Epidemiology of Ticks and Tick-borne Diseases in Eastern, Central and Southern Africa

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Edited by

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Tribute

Shortly after the workshop, the organisers were saddened to learn of the death of Dr Soviet Kamwendo, Controller of Agricultural Services and former Chief Veterinary Officer of the Government of Malawi. Dr Kamwendo played a prominent and distinguished role in promoting the control of ticks and tick-borne diseases in Malawi and elsewhere in Africa, and in recognition of Dr Kamwendo's contributions, the editors wish to dedicate these proceedings to his memory.

Background to the workshop

Purpose of the workshop

A Food and Agriculture Organization/International Laboratory for Research on Animal Diseases (FAO/ILRAD) workshop on training and impact assessment in relation to control of ticks and tick-borne diseases (TBDs) was held in Nairobi in August 1994 (FAO 1994). This workshop recommended the standardised collation and dissemination of data and of reports on tick control and TBD vaccination, and further training in immunisation and monitoring. However, country needs and proposals for specific priority actions were not identified. From this starting point, the present workshop took the position that there are now appropriate technologies for the control of ticks and tick-borne diseases which, if correctly applied, can have a major influence in reducing the impact of ticks and TBDs on livestock productivity in Africa. Although technological improvements are still required in development of vaccines and diagnostic tools, the present tools and technologies can now be used with a degree of confidence and knowledge that was, until recently, lacking.

Against this background, the emphasis can now shift away from technology development to assessing the efficacy of the technologies; to improving their application and delivery; and to determining the epidemiological and socio-economic implications and consequences of applying tick and TBD control at field level, particularly amongst smallholder farmers. It was these areas that the workshop set out to explore under a number of themes within which a series of questions was posed. The final session was devoted to identifying priorities for future work and collaboration. This included consideration of a number of issues which related specifically to the FAO Regional Programme; these were:

1. To identify priorities and develop plans for the epidemiology component of the FAO/Multi-Donor Regional Programme on Control of Ticks and Tick-borne Diseases in Eastern, Central and Southern Africa.
2. Taking account of the Programme's comparative advantage with respect to other groups and organisations:
   - i) to establish regional and country needs
   - ii) to identify potential collaborating partners
   - iii) to determine needs for research, data collection and information exchange

Workshop themes and questions

1. Theme 1. Assessing the *efficacy* of control methods and immunisation against TBDs

- i) How to measure
  - indicators (serology, morbidity, mortality etc)
  - methodology (design, clinical trials, demonstrations etc)
- ii) What are country needs?
  - common needs
  - country-specific needs

desired standards
regulatory demands

iii) What is being done already?
national programmes
international programmes

iv) What can the Programme do?
planning, priority setting and coordination
communications and information exchange
training
regional research
collaborative research

2. Theme 2. Evaluating *delivery systems* for the control of TBDs

i) Planning and allocation of resources
what are the options/mechanisms for delivery (veterinary departments, private veterinarians, task forces, commercial sector, non-government organisations (NGOs), combinations)
deciding on options (availability of funds, trained staff, infrastructure, demand)
sustainability (ability to pay, subsidies, cost-recovery)

ii) Evaluation
how to measure success (indicators, experimental design, data to collect)

iii) What is being done already?
national programmes
international programmes

iv) What can the Programme do?
planning, priority setting and coordination
communications and information exchange
training
regional research
collaborative research

3. Theme 3. Measuring *impact* of immunisation and TBD control on livestock productivity

i) How to measure impact
direct (production and economic indicators, adoption rate, environmental impact etc)
indirect (changes in TBD control practices and livestock production opportunities, sustainability)
data collection (systems, exchange, sharing)

ii) Information priorities
how to collect
what to collect

who requires this information (governments, veterinary services, farmers, donors, researchers etc)

iii) Benefits/dangers of improved TBD control

opportunities (reduced tick control, reduced acaricide use, improved cattle, improved household income etc)

problems (cost, availability of vaccines and inputs, sustainability, external funding, lack of trained staff etc)

iv) What is being done already?

national programmes

international programmes

v) What can the Programme do?

planning, priority setting and coordination

communications and information exchange

training

regional research

collaborative research

4. Session 4. Coordination, collaboration and planning

i) Coordination

on-going programmes and interactions

role of Regional Programme

role of other groups (national and international)

ii) Collaboration

data sharing and information exchange

collaborative research

standards and quality control

iii) Planning

common problems, needs and priorities

country-specific problems, needs and priorities

training

role of Regional Programme

role of other groups (national and international)

iv) Action points

five-year plan for the Regional Programme

complementary/collaborative priorities for other programmes

Workshop proceedings

follow-up

Reference

FAO/ILRAD (Food and Agriculture Organization of the United Nations/International Laboratory for Research on Animal Diseases). 1994. *Planning of Training Activities and Studies on Impact Assessment. Report of a Workshop, Nairobi, 22–24 August 1994.* FAO Regional Coordination and Training Project, Harare, Zimbabwe. 36 pp.

Future approaches to the control of ticks and tick-borne diseases in Africa and the role of the Food and Agriculture Organization/Multi-Donor Regional Programme

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Introduction

Technologies for the control of ticks and tick-borne diseases (TBDs) in sub-Saharan Africa still need improvement but many are now at the stage where, if correctly applied, they can have a major impact on reducing the deleterious effects of ticks and TBDs. However, uptake of these technologies is slow, and programmes must in the future focus more on delivery than on technology development.

If the technologies are to be adopted, policy makers, veterinarians and farmers have to perceive them as reliable, affordable, available, appropriate and sustainable. The current paper examines each of these considerations in turn and suggests where future priorities should lie.

Reliability

Farmers' needs

Reliance must not be placed on a single approach to control ticks and TBDs. Integrated approaches are required which combine an appropriate balance between tick control, vaccination, chemotherapy and management. Veterinary and other delivery services must be sufficiently effective and reliable to provide these inputs and back-up at the time that they are needed.

Tick control

The present-day acaricides, if used properly, are very reliable in controlling ticks but, as so often happens, they are used incorrectly and the reliability of the compounds may be unjustly questioned. However, their reliability can decline when resistance to their use builds up in tick populations. This is most frequently a problem in *Boophilus* spp. ticks; less so with *Rhipicephalus* spp.

Vaccines

The blood vaccines against babesiosis and anaplasmosis have been widely and successfully used in Australia, South America and South Africa and, apart from a few problems with contamination (e.g. with bovine leucosis virus), have generally been reliable. A similar vaccine for control of heartwater is widely used in South Africa. The sporozoite stabilate vaccine for the control of theileriosis by infection and treatment is becoming increasingly applied in East Coast fever (ECF) endemic areas with considerable success. However, attempts to increase the scale of vaccine production to a semi-commercial level by construction of a 'vaccine factory' in Malawi, ran into difficulties when the product, for a variety of reasons, was perceived as being unreliable. As a consequence ECF vaccine production at this unit has now been suspended.

In order for any vaccine to be acceptable for field use it must be shown to be effective against the target disease(s); safe, so that it causes neither disease nor adverse reaction; and pure and free from extraneous contaminants or other agents. The current vaccines for control of TBDs are now meeting these requirements but, as international standards for vaccine production become more stringent, quality assurance and control procedures become more complex and costly, and vaccine prices inevitably rise. We must guard against seeking to attain standards beyond what is practically and economically feasible.

Role of FAO

FAO's particular strength lies in its ability to operate apolitically in the different African countries. Within the present context, this means that it can assist in steps to standardise vaccines, diagnostics and their application. FAO specialists currently participate in the FAO/OAU/ILRI committee that is seeking to improve and regulate the standards used in production of TBD vaccines. The Organisation is also leading in negotiations with relevant institutes to revive production of the cryopreserved stabilate vaccine for control of ECF. This thrust will seek to draw on the combined expertise of relevant research and production laboratories and of the private sector, so that a reliable, safe and effective product can be produced. Not only must this product be seen to be reliable under laboratory conditions, but it must also be able to stand up to the rigours of use in the field when used in less than ideal conditions and by operators not wholly familiar with the product and procedure. If these qualities can be built into the technology, its widespread adoption is likely to be assured. The reliability of any technology depends very much on the competence of the people applying it and FAO places emphasis on training at all levels.

Affordability

Farmers' needs

No farmer is prepared to pay for inputs the costs of which exceed the possible benefits which might accrue. This particularly applies to the infection-and-treatment method of immunisation against ECF, where a major cost lies in the concurrent chemotherapy which has to be given with sporozoite stabilate. Similar costs are faced with the blood vaccine for control of heartwater.

In future, particular attention must be paid to reducing costs of delivered product (vaccines) and, while donors may be prepared to meet capital and development costs of such products, they are most reluctant to enter into programmes which depend on continuous external support for their sustainability. Since control of TBDs is largely of benefit to the individual animal owners and is only of indirect benefit to the public good, it is increasingly felt that it is the beneficiaries (farmers) who should pay for control, rather than national governments which need to prioritise expenditure ever more strictly within their declining budgets. However despite this budgetary decline, government veterinary departments are, in many cases, reluctant to recognise that their former policies for tick and TBD control are no longer working or are on the brink of collapse. Against this background, it seems that tick and TBD control will have, in future, to rely increasingly on establishment of disease endemic stability and/or farmers paying for control. In this latter context, only those farmers with regular cash income will be able to afford to pay; thus, immunisation schemes can only realistically be adopted where farmers obtain income from sale of milk or meat, or are prepared to subsidise inputs to their livestock from other sources of income such as sale of crops or labour. Furthermore, it is essential that revenue that is collected from sale of vaccines or from tick control should mostly be returned into the system and not disappear into government treasury departments from where it is most unlikely to emerge for the purposes of tick and TBD control. It is clear that the whole economic strategy of tick and TBD control needs a major re-appraisal if a sustainable system is to emerge within the current economic environment of Africa.

Tick control

Acaricides are mostly manufactured by commercial companies who not only need to recover developmental costs from the sale of products but also rely on making a profit from the sale of those products to remain in business. With the increasing complexity of acaricides there is a continual rise in their cost to the end-user and, while commercial farmers generally have the resources to pay, many others do not. This applies, at one end of the scale, to the smallholder farmer and, at the other end, to governments of developing countries who lack the necessary foreign exchange. As a consequence of cost, the former wide-scale practice of regular (weekly) tick control is no longer possible for many farmers. Furthermore, it is now clear that for many situations total elimination of ticks is not a desirable aim, since it removes the element of challenge to TBDs which is required to establish and maintain endemic stability to the diseases. This is a biologically more robust state than maintaining populations of tick-free but disease-naive animals, which can suffer high mortality if tick control breaks down. More research and attention needs to be given to determining appropriate post-vaccination strategies for tick control which balance the needs of establishing and sustaining endemic stability, but at the same time reduce frequency and cost of acaricide application without allowing significant tick worry or tick damage to occur.

Vaccines

If one excludes the developmental costs (which may be very high, particularly for future sub-unit vaccines) the cost of TBD vaccines is generally not a major concern, even to smallholder farmers; the costs lie in supportive therapy and in back-up and monitoring. This is particularly the case with heartwater and ECF vaccines, both of which require prophylactic drug cover, and in many cases other forms of back-up as well. Nonetheless, the economic impact of ECF is such that many farmers in endemic areas, especially those in dairying, are prepared to pay for vaccine with concomitant prophylaxis at a cost in the region of US$10.00 an animal. However, the recent successes in Zimbabwe, immunising cattle with locally-produced theileriosis vaccine (Bolvac) without chemotherapy, give hope that this approach may also find application in other countries where the more virulent form of theileriosis (ECF) occurs.

Role of FAO

The Programme will be looking particularly at ways to reduce the cost of tick and TBD control, especially by promoting an integrated approach to control which is both affordable and sustainable. This will mean looking at improved and alternative ways of delivering control measures, for example developing, in association with the private sector, a package of control measures which target a range of conditions. The development of such a package will require an improved understanding of both tick and TBD epidemiology, and the socio-economic constraints facing smallholder farmers.

As the benefits of control begin to have an impact, livestock productivity (particularly milk production) will increase, income will be generated from sale of products, and control measures will become increasingly cost effective. Cost recovery will then enable control measures to move onto a more sustainable footing with farmers being increasingly willing and able to pay for the inputs, with a concomitant reduction in the need for donor intervention.

On the technological side, FAO will work closely with vaccine producers to explore ways of improving quality and cost-efficiency of production of ECF and other vaccines.

Availability

Farmers' needs

Because of poor communications in so many African countries, there are problems in getting drugs, vaccines and acaricides to farmers. There are at present many weak links in the delivery chain from producer to end user and, in each country, the nature of the problem is different. In general, delivery programmes which rely on the government sector are weak and attention is increasingly turning to the commercial companies, the private sector and even non-governmental organisations (NGOs), which often have their own communication networks and delivery chains which are not subject to the same constraints that national delivery programmes sometimes face.

In several African countries there is a strong move to privatise veterinary services and use this channel to deliver ECF immunisation. However, the 'top-down approach' to privatisation is generally not working well, particularly where veterinarians are expected to take out loans to capitalise their practices. On the other hand, where a 'bottom-up approach' can be developed with the impetus coming from the farmers themselves employing their own veterinarians (for example through cooperatives), then there is a good prospect of private veterinary service being viable and sustainable. Such a system is now gaining momentum in the smallholder dairy sector in Kenya and needs to be explored in other countries. This approach, if linked to commercial delivery and back-up, may well be the key to making tick and TBD control more readily available to the smallholder farmer.

Tick control

The availability of acaricides depends on an effective delivery chain which, in turn, is essentially linked to the purchasing power of either the farmer or, if a national delivery service is offered, the government. In this latter context the usual scenario is that the veterinary department requests treasury for X amount of funds for purchase of acaricides; the treasury agrees to contribute Y, which is substantially lower than that requested; in the end, the amount provided (Z) is substantially less than Y, and is usually provided late. Under this scenario, which unfortunately occurs in so many African countries, the availability of acaricides becomes very unreliable and regular acaricidal control programmes break down. Farmers are then forced to abandon a regular tick-control schedule unless they have sufficient resources to purchase acaricides direct from the commercial sector.

Vaccines

Only in South Africa is there a reliable source of TBD vaccines, but here ECF does not occur. Elsewhere on the continent, availability of TBD vaccines is still irregular. In the case of ECF, infection-and-treatment immunisation has been demonstrated to be very effective and the demand for vaccine is increasing, particularly in the dairy sector and where improved/cross-bred cattle are kept. Although ECF immunisation programmes are progressing well in a number of countries, present demands cannot be met, either because of the shortage of vaccine or the inadequacy of the delivery service. Both these aspects need to be urgently addressed in the future.

Role of FAO

FAO is placing particular emphasis on the establishment of a reliable and sustainable source of ECF vaccine which can be made available throughout the region to meet the specific requirements of the individual countries. Negotiations are currently in hand to identify and contract a suitable producer. Discussions are also being held with the commercial sector about their possible role in supporting marketing and delivery of vaccine. If negotiations are successful, they will go a long way to solving the problems of availability of vaccines which farmers currently face. Once adequate stocks of vaccine are available, FAO can assist countries to develop improved delivery systems.

Appropriateness

Farmers' needs

Farmers' perceptions of their needs and priorities in terms of disease control are not always in line with those of veterinary authorities. In order that more appropriate control methods of tick and TBD control can be developed, more attention needs to be given to understanding farmers' needs and priorities. This can be done by improving extension linkages and communications with farmers, and adopting participatory appraisal methods to involve farmers in decision-making. It is also important that tick and TBD control methods become recognised and accepted as an appropriate part of an integrated package of improvements aimed at increasing livestock productivity and not as stand-alone interventions.

Tick control

More attention needs to be given to developing appropriate methods of strategic tick control as the ability or willingness of many farmers to purchase acaricides declines. The 'once-a-week' dipping mentality that still persists in the minds of many farmers and veterinarians must be critically questioned and examined according to circumstances that prevail at farm level. Tick control by rote is neither biologically sound nor currently affordable. Opportunities for moving to cheaper and more appropriate strategies for tick control are now presented with the advent of effective vaccines and therapeutics against TBDs, particularly ECF. These opportunities must be explored and appropriate strategies formulated. Farmers must be given scientifically sound advice on which to revise their tick control strategies; they should not need to be left to make *ad hoc* decisions which may be biologically or economically unsound and inappropriate.

Vaccines

The current drive to produce sub-unit or genetically engineered vaccines for the control of TBDs is an indication that present-day vaccines are not wholly appropriate or acceptable for field use. The present shortcomings relate to a variety of factors including the need for cold or liquid nitrogen chains, the dangers of adverse or severe vaccine reactions, the difficulties in quality control and assurance, and the need for post-vaccination follow-up and monitoring. While many of these problems can be avoided with molecular vaccines, such vaccines are not yet available except at laboratory level. Until they are available for field use, efforts must continue to be made to improve the existing vaccines, particularly in terms of their quality control and ease of delivery and application.

Role of FAO

FAO can assist countries to develop integrated approaches to tick and TBD control which are more appropriate to circumstances which currently prevail. This can be particularly achieved through training of veterinarians and field staff, improved communications, information dissemination and exchange, and by establishing linkages between projects and programmes.

Sustainability

Farmers' needs

In order for the methods which farmers adopt for control of ticks and TBDs to be sustainable, all the above criteria of reliability, affordability, availability and appropriateness must apply. This is most likely to be achieved if a package of balanced technologies is adopted which are integrated into the particular farming system being practised. Furthermore, in adopting such technologies the farmer must see the benefits in terms of improved productivity, increased profits or reduced risk and costs.

Tick control

As already discussed, the key to sustainability of tick control lies in moving towards endemic stability which allows a reduction in frequency of acaricidal application in strategic ways which are targeted at reducing tick populations at critical times of the season when challenge is highest or populations particularly vulnerable. For example, in areas where tick populations show strong seasonality, it may be more cost effective to intensify tick control when ticks are in their nymphal instar and thus reduce the numbers which progress through to the adult stage, rather than reserve intensive control for the adults which are less easily killed by acaricides and which are more damaging to their hosts in terms of both tick worry and disease transmission. Such an approach requires a good knowledge of tick biology and behaviour, which needs to be passed onto the farmers, since one is advocating control at a time of year when, to the untrained observer, cattle may appear tick-free.

Vaccines

As with other forms of control, if vaccination to control TBDs is to be sustainable, farmers must perceive it as being beneficial and cost-effective. In particular, self-financing operations must become established which do not require subsidising from external sources, whether in terms of vaccine production or delivery. Where vaccine delivery has relied on government services, whether in human or livestock health, the programmes have generally failed, except in wealthier countries where governments are able to subsidise delivery or where there is substantial donor funding from outside. However, governments are normally only prepared to subsidise vaccination against epidemic diseases which pose a threat to national disease security. Where TBDs are endemic they do not pose such a threat, and delivery services will need to become privatised in response to need at the field level if they are to be sustainable. In other words, the beneficiary (farmer) must pay for his animals to be vaccinated against TBDs.

Role of FAO

FAO now recognises that tick and TBD control programmes must no longer be free-standing if they are to be sustainable but must be integrated into existing farming systems alongside or in collaboration with other development programmes as part of a package aimed at improving livestock production as a whole (particularly in the smallholder sector), with tick and TBD control being but one component of the package. In this respect, FAO can play an important role in establishing contact and linkages with other programmes and projects, and thus help to achieve a common objective of sustainable development at both national and regional levels.

Country reports

Epidemiology of ticks and tick-borne diseases in Ethiopia: future research needs and priorities

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Introduction

Livestock and livestock products play an important role in the socio-economic development of Ethiopia. There is a growing demand for meat, milk and eggs to improve the nutritional status of the population. Hides and skins are important components of the agricultural sector in generating foreign export earnings. draft animals provide power for cultivation of many peasant agricultural holdings. Moreover, livestock help as a source of security and supplementary cash income for rural agricultural households.

Improved dairy animals are increasing in numbers and there are now estimated to be 100,000 head of *Bos taurus/B. indicus* crosses which are the basis of the attempts by the government to strengthen dairying in both the commercial and smallholder sectors. All these cattle are at risk from the effects of ticks and tick-borne diseases (TBD).

Anaplasmosis, babesiosis, cowdriosis and theileriosis *(Theileria mutans)*, together with a range of vector tick species, have been demonstrated to be important, and streptothricosis *(Dermatophilus congolensis* infection) is becoming more important. Although East Coast fever *(T. parva* infection) and its vector *Rhipicephalus appendiculatus* have not been found, the relatively uncontrolled passage of livestock from the southern Sudan ensures a considerable risk. (Norval et al 1991)

Losses from tick damage to hides and skins were claimed in 1979 to be in the region of one million Ethiopian Birr (US$ 500,000) per annum (Radley 1980), but are likely to be much higher. An estimate of the yearly cost of acaricides in 1989 was 3 million Birr (US$ 1.5 million) (Newson 1991). When other losses such as deaths, reduced growth rate and reduced milk production are added, economic losses due to ticks and tick-borne diseases are highly significant. Ticks are controlled mainly by the application of acaricides. A national policy on ticks and tick-borne diseases control was recently drafted and submitted to the government for approval.

The objective of this paper is to review the available information, including that recently collected, on the occurrence of ticks, tick-borne diseases and the control strategies practised in Ethiopia.

Ticks

Tick surveys have been carried out through the Food and Agriculture Organization (FAO) projects ETH/83/023, TCP/ETH/0053 and GCP/ETH/048/DEN in different

Table 1. *Major tick species of livestock recorded in Ethiopia.*

Tick spp	Host from which ticks were collected
Amblyomma cohaerens	Cattle, sheep, goat, camel, equine
A. gemma	Cattle, sheep, goat, camel
A. lepidum	Cattle, sheep, goat, camel
A. variegatum	Cattle, sheep, goat, camel, equine
Boophilus annulatus	Cattle
B. decoloratus	Cattle, sheep, goat, camel, equine
Haemaphysalis aciculifer	Cattle, sheep, goat, equine
H. parmata	Cattle, sheep, goat
Hyalomma dromedarii	Cattle, sheep, goat, camel
H.m. rufipes	Cattle, sheep, goat, camel
Rhipicephalus bergeoni	Cattle, sheep, camel, equine
R.e. evertsi	Cattle, sheep, goat, camel
R. pulchellus	Cattle, camel, equine
Argas persicus	Chicken

ecoclimatic zones of the country. The major tick genera recorded during the tick distribution survey were *Amblyomma* (40%), *Boophilus* (21%), *Haemaphysalis* (0.5%), *Hyalomma* (1.5%) and *Rhipicephalus* (37%) (Table 1). However, over 60 species are known to exist in the country. *A. variegatum* (vector of *Cowdria ruminantium* and *T. mutans)* and *B. decoloratus* (vector of *Anaplasma marginale* and *Babesia bigemina)* are the most widespread of the ticks collected. The distribution of *A. variegatum* is similar to that of *B. decoloratus* (Pegram et al 1981), and together these two species constitute more than 40% of the total collections. More than 80% of ticks were collected from cattle and *B. decoloratus* (28%) was the most abundant tick found and heavy infestations by this species were observed on cross-bred cattle. *B. annulatus* is restricted to Gambella, south-west Ethiopia. *A. cohaerens* predominates in western Ethiopia (de Castro 1984) and *R. pulchellus* was mostly found in southern Ethiopia along the Rift Valley. *R.e. evertsi* appeared to occupy a wide range of climatic and ecological zones.

A. gemma and *R. pulchellus* are confined to semi-arid areas (Pegram et al 1981) and lowland tick densities are usually greater than those in the highlands. *Amblyomma*, *Boophilus* and *Rhipicephalus* ticks are mainly found on livestock. The remaining species occur in limited numbers and have little practical significance to livestock production. Tick population levels in local cattle are generally low for most of the year but numbers increase during the rainy season.

Tick seasonal dynamics studies were carried out at four sites over a 30-month period. Monthly collections from six cattle were made at three sites in Region 4 (Agaro, Arjo and Bedelle) and one site in Region 12 (Gambella). Additional seasonal collections were made at another three sites in Region 4 (Bonga, Fincha and Tepi). The Region 4 sites had rainfall for most of the year and were characterised by moderate tick infestations *(A. cohaerens, A. variegatum, B. decoloratus, R. bergeoni, R.e. evertsi, R. lunulatus, R. praetextatus)* throughout the year although a peak occurred at the beginning of the heavy rains (June–July). At the Region 12 site, with only May–August rains, tick numbers *(A. variegatum, A. lepidum, B. annulatus, B. decoloratus, H.m. rufipes, R. praetextatus)* were low in the dry months and increased markedly at the start of the rains and remained relatively high throughout the rainy months.

Tick-borne diseases

The major cattle tick-borne diseases in Ethiopia are anaplasmosis, babesiosis, cowdriosis and theileriosis. There are no reported cases of bovine tropical theileriosis *(T. annulata)* or East Coast fever *(T. parva)*.

Infection by *A. marginale* is widespread in the country as is its major vector *B. decoloratus* (Table 2). Serological studies carried out in different ecological zones in Ethiopia showed that the prevalence of antibodies against *A. marginale* in dairy cattle was 99% (Table 3) but few showed parasitaemia on examination of thin blood smears (Table 5). The impact of this disease on the livestock industry in the nation is negligible.

Table 2. *Distribution of tick-borne disease agents in Ethiopia.*

Species	Principal vector	Distribution
Anaplasma marginale	*Boophilus decoloratus*	Country wide
Babesia bigemina	*B. decoloratus*	Country wide
B. bovis	*B. annulatus*	South-west Ethiopia (Gambella)
Cowdria ruminantium	*Amblyomma variegatum*	Country wide
Theileria mutans	*A. variegatum*	Country wide
T. buffeli (=T. orientalis)	Unknown	South-west Ethiopia

Table 3. *Prevalence of antibodies against tick-borne diseases in dairy cattle using ELISA tests.*

	No. of animals sampled	*A. marginale* (+ve)	*B. bigemina* (+ ve)	*T. mutans* (+ ve)
Private dairy farm	80	79	49	20
State dairy farm	162	161	112	66
Total	242	240		(99%)

Babesiosis is mainly a disease of cattle and is caused by *B. bigemina* (vector *B. decoloratus)* and *B. bovis* (vector *B. annulatus)* (Table 2). Infection with *B. bigemina* is widespread in the country and *B. bovis* is of recent origin in the livestock disease scenario of the country and has so far only been detected in Gambella, south-west Ethiopia. The occurrence of *B. bovis* was confirmed serologically in sera taken from Sudanese refugee cattle in this area. Serum samples from these cattle were tested by IFAT at Lilongwe, Malawi and 59% were shown to be positive for *B. bovis* and 59% for *B. bigemina* (Table 4). During a serological survey of tick-borne diseases in private and state dairy farms, which was carried out in 1992, ELISA test results indicated that over 60% were positive for *B. bigemina.* In another serological survey in which sera were tested by IFAT, 49% showed the presence of antibodies to *B. bigemina,* but very

Table 4. *IFAT results for* B. bigemina *and* B. bovis *on samples from Sudanese refugees' cattle.*

	No. of animals sampled	*B. bigemina* (+ ve)	*B. bovis* (+ ve)
Pignudo	38	15	18
Itang	20	19	16
Total	58	34	34
		(59%)	(59%)

Table 5. *Blood smear results of tick-borne diseases.*

	No. of animals sampled	*A. marginale* (+ ve)	*B. bigemina* (+ ve)	*T. mutans* (+ ve)
State dairy farms	1871	15	33	220
Private dairy farms	260	—	3	53
Cooperative	278	9	2	143
Local cattle	2799	93	58	1132
Total	5208	117	96	1548
		(2.2%)	(1.8%)	(29.7%)

few parasites were detected in blood smears collected from indigenous cattle. Clinical cases of babesiosis are encountered rarely and reported losses are minimal. *B. motasi*, *B. equi* (Radley 1980) and *B. canis* have also been reported.

Cowdriosis (heartwater) caused by *C. ruminantium* is considered to be the most important tick-borne disease of exotic and cross-bred cattle. Its economic importance is recognised but not well documented. The most important tick vector is *A. variegatum* which is widespread in the country. For years, the disease has been known to be present in Ethiopia. Outbreaks have occurred in some dairy farms in which mortality rates have reached as high as 25%. In 1992 a devastating outbreak occurred at Abernosa ranch where Boran × Friesian crosses are kept (Solomon Gebre, personal communication). *Cowdria ruminantium* was demonstrated in brain crush smears in 17 of 40 carcasses. Heartwater is regarded as a problem in this ranch causing high losses, particularly in young animals of 2–8 months of age. Pegram et al (1981) isolated the agent and a suspected outbreak has been reported by Hailemariam (1980).

Theileria mutans has been known for a long time to occur in Ethiopia. It is certainly as widespread as its vector *A. variegatum* (Morel 1980). During a serological survey of TBDs in private and state dairy farms carried out in 1992, ELISA test results indicated that over 30% of sera tested were positive for antibodies to *T. mutans* (Table 3) and in 1993, of 190 sera collected from four state dairy farms, 27% were positive for *T. mutans*. Of 5208 blood smears collected from different ecological zones of the country, *T. mutans* was identified in 29.7% (Table 5).

From 700 blood smears collected in the western zone of the country, laboratory findings indicated that over 40% were positive for a *Theileria* species (Mekonnen et al 1992). This species was more prevalent in indigenous cattle than crosses and clinical symptoms observed were minimum. It is regarded as almost entirely non-pathogenic in nature.

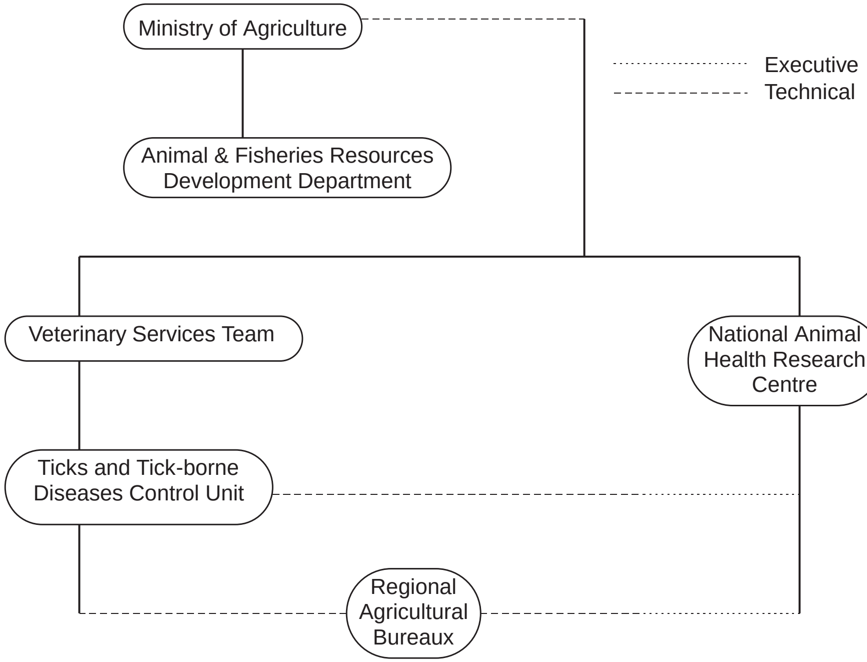

Figure 1. *Organisational structure.*

The occurrence of *T. orientalis* in cattle in western Ethiopia was confirmed on morphological and serological grounds (Becerra et al 1983). *T. velifera* was observed in bovine blood smears (Radley 1980). Nairobi sheep disease was reported in Ogaden rangelands with its vector *R. pulchellus* (Pegram et al 1981).

Dermatophilosis was reported as being an emerging concern in dairy farms where crosses and exotic cattle breeds are kept. It was reported that cases appeared in the month or so before the start of the main rains. This correlates with the start of attachment of *Amblyomma* males and is thus yet another suggestion that these ticks have some sort of causal relationship (Norval 1986). However, the predisposing factors need further investigation. In 1992, an outbreak of dermatophilosis occurred in Abernosa ranch in which many animals had to be culled because of the presence of severe lesions, although some animals recovered without treatment. Its occurrence would appear to be seasonal and cases are expected to recur with rains and high numbers of ticks.

Control strategies

Acaricide application is still the main tick control method in Ethiopia. A multitude of acaricide is used and their application seems to be regulated primarily by their availability. Two formulations of camphecheor have been banned by the Ministry of Agriculture on residue and public health grounds. Bacdip (quintiofos), Bercotox (dioxathion), tick grease (quintiofos) and Steladone (chlorfenvinphos) are mainly used to treat indigenous cattle. CBM-8 (carbaryl), Bayticol pour-on (flumethrin) and spot-on (deltamethrin) are used to control ticks on cross-bred animals. Very few functional dips and spray races are present. Acaricides are mainly applied by hand spraying and hand dressing.

