

Economics of theileriosis control in Zambia

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Summary

For an economic analysis of theileriosis control, we adopted the total economic cost (TEC) method, which calculates the sum of output losses from tick damage, theileriosis mortality and morbidity, and expenditures for treatment or prevention of the disease. At farm level, the TEC can be minimized by a specific combination of vector control and/or immunization and an acceptable level of losses. Expenditures for vector control include acaricides, construction of dipping or spraying facilities and their maintenance, and variable costs such as those for water and labour. Economics of vector control depend on the herd size and the method of application of the acaricide. Morbidity, mortality and tick damage losses are effectively reduced by correct and intensive vector control programmes. Expenditures for vector control are estimated at US\$ 8.43, 13.62 and 21.09 per animal per year for plunge dipping, hand spraying and pour-on, respectively. Immunization costs comprise production of parasite stabilates, storage and application, delivery and treatment. At US\$ 9.5 per animal, immunization limits losses caused by *Theileria parva*, but ticks still may reduce the productivity of the animals. Expenditures for treatment after natural infection involve drugs, transport, veterinary fees and farm labour costs. Treatment has a moderate success rate, hence both morbidity and mortality remain important factors. Equally, it does not affect the vector, which may continue to reduce overall productivity of cattle. Expenditures for treatment range between US\$ 9.04 and US\$ 27.31 per animal. To compare different TECs in relation to different control strategies, assumptions have to be made on disease occurrence, case fatality, value and productivity of the cattle, reductions in productivity due to morbidity and number of animals under a specific control regime. Calculations based on data from Southern Province, Zambia show that large-scale immunization reduces the TEC by 90% compared to no intervention. Treatment, which is the second-best option, reduces the TEC by 60%.

keywords theileriosis control; Zambia; veterinary economics

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Introduction

Theileriosis, caused by the protozoon *Theileria parva*, is a cattle disease transmitted by the brown ear-tick *Rhipicephalus appendiculatus*. It is widespread in 11 countries in eastern, central and southern Africa (Perry *et al.* 1991). In Zambia it is usually referred to as East Coast Fever (ECF) or Corridor Disease (Nambota 1991). Traditionally, Corridor Disease refers to the disease caused by *T. parva* transferred from buffalo (*Syncerus caffer*) to cattle (Grootenhuys 1989), but in Southern Province, Zambia, it is commonly used for any form of ECF. The disease can be relatively mild, causing low mortality, restricted to calves only, but full-scale epidemics affecting all age groups do occur (Berkvens 1991). Different breeds of cattle react differently to ECF challenge,

with Zebu cattle showing more resistance than taurine breeds against both the parasite (Guilbride & Opwata 1963) and the vector (Jongejan *et al.* 1989; Fivaz & Norval 1990).

Other tick-borne diseases such as anaplasmosis, babesiosis and cowdriosis in Southern Province cause low mortality: 0.1, 0.01 and 0.02%, respectively, in 1996 (Animal Production and Health Sub-Program 1996). Moorhouse and Snacken (1984) reported that babesiosis (*Babesia bigemina*) and anaplasmosis are enzootically unstable and that their inoculation rates are unlikely to be of economic importance. Jongejan *et al.* (1988) reported that tick control has little effect on the control of anaplasmosis due to the presence of other vectors. It appeared that none of these other tick-borne diseases caused significant problems once tick control was abandoned following immunization against ECF in Eastern Province

(Berkvens 1991). Hence this discussion will mainly focus on ECF-control.

At farm level, ECF is traditionally controlled by vector control, by immunization against the parasite or by treating natural infections. Ticks can be controlled with acaricides by plunge-dipping, where animals plunging into and swim through dipping tanks containing an aqueous emulsion, suspension or solution of acaricide. Complete or almost complete immersion of cattle during dipping ensures adequate exposure of ticks to acaricide. The frequency of treatment depends on the acaricide used (Norval *et al.* 1992b).

Other widely used methods of acaricide application involve hand or engine-powered spraying. These methods of spraying seldom achieve complete wetting of the animal, usually resulting in poor tick control (Norval *et al.* 1992b). Excess acaricide solution drips off the animal and is not recycled as in dipping tanks, where cattle are held in draining pens after treatment. Nevertheless, if used correctly, spraying offers small-scale farmers a means to control ticks. The spray race is very common at commercial dairy farms (Norval *et al.* 1992b) but virtually absent in the traditional sector.

