, owing to the fact that the ranchers were improving their cattle herds with tick-borne disease' susceptible dairy breeds, resulting in high mortality rates due to TBDs. On contrary, pastoralists keeping indigenous cattle were enjoying economies of scale, with economic cost due to TTBDs decreasing with increasing herd size.

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