Apart from the use of chemical compounds for tick control, certain cultural practices, such as the hand picking of ticks, burning with a hot iron, and application of plant preparations, are widely used by cattle owners in the rural areas. Ticks on indigenous cattle are treated whenever the farmers bring their animals to the veterinary clinics either for tick control or for other complaints. There is no planned programme of tick control except on dairy farms. The majority of tick infestations on local cattle are mild and can be solved by spraying a localised part of the animal such as axilla, ventrum, abdomen or udder—common sites for *Amblyomma* ticks. Reduction in *Amblyomma* tick numbers would be beneficial in controlling heartwater and dermatophilosis, thus preventing udder damage which can lead to loss of udder quarters or, in bulls, sterility from testicular abscesses (Tatchell 1992). Within the country's indigenous zebu cattle population there appears to exist a high degree of endemic stability to tick-borne disease. In the dairy herds with their cross-bred cattle, the high percentages of anti- bodies against *A. marginale* (>90%), *B. bigemina* (60%) and *T. mutans* (30%) found during the project's surveys seem to indicate a high degree of endemic stability in respect to these tick-borne diseases.

Boophilus decoloratus ticks collected from most of the dairy farms were resistant to toxaphene, but no resistance was detected in ticks collected from indigenous cattle (Regassa and de Castro 1993). Ali and de Castro (1993) carried out a study to obtain information on tick burdens as an indication of differences in host resistance to ticks between the different breeds of cattle. They indicated that Horro (zebu) animals had the lowest tick burdens when compared with crosses with *B. taurus* breeds, although Horro × Jersey crosses had a high degree of resistance.

The Veterinary Service Department accepts that dependence on acaricides is expensive, both in terms of local and foreign currency. It is against this background that the department is now reviewing the current strategy of tick and tick-borne disease control, and considering possible alternative options to reduce the cost.

Chemotherapy and chemoprophylaxis provide useful tactical alternatives within a tick-borne disease control programme. Oxytetracycline has a therapeutic effect against *C. ruminantium* when administered at an early stage of the infection. Tetracyclines have long been the only drugs with a significant effect on *A. marginale*. Diminazene is used against *B. bigemina* and it has been shown to be protective for two weeks (Lawrence and de Vos 1990).

Future research needs and priorities

Research on dermatophilosis and cowdriosis

Tick-associated dermatophilosis and cowdriosis are the most serious disease constraints to increased livestock production in Ethiopia. The development of the livestock sector is essential to increase the quantity of protein available for local consumption. To achieve this, the productivity of local cattle must be increased or more productive exotic breeds introduced. However, dermatophilosis and cowdriosis are regarded as a serious obstacle to the future of cross-breeding programmes for dairy cattle. These diseases can also affect the utilisation of draft oxen and thus crop production. Therefore, it is essential to carry out epidemiological and economic studies on them to generate adequate data which can be used in planning and implementing cost-effective disease control alternatives.

Long-term objective

The long-term objective of the proposed research concentrates on reducing mortality and morbidity due to dermatophilosis and cowdriosis in improved dairy cattle leading to increased milk production, reliable income for the smallholders and improved nutritional status at national level.

Specific objectives

- To alleviate problems due to dermatophilosis and cowdriosis currently threatening the dairy industry.
- To establish long-term research and dissemination initiatives on environmentally safe, economically feasible and acceptable tick management strategies.
- To reduce the overall national level of potential environmental contamination with acaricide, and decrease land degradation through improved management of livestock.
- To increase livestock production for local consumption and enhance the possibilities for increasing exports of meat and milk.
- To strengthen capacity building of local staff and expertise through training and improvement of laboratory capabilities in the diagnosis of TBDs using serological tests.
- To identify the mechanism of resistance of certain breeds of cattle to dermatophilosis, cowdriosis and *A. variegatum*, and to establish threshold numbers of ticks for the development of immunity to these two diseases.
- To assess the epidemiology and economic impact of dermatophilosis and cowdriosis in crosses and exotic dairy cattle.
- To identify possible ways in which cost-effective treatment of clinically affected animals, especially valuable breeding stock, might be made more effective.

Activities

Dermatophilosis:

- Epidemiological data on the occurrence of dermatophilosis and *A. variegatum* will be collected in herds having cattle of different breeds. Monthly tick counts of the various species present will be carried out on a number of tagged animals in each herd and the whole herd examined for the presence of skin lesions. The frequency and method of acaricide application in each herd will be noted.

- Studies will be carried out on the apparent resistance of certain breeds of cattle to ticks to see if such cattle pick up fewer ticks, the ticks remain attached for a shorter period, or they engorge less well. *A. variegatum* tick counts will be carried out on cattle kept under similar field conditions in experimental herds and in local herds. The stage of feeding of female ticks will be noted. The number of ticks picked up by cattle of the various breeds within a set period of time will be recorded and the time that ticks remain attached will be investigated.
- Studies will be carried out to determine the threshold number of ticks required for the development of chronic dermatophilosis in two breeds of cattle of different susceptibilities which will be experimentally infested with different numbers of *A. variegatum* and observed closely for the development of dermatophilosis.
- Friesian cattle will be experimentally infested with the different *Amblyomma* species and observed closely for the development of dermatophilosis.

Cowdriosis: Sero-epidemiological studies of cowdriosis on crosses and exotic dairy cattle will be conducted.

Progress in the research will help in the development of control methods for dermatophilosis and cowdriosis which could ultimately lead to increased production of meat and milk and increased work output of draft animals, and thus improved nutrition of the local population.

Research on East Coast fever *(T. parva)* and cerebral babesiosis *(B. bovis)*

Despite the importance of the TBDs present in Ethiopia, the country is spared the three most serious TBDs found in neighbouring countries. These are *Theileria annulata* tropical theileriosis (vector *Hyalomma a. anatolicum), Babesia bovis* cerebral babesiosis (vector *B. annulatus)* and *Theileria parva* East Coast fever (vector *R. appendiculatus)*.

Although ECF *(T. parva* infection) and its vector *R. appendiculatus* have not been found in Ethiopia, the relatively uncontrolled passage of livestock from the southern Sudan and Kenya where the disease and vector are found ensures that a considerable risk exists. If infected ticks become established on the climatically favourable highlands of Ethiopia, close to 100% mortality of improved and indigenous cattle could occur (Norval et al 1991).

Boophilus annulatus ticks carrying *B. bovis* have moved east across the Sudan into western Ethiopia. Further movements into the central part of the country could have disastrous epidemic results.

Objectives

- To prevent the establishment of ECF *(T. parva)* and its tick vector *R. appendiculatus* in the country.
- To limit further spread of *B. bovis* and *B. annulatus*.

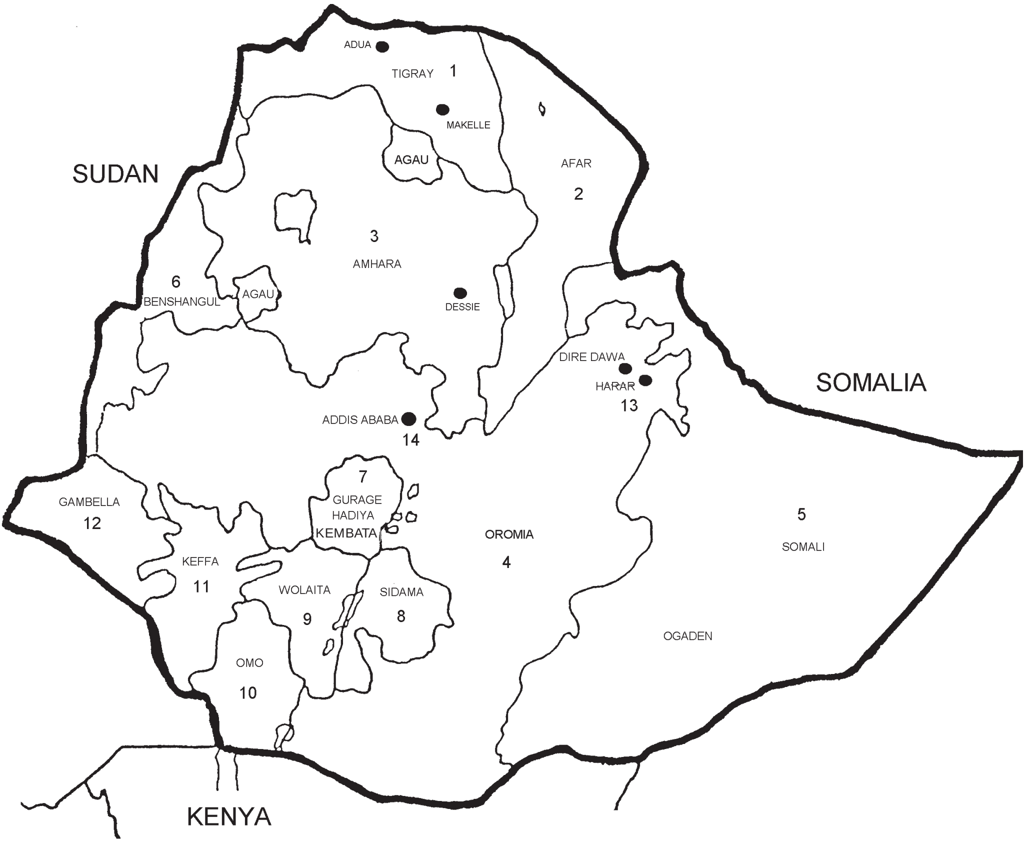

Figure 2. *The administrative regions of Ethiopia.*

Activities

- Sero-surveillance of *T. parva* and *B. bovis* in Sudanese refugee cattle and local cattle in south-west Ethiopia.
- To monitor the presence of *R. appendiculatus* and possible spread of *B. annulatus* in south-west Ethiopia.

Policy and strategy for control of ticks and tick-borne diseases

Background

Ticks and tick-borne diseases are some of the most significant and serious constraints to the improvement of livestock production in Ethiopia. Tick-borne diseases and their vectors are wide spread in the country. They affect production in various ways, such as growth rate, milk production, fertility, the value of hides and mortality.

Attempts have been made to control ticks and tick-borne diseases in Ethiopia. However, these have failed due to shortage of trained manpower, financial constraints and lack of policy.

It is therefore extremely important to have a national policy and a strategy to tackle these problems.

National policy

Minimise the adverse effects of ticks and tick-borne diseases by using cost-effective, environmentally safe, sustainable and integrated control methods.

Objectives

- A sustained increase in the production of milk and meat in Ethiopia by mitigating the harmful effects of ticks and TBDs on the national dairy hard.
- To develop strategies for integrated tick control, making maximum use of naturally induced host resistance to ticks, minimal use of chemical accentuates incorporating any traditional practices or remedies that appear to be of value.
- To develop and implement surveillance systems and action plans to prevent exotic infections such as *T. parva* and *T. annulata* from becoming established in the country, and *B. bovis* from spreading.
- To reduce expenditure of foreign exchange resources for ticks and TBD control and an increased GNP that will include a higher value for hides and skins on the international market.

Strategies

Ticks and tick-borne diseases: control strategies

For dairy farms stocked with crosses and exotic breeds:

- To combine strategic and threshold acaricide application with due attention to inducing enzootic stability.
- To closely supervise use of acaricides and monitor acaricide resistance.
- To encourage good management practices.
- To closely monitor TBDs and institute chemotherapy as required.
- To implement planned, safe, effective and economically sound immunisation of animals at risk from TBDs, based on epidemiological findings.

For indigenous zebu cattle maintained under traditional management practices:

- To institute threshold level acaricide application by farmers in order to maintain endemic stability to TBDs.
- To encourage minimal use of acaricide with emphasis to local application.

- To install use of existing, safe and environmentally sound traditional tick-control methods.

Other livestock (ovine, caprine, equine, avian, camel etc):

- To install threshold level tick control with minimum acaricide application.
- To encourage use of safe, existing and environmentally acceptable traditional tick-control methods.

Strategies for capacity building

- Allocate adequate and consistent funds to establish new and rehabilitate existing facilities and infrastructures.
- Establish purpose-oriented and efficient manpower training system.
- Establish relabel data management and communication system.

Strategies for research and networking

The ticks and tick-borne disease control unit, in collaboration with the relevant governmental and non-governmental organisations, will carry out the following research.

- Epidemiological studies of tick-borne diseases to provide the necessary incidence and prevalence data.
- Distribution and population dynamics studies of economically important ticks.
- Studies on different breeds to select an appropriate tick resistant breed.
- Further investigation on traditional tick-control practices.
- The role of wildlife in the epidemiology of tick-borne diseases.
- Economic impact of ticks and tick-borne diseases.

Strategies for extension

- Educate farmers on the importance of ticks not only as external parasites but also as vectors of diseases.
- Train farmers/peasants to be actively involved in restricting free livestock movement across international boundaries in order to protect the country from importing dangerous exotic tick-borne diseases and vector ticks.
- Educate farmers on the importance of reduced (relaxed) chemical (acaricidal) control of ticks in order to establish and maintain endemic stability and also produce safe livestock products.
- Encourage community to practice safe and economical traditional control methods as part of integrated tick management.

Strategies for service delivers

- Planning, guidance, monitoring and evaluation of all services will be undertaken by the responsible government body.

- Encourage the private sector to be involved in the control of ticks and tick-borne diseases.
- Encourage the involvement of non-profit making international and other non-governmental organisations in the control of ticks and tick-borne diseases.

Organisational set-up

Ticks and Tick-Borne Disease Control Unit (TTBDCU) being accountable to veterinary service team shall undertake the following activities.

- Conduct further surveys on ticks and tick-borne diseases.
- Coordinate, monitor and evaluate tick and tick-borne diseases control activities.
- Initiate and assist in generation of guideline policies and regulatory issues on matters related to tick and tick-borne diseases control.
- Formulate, monitor and evaluate ticks and tick-borne diseases-related projects.
- Prepare and organise workshops, seminars and training courses.
- Prepare and develop extension package and information dissemination.
- Perform other relevant tick and tick-borne diseases-related activities.

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Epidemiology of ticks and tick-borne diseases in Kenya: future research needs and priorities

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Introduction

Kenya, which occupies an area of 582,670 km^2, has 25 million people. Farming is the country's main economic activity. The country has 13.5 million head of cattle, out of which 3.2 million are exotic *(Bos taurus)* breeds (Appendix 1). The dairy industry is ranked second to maize as the most important agricultural income-generating enterprise. Unfortunately, ticks and tick-borne diseases particularly East Coast fever (ECF) are major constraints to this industry.

East Coast fever, which is a febrile, lymphoproliferative disease of cattle caused by the protozoan parasite *Theileria parva* and transmitted trans-stadially by the brown ear tick, *Rhipicephalus appendiculatus*, is by far the most economically important tick-borne disease in Kenya. In 1993, 230,000 cases of ECF were reported and many more may have occurred without being reported. Four other *Theileria* species *(T. taurotragi*, *T. mutans*, *T. velifera* and *T. buffeli)* which are usually benign, have also been reported in Kenya.

The other important tick-borne diseases of cattle in Kenya are babesiosis (caused by *Babesia bigemina)*, anaplasmosis (caused by *Anaplasma marginale)* and heartwater (caused by *Cowdria ruminantium)*.

Current strategies for the control of ticks and tick-borne diseases

Epidemiologically, Kenya can be divided into endemic areas and epidemic areas. Areas where exotic cattle and their crosses exist, and acaricide has been applied for a long time on a regular basis are classified as epidemic while areas where indigenous Zebu cattle dominate and acaricide application has not yet been introduced or has been used minimally are termed endemic.

In ECF epidemic areas, tick-control measures are enforced by the Cattle Cleansing Ordinance Act, under which the Minister in charge of Livestock Development is empowered to proclaim infected areas and enforce weekly cattle cleansing with government-approved acaricides.

Before 1977, the Veterinary Department was responsible for supervising the Cattle Cleansing Act but not for managing dip tanks and spray races. Concern over escalating losses due to tick-borne diseases, in particular ECF, and emergence of acaricide resistance accentuated by inefficient acaricide application caused the Department, through the Tick Control Programme, to assume the management of communally operated dip tanks serving small-scale farmers in the proclaimed areas. Under the Tick Control Programme, there are 3,330 dip tanks serving just over six million head of cattle, one-third of which are exotic or improved dairy or beef stock. In 1995, out of 5,100 completed communal dips, 3,800 were operational while the rest were non-functional due to lack of acaricide supply, breakdown or abandonment as farmers had switched to hand spraying.

Except on an experimental basis, other methods of tick control such as the use of acaricide-impregnated ear tags, 'pour ons', the use of tick-resistant cattle and vaccines against ticks have not been encouraged in Kenya.

In the past decade or so it has become apparent that intensive tick control is prohibitively expensive. The government's policy is to privatise tick control. This has resulted in a decline in control since it has become difficult to enforce the Cattle Cleansing Ordinance Act to farmers who are expected to pay full costs for tick control. This may be advantageous since it is now recognised that many animals, in the absence of any tick control measures, readily acquire immunity to both ticks and tick-borne diseases as a result of natural challenge. Indeed, intensive use of acaricide may lead to the loss of both resistance to ticks and endemic stability to tick-borne diseases.

Recently, smallholder cattle have been immunised against ECF by the infection-and-treatment method using *T. parva* (Marikebuni). This is being encouraged but there are no plans, at least in the near future, to immunise cattle against other tick-borne diseases.

The Veterinary Department classifies cattle diseases either as 'public good' or as 'private good'. Under 'public good' are listed diseases that are contagious and can affect the whole national herd and/or international trade. This includes viral diseases like rinderpest and foot and mouth disease. These diseases are controlled by the Veterinary Department at a greatly subsidised rate. Under 'private good' are listed diseases that affect individual farms without necessarily affecting the neighbouring ones. This includes diseases like mastitis and tick-borne diseases. Control of these diseases is left largely to the individual farmer. Consequently, ECF immunisation is expected to be performed by private veterinarians. Where private veterinarians are lacking, government veterinarians are allowed to immunise cattle against ECF but in their private capacity. The farmer is expected to meet the full cost of the immunisation.

Before any veterinarian is allowed to immunise cattle against ECF, he or she must have undertaken a training course on ECF immunisation run by the National Veterinary Research Centre (NVRC).

Projects involved with control of ticks and tick-borne diseases

The key players in the control of ticks and tick-borne diseases in Kenya are the Veterinary Department and the NVRC. The Veterinary Department plays the role of testing efficacy of acaricides and acaricide resistance, and making recommendations on the acaricides to be used. They also treat for tick-borne diseases.

Presently there is a project funded by the Kenya Agricultural Research Institute and the Overseas Development Administration of the United Kingdom (KARI/ODA) at the NVRC. The project, entitled 'Support to research into the field application of East Coast fever immunisation and the epidemiology of related tick-borne diseases', project is manned by 10 scientists, 14 technologists and 17 technicians (Appendix 2). Its main objective is 'to generate an affordable, easily managed, effective and safe ECF vaccine and to evaluate and use it under field conditions with smallholder farmers'.

To make the method affordable, research at the centre has shown that:

- oxytetracycline preparations that are much cheaper than the ones previously used are equally effective;
- monitoring after immunisation can be reduced from daily to once every three days;
- one-month old calves can be successfully immunised. Since calves are easier to handle, this will lead to reduction of the cost and, therefore, more cattle can be immunised per day, require less drugs and there is no additional cost associated with milk withdrawal.

Recently, a *T. parva* parasite of low pathogenicity has been identified. This parasite does not cause clinical disease and confers a very broad spectrum of protection. Studies are being undertaken to determine whether virulence will change after cattle-tick-cattle passage and whether daughter stabilates will maintain similar low virulence and broad spectrum of protection.

To make the immunisation procedure easily manageable, studies have been undertaken to determine the duration the stabilate can stay at room temperature or on melting ice after reconstitution to eliminate carrying of liquid nitrogen containers to the field (these items are not readily available). These studies have shown that the stabilate remains viable for 24 hours and protective up to four hours if kept on melting ice after reconstitution. In addition, stabilates are stored in 0.5 ml straws instead of the original 2.8 ml vials. Stabilate in the 0.5 ml straws can be easily thawed just by rubbing the straw between the palms of the hands.

To make the procedure safe, field trials have shown that immunisation does not precipitate other tick-borne diseases, a fear expressed since ECF is immunosuppressive. The stabilate undergoes quality control testing in the laboratory before it is used in the field to avoid transmission of any other livestock diseases. In addition, very elaborate training is given to the immunising personnel informing them how to handle the risks involved. The reactor rate has been reduced to 3% and, as a precaution, where cattle handling facilities are very poor, long-acting tetracycline (TLA) is given before the stabilate to avoid cattle running off with the potentially lethal stabilate. A training manual for use by field staff during immunisation has been produced.

To prove that the procedure would be cost-effective, a model has been developed to compare the financial implications of immunisation of calves, immunisation of whole herds, treatment of clinical cases without immunisation or a 'do nothing' option. These factors are considered before immunisation is undertaken.

To make the procedure acceptable to the user (small-scale farmer), meetings are held with the farmers to explain to them about the potential risks and benefits associated with the immunisation. To date, 600 cattle have been immunised and the full costs paid by the farmers.

Epidemiological issues that need to be addressed

Despite successful immunisation against ECF, Kenya has not produced an integrated tick and tick-borne diseases control package. To do this, it would be necessary for research workers to generate information from various agro-ecological zones so that livestock keepers can control ticks and tick-borne diseases in an integrated manner so that the tick population is maintained at a level below that causing economically unacceptable damage and loss, while at the same time maintaining a tick-borne disease stable situation after ECF immunisation. This information should be made available to farmers and policy makers so as to determine where intensive, strategic or threshold tick control should be conducted.

For the full benefits of immunisation against ECF to be realised, tick control must be reduced after immunisation. However, since vectors for ECF coexist with vectors of other tick-borne diseases like anaplasmosis, babesiosis and heartwater, before tick reduction can be advised, the incidence and severity of these other tick-borne diseases must be established. Preliminary data using sera from animals immunised against ECF indicate that up to 70% of the animals have antibodies to *Babesia bigemina* antigens.

Cowdria ruminantium has been readily isolated in 10 different ecological zones in Kenya where heartwater is not reported as a problem. The ease with which *Cowdria* was isolated from these areas indicates that endemic stability may have been established in these areas. This would mean that it is not necessary to control ticks to control either babesiosis or heartwater and therefore tick control can be relaxed after immunisation against ECF.

Cattle movement in Kenya is not well regulated. This means that cattle found in a particular area may have originated from different places. During these movements, different parasite strains may be introduced in an area. It is therefore important to periodically isolate parasites from areas where cattle have been immunised to study changes in parasite population dynamics. The parasite population has potential to change enough to resist the immunising parasite stock.

Cattle immunised against ECF become carriers and consequently a source of infection to ticks. It would therefore be useful to assess the effects of these cattle on tick-infection rates. Increased infection rates would increase disease risk in the susceptible population. In addition, since immunity in the field may be maintained by continuous low challenge, the effects of a higher challenge would require studying.

In Kenya, buffalo-derived *T. parva* parasites occur. However, apart from cattle kept by pastoralists, smallholder cattle and cattle in well-maintained large-scale farms are unlikely to graze together with buffalo. Therefore, there may be need to quantify the threat due to these buffalo-derived *T. parva* parasites.

Currently, there is no *in vitro* test to determine protection after immunisation. This is required to avoid expensive *in vivo* cross-immunity studies using cattle. There is need to differentiate between the immunising parasite from the field parasite. This would help differentiate between real reactors and those cattle that get infected before acquiring immunity.

To avoid expensive, tedious titration trials to determine dose of stabilate to use for immunisation, a simple method to quantify infective sporozoites is needed.

Future plans and priorities

The immediate priority is to deliver immunisation against ECF to the Kenyan farmer in a cost-effective way that will ensure its sustainability. The problems raised under 'epidemiological issues that need to be addressed' need to be solved to achieve this objective.

Possible role of national and international organisations in future programmes

The NVRC has the ability to produce enough stabilate to cater for the country's needs. Its role would be to provide the stabilate and to train veterinarians to immunise cattle against ECF. It should also offer the necessary 'back stopping'.

The role of the international research organisations would be to provide improved diagnostic tools and new technologies for use in parasite characterisation. Recently, a diagnostic test introduced to NVRC by the International Livestock Research Institute (ILRI) appears to show real *T. parva* prevalence before and after immunisation. A group of cattle were shown to be 70% sero-positive before immunisation by the indirect fluorescence antibody test (IFAT) using *Theileria* schizont antigens. The same cattle were shown to be 40% sero-positive using the 'ILRI test'. From the IFAT results, endemic stability looked likely and therefore those cattle may not have required immunisation. However, using the 'ILRI test', the cattle would have required immunisation. Since the 'ILRI test' is specific for *T. parva* it showed that those cattle were likely to be harbouring other *Theileria* parasites. A test that is able to prove that daughter stabilates produced at different places and times are similar should be developed.

International organisations like the Food and Agriculture Organization (FAO) should provide expertise (where and when required) and the necessary logistical support. For immunisation programmes to be effective, good diagnostic facilities are required. International organisations should assist by providing the Veterinary Department with the minimal requirements.

Appendix 1

Kenya country profile

Size:	582,670 km^2
Population:	25 million
Cattle population:	13.5 million
Number of exotic cattle *(Bos taurus):*	3.2 million
Number requiring immunisation against ECF:	3.2 million
Number requiring immunisation against other tick-borne diseases:	None

Appendix 2

Project involvement with immunisation against ECF in Kenya

Name: KARI-ODA Tick-Borne Diseases.

Objectives: To generate an affordable, easily managed, effective and safe ECF vaccine.

Duration: Four years (1 January 1993–31 December 1996).
Very likely to continue for another three years (necessary funding already available).

Funding: Kenya Government—825,000 Kenya pounds. Overseas Development Administration (ODA) 1.998 million sterling pounds.

Staffing: 10 scientists (3 PhDs, 2 PhD trainees, 1 MPhil, 4 MScs), 2 technical co-operation officers (TCO) employed by ODA), 14 technologists (All with Higher National diplomas) and 17 technicians.

Facilities: Good (first laboratory to make *Theileria* stabilates).

Epidemiology of ticks and tick-borne diseases in Malawi: future research needs and priorities

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Introduction

Ticks and tick-borne diseases are amongst the major constraints to improvement of the cattle industry in Malawi. Conventional intensive tick control for purposes of controlling tick-borne diseases has proved very expensive, difficult to implement in the traditionally managed cattle and smallholder dairy sectors. Alternative practical means are being sought. In this report, we summarise the changes in tick and tick-borne disease control in Malawi, highlight the key epidemiological issues and indicate future plans with regard to tick and tick-borne disease control in the country.

Current strategies for the control of ticks and tick-borne diseases

In formulating the current control strategies, Malawi recognised the existence of two major groups of cattle in the country. These are the indigenous breed, the Malawi Zebu (forming over 97% of the cattle population) and the high-yielding group comprising both pure taurine breeds and their crosses. In 1993, Malawi reviewed its dipping policy on the basis of available data and cost-effective measures were recommended for the ecological zones as stated below.

'For the indigenous breed of cattle under traditional management systems, from mid-November 1993, all government dip tanks (371 in number), except those in Shire valley where dipping was abolished, would only operate fortnightly a non-compulsory dipping in Chlorfenvinphos throughout the rainy season (i.e. mid-November to end April). There would be no dipping in the dry season (May to mid-November). Veterinary assistants would continue to provide alternative tick-control measures on a cost recovery basis'. This policy statement also ended the use of arsenic trioxide which was an environmental hazard.

On premises in the milkshed areas of Blantyre, Lilongwe and Mzuzu, where pure taurine breeds and their crosses are reared, Chlorfenvinphos had been recommended for use a decade earlier before the above policy came into being. Safer acaricides continue to be used at intervals recommended by the manufacturers. In addition, the government is encouraging adoption of immunisation against tick-borne diseases,

1 Deceased.

Table 1. *Cattle types, their distribution and potentially available catte for immunisation against TBDs (1995 figures).*

Group*	KRADD	MZAAD	KADD	SLADD	LADD	MADD	BLADD	SVADD	Total
Total population	87,873	139,763	117,990	53,102	138,967	43,066	782,760	88,856	748,377
High risk group	178	5,182	4,130	1,665	4,416	1,507	13,526	3,110	33,714
Dairy cattle	—	2,363	985	—	2,740	1,420	12,148	—	19,656
Dairy cows	—	945	394	—	1,096	568	4,859	—	7,862

All high risk group cattle are potential candidates.
*Agricultural development divisions (ADDs of Malawi).

particularly East Coast fever (ECF), in the taurine breeds and their crosses with the hope of eventual reduction in the intensity of application of acaricides. Similarly, Zebu cattle which for various reasons have been under similar intensive tick control are also considered candidates for immunisation against TBDs.

Ongoing projects involved with control of ticks and TBDs

Although in the past Malawi had several projects involved with ticks and tick-borne diseases control, there are only two projects which, amongst other things, currently deal with control of ticks and tick-borne diseases, these are: the Malawi German Basic Animal Health Services Project (MGBAHSP) based in Mzuzu, northern region of Malawi; and the Vaccine Production Project.

The MGBAHSP has been in existence since 1989, and its third phase is due to terminate in 1997. Its main objective is to establish a primary animal health care programme in Mzuzu through introduction of village-based animal health and production services (i.e. run by the rural people/farmers). The project activities include:

- analysis of the disease constraints to livestock productivity;
- setting up a cost-effective drug revolving fund for treatment of economically important livestock diseases; and
- depending on success in achieving the original objective, extending the basic animal health programme to other areas of Malawi.

The main achievements of the project so far have been:

- identification of tick-borne diseases and helminthiasis as major disease constraints in the pilot area;
- successful establishment of the drug revolving fund which is managed by farmers with logistical support from project personnel;

Table 2. *Ongoing/proposed projects.*

Title	Objectives	Funding	Staffing	Facilities	Timing	Duration
MGBAHSP	Establish primary animal health care programme at Mzuzu ADD	DM 12m Malawi	TL—Vet and expatriate Field Invest. Officer—Vet Extension Officer—Economist CP TL & PM., DVO—Vet CP Field Invest. Officer—Vet CP Economist—Animal Health Officer Plus 7 support staff in DVO's office and 4 drivers.	Office building Office equipment Furniture Supplies Vehicles	3/89–2/92 Phase I (orientation)12 years 3/92–2/95 Phase II (1st implementation phase) 3/95–2/98 Phase III (2nd implementation phase) 3/98–2/01 Phase IV (consolidation phase)	12 years
IT & TBDC for SH Dairy in Malawi*	Improve s/holder dairy productivity evolution of an effective, sustainable, and environmentally friendly IT&TBDC	Not yet identified but being sought; $1.5m US$ 0.5m (Malawi)	TL/CTA (long term) consultancies CP TL/project manager CP 2 veterinarians Other CPs; veterinary assistants (20)	Office buildings Office equipment Supplies Vehicles	Dependent on identification of external funding	3.5 years
TBD Vaccine Project	Original: production of TBD vaccines for the region. Operations suspended. Currently just safeguarding facilities		CTA—expatriate 8 Technical Support staff 1 Farm Manager Driver and Cleaners	Office buildings Research labs Office equipment Lab equipment Hostel for trainees Cattle farm Isolation units	(1/94–6/98)	3.5 years

DM—Deutschmark; TL—Team Leader; PM—Project Manager; CP—Counterpart; ADD—Agricultural Development Division; IT & TBDC—Integrated Tick and Tick-Borne Disease Control; SH—smallholder.

*Proposed project.

- capacity building with particular emphasis on training of veterinary experts, financial management personnel and the farmers; and
- strengthening of the Mzuzu veterinary laboratory with regard to physical infrastructure, equipment and supplies.

The Vaccine Production Project is based at the Central Veterinary Laboratory, Lilongwe. The main immediate objective was initially to establish an operational, independent, financially responsible company (parastatal or private) capable of manufacturing vaccines and biological materials connected with the diagnosis and prevention of tick-borne diseases. Following suspension of vaccine production since 1994, the Project has:

- maintained a minimum level of activity to safeguard the equipment, biologicals and experimental animals on site;
- provided serological services to countries requiring such in the region;
- provided veterinary advisory services related to the products from the vaccine production laboratory; and
- participated in discussing and formulating standards for the production of live veterinary tick-borne diseases vaccines with personnel from other institutions.