To control ticks at specific body sites only, such as the ears or the perineum, tick grease, an acaricide in a petroleum jelly base, is applied with a brush. More recently 'spot-on' and 'pour-on' acaricides have become available. These formulations include propellants that spread readily over the surface of skin and hair (Norval *et al.* 1992b). Acaricides are thus applied to limited areas of the body, from where they spread to much larger areas. Spot-ons are normally used to control ticks on a particular body part such as the head, while pour-ons are applied in a strip down the length of the back to give tick control over the entire body.

Four chemical products are known to have an effect against *Theileria parva* infections: menoctone, parvaquone, buparvaquone and halofuginone. Menoctone has not been developed as a commercial product because its synthesis is too expensive. Parvaquone has been commercialized as Clexon, and more recently as Parvexon, whereas buparvaquone is available as Butalex, and halofuginone is sold as Terit. *In vivo*, buparvaquone is more effective than parvaquone against *T. parva* infections (McHardy *et al.* 1985) but in Zambia Butalex is 5 times more expensive than Parvexon. Terit does not work in the early stages of the disease (Norval *et al.* 1992b) and it is no longer commercially available in Zambia. Hence, we only calculated the TEC for treatment with buparvaquone (Butalex) and parvaquone (Parvexon).

Efficacy of chemotherapy depends on early and fast diagnosis. Treatment should be given in the early stages of clinical disease; after the onset of respiratory symptoms none of the chemotherapeutic agents is effective any more (Norval *et al.* 1992b). Recovered animals can remain carriers of the parasite (Maritim *et al.* 1988) and it is suspected that this occurs more

frequently after parvaquone treatment (Dolan 1986a,b) than when buparvaquone (Mutugi *et al.* 1988) was used. The current immunization used for ECF is the 'Infection and Treatment method' (Radley 1981) whereby a titrated sporozoite stabilate of infected ticks is injected simultaneously with a 20-mg/kg b.w. dose of long-acting tetracyclines. Selection of the immunizing stock(s) of *T. parva* should ensure that cattle are immunized against subsequent field challenges with all *T. parva* stocks in the area.

Materials and methods

Theileriosis results in inevitable costs for cattle keepers, either by losses in productivity or by expenditures for disease and/or vector control. Cattle owners will try to adopt a strategy which minimizes the overall costs. It would not be economical to maximize output at any cost. We used the total economic cost (TEC) methodology proposed by McNerney *et al.* (1992), which calculates the sum of output losses due to theileriosis mortality and morbidity, tick damage, plus the expenditures for treatment or preventive measures. At the optimal level of control marginal cost equals marginal savings in production losses, thus minimizing the TEC of the disease.

In scrutinizing the costs of the different control strategies, i.e. no intervention, treatment, vector control and immunization, we distinguished between productivity losses (morbidity, mortality and productivity losses due to the presence of ticks) and expenditures (fixed costs and variable costs). Productivity losses were derived from literature and expert opinions, expenditures were quantified based on data gathered in Southern Province, Zambia. Drugs and acaricides were used as recommended by the manufacturer, even when these doses had been reported to be insufficient.

The TEC for the available control strategies are estimated as a function of disease occurrence, based on the herd-projection model developed within the ASVEZA (Assistance to the Veterinary Service in Zambia) project (Penne & D'Haese 1997). This model calculates the impact of different control strategies over the next 30 years and integrates chemotherapy as an alternative, which so far was not included in similar models. The model provides a number of economic parameters (such as TEC, benefit/cost ratio, Net Present Value of cattle farm) and graphs (herd size, animal production, income and annual costs) for the evaluation of different control strategies. It is a drawback that strategies cannot be combined (e.g. 50% dipping combined with immunization). The deterministic nature of the model leaves little room for evaluation of risk and variability in the epidemiological environment, which are typically stochastic. In our calculations, expenditures for each of the preventive and curative actions was estimated at farm level. The exchange rate from

Zambian Kwacha to US dollar is 1300 ZK = 1 US\$. Prices indicated are those of September 1997.