The Project has endeavoured to deal with the above objectives within the limited available human and financial resources.

Specific epidemiological issues to be addressed

The following are the main epidemiological issues to be addressed:

- proper assessment of endemic stability to TBDs, particularly ECF.
- evaluating suitability of TBD immunisation in indigenous, traditionally managed cattle.
- monitoring the impact of TBD immunisation (particularly in regard to productivity).

Future plans and priorities

Depending on availability of funds:

- define appropriate tick control regimes following immunisation of the high grade cattle.
- conduct further investigations on undipped herds of cattle to clarify the status or otherwise of endemic stability to TBDs and the possibility of allowing a non-dipping policy to be extended much more widely than at present.
- continue and extend immunisations against TBDs in the field through a national delivery project focusing on the smallholder dairy sector based on a systems approach.

Possible role of national and international organisations in future programmes

The main areas of cooperation between national and international organisations should include provision of the following:

- Technical assistance (personnel);
- Training (workshops, study tours, seminars etc);
- Equipment and supplies (laboratory equipment, motor vehicles, chemicals, biologicals etc); and
- Coordination of efforts to combat ticks and tick-borne diseases in the region.

Epidemiology of ticks and tick-borne diseases in Mozambique: future research needs and priorities

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Introduction

The livestock population in Mozambique has decreased drastically in the last fifteen years. For example, the cattle population has reduced from approximately 1.3 million in 1982 to only 238,000 in 1994. This was mainly due to prolonged drought, indiscriminate slaughter and poor disease control. All these factors were associated with the civil war that devastated the economy of the country. As a result of all these problems, the control of ticks and tick-borne diseases during that period was also poor. Although few attempts were made in the early 1980s, no sound studies towards a better understanding of epidemiology and control of ticks and tick-borne diseases have been carried out in Mozambique.

Current strategies for the control of ticks and tick-borne diseases

Strategies for tick control are mainly based on the application of acaricides. The most widely used method is dipping. The total number of dip-tanks in the country is around 690 of which only 38% were operating in 1994 (National Directorate for Livestock, 1994). Most of the dip-tanks were destroyed and others were paralysed due to safety reasons.

From the late 1980s to date, "Pour On" acaricides have become popular in the country. These constitute an alternative where, for several reasons, dipping facilities are not available. However, these acaricides are too expensive for the majority of livestock farmers in the country. About 85 to 90% of cattle in Mozambique are kept by smallholders.

Studies on tick resistance carried out in the early 1980s showed that several species of ticks were resistant to several drugs then used (Arsenical, Bacdip, Delnav, Neocidol, Ektaphos and Toxaphen). This might have occurred due to the irregular supply of these drugs which caused irregular utilisation.

Although some trials on tick-borne disease vaccination were carried out by the Veterinary Faculty of the Eduardo Mondlane University in the 1980s, there is no vaccination programme against these diseases taking place in the country at present. One reason for not producing tick-borne disease vaccines in Mozambique is the absence of susceptible animals for the dissemination of the agent which makes the programme economically not viable (Jacobsen 1985).

Projects involved with the control of ticks and tick-borne diseases

Recently, there was an FAO project at the National Veterinary Research Institute whose main objective was to establish the current tick and tick-borne disease situation in Gaza Province in the south of the country. Currently, there is no project involved specifically with the control of ticks and tick-borne diseases in Mozambique. However, some projects run by NGO's and one funded the by the African Development Bank, which are primarily involved with livestock restocking programmes, also help to rehabilitate livestock infrastructures which are the main contribution to the control of ticks and tick-borne diseases.

Epidemiological aspects

Ticks

Studies carried out on tick infestation in the early 80's showed that the commonest species of ticks of importance for cattle in Mozambique were *Amblyomma hebraeum*, *Boophilus microplus*, *Boophilus decoloratus*, *Rhipicephalus appendiculatus* and *Rhipicephalus evertsi*. Taking into account the numerical data of infestation, *A. hebraeum* is economically considered the most important. The *Amblyomma* infestation is frequently associated with the reduction in weight gain, abscesses, loss of udder quarters and lesions which frequently lead to male sterility (Asselbergs and Lopes Pereira 1990). Its maximum infestation is observed in November and its minimum in May–July depending on the region of the country concerned.

The highest infestation of *B. microplus* varies according to the region of the country. In relatively dry areas the maximum infestation is observed in October/November whilst in others this occurs during the winter season but also in the month of September. *R. appendiculatus* also has a seasonal distribution. Its infestation generally increases during February/March in most of the country. *R. evertsi*, however, has no marked seasonal distribution and its infestation is generally low.

The distribution of these species of ticks in the country is not clear as no specific study has been carried out. This distribution is only deduced from the prevalence of tick-borne diseases that these ticks transmit.

Tick-borne diseases

Although the diagnosis of TBD's which has been carried out by the Central Veterinary Laboratory does not reflect the real situation in the country because very few samples are from the smallholder sector, which owns most of the cattle in the country. There are indications that tick-borne diseases are mostly caused by *Anaplasma marginale, Babesia bovis, Babesia bigemina, Theileria parva* and *Rickettsia*.

Serological studies carried out in the early 1980s in undipped cattle have revealed the existence of a high level of endemic stability in relation to most tick-borne diseases. In addition, there was no significant difference between these animals and those which had access to dipping facilities (Jacobsen 1985). However, newly imported cattle from neighbouring countries, and dairy cattle, are highly susceptible to tick-borne diseases and there have been considerable losses.

An interesting result of these studies is the almost non-existence of clinical cases due to *T. parva* in the southern part of the country. The only known region of the country with endemic East Coast fever is Angonia District which borders with the south-west part of Malawi.

However, the results of the studies mentioned here should be interpreted with caution as most of the samples were collected from the south of the country where the Central Veterinary Laboratory is located. Another reason for such precaution is that the epidemiology of ticks and tick-borne diseases might have changed during the last thirteen years and little is known regarding this situation.

Future plans and priorities

All future plans regarding control of ticks and tick-borne diseases have to be based on the results of epidemiological studies and economic assessment of different control strategies. Currently, most of these aspects are not well understood and therefore, there is a need to prioritise these studies in Mozambique. Meanwhile, in parallel with the restocking programme being carried out in the country using imported animals, the rehabilitation of livestock infrastructures, mainly geared to the control of ticks, is being prioritised.

The low incidence of clinical cases of tick-borne diseases observed in indigenous breeds when, for several reasons, there were no acaricides available for tick control, brings new hope for tick-borne disease control strategies. Taking into account the eco-climatic conditions of each region of the country, dipping can generally be concentrated in periods of high tick infestation rate and suspended during those periods in which tick infestation is low. However, special tick control strategies in areas such as Angonia District are recommended until immunisation against theileriosis is possible. For animals susceptible to tick-borne diseases, such as dairy and imported cattle, intensive tick control programme is likewise recommended.

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Epidemiology of ticks and tick-borne diseases in South Africa: future research needs and priorities

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Current strategies for the control of ticks and tick-borne diseases

South Africa, with the exception of KwaZulu-Natal, has no national or provincial control programmes for ticks or tick-borne diseases (TBDs). It is entirely up to the primary livestock producer 'farmer' to decide what strategy to follow. Information and 'technology' are available/accessible and role players in this regard are organised agriculture, veterinarians, state departments (veterinary laboratories), private sector (pharmaceutical companies), Onderstepoort Veterinary Institute, veterinary faculties at universities etc

Certain scientists, recognised experts in this field, are involved in policy making and strategic planning. The available information and technology, however, are not always effectively transferred or applied, for reasons that will not be discussed here.

Biological and geographical diversity do not allow blanket approaches to control ticks and TBDs. The pursuit of endemic stability of TBDs is generally propagated through integrated control measures and is adapted to best suit the circumstances.

Government funding has fully supported research, development and vaccine production in the past. However, since the parastatal Agricultural Research Council was set up in April 1993, cost recovery (varying rates) has been implemented for client-driven needs, including products, research, development of technology and diagnostic services.

Special approved programmes directed at the needs of the small-scale farmer will also be funded by the government's Reconstruction and Development Programme.

To demonstrate the current prevailing tick and TBD strategies from a commercial farmer's perspective the following information was obtained from two recent surveys (questionnaires).

According to Du Plessis et al (1994) in the first survey, neither does the present vaccine control heartwater adequately, nor do anaplasmosis or babesiosis vaccinations have any beneficial effect on the mortality rates of these diseases in heartwater endemic areas.

The authors believe that the frequency of acaricide application is too high in heartwater endemic areas but recognise the inability to lay down epidemiological parameters that will achieve endemic stability. They conclude that farmers do not

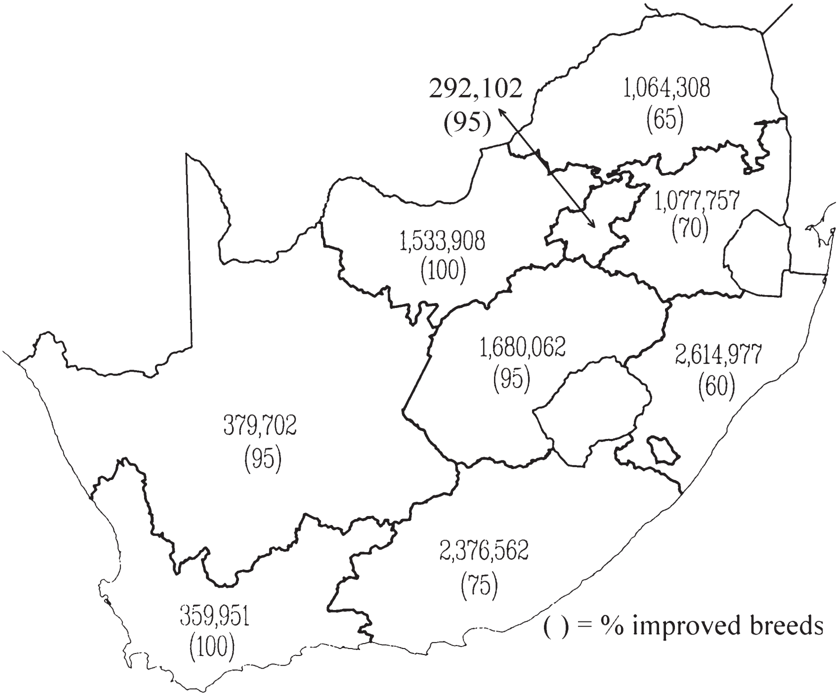

Figure 1. *Total cattle population (11,379,329) in the Republic of South Africa in March 1995.*

regard heartwater in cattle as a serious problem as it is generally believed to be. However, small stock in the bushveld regions and especially Angora goats in the valley bushveld of the Eastern Cape Province are seriously affected.

In the other survey (Spickett and Fivaz 1993), dealing with current cattle tick-control practices and attitudes of commercial farmers towards tick control in South Africa, it was found that:

- Producers favoured intensive tick control (25 times per annum).
- Beef and dairy farmers preferred synthetic pyrethroid acaricides.
- Most farmers change acaricides because of price.
- Hand-spray application techniques resulted in higher confirmed acaricide resistance.
- Relatively small numbers of producers use TBDs vaccines.

Much criticism is often directed at questionnaire-type surveys. However, the relevant information obtained compensates for the absence of adequate reporting systems and lack of empirical data, and offers the scientists and policy makers a different perspective.

Ongoing projects involved with control of ticks and TBDs

These projects are listed in the appendix to this paper.

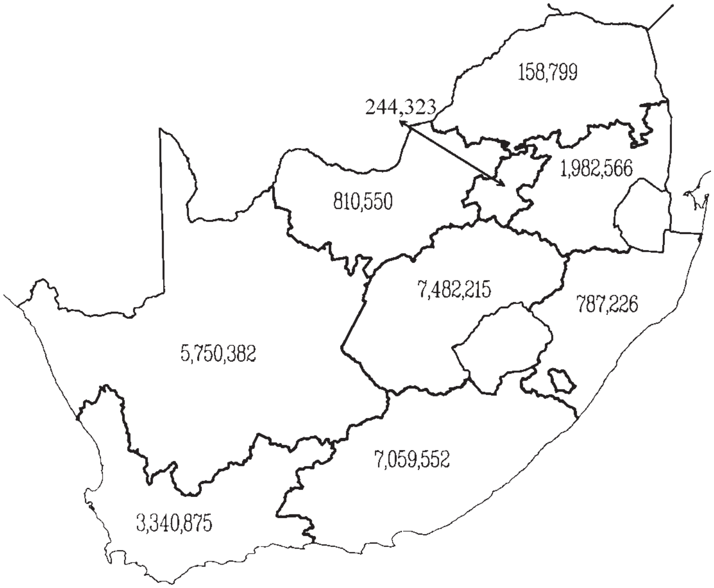

Figure 2. *Total sheep population (27,616,488) in the Republic of South Africa in March 1995.*

Particular epidemiological issues

Epidemiology of TBDs is understood to be the interaction between host, parasite and vector. This was probably true before man arrived on the scene, because he has now become such an integral part through his creative attempts at manipulation of the epidemiological parameters that special mention should be made of these 'issues'.

- If man wants to intervene in this relationship through the use of vaccines he must focus attention on the low temperature cold chain dependence of the existing vaccines.
- He must be able to measure performance of the vaccine effectively in the field.
- Potential sub-unit vaccines are envisaged but not much thought has been given to the impact which such vaccines might have on the epidemiology of TBDs.
- Game ranching is increasingly competing with livestock practices. The impact of African wild ruminants as important role players in the epidemiology of TBDs should be taken into account.
- Technology should be user friendly and sustainable.

Future plans and priorities

One of the problems with making future plans and determining their priorities is forgetting to maintain and improve existing technologies where possible. A lot is said and written about the disadvantages of the use of live blood vaccines. Unfortunately, there are no substitute vaccines at present except the ones which exist to motivate applications for funding of research and development of new technologies.

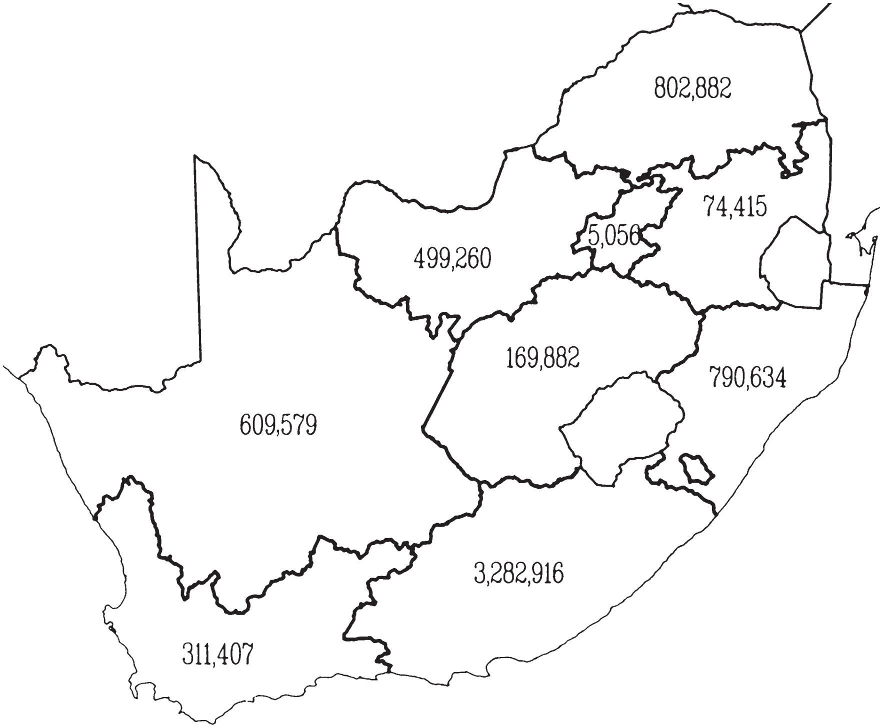

Figure 3. *Total goat population (6,545,971) in the Republic of South Africa in March 1995.*

The blood vaccines play an important role in disease prophylaxis as judged by existing markets and the demand for these vaccines.

In the 'interim', almost 85 years since the first dose of anaplasmosis vaccine was sold in South Africa in 1912, we seem to be reliant on basically the same crude methods of immunising cattle and small stock against TBDs.

A future priority/objective should be not necessarily to substitute the live blood/tick vaccines with sub-unit vaccines as is often proposed, but rather apply the new-found molecular technology to characterise these vaccine isolates and improve the existing diagnostic 'tools' for which there will be wide application for many years to come. It is estimated that effective sub-unit vaccines will not be available within the next 10 years.

There should probably be a 'concerted action plan' for the maintenance and improvement of the only existing methodology of immunising livestock against TBDs. Characterisation, standardisation, quality assurance and validation of live TBD vaccines are indicated.

Summary of long-term objectives

Ticks:

1. Develop improved technology to control ticks.
2. Maintain tick biosystematics as a support service to research and training.

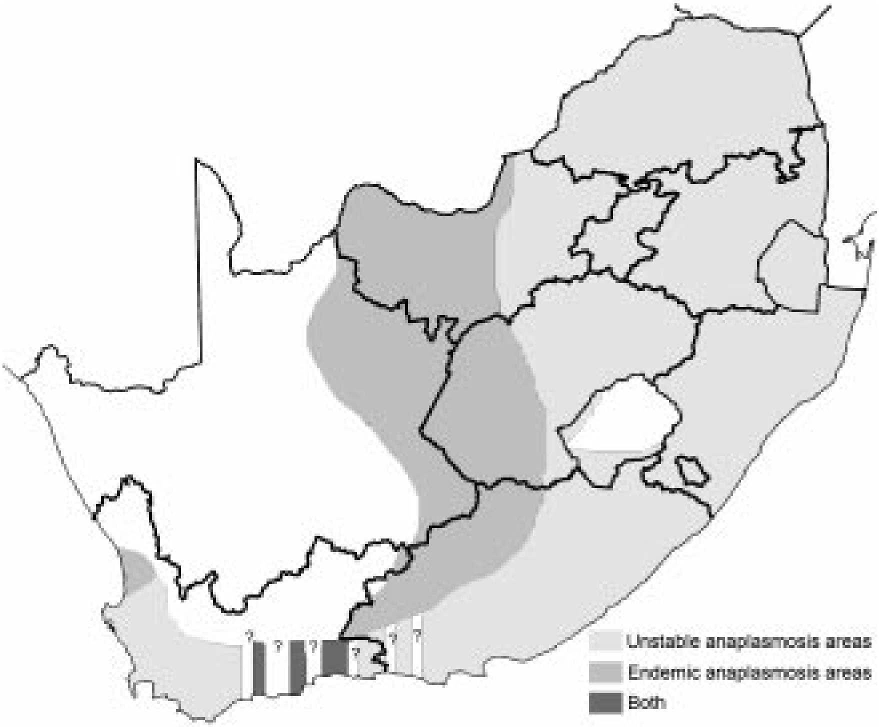

Figure 4. *Estimated distribution of bovine anaplasmosis.*

3. Develop control strategies which are economical, effective, sustainable and acceptable.
4. Provide tick identification as a diagnostic service.

Tick-borne diseases:

1. Theileriosis
   - Study and monitor the epidemiology, especially of the *Theileria parva* group.
   - Provide parasitological support to molecular biological projects.
   - Consider possible involvement in East Coast fever vaccine production.
2. Cowdriosis
   - Attempt molecular genetic analyses of *Cowdria*.
   - Develop 'molecular tools' for the diagnosis and characterisation of organisms associated with heartwater.
   - Study the mechanisms of protective immunity to heartwater.
3. Diagnostic service
   - Establish a centre of excellence for the diagnosis of tick-borne protozoal and rickettsial diseases.
4. Vaccines
   - Improvement of all existing live blood vaccines.
   - Development of a recombinant heartwater vaccine.
   - Sustainable production of quality vaccines based on cost recovery.

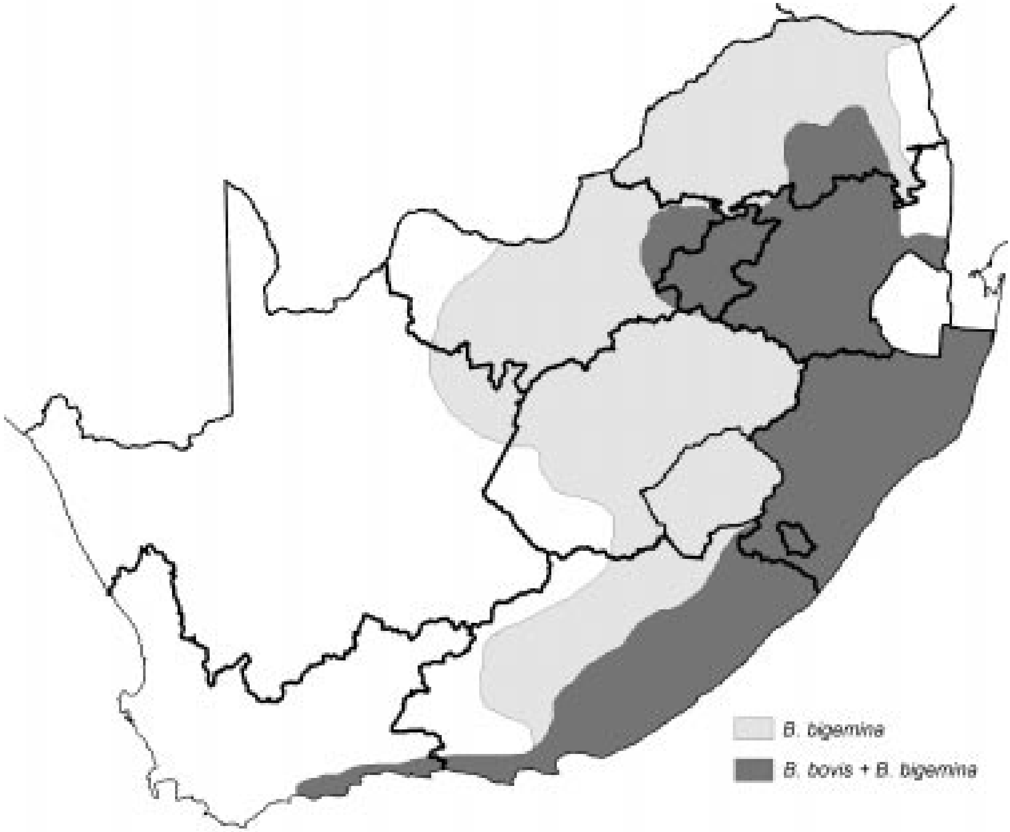

Figure 5. *Distribution of* Babesia bigemina *and* Babesia bovis *in the Republic of South Africa.*

5. Economic impact
   - Development of relevant databases to determine the economic impact of ticks and tick-borne diseases necessary to develop and implement integrated control programmes.

Possible role of national and international organisations in future programme(s)

EU Funding: concerted action: integrated control of ticks and tick-borne diseases

Participating countries: 6 European, 1 Caribbean and 7 African countries.
Coordinator: Prof Frans Jongejan, The Netherlands.
Total budget: R1908 million over 4 years.
Allocation to South Africa: not fixed, depends on applications for travel grants, workshops etc

Figure 6. *Distribution of* Amblyomma hebraeum/*heartwater.*

EU Funding: 'Integrated control of cowdriosis: development and field assessment of improved vaccines and epidemiological tools'

The project is coordinated by Dr Albert Bensaid of the French CIRAD-EMVT institute in Montpelier. The other partners are the University of Utrecht (Holland), the University of Bern (Switzerland), the University of Zimbabwe, the Centre for Tropical Veterinary Medicine (UK), the Pirbright Veterinary Laboratory (UK), CIRDES (Burkina Faso), and LNERV (Senegal).

The total budget is ECU 700,000 of which OVI will receive ECU 115,340. This is 16.5% of the total, amounting to R556,900 at today's conversion rate, over a period of four years.

USAID funding

A USAID grant has been approved and formally runs for three years from January 1996 to December 1998. The official designation is CDR Grant TA-MOU-95-C15-194 entitled 'The use of T-lymphocytes to identify vaccine antigens against heartwater'.

This is a three-way grant, funded by USAID and coordinated by Dr Varda Shkap of the Kimron Veterinary Institute, Beit Dagan, Israel. The other partner is Washington State University, Pullman, USA.

The total budget is $199,893 of which OVI will receive $138,675. This is 69.4% of the total, amounting to R531,800 at today's conversion rate, over a period of three years.

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Spickett A.M. and Fivaz B.H. 1992. A survey of small stock tick-control practices in the Eastern Cape Province of South Africa. *Onderstepoort Journal of Veterinary Research* 59:197–201.

Appendix

Table 1. *Livestock census 1994/95.*

	Cattle	Sheep	Goats	Horses	Donkeys/mules
Total: RSA	11,379,329	27,616,488	6,545,971	324,520	132,971

Table 2. *Relevant information regarding immunisation against TBDs.*

TBD	Anaplasmosis	Babesiosis	Cowdriosis
Known vectors in South Africa	*R. simus* *R. evertsi* *B. decoloratus* *B. microplus* *H.m. rufipes* *S. calcitrans*	*B. decoloratus* (Af) *B. microplus* (Af + As)	*A. hebraeum*
No. of hosts in tick-endemic areas as % of total populations	Cattle (99.2)	Cattle (91.8)	Cattle (38.1) Sheep (9.2) Goats (42.3)
No. of vaccine doses sold 1994/95	102,445 (chilled)	126,695 (frozen)	54,027 (chilled) 95,900 (frozen Af) 83,515 (frozen As)
Peak historical figures of vaccine sales	800,000 (1996)	210,000 (1981)	200,000 (1983)

Table 3. *Other important tick-borne diseases (TBDs) of farm animals.*

TBDs	Corridor disease	Babesiosis		Ehrlichiosis
Host	Cape Buffalo 'Cattle'	Cattle	Equines	Cattle 'Sheep'
Parasite (vector)	*T. p. lawrencei*	*(R. appendiculatus)* *(R. zambeziensis)*	*B. occultans* *(H. m. rufipes)* *Babesia* sp *(H. truncatum)*	*B. equi* *(R. evertsi)* *B. caballi* *(R. evertsi)* *(H. truncatum)*
Importance	East Coast fever	Serological cross reactivity with economically important spp	No. vaccine Horse exports	Serological cross reactivity with cowdriosis Possible vaccine failure

Table 4. *Ongoing projects involved with control of ticks and TBDs.*

Programme OV 008: Ticks and Tick-borne Diseases (Manager: Dr D.T. de Waal)

Project No.	Project title	Long-term objective	Total cost US$	Income
OV 08/01	Isolation and characterisation of tick antigens for potential tick vaccine development (Including 93/94 project 8/5 Contract)	1. To develop an anti-tick (broad spectrum) vaccine using antigens derived from a tick source (2000) 2. To characterise and sequence candidate target antigens and toxins (2000) 3. To develop an antitoxin/vaccine against tick toxicoses (2000)	54,646.00	
OV 08/02	Tick biosystematics	1. To produce/update publications (e.g. Bulletin 393) to provide information on ticks, mites and insects in southern Africa to farmers and veterinary students (2000) 2. To maintain, expand, update and catalogue (computer) the Onderstepoort tick collection as well as associated literature collections (2000) 3. To provide tick identification courses as required on southern African species (Ongoing) 4. To study phylogenetic relationships of ixodid tick species to clarify interrelationships (2000)	43,995.50	
OV 08/06	Environmentally sustainable, acceptable control of ticks and diseases of livestock in KwaZulu-Natal	1. To develop strategies for the control of ticks and tick-borne diseases of livestock that are economical, effective, sustainable and acceptable (2000) 2. To study tick populations, prevalence and the incidence of tick-borne diseases under different tick management systems in KwaZulu/Natal (1998)	19,926.25	
OV 08/07	Epidemiology of *Theileria* spp infections of cattle and African buffalo	1. Evaluate the prevalence of *Theileria* spp infecting cattle and buffalo, investigate outbreaks of disease, isolate and characterise the parasite species involved and advise on measures to control further occurrences (2000) 2. Provide epidemiological and diagnostic support (*Theileria* spp) for the establishment of breeding populations of African buffalo whilst minimising the disease threat to cattle populations, particularly with regard to *Theileria parva*-group infections (2000). 3. Provide traditional parasitological and epidemiological support to molecular biology projects developing PCR-based diagnostic procedures for *Theileria* spp (2000)	47,524.75	

Project No.	Project title	Long-term objective	Total cost US$	Income
OV 08/08	Development of sero-diagnostic assays for protozoal and rickettsial diseases	1. Improve the diagnostic technology for bovine and equine *Babesia* spp 2. To utilise *in vitro* culture techniques to investigate other aspects of *Babesia* biology 3. To improve existing *in vitro* culture techniques for *Babesia* spp	62,856.00	
OV 08/09	PCR diagnosis and characterisation of blood protozoan parasites	1. Development of probes to distinguish between *T. p. parva* and *T. p. lawrencei* based on differences in their ribosomal RNA (rRNA) gene sequences (March 1996) 2. Offer a diagnostic service to the animal production industry for *Theileria* and *Babesia* species using existing probes (Ongoing) 3. Design new *Babesia* and *Theileria* probes as necessary (Ongoing) 4. To clarify the relationships between protozoal organisms (Ongoing) 5. To evaluate the *T. p. parva* and *T. p. lawrencei* probes to study the epidemiology of the two diseases (March 1997) 6. To streamline the diagnostic protocols for the existing PCR probes (March 1997) 7. To modify the current probing technology to an enzyme linked system (1999)	0.00	
OV 08/10	Genomic analysis of the *Ornithodoros moubata* complex in order to derive phylogenetic relationships	Study the phylogenetic relationships between the *Ornithodoros moubata* complex and their role in the epidemiology of African swine fever in southern Africa	8,250.00	
OV 08/11	Epidemiology of protozoal and rickettsial infections of rare or endangered African antelope species	1. Develop diagnostic techniques, and apply these and existing techniques to detect the prevalence of tick-borne protozoal and rickettsial infections of disease significance in wild ruminants from different geographic areas (particularly rare or endangered African antelope species) (April 1998) 2. Develop appropriate control measures (incl. possible vaccines) for these diseases, to reduce the risks involved in relocation/re-introduction of species and improve population growth in disease-endemic areas (April 1998) 3. Evaluate the prevalence of tick-borne protozoal and rickettsial infections of wild ruminants, investigate outbreaks of disease, isolate and characterise the parasite species involved and advise on measures to control further occurrences (April 1998)	23,685.50	
		Overheads	87,258.50	
		Total US$	348,142.50	

Contract income—Meatboarb

Programme OV 009: Heartwater (Manager: Dr B.A. Allsopp)

Project No.	Project title	Long-term objective	Total cost (US$)	Income
OV 09/01	Development of a heat stabile heartwater vaccine for remote areas	1. Improvement of the present heartwater vaccine and the method of vaccination 2. Use of the vaccine to create endemic stability and thus better disease control (1998)	53,973.50	8,625.00
OV 09/02	Molecular genetic analysis of *Cowdria*	1. Map the Cowdria genome (essential to address long-term goal #2) 2. Identify parasite genes which provide CTL targets for immunity; these will be used by OV9/16 for the eventual production of a recombinant vaccine against heartwater 3. Confirm the presence of a plasmid and determine if it is responsible for virulence (2000)	72,762.00	
OV 09/03	*In vitro* culture of *Cowdria ruminantium*	1. Improve the productivity and reliability of the culture system 2. Define the nutritional needs of *C. ruminantium* 3. Meet programme needs for cultured heartwater organisms	79,031.25	
OV 09/11	Molecular data handling and electronic communications project	The objective of this project is to continue to provide a service to the molecular researchers working in OV9, OV11, and other programmes at OVI The project provides the most up-to-date genetic data banks and rapid molecular data analysis. International communications will be maintained and will, where possible, be improved	40,800.75	
OV 09/15	PCR diagnosis and characterisation of organisms causing heartwater	1. Develop molecular tools to investigate the variety and importance of organisms associated with heartwater 2. Use the tools (srRNA-based probes and map-1 gene probes) to determine the distribution of heartwater-associated organisms and *Cowdria ruminantium* genotypes in ticks and the blood and tissues of wild and domestic animals in South Africa and elsewhere 3. Develop PCR *in-situ* hybridisation techniques to determine the location of heartwater-associated organisms in fixed tissue samples 4. Develop an enzyme-linked oligosorbent assay (ELOSA) for the specific detection of *C. ruminantium* in large numbers of field samples. The ELOSA format will be quicker and cheaper than existing methods and will eliminate the use of radio-active labelling of probes	38,759.25	
OV 09/16	Cowdria vaccine vector development	The development of a recombinant vaccine for the control of heartwater	43,869.00	

Project No.	Project title	Long-term objective	Total cost (US$)	Income
OV 09/18*	The Cowdria genome project	1. To obtain the complete sequence of the genome of *Cowdria ruminantium* 2. To subject the data to computer analysis using both existing and new bioinformatics tools as they become available 3. To locate genes which are suitable candidates for incorporation into a recombinant vaccine 4. To locate and modify genes linked to virulence so as to construct attenuated strains for immunisation (The above will depend entirely upon the amount of support given by ARC and the extent to which external collaborators can be found)	30,209.00	
		Overheads	119,321.00	
		Total US$	478,725.75	8,625.000

* Joint venture—Onderstepoort Biological Products/Blood Vaccine Sales.

Programme OV 014: Blood vaccines (Manager: Dr D.T. de Waal)

Project No.	Project title	Long-term objective	Total cost (US$)	Income
OV 14/01	Blood vaccine production	1. The cost effective production of quality blood vaccines (Ongoing) 2. Appropriate price allocation to all of the individual vaccines to recover the cost of production (March 2000) 3. Reduce production costs by implementation of an in vitro cultured heartwater vaccine (April 1998) 3. Implement production of improved redwater and anaplasmosis vaccines (April 1998) 4. Use dairy bull calves for vaccine production which could result in further cost saving through the reduction in breeding herd numbers (April 1997)	174,618.75	226,000.00
OV 14/02	Monitoring vaccine performance to maintain or improve the efficacy of redwater, heartwater and anaplasmosis vaccines	1. To do need-specific research and product development on blood vaccines 2. To monitor all reported cases of vaccine breakthroughs to evaluate the efficacy of the current vaccine strains 3. To improve the efficacy of the frozen redwater and anaplasmosis vaccines through the use of an alternative cryoprotectant (June 1997) 4. To reduce the number of sheep required for the production of the heartwater vaccine (October 1998)	68,590.75	
		Overheads	91,604.50	
		Total US$	334,814.00	226,000.00

Programme OV 015: Veterinary diagnostics (Manager: Dr L. Prozesky)

Project No.	Project title	Long-term objective	Total cost (US$)	Income
OV 15/08	Tick identification and diagnosis of protozoal and rickettsial diseases	1. To maintain and provide a reliable and effective tick identification and diagnostic service of protozoal and rickettsial diseases to clients of the OVI 2. To establish a reference centre for the diagnosis of protozoal and rickettsial diseases 3. To maintain set standards for all diagnostic procedures 4. To provide training in diagnostic techniques 5. To use diagnostic results to determine disease prevalence/distribution on a national scale 6. To collect and maintain gold standard sera and blood smears as reference collection of protozoal and rickettsial diseases	81,997.50	
		Overheads	31,250.00	
		Total US$	113,247.50	

Programme OV 017: Economic impact of animal diseases (Manager: Dr J.D. Bezuidenhout)

Project No.	Project title	Long-term objective		Total cost (US$)	Income
OV 17/01	The composition and distribution of animal populations in South Africa (Demography)	Establish data base of animal livestock populations and zoography Form part of Animal Health GIS and determine animals at risk Factor for direction of research on geographical/regional basis and setting priorities (Establish by 29 March 1996 — Maintain and update thereafter)		9,314.50	
OV 17/03	The socio-economic impact of ticks in South Africa	To assimilate the necessary data with the aid of a computer geographic information system database in order to determine the social, economic and productivity impact of ticks on South African livestock. The eventual application would be the implementation of cost effective integrated tick control strategies (1999)		9,013.50	
OV 17/06	The socio-economic importance of tick borne diseases in South Africa	To develop a database of all relevant data necessary to determine the socio-economic impact of tick-borne diseases in South Africa		7,855.25	
			Overheads	19,080.75	
			Total US$	45,264.00	

Programme OV 019: Immunological approaches to disease control (Manager: Dr D.H. du Plessis)

Project No.	Project title	Long-term objective	Total cost (US$)	Income
OV 19/03	Mechanisms of protective immunity to heartwater	To study the cellular immune response to heartwater to identify protective antigens: 1. Improvement of knowledge of immune response 2. Identification of protective antigens 3. Establish cellular immunological techniques e.g. proliferation and cytotoxicity assays 4. Determine the role of activated macrophages in immunity to *Cowdria* in mice.	54,098.00	
		Overheads	19,532.50	
		Total US$	73,630.50	

Epidemiology of ticks and tick-borne diseases in Swaziland: future research needs and priorities

P. Dlamini

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Introduction

Swaziland covers an area of 17,363 km^2 and is geographically divided into four distinct agro-ecological zones (AEZs) namely: highveld, middleveld, lowveld and Lubombo plateau (Figure 1). These AEZs have further been divided into physio-graphic zones (PGZs) which not only delineate altitude, climate, vegetation and topography, but also land-use patterns. These are highveld, upper middleveld, lower middleveld, western lowveld, eastern lowveld, and Lubombo plateau (Figure 2).

The major tick-borne diseases (TBDs) in order of importance are Asiatic babesiosis *(Babesia bovis* infection), anaplasmosis, heartwater, sweating sickness, and African babesiosis *(B. bigemina* infection) (Figure 2). Previous work and recent disease outbreak patterns suggest there is widespread endemic instability to Asiatic babesiosis at national as well as at area (diptank) level. Heartwater does not appear to be a serious problem on Swazi national land (SNL) cattle but can be serious on farms with stringent tick control, particularly in exotic breeds of cattle and goats. This disease which is endemic in the lowveld, Lubombo and the middleveld is a problem in goats. Goats are not dipped for ticks but for mange only once yearly.

Current strategies for the control of ticks and tick-borne diseases in Swaziland

Since the early 1900s when East Coast fever (ECF) control was instituted, Swaziland has been using intensive dipping to control ticks and TBDs. The current system of tick control differs little from that employed then to control ECF whereby chemical application is the main form of reducing tick attachment and tick numbers (Nxumalo 1991).

Legislation established during the ECF era still features to date in the regulation of dipping. The government requires that all cattle must be dipped or sprayed at frequent intervals (Nxumalo 1991). Veterinary assistants (VAs) supervise all dipping whether at communal dips (which are on Swazi national land—SNL) or private farm dips (on title deed land—TDL).

The country is presently served by a network of some 417 communal dips (SNL dips) and 298 private dips (TDL dips). The SNL consist almost entirely of plunge dips (414, with 2 spray races); while TDL have 165 plunge dips and 133 spray races.

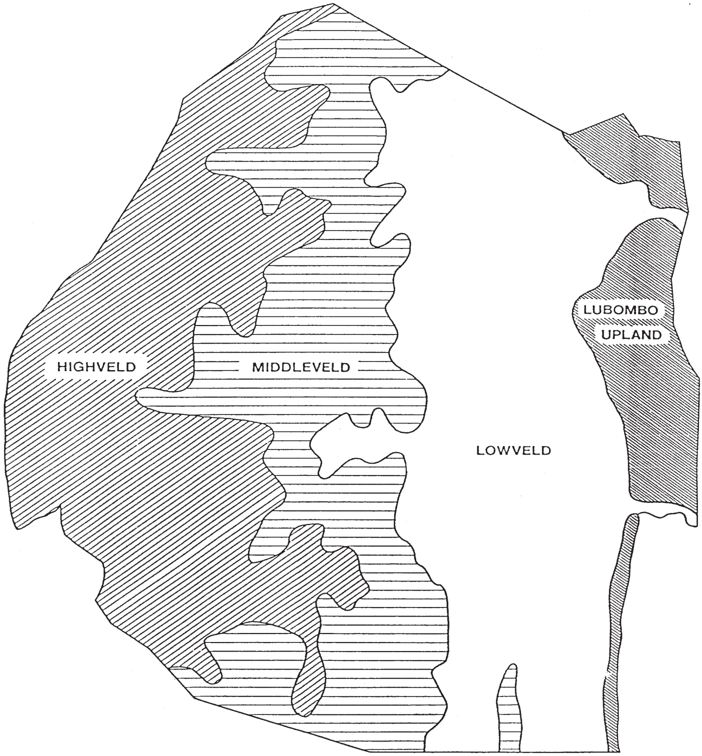

Figure 1. *Major natural regions of Swaziland.*

Weekly dipping/spraying is compulsory in summer months (usually beginning of October to end of May) in all regions except the highveld, where dipping is done fortnightly. During the winter months, dipping is done fortnightly in all regions except the highveld where dipping is done monthly. This means that animals are exposed to acaricide about 40 times per year in all regions except the highveld where the figure is about 22 times. The present schedule of dipping was based on the life cycle of the ticks involved, the observed effects of the climate and to some extent the epidemiology of the parasites transmitted. Ticks of importance are the two *Boophilus* species *(B. microplus* and *B. decoloratus), Amblyomma hebraeum, Rhipicephalus appendiculatus, R. evertsi evertsi* and *Hyalomma truncatum* in order of importance.

The main types of acaricides, from arsenic through organochlorines, to the latest synthetic pyrethroids, have at one time or another been used in Swaziland. Presently, the most-used chemical is Amitraz applied mostly in powder form in a total replacement system. Amitraz is usually used in government communal tanks; more recently, government cattle stations and private farms have been using synthetic pyrethroids which are claimed to provide better fly control. Triatix liquid is now used in a few spray races.

Amitraz degrades rapidly and is inactivated by dirt—the reason why the total replacement system is used. This ensures that the acaricide is used at full strength. Lime-stabilised Amitraz was initially used when few animals were being dipped as the total replacement system is uneconomical (Nxumalo 1991). This is no longer done.

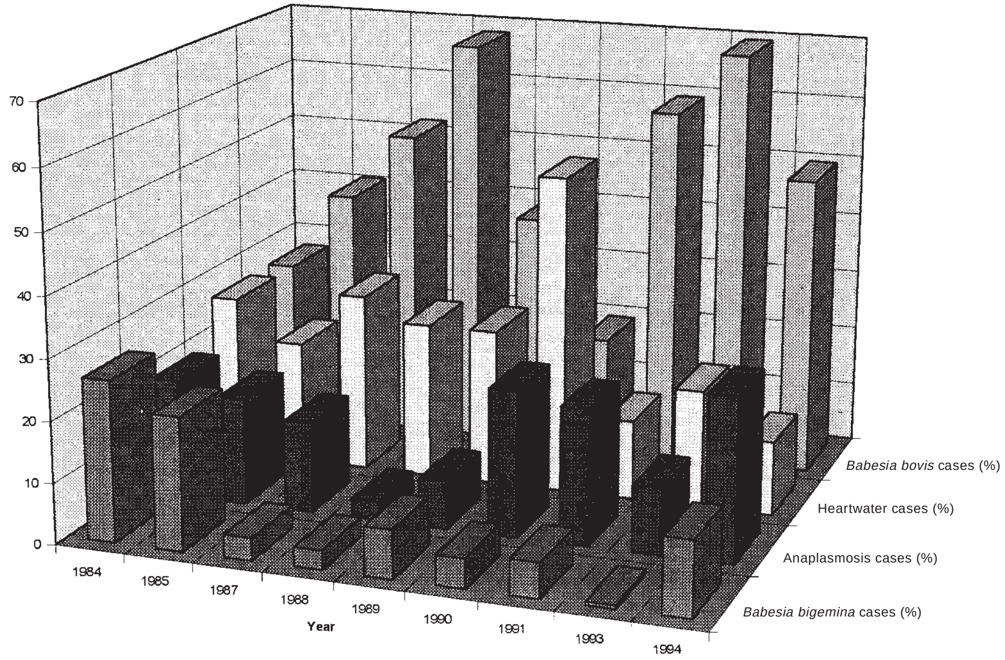

Figure 2. *Tick-borne diseases diagnosed at the CVL Manzini, Swaziland from 1984 to 1994.*

Ongoing projects involved with the control of ticks and tick-borne diseases

Swaziland used to produce sheep blood infected with *Cowdria* for developing artificial immunity to cattle coming from heartwater-free to heartwater-endemic areas. This project was sponsored by the Swaziland Government (GOS) in the 1960s and 1970s. In 1989 Callow did a review on the epidemiology and control of ticks and tick-borne diseases in Swaziland, and in 1991 Ramsay did some immunisation trials using *Babesia bovis* and *B. bigemina*, as well as *Anaplasma centrale* vaccine from the Vaccine Production Centre in Wacol, Australia. Unfortunately the sponsorship of the project was not sufficient to carry through the work started and there was no follow-up and monitoring.

Today the only ongoing project that is involved with ticks and tick-borne diseases is the Food and Agriculture Organization–Swaziland Government (FAO–GOS) project TCP/SWA/4452—Immunisation Against Tick-borne Disease in Cattle. The project started in March 1995 with the following objectives:

- to provide support to the Department of Veterinary Services for developing an integrated tick and TBD control policy to be implemented at national level;
- to establish an epidemiology unit; and
- to reduce the overall regional level of environmental contamination with acaricides and decrease environmental degradation through improved livestock management practices.

The project has so far undertaken the following research activities in pursuance of the above objectives:

- The analysis of past work on TBDs in Swaziland has been reviewed.
- Pilot vaccination trials have been undertaken at four government breeding stations, two TDLs, two Tibiyo and two SNLs. The effects of breed, age and efficacy of previous tick-control methods on immunity and sero-prevalence are being monitored.
- Pre- and post-vaccination sera have been taken and assayed for TBD titres.
- National tick collection and tick identification to genus level only has been undertaken.
- A functional epidemiological unit with computerised data handling facilities has been established.

The number of cattle immunised against specific TBDs and numbers intended for vaccination are given in Appendix 1.

Particular epidemiological issues that need to be addressed

Having set up the epidemiology unit, there is still a lot to be done in terms of the functions of this unit. Due to too much time being taken by the TBD project, not much attention has been given to other aspects of veterinary epidemiology including other diseases of national importance such as rabies, bovine tuberculosis, *Brucella abortus* and *Brucella mellitensis*, among others.

Epidemiology of tick-borne diseases

1. There is a need to explore the concept of exploiting natural calf-hood immunity to TBDs as the foundation of a strategy to progressively convert the national (SNL) herd of indigenous cattle from a state of variable endemic instability to general endemic stability. This should be epidemiologically sound with respect to the host, the environment and the parasites involved in TBDs in Swaziland.
2. There is also need to establish the seasonality of tick species and to conduct tick-population studies in the different physiographic zones. This will assist in the understanding of tick-population dynamics. Tick studies done by Ramsey in association with Michael Bowie and Dr Charlie Pitss of the USAID Cropping Systems Project, Ministry of Agriculture and Cooperatives, in 1991 were identifying species in the different agroecological zones in Swaziland. No population studies were done.
3. Regular testing of acaricide resistance to monitor areas where resistance might be developing or have developed should be initiated. The capacity for the Department of Veterinary Services to do its own testing will greatly enhance the capacity of the epidemiology unit. Resistance testing is done by Hoechst on request and certain dip-tank areas, although few and scattered so far, have had resistance to Amitraz detected. When farmers report less than adequate tick control, rapid and detailed investigations should follow to find out the cause of the reduced efficacy of the acaricide.

4. The impact of immunisation against TBDs on livestock productivity needs to be assessed or measured. Both the productivity and economic impact will need to be established for a sustainable and economic TBD control method applicable to each of the different production systems. Private farms have made their own assessment of the economic viability of immunisation against TBDs in cattle, with favourable cost/benefit ratios. Greater challenges lie in the assessment of these factors for the smallholder traditional livestock owner/farmer.
5. There is a need to find out if a single strategy for achieving endemic stability in the SNL sector will be applicable as a standard approach for the whole country, or if there is a need to tailor the strategy to suit different areas?
6. Find out if indigenous breeds, e.g. the Nguni, are more suited to the strategy of exploiting natural resistance.
7. Specific instructions for incorporation into simple guidelines to enable field staff and farmers to understand and manage threshold dipping should be prepared.
8. The role of chemotherapy in immunisation needs to be elucidated and exploited in Swaziland. It is likely that immunisation will not be recommended for the widespread development of endemic stability, thus the role of chemotherapy and natural immunity mechanisms need to be clarified.
9. Increased capacity of diagnostic methods for TBDs is needed for the evaluation and monitoring of alternative control strategies. ELISA techniques could prove more valuable for TBD diagnosis as well as in the diagnosis of other diseases. ELISA techniques also have better specificity especially for *Cowdria* detection.

Future plans and priorities

On the Tick-borne Diseases Project

The overall strategy is one that will promote endemic stability to TBDs in mainly SNL herds. The following outlines some of the major activities being undertaken by the project.

1. Extension of SNL trial sites for immunisation against two or all three of the TBDs.
2. Continuation of TBD immunisation in yearly calf crops and older animals to establish the reactivity of different ages to the TBD vaccines.
3. Continued serology and clinical surveillance to monitor the development of immunity in trial and control calves at the same sites.
4. Application of alternative dipping programmes (threshold dipping) once the TBD epidemiological status of the herd is established.
5. Assessing the delivery mechanisms of alternative TBD control methods recommended to the SNL areas. This will be addressing issues like cost recovery and the integration of such a strategy with other programmes.

On other diseases/issues

The Department intends to broaden its understanding on the endemicity and epidemiology of diseases like *Brucella mellitensis* (and *B. abortus*), *Mycobacterium bovis* and other zoonoses. A national survey on the prevalence of *B. mellitensis* in goats is under way and is sponsored by the government.

Priorities exist in the following:

1. Training of the TBDs diagnostic staff in alternative and improved TBD diagnostic methods that could be applicable in continued monitoring and surveillance of TBDs in Swaziland. This includes more especially ELISA techniques. Training of a full time epidemiologist is also a priority. In the meantime an epidemiologist with experience in TBD control programmes is required.
2. Tick resistance monitoring.
3. An extension of the present technical cooperation programme (TCP) to successfully complete the tasks set to achieve laid-down objectives. The present project expires in August 1996.
4. There is need for the epidemiology unit to get linked into electronic mail, especially Internet. This will make communication with other researchers and research centres easier.

Possible role of national and international (including FAO) organisations in future programmes

The role of national organisations

There are not many national organisations that can be seen assisting the present TBD project and future programmes. An institution such as the local university could play an important role in collaborative research with the Ministry of Agriculture, Department of Veterinary Services. Programmes involving disease sero-surveillance, e.g. brucellosis, seem to attract the university's researchers. The TBD control programme will need regular monitoring for changes in tick and tick-borne disease dynamics, and such surveillance could be undertaken with research components from the Faculty of Agriculture.

The pharmaceutical companies could also play an important role in limited research, and also in disease monitoring and surveillance. Research trials can be tailored to improve the company's understanding on the suitability of their products and show the commitment of the company to improving the welfare of their customers. This could ultimately improve sales.

Role of international organisations

International organisations could assist in supporting the following activities:

- Training of personnel in diagnostics. A training component is accommodated in the present TCP but this has budget limitations for the amount of training necessary.
- Training of the local epidemiologist.
- Providing the tick-resistance monitoring kit, e.g. the World Acaricide Resistance Reference Centre (WARRC), Berlin.

- Procuring equipment for the epidemiology unit, equipment such as a light microscope, dissecting microscope (for tick identification) and e-mail facilities installed for better communication. These would assist in diagnosis and monitoring of diseases. ELISA equipment would also be very valuable.

References

Ministry of Agriculture and Cooperatives. 1994. *Census of Livestock 1994.*

Nxumalo R.S. 1991. *The Epidemiology of Ticks and Tick-borne Diseases in Swaziland*. Dissertation submitted in partial fulfillment of a Master's degree, University of Edinburgh, UK.

Appendix 1

Cattle population statistics (Swaziland 1994).

Agro-ecological zone [AEZ]	Total cattle population	Swazi Nation Land [SNL] + (ha/LSU*)	Title Deed Land [TDL] + (ha/LSU)	Government stock	Number of dip tanks SNL	Av no. cattle/dip tank SNL
Highveld	171,671	153,403 (3.2)	17,571 (1.7)	697	125	1,227
Middleveld	246,117	199,620 (1.8)	40,509 (1.5)	5,988	159	1,255
Lowveld	182,735	143,587 (1.2)	34,860 (4.3)	4,288	133	1,270
Lubombo	25,833	22,028 (4.1)	2,403 (4.2)	1,402	20	1,101
Totals	626,356	518,638	95,343	12,375	437	1,243

Source: MOAC Census of Livestock (1994); FAO Range Resources Report (1993).
* Hectares/livestock unit.

Appendix 2

Beef and dairy cattle population statistics (1994 livestock census).

Tenure	Beef	Dairy
SNL	516,888	1,750
TDL	91,576	3,767
GOV	12,063	312
Total	620,527	5,829

Appendix 3

Numbers of cattle immunised and to be immunised for TBDs.

	Tenure		Immunised		Yet to be immunised by end of project			
	HW	*Anaplasma*	*B. bovis*	*B. bigemina*	HW	*Anaplasma*	*B. bovis*	*B. bigemina*
SNL	13	102	102	102	?	~250	~250	~250
TDL	97	57	57	57	?	?	?	?
GBS	264	293	293	293	~350	~350	~350	~350
Total	374	452	452	452	~400	~600	~600	~600

Note: Figures under ‘yet to be immunised’ do not include those already vaccinated. These are estimates.

Epidemiology of ticks and tick-borne diseases in Tanzania: future research needs and priorities

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Current strategies for the control of ticks and tick-borne diseases in Tanzania

The general policy of the Ministry of Agriculture has been formulated with four approaches in mind:

1. Manipulation of the environmental ecology in relation to vector biology.
2. Destruction of the vectors by application of effective pesticides to their habitat/ hosts.
3. Application of chemo-prophylactics, chemo-therapeutics or immunisation against parasites transmitted by the vectors.
4. Integrated interventions whereby strategic/threshold pesticide vector control, chemo-therapeutics and/or chemo-prophylactics, immunisation, endemic stab-ility and genetic resistance may be interwoven as deemed feasible.

Traditional control of ticks and tick-borne diseases

The principal method used for the control of ticks and tick-borne diseases (TBDs) from 1900 to date has been application of acaricide to livestock through dipping, spraying or dusting. This traditional control has been constrained by two main factors, namely: inadequate finance, and poor management. Reports available from the regions show that of the 2100 dips in the country less than 5% are operational.

New approaches towards control of ticks and TBDs

Considering the myriad of co-existing problems relating to application of acaricides in the control of ticks and TBDs, which include high costs (acaricide cost, maintenance of infrastructure and operational costs), toxic food residues, environmental pollution, emerging resistance to acaricides etc, the Ministry of Agriculture is planning to embark on integrated intervention for the control of ticks and TBDs. This new approach will embrace rational, integrated, cost-effective control methods such as threshold or strategic dipping, selection of genetically resistant breeds to ticks and/or TBDs, immunisation against TBDs and/or ticks, pasture management (including inter-planting of plant species toxic to ticks), study of seasonal tick distribution according to ecological zones for strategic acaricidal application, and exploitation of endemic stability.

In the current programme to immunise cattle against East Coast fever (ECF), immunisation against the other TBDs will be included for exotic and grade animals as deemed necessary. It will also be essential to vaccinate cattle moving from tick- and TBD-free areas to endemic areas in order to avoid mortalities due to TBDs.

In places where intensive dipping/spraying has been practised for a long period and the animals rendered highly susceptible to TBDs, it will be rational to vaccinate herds, especially the adults, in order to prevent epidemics in the event that acaricide application ceases.

Eventually vaccination of young stock will be promoted country-wide when (if) endemic stability is re-established and the safety and delivery of the vaccines has improved. The vaccine delivery will be privately done by certified registered veterinary surgeons.

On-going projects involved with control of ticks and TBDs

1. Integrated Tick and Tick-Borne Disease Control Project GCP/RAF/299/NET—Tanzania mainland.
2. Field ECF immunisation in Zanzibar URT/86/022—Food and Agriculture Organization of the United Nations (FAO) through cooperation with the International Livestock Research Institute (ILRI).
3. Tanga Small Scale Dairy Development Project (TSDDP): Dutch-funded feasibility study on the delivery of ECF immunisations in the different livestock production systems in Tanga region.
4. Central Veterinary Laboratory (Animal Disease Research Institute) under the umbrella of the National Agriculture and Livestock Research Project funded by the World Bank.

Particular epidemiological issues that need to be addressed

In spite of the importance of ECF and other TBDs, together with the increasing popularity of keeping dairy cattle, very little is known regarding the epidemiology and socio-economic impact of these diseases in small-scale dairy units. Likewise, no up-to-date information is available regarding numbers, breeds and distribution of dairy cattle and socio-economic factors affecting these within Tanzania; nor between the two social groups: full-time and part-time small-scale dairy farmers.

There also exists an increasing demand from the indigenous livestock keepers to immunise calves against ECF.

Recent activities and sero-surveys have confirmed the presence of *Babesia bovis* in the northern region of Tanzania, previously believed to be free of this disease and its vector *Boophilus microplus*.

Field exposure experiments in Tanga have clearly demonstrated the importance of heartwater *(Cowdria ruminantium)* in dairy animals. Although this TBD has always been recorded as suspected cases, no relevant information is available on the distribution within Tanzania and sero-prevalence among traditional and improved cattle.

We therefore propose studies on epidemiology and socio-economic impact of ECF and other TBDs on small-scale dairy farms in Tanzania to be conducted in the areas of Southern Highlands, Dar es Salaam, and Coast, Mwanza, Arusha, Kilimanjaro, Tanga and Morogoro regions, where ECF immunisation is currently going on. These studies should be complemented with investigations in the indigenous cattle population to estimate prevalence rates of TBDs and morbidity/mortality figures for the different age groups.

There is a need to re-address tick distribution and dynamics particularly in respect of *B. microplus* (possibly *B. annulatus)* in the northern zone of Tanzania.

There is need to quantify the economic importance of heartwater in relation to cattle mortalities in the different livestock production systems.

The socio-economic and epidemiological studies to be carried out will have the following objectives and outputs:

Objectives

1. To conduct a census of dairy cattle and explore socio-economic factors affecting the populations of dairy cattle in small-scale farms in the present ECF endemic areas.
2. To determine prevalence of *T. parva*, *T. mutans*, *Cowdria ruminantium* and other TBDs in the present project areas.
3. To monitor incidence of ECF, other TBDs and host tick burdens over a two- to three-year period in both livestock production systems (traditional and improved breeds), and explore factors affecting these, such as environmental, socio-economic, practised control measures etc
4. To assess socio-economic impact of ECF and other TBDs in the ECF endemic areas.
5. To assess the revised and adapted tick-control measures after ECF immunisations have been carried out.

Outputs

The following information should have been gathered:

1. Exact information on numbers, breeds and distribution of dairy cattle in ECF endemic areas and between the social groups, together with socio-economic factors influencing the observed distribution.
2. Prevalence of *Theileria* species and other TBDs will provide useful baseline data for implementing immunisation activities and adjusting current tick-control strategies.

3. Incidence of ECF, other TBDs and host tick burdens will outline the magnitude of the problem and assist the government in planning and budgeting control programmes.
4. Information on socio-economic impacts will enable programme managers and policy makers to estimate a realistic cost-benefit factor for the projected control methods against TBDs.
5. Develop an adaptable and sustainable tick-control strategy for the different ecological zones and different farming systems in Tanzania.

Future plans and priorities

1. Qualitative and quantitative evaluation and impact analysis of immunisation against TBDs remain a high priority project activity for immediate implementation. This evaluation should be based on data derived from studies on TBD epidemiology, seasonal vector dynamics and ecology, strategy for integrating other control approaches with immunisation to obtain optimal cost-benefit ratios, production indices, socio-economic effects including community awareness and follow-up on possible TBD parasite strain variation in the regions where immunisations are carried out.

   A work plan to study cost-benefit ratios (based on comparison of morbidity, mortality and performance between ECF immunised and non-immunised dairy animals) in Southern Highlands, the lake zone and Tanga has been included in the activities for 1996. The study will use the available databases of the dairy projects active in these regions and embrace some of the above parameters.

   Since the present project budget may not allow implementation of the recommended evaluation adequately, there exists a need to consider additional funding from both the government and the donors.
2. Building up of institutional capacity nationally by deliberate development of local expertise, further long-term training (MSc/PhD level) of national experts, development of facilities and constant flow of implementation supplies.
3. Creation of capable programme management with well informed and motivated manpower.
4. The scope of the present TBDs immunisation project should be expanded as soon as possible into a true integrated tick- and TBD-control programme which will address both the improved cattle breeds and the indigenous cattle, through various proven strategies.

Possible role of national and international organisations in future programmes

The government's contribution to the project so far has been very low in comparison to the committed obligation by the donors and the executing agency FAO. However, despite the existing economic problems, we believe that agriculture, including livestock development, is the mainstay of the country's future economic development. The government will sooner or later need to consider a higher financial allocation to the project, commensurate to its high economic importance and magnitude.

The Central Veterinary Laboratory should play an important role in the coordination of survey activities related to TBDs programmes.

Sokoine University of Agriculture has already pledged its support in some of the research activities and in the provision of manpower to assist in projected surveys as part of field training activities for veterinary students.

The National Livestock Extension Programme (NALEP) could assist in the extension activities related to an integrated tick- and TBD-control programme.

In addition to the FAO/multi-donor-funded Integrated Tick- and Tick-Borne Disease Control Project GCP/RAF/299/NET, extra funding should be sought from multi-lateral and bilateral donors such as the Overseas Development Administration (ODA) and the European Union (EU).

Besides this, there is need for a more extensive collaboration with other existing relevant livestock development projects and programmes in the country such as the Kagera Livestock Development Project (KALIDEP) in Kagera region, west of Lake Victoria, financed by the Netherlands; the Small Scale Dairy Development Project (SSDDP) in the Southern Highlands, financed by Switzerland; Tanga Small Scale Dairy Development Project (TSDDP), financed by the Netherlands; and the Livestock Development Services Project (OAU/IBAR Pan African Rinderpest Project), financed by the European Union.

External collaboration with the Regional Coordination and Training Project, Harare, the Vaccine Production Centre, Lilongwe, the Onderstepoort Veterinary Institute, Pretoria, and the International Livestock Research Institute, Nairobi, is already proposed in the project document and assistance in training national experts will be invaluable.

Collaboration between international laboratories and field projects with regard to heartwater serology surveys is requested as the information gathered will help in addressing TBD-control programmes.

Already there has been collaborative work to study the impact of immunisation between the project and SSDDP in the Southern Highlands where computerised data from immunised and non-immunised animals is being analysed. Similar data will be available from KALIDEP and TSDDP.

Cross-immunity trials to study possible *T. parva* strain variation has recently been conducted by TSDDP in collaboration with FAO, while KALIDEP intends to carry out studies on the broader spectrum of the pre- and post-immunisation effects. Collaboration is thus effectively desirable and applicable.

Further efforts to broaden the scope of the project has been expressed by the Ministry of Agriculture to the executing agency, FAO, on various occasions from 1992 to date. There has been a promise to look into the possibility of instituting a tick- and TBD-control programme which will address the indigenous national herd. This requires further follow-up especially when the present programme comes up for review.

Livestock census

Livestock censuses were conducted in 1971, 1978, 1984 and 1993. The censuses of 1978 and 1984 were complete counts while those of 1971 and 1993 were sample censuses.

Livestock numbers (millions)			
Census Year	Cattle	Goats	Sheep
1971	8.0	4.3	2.6
1978	12.0	5.5	3.6
1984	12.5	6.4	3.1
1993	13.6	8.6	2.7
1995	12.2[†]		

[†]Estimation from the Tanzanian Livestock Marketing Project (TLMP).

1993 livestock census

There were 1,027,000 households with cattle which was about 28% of all agricultural households on Tanzania mainland. The total number of cattle kept was 13,618,000. The average number of cattle per household was 13. The cattle population was about half the human population. Most cattle are of indigenous Tanzanian Zebu type.

The regions with most cattle were:

Shinyanga	1,866,000
Mwanza	1,652,000
Dodoma	1,600,000
Arusha	1,399,000
Singida	1,382,000
Tanga	1,087,000
Mbeya	911,000

In Morogoro region there are a few agricultural households with cattle but these have a large number of cattle (average 68.46 cattle).