Results and discussion

Identification of losses and expenditures

An overview of the different components to calculate the TEC for different control strategies is given in Appendix 1. The model evaluates the TEC at farm level; therefore certain costs such as environmental costs, opportunity cost for foreign exchange and research are not included. These should be included in analyses at national level. Some authors have reported traditional ways of ECF-treatment (Okamoto 1993) and tick control (Mwangala 1997) in Zambia. These methods are largely based on experiences from traditional herb doctors and have not yet been evaluated scientifically. Therefore these methods could not be taken into account.

No intervention

Morbidity and mortality losses follow the occurrence of tick-borne diseases. If case fatality rates (defined as number of fatal cases divided by total number of cases times 100, during a given period) are high, animals die quickly and morbidity losses are negligible. An indirect, but significant, morbidity loss may be related to the drying-off of cows after loosing their calves (Van Doorslaer 1996). If the case fatality is low, more animals survive and morbidity losses will be more prominent. Ticks, in Southern Province mainly *Amblyomma*, *Hyalomma*, *Boophilus* and *Rhipicephalus* species (Speybroeck 1994) affect productivity. The entire feeding period of a single engorged female *Amblyomma* spp. or *Rhipicephalus* spp. lowers milk production by 7 g (Norval *et al.* 1990a,b). Life weight gain is reduced by, respectively, 4 g, 10 g and 41–61 g per engorged adult female of *R. appendiculatus*, *Amblyomma hebraeum* or *Amblyomma variegatum* (Norval *et al.* 1988, 1989; Pegram *et al.* 1989). Hides infested by ticks have lower commercial value. In this scenario, without intervention, there are no expenditures.

Treatment

According to Musisi *et al.* reported by McHardy (1988), a single intramuscular dose of Butalex(c) 2.5 mg/kg in 68 cattle with theileriosis in Zambia achieved a cure rate of 91%. Treatment by the ASVEZA-project of 48 confirmed theileriosis cases with the same dose achieved a cure rate of 85% in Nteme (Monze district) in 1994. Thus treatment leads to a drop in case fatality from 95% (no intervention) to less than 20% (after treatment). Consequently, losses due to mortality decrease by the same factor. Losses due to morbidity

will increase because more animals survive clinical disease. Mukhebi *et al.* (1992) estimated morbidity losses in animals surviving clinical theileriosis at 25% loss in milk production in affected cows, 5% and 10% loss in beef production in recovered calves and preadult animals, respectively, 3% reduction in draft capacity and 12.5% reduction in manure production. These losses are assumptions by experts, and more accurate data are not available. The reproductive function of *T. parva* infected animals is also affected (Rumberia *et al.* 1993). Productivity losses caused by tick loads remain in this scenario, where treatment is limited to ECF.

There are no fixed expenditures at farm level. At macro level, a drug delivery system has to be maintained involving research, infrastructure, production, storage, transport, and import. At farm level, expenditures for treatment comprise the costs for the theilericide plus field delivery. The former is determined by product price, dosage and body weight (b.w.). Delivery cost is the sum of transport costs, professional fees for a veterinarian or a veterinary assistant and their equipment and farm labour cost to round up and restrain the animals. These expenditures vary according to the drug used. Transport cost, professional fees and farm labour cost are higher when Parvexon is used, because it requires two injections as opposed to only one with Butalex. However, professional fees, in relation to the former product, are only 50% higher because an assistant rather than a veterinarian can administer the second injection, and since an assistant lives nearby and travels by motorbike rather than car, transport costs are only 20% higher. The expenditures related to these interventions are given in Table 1. Per treatment they vary from US\$ 9.04–27.31 depending on the weight of the animal.

Vector control

When correctly implemented, vector control effectively reduces losses due to morbidity, mortality and tick loads (Pegram *et al.* 1991; Minjauw *et al.* 1997). In Zambia's

Table 1 Treatment

	Parvexon	Butalex
Price (US \$/ml)	0.30	1.46
Dose (ml/kg LW)	0.15	0.05
Transport cost (US \$)	2.31	1.92
Professional fee (US \$)	4.62	3.08
Farm labour cost (US \$)	0.77	0.38
Treatment cost (in US \$)		
Calf 50 kg	9.94	9.04
Immature 125 kg	13.32	14.52
Adult 300 kg	21.19	27.31

(Source: ASVEZA, unpublished).