Improved dairy cattle amounted to 302,000 or 2.2% of the total cattle population. The following were the regions with most improved cattle:

Kilimanjaro	48.0%
Arusha	16.4%
Kagera	11.8%
Dodoma	6.6%
Tanga	6.4%
Mbeya	4.7%

Together these regions accounted for 93.9% of the improved cattle herd. The remaining 14 regions had only 6.1% of the improved cattle. Improved cattle, particularly improved dairy cattle, are near urban centres or on commercial farms.

Target numbers for immunisation

ECF

Since 1990 when ECF immunisations started on trial basis, some 10,000 cattle, mostly dairy crosses, have been immunised (about 3–4% of the target population of grade animals).

In the next three-year phase of the proposed new project, it is expected that 15,000–25,000 cattle will be immunised against ECF annually.

The estimated target numbers (long-term) for improved breeds (dairy + beef) is 100,000 animals annually (Tables 1–2).

Table 1. *Beef population (ranches).*

Zone	Region	Estimated beef population†	Annual no. expected for ECF immunisation
Southern highlands	Iringa	2,900	
	Mbeya	300	
Morogoro	Morogoro	15,000	
Coastal zone	Dar	100	
	Coast	6,200	
Northern zone	Arusha	22,800	
	Kilimanjaro	9,600	
	Tanga	23,400	
Lake zone	Mwanza	2,000	
	Kagera	13,700	
	Total	96,200	33,670

Areas to be considered but not yet included in immunisation activities:

Region	Estimated beef population†
Dodoma	14,300
Kigoma	400
Mara	4,300
Rukwa	1,600

†Basic data, agriculture and livestock sector, 1992.

Most of the cattle (97%) in Tanzania belong to the traditional extensive livestock production system and demand is now coming from this sector for immunisation of indigenous calves in order to reduce the high calf mortality, mostly due to ECF, and halt the decline in cattle numbers in Tanzania.

B. bovis

Target numbers for *B. bovis* immunisations can be determined on the basis of information from the epidemiologic studies. As more than 75% of the improved dairy animals are present in the northern region (Kilimanjaro, Arusha and lake zone), target

Table 2. *Dairy population targeted for ECF immunisation in areas already involved in this activity.*

Zone	Region	Estimated dairy population†	Number immunised November 1995	Estimated number remaining	Annual no. expected for ECF immunisation
Southern highlands	Iringa	10,700	5,925	8,775	5,145
	Mbeya	10,500	179	10,321	3,675
Morogoro	Morogoro	10,300	84	10,216	3,605
Coastal zone	Dar	3,700	407	3,293	1,295
	Coast	4,600	200	4,400	1,610
Northern zone	Arusha	40,000	158	39,842	14,000
	Kilimanjaro	93,400	120	93,280	32,690
	Tanga	18,900	240	18,660	6,615
Lake zone	Mwanza	4,300	1,783	2,517	1,505
	Kagera	11,400	120	11,280	3,990
	Total	207,800	9,253	202,584	74,130

Areas to be considered but not yet included in immunisation activities:

Region	Estimated dairy population†
Dodoma	3,300
Kigoma	800
Mara	4,800
Rukwa	2,800

†Basic data, agriculture and livestock sector, 1992.

numbers will be equally high if the presence of the tick vector and prevalence of the disease can be demonstrated. The need for immunisation and the duration of this exercise will, however, depend on the feasibility of (re-)establishing endemic stability.

Anaplasmosis

Sero-surveys to record the prevalence of *Anaplasma* have shown that, in the commercial sector (high density of livestock units), a high prevalence exists and the need for immunisations is not urgently required. Further information is needed to address the possibility and need for *Anaplasma* immunisations in the small holder dairy sector.

Cowdriosis

Heartwater will most likely be the next disease candidate for vaccination after ECF immunisations have been carried out. Target numbers will depend on available information from the epidemiology studies.

Relevant ongoing and proposed projects

Ongoing projects

1a. Integrated Tick and Tick-Borne Disease Control Project (GCP/RAF/299/NET), Tanzania Mainland
Funding: Dutch Government (multi-donor regional programme)
Duration: Ongoing till December 1996. Project document for extension 1997–2000 awaiting approval.
Staffing: 1 international expert; 2 international experts foreseen for the next phase.
Objectives: Promote and introduce integrated tick and tick-borne diseases control measures. Immunise target populations with available vaccines against TBDs under full cost-recovery policy.

1b. Tanga Small Scale Dairy Development Project (TSDDP)
Funding: Dutch Government (bilateral programme).
Duration: 1 year study.
Staffing: 1 international expert.
Objectives: Feasibility study on the delivery of ECF immunisations in the different farming systems in Tanga region.

2. GOZ/FAO/Donor Project URT/86/022, Zanzibar
Request from ILRI to cover this project or project activities under the umbrella of the mainland project (1a) is being considered.

3. Livestock Service Development Project
Funding: European Union.
Duration: December 1993–December 1996.
Staffing: 1 international expert; 2 national experts.
Objectives: The EEC veterinary services privatisation project is supporting rehabilitation and devolving of drug procurement and distribution mechanisms, rinderpest eradication and privatisation of veterinary practice. Support for the Central Veterinary Laboratory is being implemented together with training of field staff in diagnosis of epidemic diseases.

4. Sokoine University of Agriculture (SUA)
Funding: Internal and external research funds.
Outputs: Small-scale investigations and research projects related to ticks and TBDs.

5. National Agriculture and Livestock Research Project (NALRP)
Funding: World Bank.
Duration: 1991/92–1996/97.
Objectives (related): Rehabilitation of the Central Veterinary Laboratory (ADRI) and availability of research funds.

6. National Livestock Extension Project (NALEP)
Phase I: July 1989–June 1996.

Funding: World Bank, African Development Bank, Tanzania Government.
Phase II: July 1996–July 2001.
Funding: World Bank, Tanzania Government.
Objectives: Training of extension officers at regional and district level through bimonthly or monthly meetings.

Proposed projects

7. Tick and TBD Control Project, Lake Victoria Zone, Tanzania
   Funding: Overseas Development Administration of the United Kingdom (ODA).
   Area of operation: Mwanza, Shinyanga.
   Starting date: projected 1997.
8. Future Role of Organisation of African Unity/Inter-African Bureau for Animal Resources (OAU/IBAR)

In the coordination of regional livestock development projects in Africa: The sixth OAU/IBAR East African coordination meeting for the Pan-African Rinderpest Campaign (PARC), held on 4–6 March 1996 in Debre Zeit, Ethiopia, highlighted the success of PARC in coordinating animal health projects in Africa, including the control of rinderpest, strengthening livestock services and privatisation, and acknowledged the support of the European Union for the livestock projects throughout the continent.

It was recommended that the role of OAU/IBAR be expanded to include the co-ordination of all regional animal health and production projects in Africa. In so doing OAU/IBAR should undertake the following:

Coordinate the control of:

- epidemic diseases of regional importance such as rinderpest, contagious bovine pleuro-pneumonia, foot-and-mouth disease, and peste des petits ruminants;
- tsetse and trypanosomiasis programmes;
- endemic diseases of regional importance; and
- ticks and tick-borne diseases.

Epidemiology of ticks and tick-borne diseases in Uganda: future research needs and priorities

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Introduction

Uganda, which is situated along the equator from one degree south to four degrees north, is fortunate to have fertile soils and abundant rainfall for much of the country. Uganda's agriculture potential is enormous with vast areas of the country suitable for livestock production. Uganda is attempting to increase cattle production by improving its national herd through the introduction of exotic cattle breeds. The same favourable climatic conditions for cattle also support a large tick population which provides transmission of four important tick-borne diseases (TBDs):

- East Coast fever (ECF) *(Theileria parva)*
- Anaplasmosis *(Anaplasma marginale)*
- Babesiosis *(Babesia bigemina)*
- Heartwater *(Cowdria ruminantium)*

The present cattle population of Uganda is estimated at 4.57 million. Improved dairy cattle and beef cattle number 231,900 and 194,294, respectively, 9.3% of the total cattle population (Appendix 1). The economic control of ticks and tick-borne diseases (TBDs) is probably the single most important animal health issue affecting cattle in Uganda.

Current strategies for the control of ticks and TBDs in Uganda

Uganda is formulating a national tick-control policy which will be advocated by the government. Presently, cattle owners must provide their own individual tick control for their respective herds. Acaricides are approved by the government and sold on the open market. Depending on each farmer's individual situation, he selects an acaricide and a tick-control method which provides satisfactory tick-control results. Some communal tick-control programmes do exist which are usually centred around a functional dipping-tank. However, most cattle owners provide individual treatment to their herds as they deem necessary.

Most veterinary officers recognise that only minimal tick control can be justified for the local cattle breeds. Owners of indigenous cattle accept participating in tick-control programmes only when their costs remain very low. This would be through communal dipping programmes or the rare application of an acaricide by a hand-pump sprayer when tick numbers are extremely high. Otherwise, the removal of ticks by hand provides some tick control.

Improved cattle must be given much better protection from ticks and TBDs. The most commonly practised method is semi-intensive to intensive tick control through the regular application of acaricides. In order to protect the more susceptible cattle from TBDs, Ugandan veterinarians and the commercial sector involved with the marketing of acaricides suggest that intensive tick control is the only method for controlling TBDs. Due to the presence of ECF, all tick-control strategies are aimed at controlling *Rhipicephalus appendiculatus*. The most popular methods for tick control for improved cattle are:

- Dipping or hand-spraying one to two times each week with an organophosphate acaricide (primarily Chlorfenvinphos preparations).
- Dipping or hand-spraying once each week with an acaricide having a longer residual effect on the treated cattle (e.g. Deltamethrin or Amidines).
- The application of a synthetic pyrethroid (e.g. Flumethrin) by the pour-on method once every 7 to 14 days.

The FAO project GCP/UGA/030/DEN (see Appendix 2) has introduced the use of immunisation using teh infection-and-treatment method to control ECF. The vaccine improves herd resistance to ECF which allows the respective tick-control programmes to be relaxed. Although this is a new concept for disease control in Uganda and this technique has been criticised by many national veterinarians, cattle raisers are increasingly demanding this vaccine in an attempt to decrease tick-control costs and mortalities due to ECF.

Ongoing projects involved with the control of ticks and TBDs

There are a number of projects either directly or indirectly associated with tick and TBD control in Uganda (Appendix 2). More effort should be made at the national level for closer collaboration between these projects which would facilitate information exchange and data collection.

Epidemiological issues of primary importance

The most important epidemiological issues concerning ticks and TBDs, and the control measures required to reduce livestock production losses created by them are centred around the economics of the various control measures. For Uganda, increased information concerning the economics of tick and TBD control is required to help establish national policies and provide better recommendations to cattle farmers.

Indigenous cattle

We understand that minimal tick control is required but what level of tick infestation is considered acceptable for these indigenous breeds? Some areas of the country may experience specific seasons when tick infestation of the bovine host is at a peak. These seasons should be determined to help direct us when planning tick control based on the presence of high tick numbers. Therefore to assist the majority of Ugandan cattle farmers with developing tick-control strategies, we should establish:

- the threshold level of tick infestation that justifies the application of an acaricide; and
- the seasonal variations of tick infestations which may help us develop a strategic tick-control approach for these cattle.

Improved cattle

Two choices still remain:

- intensive tick control, attempting to keep the cattle tick-free and having no contact with TBDs; or
- immunisation against ECF (and possibly other TBDs) coupled with a more relaxed tick-control policy.

Further tick-control evaluations are required to develop optimal tick control for these two situations.

Intensive tick control

There is a wide range of very diverse acaricides which are available to cattle owners. Unfortunately, these cattle owners do not have enough information to allow these acaricides to be used effectively and economically. The available acaricides should be evaluated in Uganda to determine how they should be utilised to achieve best results. Information should include:

1. Optimal application method for each acaricide (dipping, hand-spraying or as pour-on).
2. Ability of the acaricide at recommended concentrations to adequately kill ticks on the bovine host.
3. The residual period of each acaricide.
4. The estimation of the optimal treatment interval of each acaricide required to keep cattle tick-free.
5. The monitoring of tick resistance to the various groups of acaricides.
6. The true cost of acaricide application to the farmer (acaricides, infrastructure, labour, etc).

Immunisation against ECF coupled with relaxed tick control

For farmers opting to follow this control strategy, many questions still remain which require further investigation:

1. What measures can be taken to keep the cost of the immunisation process as low as possible (reduced inputs, reduced monitoring, etc)?
2. How can the impact and efficacy of ECF immunisations be most accurately measured?

3. What type of tick control should be advocated for a particular herd following ECF immunisations (relaxed but adequate)?
4. When should other TBD vaccines be advocated?
5. What is the overall cost/benefit of this control measure?
6. Given the socio-economic situation of the various participating farmers, what price could they justify to pay for this immunisation service?
7. How can the TBD vaccine delivery service be structured so that it will remain self-sustainable and permanently available to cattle owners?

Future plans and priorities

Although the national tick and TBD control policy for Uganda has not been finalised and there are several different opinions concerning this subject, it is widely accepted that all control programmes must be economically justifiable. The future plans and priorities concerning tick and TBD control for Uganda are to address the priority issues outlined above, and establish extension links to the cattle farmers that require this information.

This up-dated approach for the control of ticks and TBDs should be integrated into an overall animal health improvement package to be proposed to the cattle farmers. Integrated tick and TBD control should not be isolated as an individual activity but combined with other basic animal health inputs and delivered to the farmer as a complete animal health improvement programme.

The largest economical impact will affect the improved cattle of Uganda which are usually raised by farmers who understand that investments in animal health programmes lead to higher animal production and more profits. Due to this, emphasis should be placed on the support of improved cattle breeds with a priority of providing assistance to the small-scale dairy farmer.

Possible role of national and international organisations in future programmes

There is still a great deal of work to be done concerning the establishment of economical tick and TBD control programmes. It takes a great deal of time and convincing in order to get national policy makers to change old traditional beliefs. Future programmes must generate enough information so that these policy makers can make accurate decisions concerning the introduction of new control methods.

National and international organisations must collaborate closely together to advance the following activities:

1. Continual data and information collection.
2. Promotion of integrated tick and TBD control strategies attempting to improve control economics.
3. The development of self-sustainable animal health improvement programmes.
4. The training of veterinary field staff in the new techniques.

5. The development of an extension system required to make the technologies available to the farmers.
6. The progressive development of a TBD vaccine delivery service.
7. Improvement of available inputs such as TBD vaccines, acaricides and thera-peutic drugs.
8. Promotion of veterinary privatisation (delivery of inputs to farmer).
9. Support to laboratory facilities associated with animal health improvement activities.
10. Assistance with the promotion of improved cattle breeds.

Appendix 1

Estimated number of cattle in Uganda

Improved dairy cattle (pure exotics and cross-bred)	231,900
Improved beef cattle (pure exotics and cross-bred)	194,294
Total cattle under intensive/semi-intensive dairy production (indigenous and improved cattle):	1,675,984
Total cattle under intensive/semi-intensive beef production (indigenous and improved cattle):	798,178
Total cattle	4,570,000

Source: Department of Veterinary Services, Epidemiology Unit, *1994 Annual Report*.

Projects involved with control of ticks and tick-borne diseases in Uganda

Project	Objectives	Funding	Termination date
1. Livestock Services Project (LSP) Director of Animal Resources - national execution	a. Increase numbers and improve quality of Ugandan livestock b. Improve delivery of livestock services c. Veterinary privatisation d. Provision of water for livestock	a. World Bank b. IDA c. Government	June 1996 (possible extension)
2. Epidemiology Unit - Commissioner of Veterinary Services - Since 06/95, national execution	a. Emergency disease investigation b. Disease information collection/reporting c. Cost-effective animal health and production strategies d. Newcastle vaccine production e. Infrastructure improvement	a. GTZ b. Government	a. GTZ = June 1995 b. Government = continuation of activities
3. PARC - Commissioner of Veterinary Services - national execution	a. Immunisation against rinderpest and CBPP b. Sero-surveillance of rinderpest and CBPP c. Veterinary privatisation	a. EEC b. FAO c. Government	Long-term funding
4. Livestock Research Institution (LIRI) of NARO - Director LIRI - national execution	a. Current status of TBDs b. ECF mortalities in calves c. Other livestock diseases	Government	Long-term funding
5. Makerere University - veterinary faculty	General research topics on ticks and TBDs.	University (government)	Long-term funding
6. Artificial Breeding Centre (ABC) - Commissioner of Animal Production - DANIDA execution	a. Dairy cattle improvement b. Promotion of AI	a. DANIDA b. Government	Long-term funding
7. Dairy cattle improvement projects - Various directors - Various executors	a. Distribution of improved cattle b. Farm assistance to improve animal production	a. Several sources	Long-term funding

Project	Objectives	Funding	Termination date
8. Berlin University Collaborative Research Unit (CRU) - Director LIRI - Berlin University execution	a. Trypanosomiasis b. Ticks and TBDs c. Impact of diseases on farm production	a. Berlin University b. Makerere University c. Government	December 1996
9. Integrated Tick and TBD Control Project - Director LIRI - FAO executed	a. Introduction of ECF immunisations to private farms b. Development of more economical tick and TBD control programmes c. Dairy sector development	a. DANIDA b. FAO c. Government	December 1996

Epidemiology of ticks and tick-borne diseases in Zambia: future research needs and priorities

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Introduction

Tick-borne diseases constitute the biggest obstacle to the realisation of the full potential of the livestock industry in Zambia. The major tick species found in the country and the corresponding diseases they are associated with are:

Rhipicephalus species	theileriosis
Boophilus species	babesiosis; anaplasmosis
Amblyomma species	cowdriosis
Hyalomma species	sweating sickness

Tick ecology

Relatively few studies in the field of tick ecology have been carried out in the recent past in Zambia. This situation is unfortunate because little is known about the factors contributing to the differences in tick abundance between different places. Knowledge on the epidemiology of different tick-borne diseases has suffered as a result. However, of late, steps have been taken to redress the situation. The Zambian Government is currently co-operating with the Belgian Government through the Assistance to the Veterinary Services of Zambia (ASVEZA) animal health project. Studies on tick ecology are among the project's mandate.

Theileriosis

Theileriosis is by far the most important tick-borne disease in Zambia. It is present in the major livestock producing provinces of the country threatening an estimated cattle population of 1.93 million out of the country total estimate of 2.6 million head.

In the Eastern Province of Zambia the disease present is typical East Coast fever (ECF) whereas in Southern Province the situation is still unclear with most people referring to the version of the theileriosis there as Corridor disease although no buffalo/cattle transmission has yet been demonstrated.

A total of 130,000 calves have been immunised against ECF in five districts of the Eastern Province since 1987. The calves included in the campaign are between two and six months old. The immunisation campaigns were initially performed by the

Belgium-funded animal health project but the situation has since changed with the veterinary department carrying out the immunisations as from last year. The ASVEZA project only supplies logistical and limited financial support. Currently the annual number of calves immunised totals 18,000. The immunisation is charged for and modalities have already been worked out to move towards a full cost recovery within a three-year period in line with the government's new policy of charging farmers the full cost for veterinary services.

Studies in the Eastern Province have determined calf mortality to be around 30% in the absence of immunisation. After immunisation the mortality rate was reduced to below 5%. The age at which calves naturally come into first contact with the disease has been shown to be between seven and eight months.

In the Southern Province large-scale surveys in all the districts have been carried out to screen for the disease and to determine the distribution of the tick *Rhipicephalus appendiculatus*. The initial screening revealed a patchy distribution of the disease. These surveys have been complemented by detailed follow-up of 12 sentinel herds in different districts of the province. Information relating to (calf) mortality rates and age at first contact is expected to be derived from the sentinel herds' follow-up. A programme to re-equip and strengthen the diagnostic capabilities of the district laboratories has also been put in place.

The government has a full cost drug delivery system running in Southern Province. The drugs included in the system are Butalex, Parvaquone, trypanocides; more than 100 bottles sold. It is still premature to consider immunisation as an option for the control of the disease in Southern Province. A clear understanding of the epidemiology of the disease is required before arriving at the appropriate control measure.

Other tick-borne diseases

Tick-borne diseases, other than theileriosis, do not cause problems under normal circumstances in traditionally kept cattle which constitute about 82% of the national herd.

In Zambia there is full endemic stability for *B. bigemina*. The situation is different for *B. bovis*, as its vector has only been recorded in Eastern and Northern Provinces.

Under normal circumstances anaplasmosis is also not a problem but poor management and stress from factors like other diseases and nutrition, coupled with high tick burdens, can lead to considerable problems.

Cases of sweating sickness occur sporadically especially in the rainy season. Control is being directed at educating the farmers on dipping or manual de-ticking of the infected animals. Removal of *(Hyalomma)* ticks normally leads to spectacular recovery.

Future research needs

Tick ecology

- Continuous studies on the population dynamics of ticks in order to understand the underlying factors.

- Continuous investigations on the spread of the ticks.
- Laboratory and semi-natural studies on the development of ticks.

Epidemiology of theileriosis

- More studies need to be conducted to acquire a full understanding of the epidemiology of the disease for appropriate control measures to be recommended.
- Further studies to determine the *T. parva* isolates occurring in Southern Province.
- Research directed at determining whether cross protection occurs between the Southern Province *T. parva* isolates.
- Determining whether mass immunisation of calves against ECF results in higher, lower or identical disease pressure in comparison to pre-immunisation levels.
- Determining the effect of mass immunisation of calves against ECF on the epidemiology of the disease.

Epidemiology of ticks and tick-borne diseases in Zimbabwe: future research needs and priorities

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Tick and tick-borne disease control strategies

The overall disease control strategy proposed for Zimbabwe is to introduce integrated tick and tick-borne disease control, which includes the eventual attainment of endemic stability to these diseases through immunisation coupled with strategic seasonal tick control.

Towards this end, the Department of Veterinary Services (DVS), in collaboration with a number of international agencies (see below), has embarked on several projects targeting the four major tick-borne diseases (TBDs) in the country, namely anaplasmosis, babesiosis, cowdriosis and theileriosis.

These projects are involved mostly in applied research on the development of vaccines and related field trials. They are also involved in some basic research where relevant as in the case of heartwater (cowdriosis).

Since 1985, the department has also been working towards implementing integrated tick and tick-borne disease control based on the need to establish endemic stability and reduced reliance on acaricide application. This has resulted in the move away from intensive tick control (averaging 42 treatments per year), which had been practised since 1912, to strategic tick control (averaging about 25 treatments per year). However, the department recognised that the actual move towards a strategic/threshold type of tick control must be a cautious one and required more epidemiological information as well as the need to minimise losses during the transition to establishing endemic stability. Now that vaccines are available against anaplasmosis, babesiosis and *Theileria parva* (January disease), there is increased confidence in advocating a policy of modified tick control. As pointed out below, the finer details of post-vaccination tick control still need to be worked out.

Ongoing projects involved with the control of ticks and tick-borne diseases

The following projects are currently going on in the department:

Anaplasmosis/babesiosis project

Title: Improved methods for the diagnosis and control of bovine babesiosis and anaplasmosis in Zimbabwe and Australia.
Funding: Australian Centre for International Agricultural Research (ACIAR).
Duration: January 1993 to date; currently on a one-year extension.
Objectives:

- To improve quality control testing of live vaccines against babesiosis and anaplasmosis.
- To improve diagnostic tests for TBDs; developing ELISA for *B. bovis*, *B. bigemina* and *A. marginale*.
- To produce effective and safe vaccines based on field trials (over 8000 head of cattle have been immunised in various trials in the past two years using vaccine produced by the project).

Future plans: A three-year replacement project is planned which will focus on field delivery systems and epidemiological monitoring.

Acaricide resistance testing project

Title: Acaricide resistance testing in the cattle ticks *Boophilus decoloratus*, *Rhipicephalus appendiculatus* and *Amblyomma hebraeum*.
Duration: 1992 to date; currently on a six-month extension.
Objectives:

- To determine the type and level of resistance.
- To map the geographical distribution of resistance.

Funding: Australian Centre for International Agricultural Research (ACIAR)

Heartwater project

Title: UF/USAID/SADC heartwater research project.
Duration: 1986 to date; current phase ends on 30 November 1996; a request for an extension is being considered by USAID.
Objectives:

- To develop improved vaccines against heartwater.
- To develop improved diagnostics against heartwater.
- To assess the epidemiology and socio-economic impact of heartwater.

Funding: United States Agency for International Development (USAID).
Future Plans: Large-scale field trials are planned in 1997 in Zimbabwe and South Africa using inactivated cell culture-derived *Cowdria ruminantium* vaccine.

Theileriosis project

Title: Integrated tick and tick-borne disease control.
Funding: Belgium and Denmark, and the Food and Agriculture Organization (FAO) as executing agency.

Duration: 1994 to date; current phase ends in May 1996. A two-year extension has been requested.

Objectives:

- To apply immunisation against theileriosis in the field with cost recovery.
- To assess prevalence and economic impact of theileriosis in immunised herds.

Major project outputs:

- Training and setting up a *Theileria* vaccine field delivery system through district veterinary officers.
- Production and subsequent registration of a locally produced *T. parva* Boleni vaccine.
- Immunisation of some 12,000 cattle in the last two years (in addition to 6000 immunised in the previous project as a pilot immunisation programme).
- Introduction of a vaccination technique without the usual oxytetracycline blockage, and subsequent amendment of registration of the vaccine.

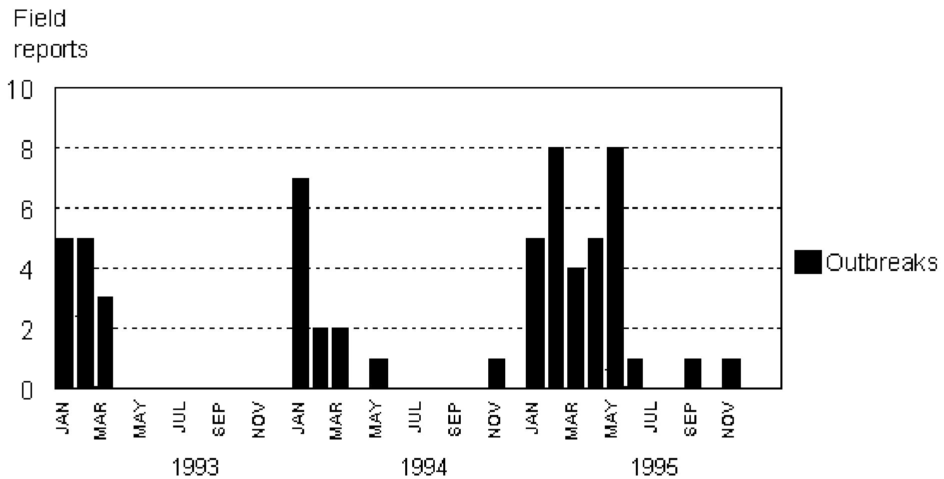

Figure 1. *Incidence of bovine theileriosis (Zimbabwe Field Reports 1993/1995).*

Epidemiological issues that need to be addressed

Epidemiology is the study of diseases in populations or the study of the health status of the population. Thus, to understand the epidemiology of theileriosis in Zimbabwe, it is necessary to know how the parasite is maintained within the host and tick vector populations.

In the epidemiology of theileriosis, patterns of disease occurrence are as follows:

- **sporadic**—where the disease occurs rarely or without regularity in a given population;
- **endemic**—where the disease occurs with predictable regularity in a given population, but with minor fluctuations in its frequency over time;

- **epidemic**—where the disease occurs at a frequency in a given time interval and is clearly in excess of its expected frequency.

As already stated, the overall disease control strategy proposed for Zimbabwe is to introduce integrated tick and tick-borne control and the eventual attainment of endemic stability to these diseases through immunisation and strategic seasonal tick control. Endemic stability to *T. parva* has been defined as the state in which the large majority of a given cattle population becomes infected and becomes immune by six months of age resulting in little or no clinical disease occurrence (Norval et al 1992). Thus, the possible epidemiological states can be described as:

- **very unstable**—when a given cattle population experiences a high case-fatality rate, occurring in all age groups and the population/herd shows a low antibody prevalence, with the incidence of disease ranging from low to very high;
- **unstable**—when a given cattle population experiences a high case-fatality rate in all groups, but predominantly in young animals, with the antibody prevalence being low to medium and the incidence of disease ranging from medium to high;
- **stable**—when a given cattle population experiences a low case-fatality rate, mainly in young animals with a low disease incidence and a medium to high antibody prevalence;
- **very stable**—when a given cattle population has a low case-fatality rate occurring in young animals only with a low incidence of disease and a very high antibody prevalence.

In Zimbabwe, theileriosis is endemic to certain farms/areas in which a stable to unstable situation appears to prevail. The majority of farms, however, are very unstable and at risk of epidemic disease outbreaks.

The determinants/factors contributing to the epidemiology of theileriosis in Zimbabwe include:

1. In the case of the tick vector:
   - a seasonal tick activity due to a seasonal rainfall pattern and day length;
   - frequency of acaricide applications and husbandry practices; and
   - level of infection in ticks dependent on infected hosts i.e. carrier cattle or cattle with clinical infection.
2. In the case of the host:
   - susceptibility of breed and type of cattle;
   - frequency of acaricide application;
   - presence of *R. appendiculatus* in the agro-ecological system;
   - infection rates in ticks; and
   - cattle movements.
3. In the case of the parasite *T. parva:*
   - presence or absence of antigenic strains; and
   - virulence of parasite strains.

From the above factors, the single most important determinant regarding theileriosis outbreaks in Zimbabwe has been the frequency of acaricide application, due to an intensive dipping policy that was practised from 1912 until recently when a strategic dipping policy was formally introduced through the Animal Health (Cattle Cleansing)

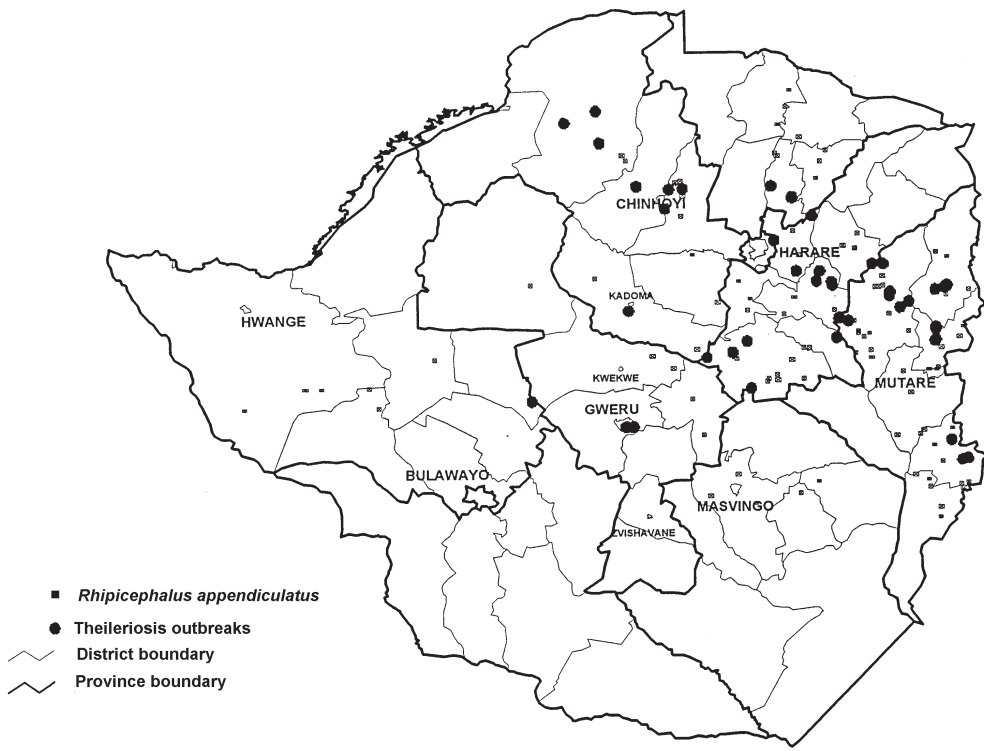

Figure 2. *Theileriosis outbreaks in 1996 and distribution of* Rhipicephalus appendiculatus.

Regulations, 1993. Intensive dipping, coupled with the seasonal and regional occurrence of the tick vector, resulted in a stable situation on most farms largely by the elimination of the parasite, resulting in no clinical disease or presence of antibodies. Unfortunately, intensive tick control is no longer financially sustainable, and is beset by the risk of tick resistance to acaricides, environmental pollution and residues in animal products. However, its greatest disadvantage is that it results in a highly susceptible and potentially unstable cattle population.

The current situation in Zimbabwe is that clinical theileriosis is restricted to the wetter provinces in natural regions (NR) II and III (i.e. Manicaland and Mashonaland East, Central and West provinces). The causative *T. parva* parasites are remarkably homogeneous and usually of low virulence relative to those causing ECF. The local parasites have also a well developed carrier state. However, accurate determination of sero-prevalence is complicated by the occurrence of *Theileria taurotragi* which is apathogenic, but is morphologically and serologically (in IFAT) indistinguishable from the more pathogenic *T. parva* parasites.

Zimbabwean theileriosis (locally known as January disease) occurs seasonally with disease incidence coinciding with the flush of adult *R. appendiculatus* activity during the rainy season (i.e. November till March).

Over the last five years a pilot vaccination programme has been implemented using a locally produced *T. parva* Boleni vaccine (Bolvac). Recently, the vaccine has been tested and registered for use without oxytetracycline blockage. This has brought down very significantly its cost of delivery, thereby making it affordable to farmers. The current policy is to vaccinate only in well defined problem farms. Such problem farms or herds are identified using a number of disease indicators, the most important being case-fatality rate.

Future plans and priorities

The availability of vaccines against tick-borne diseases creates the option of establishing endemic stability in a herd artificially. It is intended to select vaccinated herds for long-term monitoring in order to fully understand post-immunisation parasite drifts. The *T. parva* carrier state should be investigated to establish whether or not, vaccinated carrier cattle constitute a practical danger to other herds. The effects of post-immunisation tick relaxation on the epidemiology of theileriosis also needs to be investigated in selected herds.

In East Africa, it has been shown that the buffalo-derived *T. parva* parasite can transform in repeated passage in cattle to be indistinguishable from the cattle-derived parasite that is normally transmitted between cattle. The implication of this needs to be validated in the case of the vaccine strain used in Zimbabwe.

The relationship between the locally-occurring *T. parva* parasites, especially in relation to the vaccine stock, needs to be further elucidated. As ample evidence also exists to show that there is cross-protection between the local vaccine strain with East African strains, investigations are needed to establish whether the local vaccine strain could be used for ECF immunisation.

From a disease control viewpoint, there is a need to consolidate and expand on the field delivery system for theileriosis and other tick-borne diseases on the basis of a sustainable cost recovery system. Above all, there is a need to develop revised tick-control strategies in an integrated package as appropriate for each agro-ecological zone.

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Assessing the efficacy of immunisation against tick-borne diseases

Monitoring the efficacy of immunisation against theileriosis caused by *Theileria parva*

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Introduction

Tick-borne diseases (TBDs) caused by different protozoan and rickettsial species occur all over the world but their greatest impact is in the tropics and subtropics where they cause huge losses mainly in improved breeds of cattle. The economically important tick-transmitted diseases of cattle are caused by the protozoan parasites *Babesia bigemina* and *B. bovis*, and *Theileria parva* and *T. annulata*, and by the rickettsial organisms *Anaplasma marginale* and *Cowdria ruminantium*.

In the tropics, countries in the eastern and central regions of Africa are probably most affected. In these regions theileriosis, caused by *T. parva*, combined with babesiosis, anaplasmosis and cowdriosis, continues to restrict the introduction of improved breeds of cattle. Live vaccines for babesiosis, anaplasmosis and cowdriosis have been available and used for several years. Despite this, the intensive application of acaricides on cattle has been required mainly to control the brown ear tick, *Rhipicephalus appendiculatus*, the principal vector of *T. parva*, for which no vaccine was available. In the last 20 years, a significant research effort has been put into the development of a vaccine against *T. parva*. This has resulted in the infection-and-treatment method of immunisation, which has opened up the possibility of reducing the use of acaricides.

The FAO Regional Programme on Control of Ticks and Tick-borne Diseases is deploying live vaccines to control TBDs (particularly theileriosis) as part of the integrated control of ticks and TBDs in the predominantly small holder dairy sector in the region. The live vaccines for tick-borne diseases other than theileriosis have been used for several decades and their efficacies have been well defined. However, the infection-and-treatment method immunisation against *T. parva* has only been used on a limited scale and the need to assess efficacy, evaluate delivery systems and measure the long-term impact of immunisation is clearly recognised. This paper attempts to identify the problems of producing and delivering a live vaccine against theileriosis and the parameters that need to be monitored to evaluate the efficacy and long-term biological impact of immunisation. The paper also briefly describes the technologies that are available to monitor immunisation.

Tick-borne disease vaccines

Currently all vaccines used against the important TBDs utilise live organisms. The vaccines for babesiosis, anaplasmosis and cowdriosis contain viable organisms in cryopreserved blood. The blood vaccines for babesiosis and anaplasmosis are prepared from donor cattle after the parasites have been rapidly passaged several times between cattle. This procedure attenuates the parasites so that they can infect recipient cattle and invoke protective immune responses without causing disease (de Vos, in press). The vaccine against cowdriosis utilises whole sheep blood containing live, potentially lethal *C. ruminantium* organisms. The blood is inoculated intravenously into susceptible cattle followed by a treatment(s) with oxytetracycline approximately five to ten days later when pyrexia is observed.

The problems associated with the use of live vaccines have been well recognised. These include requirement for a cold chain for delivery, severe reactions following immunisation, introduction of new strains of parasites and potential danger of spreading other organisms contaminating the vaccines. Therefore attempts are being made in various countries in Africa, Australia, Europe and the USA to use recombinant DNA technologies to produce subunit vaccines against various tick-borne pathogens (Musoke et al, in press). So far, a vaccine against theileriosis based on the antigen p67, found on the surface of *T. parva* sporozoites, shows promise in laboratory immunisation trials (Musoke et al 1992). However, this vaccine still needs further development and evaluation in the field. Therefore, in the short to medium term, live vaccines will continue to be used in the field. This paper focuses on the use of the infection-and-treatment method of immunisation against *T. parva* and the level of monitoring required to determine the efficacy of the method.

The infection-and-treatment method of immunisation against theileriosis caused by *T. parva*

Background

The method as it is currently used for immunising cattle against *T. parva* involves the use of live, potentially lethal parasites inoculated subcutaneously over a lymph node (usually the parotid) and the simultaneous intramuscular injection of a long-acting oxytetracycline at 20 mg/kg body weight. This method induces mild theileriosis followed by recovery. The drug provides prophylactic cover for up to five days. The vaccinated animals are subsequently immune to homologous challenge. Several formulations of long-acting oxytetracyclines are available through commercial companies while stabilates which could be used in immunisations are produced by only a few laboratories. The most critical element in the immunisation method is the availability of a well-characterised sporozoite stabilate(s). Only a few such stabilates are produced on a large scale and none is available commercially.

Over the years several stocks of *T. parva* have been identified to be suitable for immunisation using the infection-and-treatment method. One important criterion for the selection of suitable immunising stocks is the ability to provide protection against a wide spectrum of parasites. For example the Marikebuni stock, isolated from the Kilifi District of Kenya, has been shown to protect against field challenges in the Coast

Province of Kenya and experimentally against 15 different stocks of *T. parva* derived from various parts of eastern, central and southern Africa (Morzaria et al 1987a; Mutugi et al 1989). This stock has been selected for wider use in Kenya and is currently produced at the National Veterinary Research Laboratory at Muguga, Kenya. Similarly, a number of other well-defined stocks produced in Zimbabwe, Kenya and Zambia are being used for immunisation (Koch et al 1990; Morzaria et al 1986; Berkvens et al 1989). These include the Boleni, Zanzibar and Katete stocks. The Serengeti transformed, Kiambu 5 and Muguga stocks have been combined to produce a cocktail, referred to as 'Muguga cocktail', that provides protection wider than any of the three stocks used individually (Radley et al 1975a; Uilenberg et al 1977). This cocktail has been used in Malawi, Zambia, Uganda and Tanzania.

Immunity induced following infection-and-treatment immunisation

The cell-mediated immune responses to schizont-infected cells are shown to play a major role following immunisation by this method. The immunity engendered is effective against challenge with high doses of the homologous stock (Morzaria et al 1987b) and, in the absence of further challenge, the immunity has been demonstrated to last for more than 36 months (Burridge et al 1972). It is known that this immunity can be prolonged through further natural challenges. Cross-immunity studies and field challenge of animals immunised by the infection-and-treatment method have shown that different immunogenic types exist and that the immunity is strain or stock specific (Radley et al 1975b; Young et al 1973; Dolan et al 1980).

Important factors that influence the selection of parasite stocks for use in the infection-and-treatment method of immunisation

Immunogenic types

It is known that stocks of *T. parva* can contain a heterogeneous population of parasites and the quality and spectrum of protection provided by these parasites depends on the immunogenic composition within stocks. Different immunogenic types can be identified by *in vivo* cross-immunity studies. Parasite stocks that cause severe ECF reactions in cattle previously immunised with another stock are classified as immunologically different and are referred to as breakthrough stocks. In many of the cross-immunity studies that have been described for cattle-derived *T. parva* parasites it is interesting to note that only a small proportion of immunised animals (between 25 and 30%) undergo severe disease (breakthrough) when challenged with a different immunogenic stock. To ensure the widest possible protection, in the infection-and-treatment method, it is a common practice to test the protective capacity of the candidate parasite stabilate against a range of field isolates, derived from the area where immunisation will be applied. However, it must be borne in mind that even the stabilate of a stock selected by this procedure may sometimes not provide the expected protection when used in the field.

Virulence of parasites

The virulence of *T. parva* stocks has not been properly characterised. It is known that different stabilates of *T. parva* cause different ECF reactions ranging from mild to severe disease. It is generally accepted that severity of ECF is related to sporozoite dose and there are certain parasite stabilates that cause mild disease in cattle. A stabilate of the *T. parva* Lanet stock, isolated in Kenya (S.K. Mbogo, D.P. Kariuki and R. Rumberia, unpublished data), has been shown to produce mild disease in cattle. If stabilates of this stock, following several passages through cattle and ticks, retain their low virulence for cattle and yet provide extensive and long-lasting immunity, the use of such stocks as vaccines will be much more acceptable since drug treatment will not be required. The Boleni stock of *T. parva*, isolated from Zimbabwe, has been reported to be a mild parasite. It is being evaluated for immunisation without the use of oxytetracycline (J.J. Mutugi, personal communication). However, it must be noted that certain passages of the Boleni stock have produced severe reactions in cattle (Irvin et al 1989). It appears that the nature of the disease produced by ticks or sporozoite stabilates may not only depend on the dose but a number of other factors, yet to be identified.

Response to oxytetracycline

Determining an optimum immunising dose requires titration of the candidate stabilate against a fixed dose of the drug in groups of cattle. This may provide a dilution of a stabilate that gives acceptable reactions upon immunisation. However, this may also result in a loss or reduction of some important immunising parasites originally present in the stock. Generally it may be difficult to achieve an ideal immunising dose of a stabilate that will not cause severe reactions and yet stimulate 100% protection. A compromise may be accepted that errs on the side of safety.

Currently, *in vitro* tests are not available that correlate with the infectivity of stabilates in cattle. Therefore, an infectivity test of a newly prepared stabilate needs to be performed in susceptible cattle. The ECF reactions obtained with this test give some idea of the potency of the stabilate.

Cattle breed effects

Susceptibility to *T. parva* infection varies among cattle breeds. It is known that *Bos indicus* cattle are more resistant to infection than the *B. taurus* breeds. This is often reflected in the way different breeds respond to the infection-and-treatment immunisation. The optimum immunising stabilate dose determined for Boran *(B. indicus)* cattle may produce severe ECF reaction in exotic *(B. taurus)* cattle. This factor needs to be kept in mind when developing and applying the vaccine in the field and consequently characterisation of immunising stabilates should be carried out in the most susceptible cattle.

Age, weight and dose-related effects

It has been observed that ECF reactions observed in cattle may vary according to the age of animals. For example, an LD70 determined for *T. parva* Muguga stock (ILRI stabilate 3087) in young Boran cattle between three and six months of age produced less severe reactions when used in cattle over one year of age (S.P. Morzaria and T.T. Dolan, unpublished results). It is not clear if this variation in infectivity was due to different age susceptibility or due to the size of the animals. Therefore further research is needed to investigate the correlation between age, weight and the dose of stabilate on the success or failure of immunisation.

Factors that influence the efficacy of the infection-and-treatment immunisation method

Several immunisation trials have shown that when the infection-and-treatment method is applied using a well-defined parasite stabilate it can provide solid protection against ECF. This success depends on the production and characterisation of the stabilate according to established standards and with correct application. However, due to the nature of the method, it is also recognised that careful supervision is required during immunisation. Experience in the field has shown that if appropriate immunisation protocols are not followed problems may arise. A number of factors have been identified that can influence the efficacy of the method. The effects of these factors can be classified into four categories. These are:

- failure to invoke protective immunity after immunisation;
- severe reactions following immunisation;
- breakthroughs following successful immunisation; and
- induction of carrier state following immunisation.

Failure to invoke protective immunity

In some instances immunised animals do not develop immunity due to the failure of sporozoites to establish infection in the recipient animal. This is due to a decrease in or a complete loss of infectivity. Freeze/thawing of the cryopreserved parasites, exposure of sporozoites to high ambient temperature following thawing, severe osmotic shock due to improperly prepared diluent and radical changes in the pH are some of the factors that affect the infectivity of sporozoites. These problems are associated with improper planning and handling of stabilates prior to and during immunisation.

Severe theileriosis following immunisation

Because live, potentially lethal *T. parva* sporozoites are used, animals can undergo severe ECF if the infection is not adequately covered by oxytetracycline. This problem occurs when lower than the recommended dose of tetracycline is used or when the drug used has expired and subsequently become ineffective. Likewise, a higher dose of stabilate than recommended can cause severe disease. Improper stabilate dilution is often the problem. Severe theileriosis might also occur if the immunising parasite is used in animals of different breeds or age groups than those in which it was initially characterised. Immuno-compromised animals may also undergo severe ECF reactions following immunisation. Severe ECF reactions due to immunisation are usually detected within the first 30 days.

Occasionally, animals are immunised while they are incubating theileriosis following natural exposure. It may be difficult to differentiate the disease due to immunisation from the disease that is caused by natural challenge under this circumstance. Characterisation tools are then necessary to identify the problem (see below).

Breakthroughs following immunisation

Following immunisation, and after exposure to natural tick challenge, some animals may develop theileriosis. This is likely to be due to new immunological types present in the natural tick population. Such outbreaks of the disease in immunised cattle are referred to as 'breakthroughs'. As described above, the immunising stocks may contain a mixture of different parasite genotypes and the protective immune responses invoked in cattle are complex. It is unlikely that any one stock will protect against all the field challenge stocks. Fortunately, breakthroughs normally occur in only a low proportion of the immunised animals.

Carrier state and sexual recombination

Most *T. parva* stocks cause a 'carrier' state (Young et al 1981). This implies the presence of parasites that are transmissible to ticks in apparently healthy animals. Carrier states occur naturally in cattle that have been exposed to infections and have recovered. Animals that have been artificially immunised using the infection-and-treatment method may also become carriers of the immunising parasites, as demonstrated with the Marikebuni, Zanzibar and Boleni stocks. It is possible that the immunisation method might introduce the immunising stock into the non-immunised cattle population. This can be determined by monitoring the non-immunised cattle population. Recently, Morzaria et al (1992) have shown in a series of laboratory experiments that a sexual cycle occurs in *T. parva* and that genetic polymorphisms exist due to recombination. The possibility that the immunising parasites may recombine with the local parasite with the emergence of new genotypes should be borne in mind. Epidemiological studies need to be integrated with the infection-and-treatment immunisation to assess the impact of introducing new parasites on endemic stability, infections rates, parasite polymorphisms in the wild population and the long-term efficacy of the immunisation method.

In vitro characterisation tools

Several *in vitro* methods are available for characterisation of *T. parva* parasites. Numerous attempts have been made to develop *in vitro* tests that would correlate with *in vivo* immunity. So far these attempts have been unsuccessful. All the tests described below are either based on the use of parasite-specific monoclonal antibodies or DNA probes. These tests demonstrate polymorphisms in *T. parva* populations and are currently used as a set of tools to define existing laboratory-maintained populations of parasites as well as for characterising new field isolates.

Monoclonal antibody (mAb) profiles

Several mAbs that recognise the polymorphic immunodominant antigen on the surface of the schizont stage of *T. parva* (Shapiro et al 1987; Toye et al 1991) have been generated (Pinder and Hewett 1980). There are a number of mAbs that are being routinely used at ILRI to define polymorphisms in this antigen. Monoclonal antibody profiles are generated by reacting a set of selected mAbs in an immunofluorescence test (Minami et al 1983) against schizont antigens made from infected cell lines. Such parasite mAb profiles can be compared with other previously characterised stocks and those with similar profiles can be grouped together. Initially, using a few mAbs, a small number of profile groups were created and it was believed that those parasites that belonged to the same mAb group were cross-protective. This belief was based on the results of cross-immunity studies carried out with a limited number of parasite stocks (Irvin et al 1983). However, as more schizont-specific mAbs were generated and further cross-immunity studies were performed, using a larger number of parasite isolates from wider geographical regions, this correlation did not hold. Currently, mAb profiles are simply used as identifiers of parasite stocks and represent one of many useful tools available to monitor any changes or selection or accidental contamination that might occur during handling of stocks.

DNA typing tools

These are generated from genomes of different *T. parva* stocks and are based on unique parasite specific DNA sequences. Several such sequences have been used to define polymorphisms in different loci in the genome (Bishop et al 1993; 1994). The currently used, most useful probes are briefly described below. These probes can be used on either schizont- or piroplasm-derived genomic DNAs. It is important to note that the polymorphisms detected in the DNAs derived from the piroplasm and schizont stages of a *T. parva* stock may be different. It is believed that this is due to differential selection of parasites that might take place during its development in culture and *in vivo*.

Tpr DNA probes: These are derived from the repetitive sequences of a multicopy gene family in the *T. parva* genome which is transcribed in piroplasms. Two specific probes, all cloned in plasmids, include PMB3, a 623 bp fragment isolated from *T. parva* Muguga, and pBOLREP1, a 2.4 kb sequence isolated from *T. parva* Boleni. Both clones have been sequenced (Allsopp and Allsopp 1988; Allsopp et al 1989). These probes detect restriction fragment length polymorphisms (RFLP) in *Eco*RI digested DNAs of different stocks of *T. parva*. These probes have been shown to discriminate 20 different stocks and isolates (Bishop et al 1993).

Telomeric DNA probe: This was generated from a sequence of a chromosome end of *T. parva* and cloned in a plasmid. The clone pTpUtel contains a 1.74 kb fragment isolated from *T. parva* Uganda DNA, and cloned in pBluescript (Bishop et al 1993). The clone includes simple telomeric repeats and subtelomeric sequences. The clone detects up to 8 loci and differentiates most stocks/isolates. In a recent study of theileriosis epidemiology in Zimbabwe (Bishop et al 1994), this probe was the most useful for parasite isolate discrimination.

LA6 DNA probes: These consist of sequences derived from a multicopy gene family in *T. parva* which is transcribed in schizonts and piroplasms. The original clone was isolated by screening a *T. parva* Muguga schizont cDNA library with total genomic DNA. This clone is predicted to encode proteins with an unusual amino acid composition. The probe discriminates all *T. parva* stocks that have been examined.

Minisatellite probe: Dispersed repeat sequences have been isolated by screening a *T. parva* genomic library with M13 'minisatellite' sequences. This probe (laboratory code 6.21) hybridises to multiple loci in the *T. parva* genome and is present on most *Sfi*I fragments unlike the other available probes which are confined to limited regions of the genome. Most *T. parva* stocks/isolates are distinguished using this probe.

The sporozoite antigen gene p67 probe: A PCR-based assay is available for identification of the presence or absence of DNA insertion potentially encoding additional amino acids in the p67 protein.

Currently the above five probes are used to provide comprehensive and reliable characterisation of *T. parva* immunising stocks.

Necessity for monitoring immunised cattle

Although it is desirable to abolish any need for monitoring cattle following immunisation, this is as yet not possible because of the nature of the immunisation method. However, good planning and adherence to the described immunising protocol can greatly reduce the need to monitor cattle intensively. At the time of immunisation it is important to observe and record accurately the procedure of thawing and inocu- lation, time from thawing to inoculation, the age and breed of animals, the method of weighing animals, the weight of immunised animals and the amount of drug used. In addition, information regarding method of tick control and type of husbandry practised is useful. The drug manufacturer and the batch of drug used should be recorded. All these data are useful background information for further investigation in the rare event of the immunisation failing.

Monitoring immunisation

The primary purpose of monitoring is to ensure that the vaccine is safe and efficacious. Information obtained from several field trials performed in various parts of the

ECF-endemic areas show that there are three different periods during and after immunisation when monitoring is required.

Monitoring during immunisation

The period between the time of inoculation and sero-conversion is referred to as the immunisation period. Following immunisation the majority of the animals should undergo a mild, transient ECF reaction. However, a small proportion of immunised animals may develop clinical theileriosis. The immunised cattle should be monitored during the critical period when such reactions are expected. This period is usually well defined (usually between 10 and 20 days after immunisation) but varies according to the parasite stabilate used. This monitoring ensures timely diagnosis of any clinical disease and administration of appropriate therapy if required. This approach is recommended and serves to increase farmer confidence in the immunisation method.

Careful planning and participation from the farmers and veterinary assistants can reduce the monitoring period and potential loss of cattle. If a disproportionately large number of animals is found to be reacting following immunisation it is essential to intervene with treatment and investigate the reasons for these reactions. The procedure should be carried out to check if the theileriosis reactions result from immunisation or other causes such as incubation of theileriosis at the time of immunisation.

The need to have biological markers such as DNA probes specific for vaccine strains is very important to discriminate disease due to immunisation from natural infection. Theileriosis due to immunisation may occur between days 10 and 30 after immunisation. Disease observed before or after this period may be due to a different *T. parva* stock or another pathogenic agent.

Monitoring after immunisation

After immunisation, acaricide control may be reduced. This may increase the risk of tick-borne diseases and farmers and veterinary assistants should be made aware of this possibility. Monitoring may be necessary at this stage to ensure that accurate diagnosis is carried out of outbreaks of disease in immunised cattle. Any outbreaks of theileriosis are likely to be due to new immunological stocks. Further investigations are necessary if a large number of immunised animals develop severe theileriosis. These breakthrough parasites need to be isolated and characterised using all the tools described above.

Long-term monitoring is required to study the effects of introducing immunising parasites into an area. This should involve the impact on infection rates in ticks, endemic stability, the emergence of new parasite populations through sexual recombination and studies of parasite population dynamics. Although these studies are not necessarily required to be carried out as part of the immunisation programme they could provide information on the long-term impact of immunisation and its sustainability.

Conclusions

The infection-and-treatment method is available for immunisation against theileriosis caused by *T. parva*. The method when properly administered provides a significant level of protection. However, due to the nature of the procedure, it is necessary to monitor immunisation. Short-term monitoring is necessary to ensure that disease reactions due to immunisation can be treated in time to prevent losses. Medium-term monitoring is required to check on the spectrum of immunity provided by immunisation. Long-term monitoring is necessary to assess the effects of immunisation on the epidemiology of theileriosis.

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Integration of tick control with vaccination against tick-borne diseases

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Introduction

The purpose of this presentation is to review briefly those developments in control of ticks which may be useful in adapting to the situation where substantial control of tick-borne diseases (TBDs) may be achieved by vaccination. Focus is on the control of *Rhipicephalus appendiculatus* on commercial dairy and beef cattle that are the primary targets for vaccination with the infection-and-treatment vaccine against East Coast fever (ECF). This topic is the best documented and of the greatest economic importance amongst the African tick-borne diseases. The review is intended to stimulate discussion and appropriate research; not to provide prescriptive answers.

It is assumed that when farmers have their cattle vaccinated they will be unwilling to spend as much as they used to on tick control. There is evidence from personal communications and observation that tick-control practices are changing rapidly regardless of professional opinion. In some circumstances of peri-urban dairy farming there appears to be negligible tick control for unvaccinated cattle, where it would be expected from previous opinion that there would be severe problems with ticks and tick-borne diseases. Possibly farmers are ahead of scientists in establishing, by trial and error, systems that adapt to rapidly changing circumstances. It is the responsibility of scientists to formally structure and promote knowledge combining correct theory and farmers' experience (Cook 1991).

History

The traditional systems of tick control established in Africa about 80 years ago were based on the need to control the severe risk of outbreaks of ECF, particularly in imported cattle, and to meet the demands for national improvements in cattle productivity. The system of intensive and continually maintained acaricide application was modelled on the attempt to eradicate the cattle tick *(Boophilus annulatus)* and babesiosis from southern USA (FAO 1987). It was substantially supported by central government subsidy as part of systems of agricultural development, and it also enabled private farmers to raise exotic cattle in the face of threatened catastrophic disease. Okello-Onen et al (1992) describe the establishment and development of such a system in Uganda.

However, the high risk of relying on one method for control of tick-borne diseases was revealed starkly in Zimbabwe when a nationally high level of tick control collapsed during the war, resulting in heavy mortalities from TBDs in herds which had not acquired sufficient immunity by natural exposure (Norval 1983). The changing attitudes and practices in Zimbabwe are detailed by Norval et al (1992); the predominant influences being knowledge of the high risk of the previous strategy and of the importance of maintaining endemic stability; the increasing cost of acaricide use; and the availability of additional methods of control, particularly vaccination.

Eradication of ticks is possible on the scale of a single farm using intensive control on fenced pastures, particularly if the pastures are improved and intensively managed. Ticks are habitat-specific vectors, with very limited independent mobility. However, such local eradication cannot be maintained without resort to some form of tick control available for newly introduced infestations. Eradication on a national scale, up to the limit of sustainable barriers to re-infestation, has only been achieved once, in the USA, at great length and cost. A similar eradication attempt against *Boophilus microplus* failed in Australia (FAO 1987). Furthermore, it can be shown by mathematical modelling, particularly of the basic reproductive rate of vectors and transmitted pathogens, that extremely high levels of control need to be sustained for a long time to achieve eradication of any vector or pathogen. This applies equally to chemical control of vectors (Medley et al 1993) or vaccination against transmitted pathogens (Anderson and May 1991).

Options for changing tick-control methods

Pegram et al (1995) have defined the terminology of tick control in three categories. *Intensive control* is ‘acaricide application aimed at keeping animals totally free of ticks to prevent transmission of pathogens causing TBDs; this usually involves frequent application of acaricide throughout the year’. *Strategic control* is ‘acaricide application aimed at (substantial) reduction of tick populations and consequent reduction of level of transmission of pathogens causing TBDs; the timing of acaricide application is based on ecological information on the seasonal numbers of ticks and the frequency of application will vary during the year’. *Threshold control* is ‘acaricide application aimed at controlling ticks when they exceed a pre-defined, economically damaging number of adult ticks’. These consensus definitions should be adhered to, but I will later introduce the additional idea of control aimed at a threshold defined by pathogen transmission.

The changes in tick control required by vaccination are toward strategic and threshold control. The former has been tested in several situations, for example Moran and Nigarura (1990), Amoo et al (1993), and Soldan and Norman (1994). The application of this method to a national strategy has been advocated by Perry et al (1990). The necessary data for threshold treatment of *R. appendiculatus* was obtained by Norval et al (1988). This is the damage coefficient of the ticks: the loss of potential gain in liveweight of cattle caused by the feeding of one female tick (4.0 g of lost weight of whole cattle carcass per adult female tick). I can find no documented example of it being put into practical use so far.

However, caution has been advocated by many who are reluctant for institutional, national strategic, and political reasons to reduce the traditional system of mandatory country-wide dipping. The ability to access cattle at dips for surveillance of foot-and-mouth disease in Zimbabwe is a powerful strategic reason. Dip construction has become part of the system of political patronage in some countries, and in some veterinary departments many jobs depend on maintenance of the old system. In addition, Norval et al (1994) presented evidence of the spread of *Amblyomma* ticks in Zimbabwe, apparently as the result of reduced application of acaricide.

The options for change are often in the context of rapidly changing environments. The rapid increase of human population in Africa should be seen as an opportunity in the context of control of livestock diseases. This is particularly true for those diseases transmitted by vectors which are habitat specific such as ticks and tsetse flies. The larger human population boosts demand for cattle products, particularly commercially available milk in large cities. This improves cash flow to the farmers, enabling purchase of veterinary products and services. More fundamentally, the land becomes more intensively used which will, at best, clear out ticks from fenced and improved pasture or, at worst, reduce ticks in overgrazed pasture. The overgrazed land and its effect on ticks has been described in Zimbabwe by Norval (1977), Perry et al (1991) and Curry (1992).

Well managed land, climatically highly favourable to ticks, but becoming hostile to them because the pasture microclimate has been modified, are typified by the fertile highland areas of Kenya. The other pre-condition to such environmental control is a political system suitable for legalised land tenure, permitting fencing and private investment in the improvement of the land.

Why control ticks after vaccination?

It may seem that the only reason for controlling ticks after vaccination would be to control tick damage and worry (Tatchell 1987), using threshold treatment. The situation is probably more complex. Individualised systems of TBD control on adjacent farms is likely to produce highly patchy distribution of ticks and pathogens. At its most extreme, a situation could arise on neighbouring farms with one farm having effective herd immunity with live parasite vaccine and no tick control giving large numbers of infected ticks on that farm, and on the other a reliance on strategic treatment and pasture management giving very few ticks but with poor herd immunity. A spread of ticks on infested cattle straying from the first to the second farm could result in a serious problem.

Furthermore, the benefits of endemic stability need to be artificially maintained by all means possible. The primary means of doing this is intended to be by vaccination, but vaccination is a controlled means of doing what the tick does naturally, that is deliver parasites. Given vaccination and backup of curative drugs then the aim should be to allow a low population of ticks which transmit a small amount of pathogen. The tick feeding will induce and enhance resistance to ticks, even in exotic cattle, and the transmitted pathogen will boost the vaccine immunity. The fundamental difficulty is maintaining the ticks at a steady level, high enough in numbers to be useful, low enough to be of minimal risk.

The approach of integrated pest management (IPM)

There is a well developed body of theory and practice in crop pest control which gains maximum benefit for minimum cost by combining several elements of control measures, particularly making use of ecological factors and natural host resistance. Theoretical frameworks for IPM of *Boophilus microplus* were published by Sutherst et al (1979) and Norton et al (1983), incorporating strategic use of acaricide, pasture management and host resistance. The same approach has been advocated for African ticks by Tatchell (1987), Young et al (1988) and Pegram et al (1993). Integrated management of a vector-borne disease of cattle depends on manipulating the rate of flow of the pathogen through the cattle population such that immunity is gained at a controlled rate and timing. Obviously vaccine pathogen is controlled, but as long as there are vectors present their contribution to the rate of flow of pathogen must be controlled as well. However, none of these papers has dealt with the problem of what level the tick numbers should be managed to.

Management information

There are three solutions to this dearth of information. All of them should be worked on simultaneously. The simplest approach is farm survey work, to learn from the trials and errors of farmers (Cook 1991; Blanc 1992; Spickett and Fivaz 1992; du Plessis et al 1994). The most expensive but most direct approach is to set up experimental herds under conditions of natural exposure to ticks and tick-borne diseases and to protect test cattle with combinations of vaccine, acaricide and drugs, and compare their fate with unprotected control cattle. This has been done for beef and dairy cattle in three different epidemiological situations of ECF in Kenya (de Castro et al 1985; Morzaria et al 1988; Young et al 1992; Amoo et al 1993). The consensus of these studies was that vaccination is an economical alternative to reliance on acaricidal control, allowing acaricide use to be considerably reduced. Amoo et al (1993) concluded that the most cost-effective treatment was once per four to six weeks, at the Kenya coast. However, the ecology of *R. appendiculatus* here is sufficiently different from other areas to require follow-up studies elsewhere.

The cheapest and most fashionable approach is the construction of mathematical models, although without the long and expensive business of field validation none of them can ever be trusted for managerial use on farms.

The earliest and still the best was the simple empirical model of Mahoney and Ross (1972) for the transmission of *Babesia* by *Boophilus*. This can be used to predict the numbers of infected ticks that are required to infect sufficient proportions of calves with *Babesia* whilst protected by maternal antibody in the first nine months of life and thus gain pre-immunity. A more highly developed model of the same type has recently been developed by Randolph and Craine (1995). This has the great advantage of having been tested by them with data on transmission of *Borrelia*, and of being mathematically simple to use involving little more than multiplication of proportions. It should be applied as soon as possible to the empirical data available on ECF.