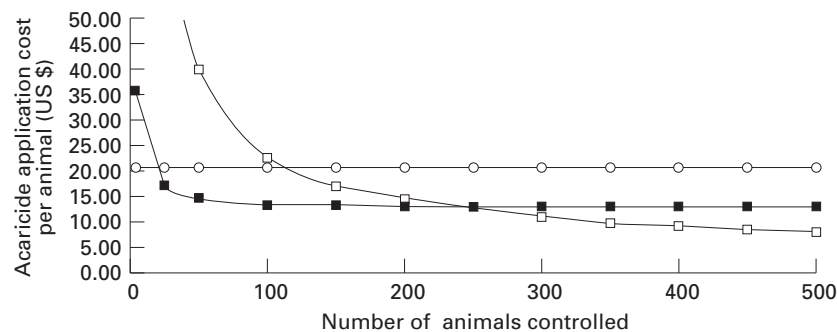


Figure 1 Acaricide application cost per animal per year (in US\$), method of application as a function of the number of animals controlled. □ Dipping; ■ Spraying; ○ Pour-on.

traditional sector acaricides are applied by plunge dipping tank, by hand spraying and as pour-ons.

Plunge dipping tank

In the following discussion a 'head dipped' should be understood as one bovine dipped once. 'Animal dipped' refers to a bovine dipped at regular intervals, as recommended by the manufacturer, for a period of one year. Initially, the cost is calculated for a dipping tank that caters for 500 animals; then the calculations are generalized for a variable number of cattle. The cut-offs between different acaricide applications are determined as a function of herd size. For our case study in Southern Province, this is assumed to be 25 cattle. Farmers are reluctant to collaborate in vector control, mainly due to lack of trust and interest in the absence of the disease for longer periods. The price per animal dipped is based on 10-year experience with a dipping tank in Monze district, Southern Province, Zambia (Penne *et al.* 1996). Expenditures

are grouped into four components: dipping tank construction (fixed), annual dipping tank maintenance (fixed), acaricides (variable) and additional costs such as those for water, labour, etc. (variable).

The total construction cost is US\$ 5000. Assuming a linear (simplification) depreciation time of 10 years, the annual cost is US\$ 500. Annual maintenance costs comprise repairs, recharging the dipping tank and daily management, and are calculated at US\$ 720. Total annual costs for construction and maintenance are divided by the number of animals dipped during that year to get the cost per animal dipped per year, i.e. for 500 animals it amounts to US\$ 2.44. In case of a herd of only 25 animals, this amounts to US\$ 48.8 per animal dipped – an unattractive option for small herds (Figure 1).

The most common acaricides used in Zambia and the number of treatments needed per year with concentrations for charging and replenishment, as specified by the manufacturer, are given in Table 2 and 3, respectively. Costs for

Commercial name	Active ingredient	Chemical category
Grenade	Cyhalothrin 5%	Synthetic pyrethroid
Supadip	Chlorfenviphos 110%	Organophosphorus compound
Triatix/Milbitraz	Amitraz 12.5%	Formamidine
Decatix	Deltamethrin 5%	Synthetic pyrethroid

(Source: ASVEZA, unpublished).

Table 2 Common acaricides used in Zambia

	Grenade	Supadip	Triatix	Decatix
Number of immersions per year	30	64	52	40
Price/l	36.62	69.23	12.11	69.45
Cost initial fill	732.31	503.85	484.62	1042.31
Initial fill/head dipped	0.05	0.02	0.02	0.05
Cost replenishment	0.13	0.16	0.10	0.16
Cost per head dipped	0.18	0.17	0.12	0.21
Annual cost per animal dipped	5.39	10.76	6.21	8.34

* based on 500 heads, dipped in Zambia in 1997, following manufacturers' instructions in order to get full tick control (Source: ASVEZA, unpublished).