Statistical or stochastic models have been applied to the forecasting of *Amblyomma* population dynamics using time series analysis (Meltzer and Norval 1992), and stochastic elements have been combined with computer calculated simulation modelling of *R. appendiculatus* population dynamics (Nokoe et al 1992). Both these studies have the advantage of the statistical methods and simulation methods being accessibly described, but neither include pathogen transmission.

Fully developed deterministic simulation models, described in the literature and available as free-ware discs, have been produced for babesiosis (Haile et al 1992) and for ECF (Gettinby and Byrom 1989). These contain simulations of the seasonal population fluctuations of the ticks, the calculations being driven by data on the development rate determined by temperature. Onto these fluctuations are superimposed assumptions on the transmission rate of pathogens. However, in some models the assumptions on the ecological factors controlling tick populations are unrealistic, keeping the models at prototype level. However, when more developed and fully validated by field data these models hold the promise of being the easiest to use managerially.

A differential equation model of *Theileria* transmission has been developed by Medley et al (1993), including much validation from laboratory and field data. This requires good mathematical knowledge to use fully, but has the advantage of providing some simple sub-models, which can be adapted, such as the risk assessment equation detailed below. It also demonstrates how non-linear or counter intuitive many epidemiological relationships are, and thus the need for these theoretical studies.

Risk assessment

Elder and Morris (1986) provided an example of economic analysis applied to control of *B. microplus* such that the costs and benefits of various managerial decisions could be predicted. What is required for assessing the appropriate level of tick control in the context of vaccination is a simple model for assessing risk. An obvious relationship can be described by multiplying proportionate estimates of susceptibility of cattle (S) with tick numbers feeding on cattle (T) with infection prevalence and density of the ticks (I), to give a figure representing risk (R):

$$R = S \times T \times I$$

A very similar equation derived from a differential equation model of ECF is in Medley et al (1993).

This type of model is most likely to be managerially useful, as long as it can be validated by field experience and data and related to a threshold for acaricidal treatment based on pathogen transmission. Furthermore, the use of such models has to be related to the practical options available to farmers. To a farmer the choice is likely to be constrained by other farming needs, to two or three simple alternatives. Thus, any decision-making model or expert system must provide simplified answers useful within the same constraints.

Previous reviews of this topic (Norval and Young 1990; Berkvens 1993) stressed the need for more field work to monitor changing epidemiology and validate models. Sadly, there seems to be less access to field reality since then. As long as there are vectors, the management of vector-borne disease will never be more than trial and embarrassing error, unless the current and local contribution of the vectors to disease is understood by means of ongoing field studies.

Conclusion

Tick control should be considerably reduced when cattle are protected by vaccination. More information is required on local variations in the degree to which control should be reduced. Better predictive and risk assessment systems will be useful for more efficient tick control.

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Evaluating delivery systems for the control of tick-borne diseases

Planning and evaluating delivery systems for the control of tick-borne diseases

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Introduction

In the tick-borne disease (TBD) control research and development continuum, delivery systems for TBD control have invariably been considered last, after diagnostic tests, vaccine development and other technical functions. This is not altogether surprising, since from an animal health research perspective the development of a TBD control technology comes before its delivery. However, from an investment and commercial perspective, the logical first step is to critically evaluate, *ex ante*, what are the potential net benefits of different control options. In the calculation of potential net benefits, the costs, feasibility and sustainability of delivery systems need to be included as factors.

The general economic and specific agricultural environments influencing the choice and delivery methods for animal health services are changing very rapidly in sub-Saharan Africa. Reduced public sector resources, privatisation and market-oriented policies are new and future realities that have been adopted by virtually all governments in the region. In the delivery of animal health services, there has been increased interest in the last 10 years in the relative role of the public and private sector and other issues related to the feasibility and sustainability of the delivery systems for animal health services (de Haan 1995; de Haan and Bekure 1991; FAO 1990; Holden et al 1996; Leonard 1985; Perry 1996; Schillhorn van Veen and de Haan 1995; Umali et al 1992). Any proposed animal health delivery service must be demonstrated to be cost-beneficial, adaptive and sustainable.

This paper will focus on the general considerations for planning and evaluating TBD control delivery systems and not emphasise technical considerations such as cold chains and handling of live vaccines. It will be argued that the net benefits, ease of delivery and sustainability of TBD control delivery systems will vary greatly between potential target groups of farmers and between specific farming systems. The identification and ranking of the most promising target groups and areas should be done using *ex ante* methods. However, for other groups and areas without a high economic or sustainability ranking, special provisions will need to be made if other criteria require that TBD control be delivered there, most probably relying on lessons learned as experience is gained in delivery methods in target groups and areas. In the planning of delivery systems for TBD control for any group within any area, special emphasis needs to be placed on the linkages between different key players, since the total system can be undermined by the failure of any one component.

Organisation and function of delivery systems

The basic organisation of any TBD control delivery system includes components at regional, national, provincial/district/area, and farm levels. An important question at each level is who should act as key players and provide specific service components. Prospective candidates include international and regional organisations, government veterinary services, private veterinarians, commercial companies, and non-governmental organisations (including farmer groups). Who does what depends on the comparative advantage of different players, the scale of operation required, sustainability considerations and the ability of the player to form linkages with other groups. Two general sustainability criteria in developing delivery systems for TBD control are that there should be a proper mix of public and private sector responsibilities, and that there should be an emphasis on transforming key players into stakeholders, who must depend on the success of the delivery system for their own success.

For the optimal functioning of a delivery system, it is important to consider linkages between the key players or stakeholders. While it is important that each group concentrate on doing their part well, it is also important that everyone considers the broader picture and contributes constructively to difficulties that other players in the system are having. This is particularly important in linkages with farmers. Ashby (1987) demonstrated that involving farmers in research and delivery planning was more cost-effective than planning by scientists and technical staff only. In these partnerships, neither farmers nor technical staff should be passive. Everyone has a role and valuable information to contribute. One example of an attempt at building linkages within a research and development project is a resource management project in Egypt which designed a programme to involve all stake-holders (de Haan 1995).

The relative roles of the public and private sector depend on who benefits. If the benefits mainly accrue to individuals, then it is mainly a private sector concern and if there are collective benefits then the public sector should be involved (Umali et al 1992). In many circumstances a mixture of public and private sector involvement will provide optimum benefits. Table 1 provides examples of delivery or delivery-support functions for which different key players at different levels would have a comparative advantage. For TBD control, I would argue that information and quality control assurance were mainly public goods, but that vaccine production and vaccine and acaricide delivery were mainly private goods, although in some settings (communal grazing), their public good function would increase. For vaccine production, it could also be argued that since many of the vaccine users would be resource-poor farmers, this would also make it an important public good. An important consideration for functions such as vaccine production and information services is the scale of operation.

Table 1. *Different levels of support required in a tick-borne disease control programme, some key players at each level and their potential roles based on comparative advantage.*

Level of support	Some stakeholders/key players	Examples of functions for which there is comparative advantage
Regional	International agricultrual research centres (IARCs)	Research information
	Multilateral technical assistance (e.g. FAO)	Information Technical assistance
	Regional institutions (e.g. SPAAR, SAADC)	Capital-intensive R&D
	International commercial companies	Manufacture Distribution networks
National	National agricultural research and extension institutes	Technical expertise Research/extension networks
	Farmers' organisations	Client perspective
	Commercial companies	Distribution networks Market orientation
District (livestock system)	Veterinary staff	Technical and local expertise
	Farmers' organisations	Coordination of small client groups
	Non-governmental organisations (development-oriented)	Local delivery networks
Animal health station	Extension worker	Local knowledge and contacts
	Local farm and other organisations	Organising farmers
Farm	Farmer	Farm management

If a standard TBD live or subunit vaccine is agreed upon, standardised quality control and production would probably be most cost-effective if the vaccine was produced at one or two sites. For information services, there will be different scales of information requirement from regional to national to local levels that can best be handled by organisations functioning at those levels.

In the delivery of TBD control, it seems likely that either joint private/public or solely private delivery systems with public sector monitoring will evolve. Different countries and perhaps different areas within countries will choose different mixtures of delivery. A guiding principle should be that whether the deliverers are in the private or public sector, they need to become stakeholders in the system.

Characterisation of areas and groups for their potential to support delivery systems

Potential impact of control measures

Risk of morbidity and mortality to tick-borne diseases

The usual starting place in determining whether an area should have high priority for TBD control efforts is the relative risk of morbidity or mortality from TBDs versus other areas. These risks need to be determined by well-designed sampling studies rather than by using secondary data from veterinary department records. Veterinary records can be biased in many cases because suspected cases of TBD are difficult to diagnose solely by clinical signs and TBDs with high case fatality rates such as East Coast fever (ECF) are more likely to attract veterinary attention.

A key concept in characterising areas as to their potential for TBD control is the notion of endemic stability and instability (Norval et al 1992). Unstable areas for specific TBDs have either high and/or fluctuating morbidity and case fatality rates for that TBD or else require careful control to prevent morbidity and mortality. The goal of a TBD control programme should be to assist in the development of endemic stability. Quick but imprecise methods to characterise areas as to their endemic stability and instability have been used and follow-up recommendations made (Deem et al 1993). Factors that influence the endemic stability and risk of TBDs include: ecologic/climatic factors, grazing system, predominant cattle breed and standard TBD control measures (Perry and Young 1995). Although the absolute and relative risk of TBD occurrence are a guide to establishing priority areas, other criteria may override them. These include the impact of control measures and the economics of livestock production.

Impact of control measures

The impact of a technology in most agricultural delivery systems cannot be assumed to be uniform everywhere and is likely to vary somewhat from area to area (Biggs and Farrington 1991). Impact estimates by major farming system and area (e.g. periurban smallholder dairy, more extensive smallholder dairy/beef, and more extensive farming systems, etc) need to be made, in conjunction with appropriately designed efficacy trials. In such assessments it is important that not just the costs of disease are estimated, the question of importance is what is the economically optimal level of control (McInerney et al 1992).

Since the impact of control needs to be considered prior to planning the delivery system, an *ex ante* assessment of net control benefits is required (Mukhebi 1992; Mukhebi et al 1992). A theoretical graph comparing net benefits under three different control programmes is illustrated in Figure 1. The shape of the net benefit curve versus time is mainly influenced by expected adoption rates. Note that if adoption is delayed this will delay the benefits resulting from the programme and adversely affect the return on investment. *Ex ante* assessments can be aided by *ex post* assessment of control programmes conducted in pilot areas. Limited *ex post* analyses could be used to refine impact of control estimates over time but in general it is better to concentrate on doing good *ex ante* assessments; just as for private practitioners it is better to perfect preventive medicine rather than *post-mortem* skills.

An important consideration in estimating the potential impact of controlling one TBD is the risk of other TBDs in that area. For example in East Africa, theileriosis is the main problem in many areas while in Central and Southern Africa a mixture of TBDs (e.g. heartwater, babesiosis, anaplasmosis and theileriosis) is more common. This will influence both impact estimates and delivery package options.

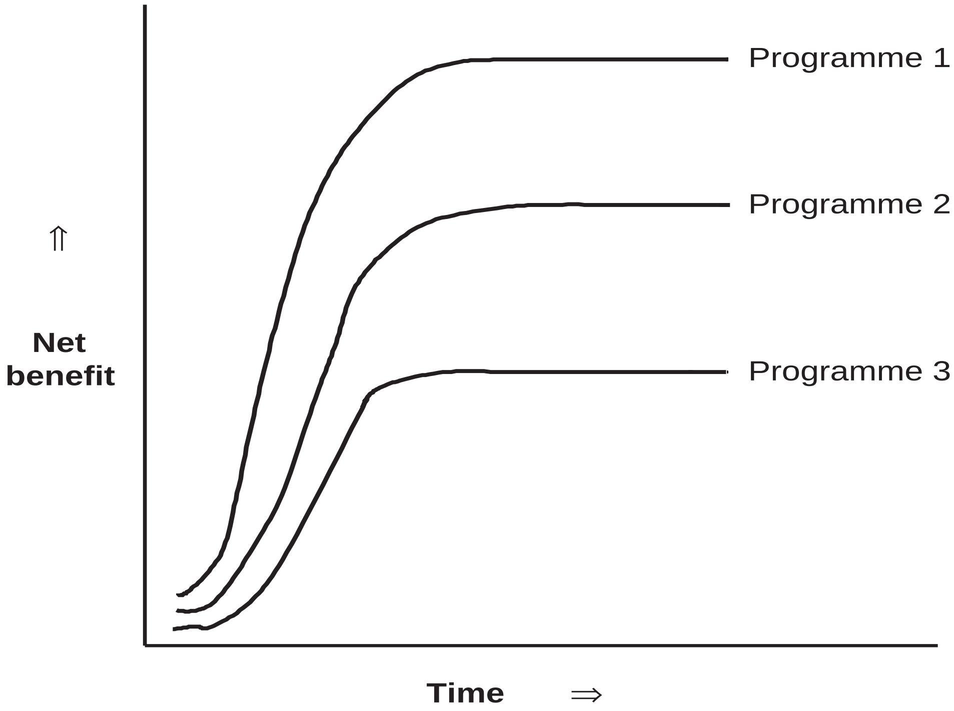

Figure 1. *Measured net benefits for potential delivery systems over time.*

Effective demand/value of livestock products

Of crucial importance in characterising areas as to their potential for sustainable delivery of TBD control programmes is to assess the effective demand for control. Canvassing farmers' views and including farmers in planning and revising delivery systems is an important beginning. However, it is not always easy in meetings, discussion groups or interviews to determine what people will actually pay. Market surveys, or pilot schemes to offer products at sustainable pricing levels can be important in quantifying farmers' willingness to pay and thus the potential adoption rate.

A number of criteria could influence the effective demand for TBD control. The value of saleable or monetarily valued livestock commodities (e.g. milk, draft) will strongly influence farmers' ability to pay, and the impact of TBDs on these, their willingness to pay. In some circumstances the average risk may not be high, but for valuable cattle, such as expensive dairy cattle on smallholdings, farmers may be very risk averse and anxious to avoid any loss.

Available infrastructure and organisations

Available infrastructure will influence the cost of delivery and will reflect the general economic demand for livestock products. Good roads and a high density of farms and cattle will greatly decrease transportation costs and minimise cold chain storage requirements. If these are not available, special arrangements to muster cattle to reduce costs will need to be made.

Two specific needs for the delivery of sustainable TBD control are the availability of an organised animal health staff and the development of effective farm organisations. Since TBD control is fundamentally a private good and unlikely to be supported for long by public funds, either an efficient private veterinary service or a cost-recovering public service is required. Farm organisations can vary in their effectiveness and sustainability. In Kenya, dairy cooperatives near Nairobi are relatively strong compared to others because they can market the majority of their milk at retail prices, thus avoiding reliance on the large Kenya Cooperative Creameries (KCC), which pays less and often months in arrears.

Factors influencing the sustainability of delivery

Clearly, the factors used above to characterise areas as to their suitability to support delivery systems will be important determinants of their sustainability. There are also some specific organisational factors that will influence sustainability. These include the development of a system in which all key players benefit, both a perceived and actual impact in reducing losses to farmers, a performance-related payment system for service deliverers, and a method by which the delivery of TBD control can be linked to the payment system for livestock products (e.g. monthly milk payments). Key players or stakeholders in the delivery system will incur different costs and obtain different benefits, some quantifiable and others difficult to quantify. In TBD control delivery systems there must be, and be seen to be, benefits for all participants.

These mutual benefits will not be obtained without effective linkages within the target livestock production and TBD control delivery systems. For TBD control to be sustainable, the livestock production system it serves must be sustainable. Thus, a key feature of delivery system planning will be to coordinate TBD control with the provision of other services to livestock farmers (Walshe et al 1991).

Assessment of delivery systems

The objective of all monitoring and evaluation efforts should be to promote learning and responsive management to improve the delivery system. It should not be viewed solely as an evaluation procedure. Little benefit is gained by assessment unless lessons learned are to be applied. Since the ultimate clients are farmers, participatory methods to obtain farmer’s assessments and suggestions for improving delivery must be an important component of evaluation (e.g. Chambers and Jiggins 1987).

Only a few assessment measures on impact should be widely collected. Otherwise, the assessment component becomes too cumbersome and costly. I would recommend changes in morbidity and mortality rates of TBDs, adoption rates by farmers, and costs of production and delivery as the essential measures. Other crucial information on changes in production parameters and changes in farm and deliverer income could be collected in specifically designed studies of sampled populations rather than on a routine basis. This additional information will allow for the assessment of cost:benefit ratios.

Delivery system function can be assessed using staged delivery designs in which the control programme is first introduced in randomly selected delivery units (e.g. area and deliverer within area) and short-term impact measures quickly assessed between programme and control areas. Then the delivery programme can be adjusted and extended to other areas. Since there are a number of levels of delivery, multi-level statistical models (e.g. Schall 1991; von Korff et al 1992) have been suggested for such assessments (Kadohira and McDermott 1994) based on the example of Entwisle et al (1984) who assessed the delivery of birth control services in Southeast Asia. Such studies can be particularly valuable in isolating the critical control points in the system. This could be important in the delivery of the live and difficult-to-handle vaccines used in TBD control since they could identify, for example, whether all or just a subset of veterinarians undergoing a certain training programme were having a poor response.

Summary

The delivery of TBD control should be targeted to areas where it will provide the greatest benefit. Potential benefits should be assessed using *ex ante* methods based on data from well-designed epidemiological studies. In the planning of TBD control delivery systems, specific attention must be paid to developing strong linkages both with other service providers in the target production system(s) and among key players concerned with TBD control. Particular attention needs to be paid to the needs and opinions of the client farmers. Since the control of TBDs is primarily a private good, development of private or mixed public/private delivery mechanisms based on full cost recovery must be emphasised. The primary objective of methods to assess TBD delivery should be proactive, to improve system management. Only a few outcome measures should be collected routinely, supplemented by targeted studies in sampled populations.

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Commercialisation of delivery systems

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Introduction

This paper briefly addresses some of the issues involved in ‘gearing up’ to full commercialisation of the system for immunising against theileriosis.

I have purposely assumed that many of the points raised in May 1994 by N. McHardy in a similar address to the Lilongwe meeting on tick-borne disease control have been answered and that it is believed by governments and donors alike that some involvement of the private sector will be crucial to the final success of delivering immunisation against theileriosis.

Secondly, I do not intend to examine the technical merits of the system, but once again I assume that we have a product which, when used according to the manufacturer’s recommendations, will immunise cattle against theileriosis within the relevant country. I will attempt to follow the logic in the text through a series of subheadings.

Systems don’t sell, products or, more correctly, product benefits do

Infection and treatment (IT) is a more difficult ‘product’ than most to sell, because the success of the product and hence the benefit to the customer is reliant on a technically involved delivery system; one cannot currently have one without the other. As has been pointed out many times previously, IT is potentially lethal and so it is unlikely that, unless significant changes to the present product can be made, ‘backup’ could be substantially reduced.

Customer need must be approached from ‘bottom up’ not ‘top down’

Whilst the successful use of IT in many countries has shown real and demonstrable demand for the system, little thought seems to have been given to the needs of the buyer i.e. the farmer.

Levitt (1983) defines the difference between marketing and selling as: ‘Marketing focuses on the needs of the buyer: selling on the needs of the seller.’

Currently there has been a crude assessment that the poor farmer requires this technology and we are now involved in a desperate attempt to ‘sell’ the system. Whereas, the real need of the customer is to control tick-borne diseases (TBDs) cost effectively and, in order to offer a real benefit, we will need to demonstrate much more than simple efficacy.

The marketing world is full of good product ideas which crashed. From my own company, FECUNDIN which successfully enhanced fecundity in sheep failed because the majority of farmers could not manage the resulting number of multiple births. In the big league, Sony's BETACAM system was acknowledged as being technically superior to Panasonics VHS, but became an expensive failure.

Product casualties arise because:

- The real needs of the customer are not met.
- The product is outsold/marketed.

In moving to the next level of achieving 'commercial success' the project would do well to consider another definition of Levitt's: 'The purpose of business is to create and keep customers. To do this, goods and services must be produced and delivered that people want and value, at prices and conditions that are more attractive than those of competitors.'

The missing link currently is the absence of a real marketing plan which should comprise the following elements:

- define target audience (partially achieved);
- SWOT (strengths, weaknesses, opportunities, threats) analysis/key success factors;
- establish pricing; and
- sales/advertising and promotion plan.

The key question is whether or not there is a product available to sell now.

At the moment the product seems stuck in the perennial battle between scientists and marketeers in the product development cycle; i.e. scientists want to continue researching until the product is 100% proven; whereas marketeers, once basic criteria are met, want to get the product to the market as soon as possible.

If the decision is that the product is 'ready to market' then the scientists must let go and abide by the SWAN principle—'sell what's available now'.

At a previous workshop I was asked to talk about the communication challenge facing popularisation of IT and I still believe this is the most difficult question facing the project for the following reasons.

Lack of trained personnel

As suggested previously, IT needs to be supported by adequately qualified people; such people are not currently abundant in the target areas. This is why IT has often been linked to the privatisation of veterinary services, but the fact is that the project cannot afford to link itself to this noble but as yet largely unachieved goal.

Advertising and promotion

IT, because of its nature, is not another product which can be sold like a soap powder. The product will become popular through demonstration which is a very effective means of advertising, although very costly as it needs to be constantly repeated on a regional basis.

Table 1. *The cost of tick-borne diseases compared to the cost of their control.*

Cost of TBD		Cost of control (US$)														
		(2) Dipping					(3) Treatment					(4) Vaccination				
Number of deaths	(1) Value of animal (US$)	Immersions	TD	TC	DX	GR	Cases/year	a) OTC	b) IMI	c) BUT	d) DOX	Head	HW	TH	RW	AN
1	303.21	1	0.13	0.06	0.14	0.11	1	4.00	4.99	21.40	2.51	1	0.89			
2	606.42	5	0.67	0.29	0.71	0.54	2	7.99	9.99	48.81	5.02	5	4.43			
3	909.63	10	1.33	0.57	1.43	1.07	3	11.99	14.98	64.21	7.53	10	8.86			
4	1,212.84	15	2.00	0.86	2.14	1.59	4	15.98	19.98	85.61	10.05	15	13.29			
5	1,516.05	20	2.66	1.14	2.85	2.14	5	19.98	24.97	105.76	12.56	20	17.72	Not available	Not available	Not available
6	1,819.26	25	3.33	1.43	3.57	2.68	10	39.95	49.94	214.03	25.11	25	22.15			
7	2,122.47	30	4.00	1.17	8.41	3.21	15	59.93	74.91	321.05	37.67	50	44.29			
8	2,425.68	35	4.66	2.00	5.00	3.75	20	79.90	99.88	428.06	50.23	100	88.59			
9	2,728.89	40	5.33	2.28	5.71	4.28	30	119.86	149.82	642.09	75.34	200	177.17			
10	3,032.10	45	6.00	2.57	6.42	4.76	40	159.81	199.76	856.12	100.45	300	265.76			
11	3,335.32	50	6.66	2.85	7.13	5.35	50	199.76	249.70	1,070.15	125.56	400	354.34			
12	3,638.53	52	6.93	2.97	7.42	5.56	60	239.71	299.64	1,284.19	150.68	500	442.93			

Figures have been converted to US dollars at the rate Z$ 8.4141 to US$ 1.00 as of 28/7/95.
All dosage and costs calculated for a 300 kg animal.

1. Value of animal at current market prices (Z$ 8.50 kg quoted for heifers and steers, Zimace report of 17 March 1995).
2. Costs/immersions calculated for:
   Triatix D (TD), amitraz 12.5% EC;
   Taktic Cattle Dip (TC), amitraz 25% WP;
   Decatix (DX), deltamethrin 5% EC; and
   Grenade (GR), cyhalothrin 5% EC.

This assumes animal removes 2.5 litres of dip wash per immersion. Costs as per Coopers price list dated June 1995.

3. Costs for treatment as per Coopers price listed June 1995.
   OTC: oxytetracycline 100 mg/ml given at dose rate of 10 mg/kg once daily for two days for heartwater (HW) and anaplasmosis (AN).
   IMI: imidocarb dipropionate 120 mg/ml given at dose rate of 120 mg/100 kg as a single dose to treat redwater (RW) and 300 mg/100 kg as a single dose to treat anaplasmosis. Figures given are for the treatment of redwater.
   BUT: buparvaquone (for treatment of theileriosis, TH) 50 mg/ml given at a dose rate of 2.5 mg/kg as a single dose. This same dose rate can be repeated in 48 hours if required.
   DOX: doxycycline hydrochloride 480 mg/tablet given as a single 5.5 mg/kg implant.
4. Cost per dose of vaccine: freeze dried live Ball 3 strain HW vaccine available from Department of Veterinary Services. No *Theileria* (TH), *Babesia* (RW) or *Anaplasma* (AN) vaccine available at time of writing (July 1995).
5. Other: Refers to costs not catered for in table, e.g. loss of breeding potential (under value of animal), cost of labour and management, costs of blocking antibiotic doses associated with vaccination as well as veterinary fees.

Communications level

Although the system can be complex to explain, final ‘buying decisions’ of the farmer may well be made on the advice of ‘lay staff’, e.g. extension officers, veterinary pharmaceutical representatives who may not have the same scientific grasp as the current project personnel. It is therefore extremely important that all communication must be at the simplest common denominator. If we can’t answer simple questions like 'how often should I dip or spray my animals after vaccination?', we are not providing the customer with evidence of the real benefit to him/her.

Summary

Given a systematic, structured approach to the marketing of IT technology by a commercial company, i.e. one that focuses on the real benefits to the customer, there is a significant market for 'the vaccine'.

However, it is doubtful that any attempt 'to market the vaccine in isolation' will succeed.

It should be centred as part of a total approach to improving the current methods for controlling TBDs. As Table 1 demonstrates, the cost-benefit equation to each farmer in using the vaccine will vary according a number of factors including: level of TBD challenge; cost of alternative methods of TBD control (analysed under current Zimbabwean costs); and cost/quality of available labour.

In reality an overall lack of 'cash in the pocket' in most parts of Africa tends to mean that the second factor will be predominant.

My final message to scientific colleagues assembled here is: if you are fully satisfied that the product you have developed works, leave the marketing to the marketeers and concentrate your efforts on what you do best, developing even better systems of control.

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Measuring the impact of immunisation on livestock productivity

Tick-borne disease control: the role of impact assessment

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Introduction

In a world of ever-increasing competition for resources, human, economic and environmental, it is now more important than ever before that a thorough understanding is acquired of the effect of large-scale interventions to relieve constraints to livestock production, such as disease control programmes. This is in order that the impacts of such actions can be defined not only in biological efficacy terms (the focus of the paper by Morzaria in these proceedings), but also in terms of the improvements in livestock productivity, and in terms of socio-economic and environmental impacts the programmes will have. In the case of tick-borne infections of livestock, which are widely distributed in Africa and many other tropical and sub-tropical regions of the developing world, their effect on livestock productivity varies widely by production system, agroecological zone, and other factors. It is thus important to define clearly their impact under priority production systems, such as smallholder dairy enterprises, and determine the impact of interventions to control them. This will help identify priority populations at which to target tick-borne disease control technologies, as well as demonstrate to farmers, implementing groups and donors the value of investing in such interventions.

At ILRI, a systems analysis and impact assessment research group exists, with the responsibility of evaluating the impact of priority constraints to livestock productivity, and predicting the impact of new technologies under development at the institute to relieve these constraints. The group operates by developing strategic impact assessment models, with the collaboration of selected national agricultural research system (NARS) institutes as case studies, and of advanced research institutes with expertise in model development. This framework (see Figure 1) permits the progressive improvement of model quality and capacity, the enhancement of data sets on impact, and the use of models in some countries to determine the impact of specific constraints. This framework has been applied in particular to determining the impact of theileriosis and its control through immunisation, and the host country for this workshop, Zimbabwe, has been an active collaborator in this research.

What is impact assessment?

Impact assessment, with reference to tick-borne disease control, is a multidisciplinary evaluation of the effect of these diseases on agricultural productivity, and the effect of

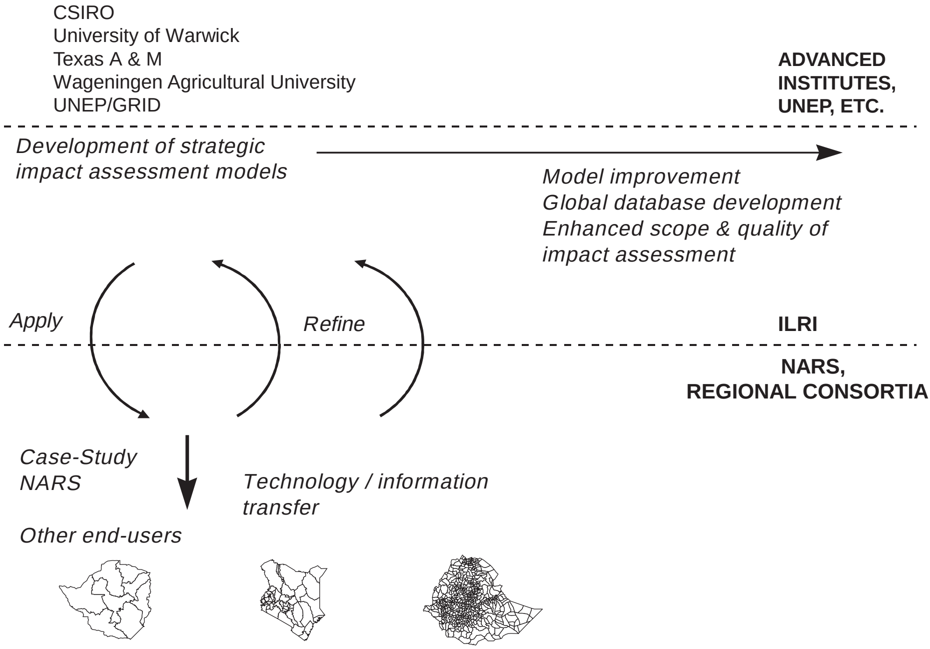

Figure 1. *Conceptual framework of the operation of ILRI's Systems Analysis and Impact Assessment group.*

alternative interventions to relieve them. It is a response to questions raised by different key stakeholders in the processes of national development, enhancing agricultural productivity, and improved tick-borne disease control. These questions include:

- How important are tick-borne diseases as a constraint to livestock productivity? This requires an evaluation of their effect on parameters such as mortality, morbidity, milk and meat production, traction and other direct and indirect products of livestock production systems.
- Where do tick-borne diseases occur, where are they a priority and where are they not? This requires an assessment of the different risks of the effects of tick-borne infections to which cattle are exposed. This will vary according to climatic factors and agro-ecological factors, cattle susceptibility factors, economic factors, as well as the relative priority attributed to different geographical regions, socio-economic groups and livestock products.
- Which is the best strategy to control tick-borne diseases? This requires an assessment of both epidemiological and socio-economic consequences of alternative disease-control interventions.
- What other constraints need to be addressed in order for tick-borne disease control to have its optimal impact? This involves assessments of the other factors likely to impede the optimal adoption and impact of tick-borne disease control measures, and often includes feed resources and the availability of improved genetic stock.

Who wants impact assessment and why?

The results of assessments of the impact of tick-borne diseases and their control are required by different client groups. These groups vary in the breadth and depth of their perspective, and may be asking different questions, so the results often have to be packaged and presented in different ways to meet client needs.

Donor agencies and national development and planning departments share some requirements for impact assessments of tick-borne diseases and their control. These include a broad understanding of the role of livestock in agricultural development in different regions, a knowledge of the relative importance of tick-borne diseases *vis-à-vis* other constraints to livestock production, a knowledge of the predicted effects of controlling tick-borne diseases, the likelihood and timing of this being achieved, and an understanding of the returns on investment if control is successful.

In addition, they will need to have an estimate of the resources required to ensure the effective control of tick-borne diseases, and an understanding of what else must be done to ensure the optimal impact of interventions.

Once resources have been allocated, the questions required of impact assessments become more specific. Thus for implementing groups such as departments of veterinary services, under whose authority tick-borne disease control programmes may lie, requirements of impact assessment would include an understanding of the character, location and size of populations at risk that are targets for control programmes, of the relative efficacy of different control strategies, of the costs and benefits, including improvements in productivity, of different control options, and of the relative merits of different delivery mechanisms to transfer the tick-borne disease control technology to the ultimate clients (see McDermott's paper in these proceedings).