Table 3 Acaricides for plunge dip

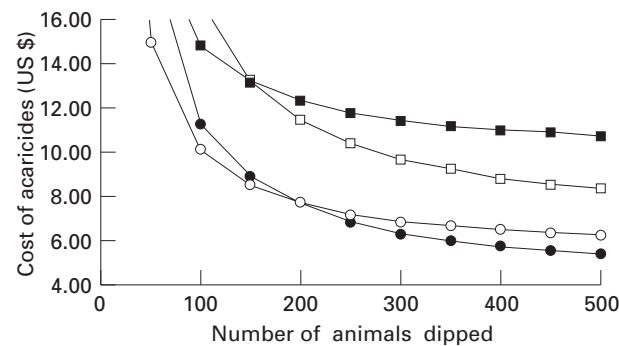


Figure 2 Cost of different acaricides (in US \$) as a function of the number of animals dipped. ● Grenade; ■ Supadip; □ Triatix; ○ Decatix.

acaricides are calculated for a herd size of 500 animals. Water (2.5 l/head) and farm labour, the variable requirements, are estimated at 0.02 US\$ per head dipped. As these are obviously related to the frequency of treatments, Triatix would incur costs of US\$ 0.60 per animal dipped and Grenade US\$ 1.04. The total annual expenditure for dipping 500 animals with Grenade is estimated at US\$ 8.43 per animal. Expenditures for plunge dipping are plotted in Figure 2 in relation to herd size and product used.

Hand spraying

The only fixed requirements are two knapsack sprayers and a crush-pen. A knapsack sprayer lasts on average four years and costs US\$ 75. With 50 animals in a herd, the average cost is US\$ 0.75 per animal per year. The annual cost for the depreciation and maintenance of a crush-pen is US\$ 80 or US\$ 1.6 US per animal. The annual cost for acaricides is calculated in Table 4. Labour at 25 animals per person per day, and water at 10 l per animal make up the variable costs for hand spraying, amounting to US\$ 0.095 per head. Spraying with Grenade, the cheapest treatment (Table 4), calculated for a herd-size of 50 animals, costs US\$ 13.62 per animal/year.

Pour-on

Spoton, with deltamethrin as the active ingredient at a concentration of 10 g/l, is used at a concentration of 10 ml per

Table 4 Acaricides for spraying

	Price (US\$)	US\$ per year
Triatix HCMV	0.77/10g	40.00
Grenade	36.6/l	12.21
Supadip	69.2/l	21.46
Decatix	69.5/l	27.78

10 l water used per animal to obtain complete wetting (Source: ASVEZA, unpublished).

100-kg body weight. To maintain constant protection it must be applied at four-weekly intervals (13 times per year). Spoton costs US\$ 12.9 per 200 ml. Farm labour is estimated at US\$ 0.01 per animal per application. The annual application cost thus is US\$ 21.09 for an animal with an average b.w. of 250 kg.

Cost of different applications in function of the herd size

The costs of all acaricide applications, except for pour-on treatments which involve no fixed costs, are scale dependent. Dipping is most dependent on herd size because of costs for construction, maintenance and initial charging of the tank. Figure 1 plots the costs as a function of the herd size with the most economical acaricide application given for a herd of 5, 25 and 500 cattle, respectively. In case of less than 5 animals, pour-on seems to be the most cost-effective acaricide application, with costing just over US\$ 20 per animal per year. If 25 animals have to be protected, spraying with Grenade is recommended at US\$ 17.20 per animal per year. The most economical vector control for a large herd of 500 cattle appears to be dipping with Grenade at US\$ 8.43 per animal per year.

However, in the traditional sector maximum efficiency in vector control is hard to achieve due to the above mentioned difficulties in implementing it on a wider scale, and for the purpose of controlling ECF it is practically impossible in Eastern Province (Berkvens 1991). Kadohira *et al.* (1996) reported losses from Corridor disease in Central Province, where 90% of farmers lost more than half of their cattle during the 1992–93 outbreaks although 40% of them carried out regular tick control.

Immunization

Immunization reduces mortality significantly. Berkvens *et al.* (1988) reported 33% mortality in nonimmunized calves as opposed to 5.5% in immunized calves in Chipata district. After 5 years of immunization (39 164 calves) these figures were reduced to 19.1% and 2.6% for nonimmunized and immunized calves, respectively (D'Haese & Thys 1993). In terms of reproduction, immunization against theileriosis has no long-term adverse effect on the cyclical status (Rumberia *et al.* 1994), nor on the calving rates (Dolan & Mutugi 1989). The same observation was made (Lynen *et al.* 1991) after large scale immunization in Eastern Province. Losses due to tick loads are the same as in the case of no intervention. Calculations on the costs for immunization (Table 5) range from US\$ 2.37–25 per animal (Radley 1981; Irvin 1984; Kiltz 1984; Mukhebi *et al.* 1990; Mukhebi *et al.* 1995; Elyn 1996; Penne *et al.* 1996). Expenditures for immunization reported here are based on figures obtained by the ASVEZA project in

Table 5 Cost of immunization (in US\$): review of literature

Author	Year	Cost/animal	Place	Remarks
Radley	1981	2.51	Hypothetical	
Kiltz	1984	20	Burundi	0.01 for stablate
Irvin	1984	5–6	Malawi	0.1 for stablate
Mukhebi <i>et al.</i>	1990	2.37	Kenya	0.89 for stablate
Mukhebi <i>et al.</i>	1995	25	Coast Province Kenya	Pilot immunization trial
Elyn	1996	9.79	Eastern Province Zambia	Mass immunization campaign
Penne <i>et al.</i>	1996	8.67	Southern Province Zambia	Hypothetical, based on Experience Eastern Province

Eastern Province since 1987 (Elyn 1996).

For both stablate production and field operations, investments and operational costs were identified, quantified and estimated at replacement price. Capital investments for stablate production consist of the laboratory buildings, stables and basic equipment. A depreciation cost for these items is included. Operating costs for stablate production cover laboratory equipment and consumables, chemicals, experimental animals and personnel. Field immunization costs comprise operational expenditures such as transport, liquid nitrogen and tetracyclines. For Southern Province, with 15 000 animals in the annual immunization programme and

an average b.w. of 250 kg per animal (i.e. immunizing all animals) immunization would cost US\$ 9.5 per animal. A breakdown is given in Table 6.

Southern Province case study

We used a herd projection model (Penne & D'Haese 1997) to calculate the TEC for the different strategies based on the above identified losses and on the calculated expenditures. The costs are calculated for a farm with 25 cattle in Southern Province, Zambia. A full list of assumptions, for a traditional farm in Southern Province, is given in Penne & D'Haese (1997). An average theileriosis occurrence of 15% with 20% of cases being subclinical is assumed. Plunge dipping and pour-ons result in a higher TEC than no intervention, i.e. US\$ 59.56, 23.55 and 21.47 per animal per year, respectively. At US\$ 2.36 per animal per year the TEC for immunization is minimal when all animals are immunized (Table 7). Disease occurrence is an important factor in the estimation of the TEC: if the disease did not occur, expenditures for prevention would be uneconomical. The TEC for some strategies (treatment, immunization of calves only) depends more on disease occurrence than other strategies (total immunization, vector control).

Figure 3 gives the TEC per animal per year as a function of disease occurrence: The most economic strategy, when disease occurrence is between 1.5% and 5% (point b), is treat-

Table 6 Immunization cost calculated for Eastern Province, Zambia

	US \$	ZK	% of Total
Cost stablate	1.80	2335	19
Cost field	7.70	1000	81
Delivery		8	
Cars	3.00	3900	32
Motorbikes	0.93	1210	10
Tetramycine	2.25	2925	24
Salaries	0.73	952	8
Others	0.78	1020	8
Total cost per dose	9.5	12343	100

(Source: Elyn 1996).

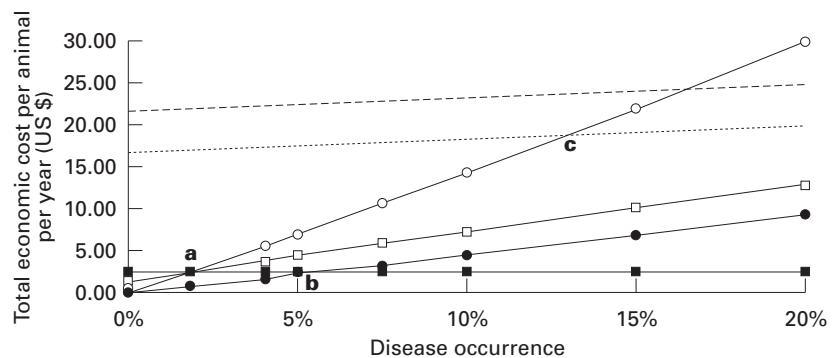
	Mortality	Morbidity	Expenditures	TEC/Animal
No intervention	21.46	0.01	0.00	21.47
Plunge-dipping	0.20	0.00	59.36	59.56
Spraying	2.01	0.00	16.84	18.85
Pour-on	2.01	0.00	21.54	23.55
Immunization calves only	8.76	0.00	1.17	9.93
Total immunization	0.20	0.00	2.16	2.36
Butalex	4.13	0.40	2.54	7.06
Parvexon	4.13	0.40	2.04	6.57

(Source: Results from TBD-Model, ASVEZA unpublished).

Table 7 TEC per animal per year (in US\$)

	Mortality	Morbidity	Expenditures	TEC/Animal
No intervention	21.46	0.01	0.00	21.47
Plunge-dipping	0.20	0.00	59.36	59.56
Spraying	2.01	0.00	16.84	18.85
Pour-on	2.01	0.00	21.54	23.55
Immunization calves only	8.76	0.00	1.17	9.93
Total immunization	0.20	0.00	2.16	2.36
Butalex	4.13	0.40	2.54	7.06
Parvexon	4.13	0.40	2.04	6.57

Figure 3 TEC as a function of control scenario and disease occurrence. ○ No intervention; Spraying; ----- Pour-on; □ Immunization of calves only; ■ Blanket immunization; ● Parvexon.



ment with Parvexon after natural infection; once incidence rises above 5%, the best strategy appears to be total immunization. Immunization of calves only is not desirable because adults will continue dying and incur mortality costs in excess of the cost to immunize them. At incidences levels below 1.5% it is cheaper to have no intervention (point a) than immunization. Spraying results in a high TEC, and only when disease occurrence exceeds 13% (point c), it is better to spray than to let the animals die.

Comparison of the Southern Province case study with other studies

Compared to acaricide applications in production systems with indigenous cattle, the scenario of immunization allows for a reduction of the TEC with 20–67% (Mukhebi 1996). However, immunization of calves only reduces TEC by 54% and 47% compared to no intervention and spraying, respectively. But the TEC increases by 51% compared to treatment with Parvexon. Total immunization leads to reductions of 89%, 87% and 36% compared to no intervention, spraying and treatment with Parvexon, respectively.

Conclusions

Losses due to theileriosis in all age groups indicate an epidemic. This leads to higher losses in productivity and hence will affect TEC in comparison with a more endemic situation in which only young animals are affected. Theileriosis incidence of less than 5% is not likely in Southern Province except during exceptional droughts. When theileriosis incidence is 15%, i.e. the average situation in Southern Province, the TEC is reduced by almost 90% if total immunization is chosen rather than a policy of no intervention.

Immunization of calves only, i.e. leaving adults unprotected during a transition period of a few years, results in lower expenditures due to less terramycin use (b.w. dependant), but this gain is completely eliminated by losses in the adult group during the transitional phase. As shown in Figure 3, whatever

the percentage of disease occurrence, immunizing all animals always results in a lower TEC than immunizing calves only. Total immunization, even though the most economic choice, has considerable practical constraints if it has to be implemented on a large scale. There are 560 000 cattle in the theileriosis-affected area of Southern Province. It is impossible to immunize all of them in one campaign. Farmers' willingness to pay for the immunization is unknown, but experience from Eastern Province shows that attendance after several years of immunization campaigns free of charge could be as low as 10–15% during the first year of implementation of payment by the farmers. With a similar attendance for Southern Province, the number of animals to be immunized in the first campaign could be around 50 000–75 000. Higher attendance could result in logistical constraints, especially during the first immunization campaign. Should stabilate production be insufficient, treatment would be the second-best intervention strategy within the limits of disease occurrence reported for Southern Province.

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Appendix I

Summary of factors influencing total economic cost

	Productivity losses		Expenditures		
	TBD –Effects	Tick loads	Fixed costs	Variable costs	
	Mortality	Morbidity			
No intervention	Both f (Occurrence) Mortality /morbidity = f(CF)	Presence of ticks can result in significant production losses	–	–	
Treatment	Reduced (CF increased 95 – > 20%)	Presence of ticks can result in significant production losses	Research Drug delivery system	Drugs Professional fees Farm labour cost Transport	
Vector control	Strongly reduced	Strongly reduced	Strongly reduced	Research F(control method)	Acaricide Transport Labour
Immunization	Strongly reduced	Immunization might result in limited productivity loss	Presence of ticks can result in significant production losses	Research Storage Production unit	Vaccine Transport Labour Professional fees