For farmers, the requirements for impact assessment are even more specific. These will include establishing whether livestock performance, in terms of milk yield, beef production, traction, etc, is optimal, and if not, determining what factors are constraining the performance. If these factors are deemed to include tick-borne diseases, farmers will wish to know the control options available, their relative efficacy, the costs and benefits, and any risks involved.

Thus it is important to see that at all levels of impact assessment, there is a need to put tick-borne diseases in a broad context that allows its importance to be ranked alongside other issues of importance to the particular client.

The scope of impact assessment

In the past, veterinarians have been somewhat conservative in their interpretation of impact assessment, and have concentrated on demonstrating biological efficacy of control measures. Thus for vaccines, this might include the demonstration of an acceptable antibody response, and reduction in mortality. With the fierce competition for resources, this interpretation is no longer adequate and greater breadth to impact assessment is now required. This includes quantitative assessment of any alteration in the productivity performance of animals subject to control programmes, and the economic impact this has on farmers, on consumers of livestock products, and on national economies. But impact assessment is extending yet further, and many donors, for example, require assessments of the social and environmental impacts of disease control interventions. It is worth noting that for many bilateral donors and international agencies, their missions are no longer to enhance agricultural productivity in the developing world, but to alleviate poverty, enhance food security and protect the environment.

Methods of impact assessment

As mentioned above, historically much of the impact assessment of tick-borne diseases control has been calculated on the basis of statistics on the reported occurrence of the diseases, and in some cases the extrapolation of these figures to other regions. This has relied on passive disease surveillance systems, which are notoriously inaccurate (FAO 1994). Impact of tick-borne diseases has been measured more effectively in a few areas and production systems through the use of longitudinal studies (e.g. Barnett and Bailey 1955; Yeoman 1966; O'Callaghan et al 1994; Okello-Onen et al 1994). In such studies, animals are observed over extended periods of time, and the relationship between tick-borne infections and productivity losses established and quantified. In addition, some indicators of tick-borne disease occurrence, particularly serology, have been used as surrogates for disease incidence and mortality data (reviewed by Perry 1996), and applied in both longitudinal and cross-sectional studies.

As far as the impacts of tick-borne disease control are concerned, these have been assessed predominantly through the use of biological efficacy studies, carried out by clinical trials. It is only relatively recently that an economic perspective has been added, and initially at ILRI this was done as a retrospective economic evaluation of a study already undertaken (Mukhebi et al 1989). However, it is now recognised that economic impact assessments should be incorporated into the design of clinical trials and field evaluation studies to ensure that the appropriate parameters are measured, and that the appropriate analysis methods are used.

Impact assessment therefore requires the selection of appropriate indicators of impact and their incorporation into well-structured methods. Common methods include surveys (in which areas or production systems are described through the use of interviews or direct observations) and studies (in which comparison groups are included). The main study designs, which are described in detail in most epidemiological texts (such as Martin et al 1987; Thrusfield 1995), comprise cross-sectional, case control and longitudinal studies. The cross-sectional study, which measures prevalence retrospectively, has been employed commonly with tick-borne pathogens (Deem et al 1993) to measure antibody prevalence, but as discussed by Perry (1996) this is often an inadequate measure of the impact of tick-borne diseases. This is because the relationships between antibody prevalence and disease incidence have not been determined for the different tick-borne infections in all the production systems. Although there is generally a relationship between high antibody prevalence and low disease incidence under conditions of endemic stability,

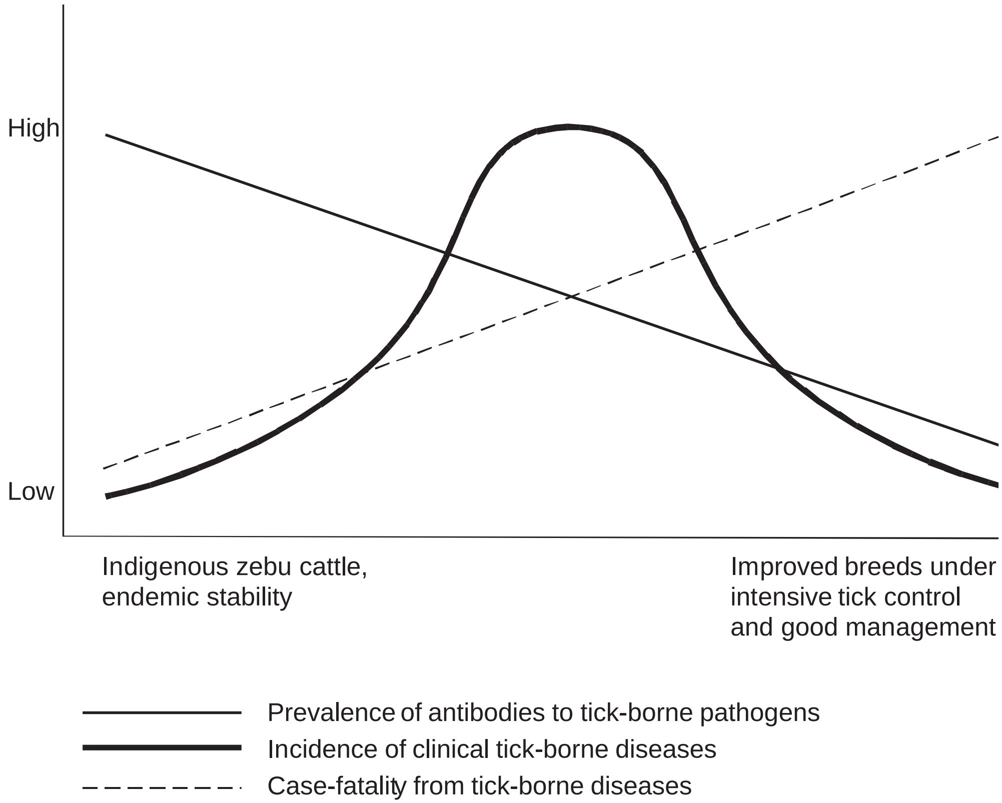

Figure 2. *The probable relationship between disease incidence, antibody prevalence and case fatality under varying conditions of endemic stability and instability to tick-borne infections.*
Source: Perry and Young (1995).

and low antibody prevalence and high disease incidence under conditions of endemic instability, there are numerous intermediate conditions which are poorly defined (Figure 2).

More valuable as a study design is the longitudinal study, which may be descriptive (e.g. Barnett and Bailey 1955) or a clinical trial in which a group receiving a tick-borne disease control intervention is compared to one which is not (e.g. Morzaria et al 1988). As for the indicators to be used in such studies, the commonly used indicators are infection prevalence, disease incidence and case-fatality. The latter two can only be measured effectively through longitudinal studies. Performance indicators, which also require longitudinal studies for measurement include weight gain, milk production, meat production, animal sales, hides/skins sales, manure use and traction use.

For economic impact assessment, there are a range of techniques that can be used, including partial farm budgets to assess farm level interventions, and benefit: cost analysis to evaluate large-scale, long-term programmes. A number of computer models are available to undertake these (e.g. Mukhebi et al 1992; Nyangito et al 1994), and this subject has been considered in detail by Mukhebi (these proceedings).

Where do the data come from?

The poor availability of appropriate data sets for impact assessment of tick-borne diseases and their control often presents a significant problem. Most broad-level studies use data from a variety of secondary sources, such as published reports, government and FAO statistics, and these are in many cases inadequate, varying in their precision, their currentness and their level of resolution. Recently, there has been a much wider availability of many digital geo-referenced databases but these tend to be of highest quality for features such as climate, and of lowest quality for the parameters required for impact assessments, such as socio-economic variables.

Better quality data are published reports of specific studies on tick-borne diseases gathered at higher levels of resolution, and there are some such data sets available in the literature. The drawback to such studies is that they are often highly specific to certain regions and production systems, and cannot be extrapolated to other areas with validity. These published reports are being supplemented in some regions of Africa by new longitudinal studies, but these are inevitably few due to the high cost of such studies. The current research of George Gitau and colleagues on the impact of theileriosis in smallholder dairying in highland Kenya and that of Trevor Peter and colleagues on the impact of heartwater on beef production in Zimbabwe are two such examples.

Outputs of impact assessment studies

There are several products of impact assessment studies. The first is the ‘bottom line’, figures on the cost of a particular disease, or the net present value or benefit:cost ratio of a particular disease control programme. While these are what are required by donors and others, they should be interpreted with caution. Mukhebi et al (1992) published a framework to evaluate the economic impact of theileriosis and its control, with the intention that the framework be used as a stimulus to refine the crude data sets used in the study. However, it is the ‘bottom line’ of the cost of theileriosis being estimated as US$ 168 million per year that has stuck in people’s minds and in the literature, rather than the methodology described by the authors. Nevertheless, such methodologies are valuable interim products of impact assessment studies, and allow others to refine and apply them to their own specific problems.

Reports are the most common product of impact assessment studies, such as the cost-effectiveness study of alternative tick-borne disease control interventions carried out in Zimbabwe (Perry et al 1990).

However, it is considered that inadequate attention is given to ensuring that the results of impact assessment studies are effectively fed back to the different clients, so that they are used effectively in decision-making on strategies and resource allocation. One medium for this is decision-support systems. These can take the form of simple guidelines, conceptual models, mathematical models or knowledge-based (expert) systems. However, there are a variety of potential products of impact assessments, and Table 1 shows the link between client needs, studies required and products (Perry and Young 1995).

Table 1. *Future contributions of epidemiology and economics to client groups in the control of tick-borne diseases.*

Primary client	Product	Epidemiology tool
Farmer	Decision support based on production targets	Longitudinal studies of production profiles; effect of infection on productivity; economic models
Veterinary services	Disease distribution occurrence	Relative importance and trends
Development planners/ donors	Information and decision support on relative importance of TBDs by production system; returns on investment and control	Impact assessment models; Investment analysis
Animal health research organisations	Information and decision support on validity	Efficacy and impact of new technologies

Conclusions

Impact assessment of tick-borne diseases and their control is an increasingly important consideration in the light of ever more scarce resources, and should be incorporated into tick-borne disease control programmes to ensure their long-term viability.

The scope of impact assessment is changing rapidly; as we are just starting to incorporate economic evaluation into our studies, the demand for broader evaluation of poverty alleviation, enhanced food security and environmental protection are becoming increasingly important considerations for the donors of disease control programmes.

Expertise for impact assessment is often lacking from veterinary departments in many national system, and is still uncommon in the animal health departments of international implementing agencies. Greater efforts will therefore have to be made to develop effective collaborations with individuals, groups, departments or institutes with such capacities to respond to the needs of different stakeholders.

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Assessing economic impact of tick-borne diseases and their control: the case of theileriosis immunisation

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Introduction

In this presentation, I first discuss why we need to assess the economic impact of livestock diseases and their control. I then discuss the conceptual framework for assessing the economic impact of diseases and their control. This is followed by a brief explanation of some of the economic concepts behind the control of livestock diseases. A computer spreadsheet model which has been used in the past for assessing *ex-ante* the economic impact of theileriosis and its alternative control by the infection-and-treatment method is explained.

The data requirements for the model are discussed. Examples of the application of the model in various case studies and some of the results obtained are discussed briefly as an illustration of the type of information that the model can generate for disease control decision-making. The presentation ends by highlighting some of the issues that need to be addressed to facilitate assessments of the economics of tick-borne diseases.

Why assess economic impact of diseases and their control?

There are a number of good reasons why we should assess economic impact of livestock diseases and their control. Some of these include the following:

- To show the importance of a disease, to help in deciding whether resources for control should be allocated.
- To determine an optimal control strategy.
- To show returns to investment into a disease-control programme to those who provide funds such as donors and government.
- To provide information for planning a control programme: costs, potential market for control technology.
- To provide information for research and development priority setting: scale of disease as a constraint; costs, benefits and returns from control investments.
- To show who benefits from disease-control investment and by how much, producers as well as consumers of livestock.

A conceptual framework for assessing the economics of livestock disease control

The control of a livestock disease can be viewed in the broader context of a farming system depicted in Figure 1. The target disease for control should have an economic importance. Economic importance can be shown by the amount of losses in outputs the disease causes, and the amount of expenditure incurred by livestock producers and government to control the disease. Control expenditure is an input of the target livestock enterprise. Together with other inputs, they affect the costs, outputs and income from that enterprise. That enterprise may be only one of several enterprises, crops and/or livestock, that a farmer may be producing. The enterprises compete for available farm resources (land, labour, capital and management) identified in Figure 1 as resource constraints. The income from the enterprise(s) satisfy the needs of the household, thus determining the human well-being or welfare of the household. The well-being of the household in turn affects the types and scale of future enterprises and the allocation of resources to them, as shown by the upward arrows from the human well-being box in Figure 1.

Farm production occurs within the context of a complex set of interacting factors, including infrastructure, government policies, markets and trade. There are additional broad factors that also impact on-farm production: the physical environment (e.g. climate and soils), the social environment (e.g. traditions and customs), the biological environment (e.g. other diseases and vectors), and the political environment that defines policies and controls public resource allocation.

The important point about Figure 1 is that we should view and analyse livestock disease control in the wider context of the farming system and economy, being cognisant of the varied and complex inter-relationships among the system's physical, biological and socio-economic components. This is important for the sustainability of the control strategy to be adopted.

Economic concepts for livestock disease control

The concept of *economic cost* is used to measure the economic importance of a disease. Economic cost may be defined as:

Economic cost = production losses + control expenditures

Production losses are the sum of the value of output (milk, meat, traction, manure) losses from mortality and morbidity; control expenditures are the value of resources that livestock producers and government spend in controlling the disease.

Another useful economic concept is that of an 'optimal level of disease control', which may be defined as:

Optimal control = when an extra $ (cost) of control expenditure yields a $ (benefit) of savings in production losses.

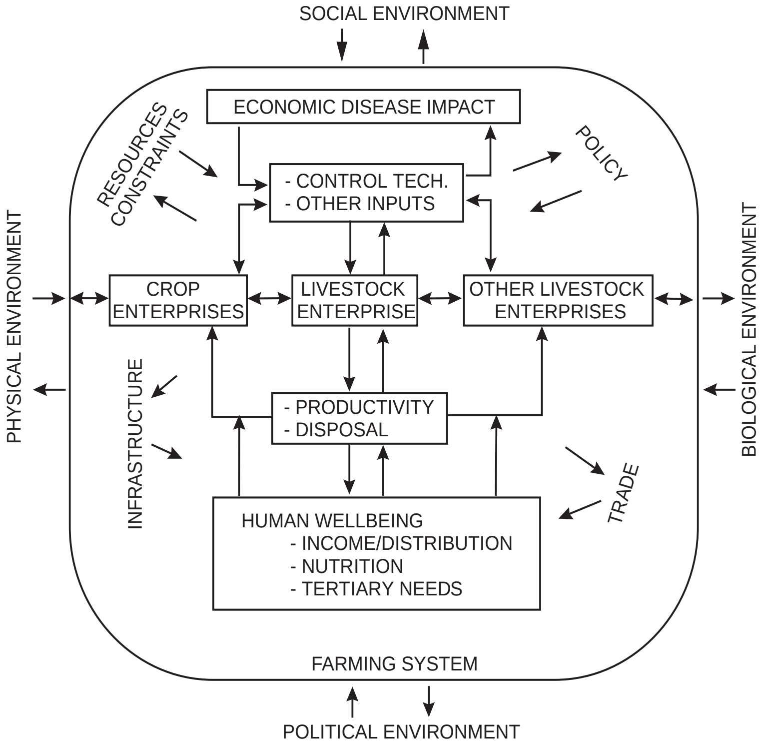

Figure 1. *Conceptual framework for economics of livestock disease control.*

The concept of economic cost can be used to show the relationship between the value of output losses from a disease and the expenditure incurred in the control of the disease (McInerney et al 1992). This relationship is described as the loss-expenditure frontier (Figure 2). At one extreme, if no expenditure is made to control the disease, the losses in output could be very large or even infinite (on the y-axis). At the other extreme, a huge expenditure may be incurred to eradicate the disease (on the x-axis), i.e. reduce the output losses to zero. Often, and especially in relation to tick-borne diseases, the options of ‘do nothing’ (zero expenditure) or ‘eradication’ are not acceptable on economic grounds. This means that a ‘control option’ is the preferred strategy, i.e. reducing the output losses to a tolerable level by spending some resources in a control programme. An optimal control point is point **A** on the loss-expenditure frontier in Figure 2. This is obtained when $\mathbf{OE_0}$ expenditure is incurred to reduce the losses in output to $\mathbf{OL_0}$.

A spreadsheet model for assessing the economics of immunisation against tick-borne diseases

The International Livestock Research Institute (ILRI) has developed a computer spreadsheet model (Figure 3) for estimating the economic costs of disease and assessing the economics of alternative control strategies for the control (Mukhebi et

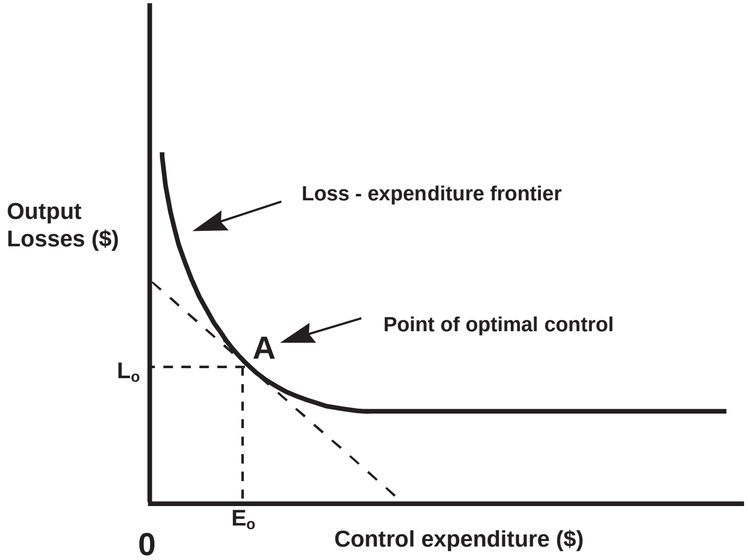

Figure 2. *Relationship between output losses and control expenditure.*

al 1992). In this model the relationships between the occurrence of a disease and its effects on livestock productivity through epidemiological parameters such as incidence, mortality and morbidity and through a control strategy are modelled. The model has been applied in a number of case studies to assess the economic impact (cost) of theileriosis and ex-ante economics of its control by the infection-and-treatment method (e.g. Laker 1993; Mukhebi et al 1995). The assessment was first conducted for the whole region of 11 countries in eastern and southern Africa where the disease occurs (Mukhebi et al 1992), and then in selected case studies in several countries (Table 1). After data requirements for the model are discussed below, some results of the case studies are briefly discussed to show what sort of outputs (economic information or indicators) the model can generate for disease control decision-making.

Data requirements for the spreadsheet model

Data required for application of the spreadsheet model can be summarised into the following groups:

- Beef and milk production and use.
- Traction and manure production and use.
- Treatment, acaricide and immunisation costs.
- Input and output prices.

It is useful to spell out the data variables in more detail as a guide for compiling sufficient data for analysing the economic costs of livestock diseases and the economics of their control by alternative control strategies.

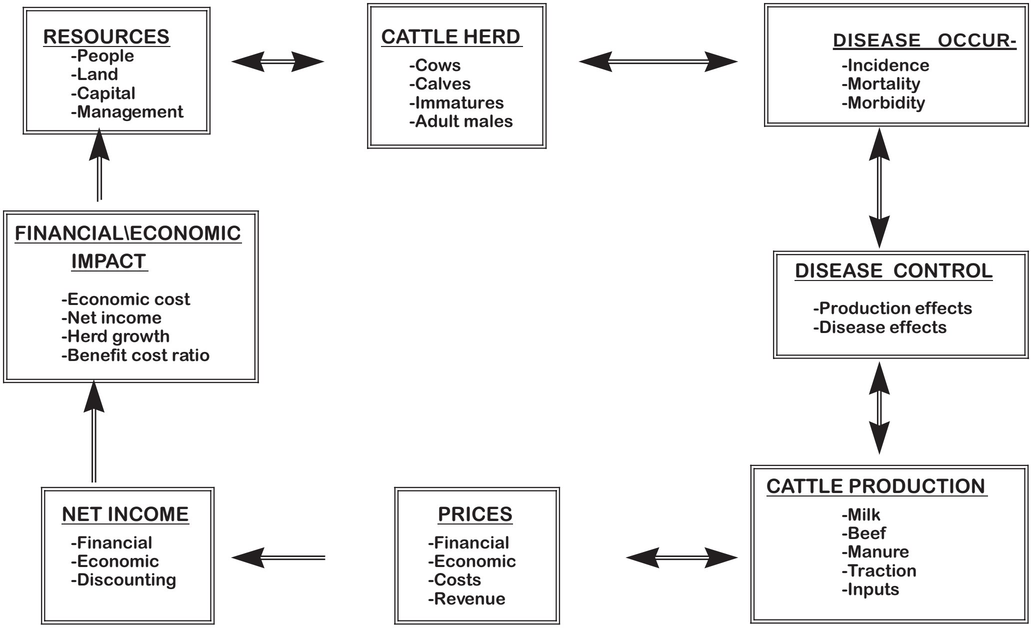

Figure 3. *Schematic representation of the spreadsheet model for assessing economics of diseases.*

Data for estimating beef and milk production

- Cattle population under risk: types, numbers, by production system.
- Proportion of breeding females and the calving rate.
- Incidence: in calves, immatures and adults.
- Case-fatality: in calves, immatures and adults.
- Milk yield per cow per year.
- Beef yield per animal in the herd per year.
- Milk loss in infected cows per cow per year.
- Beef (liveweight) loss in infected calves and immatures per animal per year.
- Traction loss in infected animals per traction animal per year.
- Total other mortality in calves, immatures and adults.
- Off-take rates in calves, immatures and adults per year.

Data for estimating traction and manure production

In production systems where animal traction and manure are important products of a livestock enterprise, these should be quantified and valued as part of the outputs of the enterprise. If these products are used in the production system but are ignored or not valued, then the output of the livestock enterprise would be undervalued. Where no market prices or rates exist for valuation, other methods have been devised, for

Table 1. *Case studies of the economic impact of theileriosis and its control in eastern and southern Africa.*

Site/country/production system/year	Cattle type
Eleven countries, 1989	National herds
Kilifi District, Kenya, 1991	Zebu and crosses
Uasin Gishu District, Kenya, 1991	Zebu and crosses
Mbarara District, Uganda, 1992	Ankole and crosses
Zimbabwe, Communal land, 1992	Sanga
Zimbabwe, Small-scale dairy, 1992	Crosses
Zimbabwe, Large-scale dairy, 1992	Crosses/exotic
Zimbabwe, Large-scale beef, 1992	Crosses/exotic
Zanzibar, Tanzania, 1993	Crosses

example using the opportunity cost of traction or manure. To estimate traction and manure production, the following parameters are needed:

- Proportion of adults used for traction.
- Crop area prepared per animal per year.
- Reduction in traction due to the disease per traction animal per year.
- Manure production per animal per year.
- Reduction in manure per animal per year due to the disease.

Costs of treatment, acaricides and immunisation

The costs of all control activities that constitute a control strategy and alternative control strategies being considered for a disease should be quantified. This requires data on the following variables:

- Proportion of clinical disease cases treated per year.
- Proportion of the herd under disease risk dipped per year.
- Number of dippings per animal per year.
- Proportion of the herd sprayed per year.
- Number of sprayings per animal per year.
- Proportion of acaricide cost due to the disease.
- Proportion of calves immunised per year.
- Proportion of adult animals immunised per year.

Input and output price data

Last but very important are the prices for valuing the inputs (especially disease control inputs) and outputs (meat, milk, traction, manure) of the livestock enterprise in order to express them into a common denominator, so that economic indicators such as net income, benefit cost ratio (BCR), etc for decision making can be calculated. The most important of these prices or values are:

- Meat or live animal and milk prices.
- Traction and manure values.
- Treatment cost per infected animal per case.

- Dipping cost per animal per dipping.
- Spraying cost per animal per spraying.
- Immunisation cost per animal.
- Other production costs (feed, labour, minerals, other animal health costs) per animal per year.

Summary results of the economic impact of theileriosis and its control: case studies in eastern and southern Africa

The regional impact of theileriosis and its control by the infection-and-treatment method was estimated using very sparse country level data (Mukhebi et al 1992). As most of the data on livestock production, productivity effects of the disease, and control strategies and costs were not available, many assumptions were made for this analysis. Efforts are now under way to compile more accurate country-by-country data to up-date the analysis. However, a very conservative approach was used in developing the parameters in the face of inadequate data, implying that the estimates presented are more likely to underestimate rather than overestimate the economic cost of theileriosis in the region.

The following is a summary of the regional results which were obtained using 1989 data.

- Cattle population at theileriosis risk: 24 million, representing 38% of the total cattle population in the 11 affected countries.
- Economic cost: (at least) US$ 168 million, or US$ 7.00 per animal per year.
- Mortality: 1.1 million head in 1989.
- *Ex-ante* returns from the infection-and-treatment method of immunisation, assuming a 50% reduction in acaricide use following immunisation: the BCR was in the range of 9–17, varying significantly among cattle types and countries.

Since the detailed results of the case studies are being submitted for publication elsewhere, only limited results will be presented here for illustrative purposes.

In all the case studies, farm surveys were undertaken to collect farm-level data on variables such as cattle types kept, yields, production costs, prices, and theileriosis effect on livestock productivity (incidence rates, mortality rates, yield reductions). Primary data were often augmented by secondary data, assumptions and expert opinions about cattle production and productivity effects of the disease. Immunisation against theileriosis by the infection-and-treatment method was evaluated against the current control strategy based wholly on acaricide application. Various levels of reduction in acaricide use ranging from 0 to 100% following immunisation were assessed.

The economic cost of theileriosis in the different study sites varied from US$ 5 to 14 in indigenous cattle, and US$ 11–105 in exotic/cross-bred cattle under the control strategy based wholly on acaricide application. Immunisation by the infection-and-treatment method reduced the economic cost of the disease in the various study sites by a range of 20–67% in indigenous cattle and 34–82% in the exotic/cross-bred cattle.

On the basis of the BCR, immunisation was not economically viable at the two Kenyan study sites in zebu cattle (the BCRs of the immunisation strategy were equal to or less than the BCRs of the wholly acaricide-based control strategy). The immunisation cost would have to decline by at least 6 and 24% to reach the break-even levels at the Uasin Gishu and Kilifi sites, respectively. At all the other study sites and for all cattle types (including cross-bred cattle at the Kenyan sites), immunisation was economically profitable. The range in the increase in net income per animal from immunisation was –5 to +36% in the indigenous cattle, and +12 to +128% in the cross-bred cattle.

The benefits from theileriosis immunisation would be much greater if indirect benefits were accounted for. For instance, the lowering of the risk of the disease could encourage adoption of the more productive exotic/cross-bred cattle by more farmers, thereby increasing food production and security; reduced use of chemical acaricides would improve environmental quality, reduce government expenditures on acaricide imports and allow time currently allocated for acaricide applications to be used for other productive household activities.

Conclusions

The following conclusions can be drawn from the results of the case studies.

- Economic impact of theileriosis and its control by the infection-and-treatment method varies significantly by country and cattle production system.
- The infection-and-treatment method appears to be financially profitable especially in exotic and cross-bred cattle.
- Economic or financial analysis can indicate to farmers, veterinary practitioners, governments and donors the profitability (return on investment) of investments in new alternative disease control strategies such as immunisation in different livestock production systems.

Research issues for addressing the economics of tick-borne disease control

As we consider the control of ticks and tick-borne diseases through the Food and Agriculture Organization’s (FAO) regional programme, we also need to identify issues that need to be addressed for assessing the economic impacts of the diseases and their control. Some of these are:

- Livestock populations at risk from the diseases; types, breeds, numbers by production system.
- The productivity effects of the diseases in those livestock populations; incidence, morbidity, mortality, yield losses by livestock age group.
- Current control strategy, its costs and benefits.
- Alternative control strategy (immunisation or integrated control) being considered, its costs and benefits.

- Potential market for the vaccine: who is likely to buy, what volume and at what price?
- Producer and deliverer of the vaccine, at what cost, return, price to the user.

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Co-ordination, collaboration and planning

Discussion, recommendations and priorities

Following presentation of the invited papers under each theme, the workshop participants went into three working groups to assess specific needs within each theme. Participants then reassembled to pool their findings and conclusions which are summarised in the 'discussion' section below. The key needs to emerge from the discussion sessions were then identified and reformulated by the workshop into a series of prioritised 'general recommendations' for future work on the epidemiology of ticks and TBDs.

Country participants then identified, from these recommendations, 'specific country needs' for their respective countries.

The final session considered, on the basis of the general recommendations and the specific country needs, what should be the future role and priorities of the 'epidemiology component of the Food and Agriculture Organization (FAO) Regional Programme'.

Discussion

Theme 1. Assessing the efficacy of immunisation against TBDs

The workshop identified the following needs for assessing the efficacy of immunisation against TBDs.

Standardisation

1. Recording—needs for standardisation of:
   - sampling methods and procedures;
   - monitoring and recording procedures (including standardisation of information collected and databases); and
   - agreed minimum requirements for recording to obtain statistically significant data.
2. Vaccine use and diagnostic methods—needs for standardisation of:
   - diagnostic parameters and tests for monitoring clinical disease, post-immunisation reactions and long-term follow-up;
   - the timing of testing and sampling pre- and post-immunisation, particularly in respect of clinical monitoring and serological testing;
   - instructions for vaccine use;
   - instructions to veterinarians and farmers in respect of post-immunisation follow-up; and
   - procedures for responding to vaccine break-downs and breakthroughs.
3. Working group on standards: such a group should be formed to prepare draft standards which should be agreed and adopted throughout the region.

Information dissemination

1. This needs to be wider and better coordinated to increase the feedback of information on immunisation efficacy.
2. Information on standardised methods, as detailed in standardisation, needs to be agreed and better disseminated with appropriate feed-back from the field.

Registration of vaccines

Governments should be encouraged to accept a single set of standards for ECF vaccine prepared centrally, without the need to re-register in each specific country.

Tick control

1. There is a need to establish appropriate levels of tick control following immunisation which are based on sound scientific principles (not *ad hoc* judgements, as at present).
2. Research on this should be focused on the target groups of farmers for vaccination.
3. The problem of acaricide resistance should continue to be monitored.

Research and collaboration

1. The epidemiological significance of carrier cattle (as a consequence of immunisation) needs to be determined more clearly, particularly in respect of their role in establishment and maintenance of endemic stability.
2. Improved strategies for tick control post-immunisation need to be developed (see tick control above).
3. More practical epidemiological modelling systems are required, particularly to investigate appropriate levels of tick control following vaccination, and in relation to the maintenance of endemic stability.
4. Improved markers are needed for identification and characterisation of strains of parasite used in immunisation.
5. More efficacy trials of vaccines should be conducted involving a wider range of theilerial stocks, particularly those with apparent mild characteristics (such as Boleni and Lanet).
6. Socio-economic studies to establish the impact and efficacy of immunisation should be conducted, including cost/benefit analyses and economic modelling.
7. The problem of the interpretation of serological data to differentiate previous exposure from protective immunity requires study.
8. The effect of immunisation on parasite population dynamics needs to be studied further.

Costs and economics

1. Improved strategies should be developed for reducing the need of post-immunisation sampling in order to reduce costs (see standardisation above).

2. Economic analyses are required to demonstrate to veterinary authorities and farmers the relative costs and risks of the different TBD control methods (immunisation, tick control, chemotherapy etc).

Training

More training is needed to inform farmers, veterinary assistants, technicians, veterinarians and commercial personnel about the impact and efficacy of immunisation, and post-immunisation monitoring.

Capacity to respond

Capacity to respond to breakdown of vaccine delivery or efficacy should be built into vaccine delivery programmes.

Theme 2. Evaluating delivery systems for the control of TBDs

Particular needs were identified as follows:

Linkages and networks

1. Improve linkages and develop networks between different key players in TBD control and delivery, recognising and exploiting the particular strengths and roles of the different players (e.g. private veterinarians, government staff, commercial sector etc).
2. Relate delivery activities to wider smallholder dairy development and support programmes.

Information

1. Improve the dissemination and exchange of information on results of immunisation programmes and product performance, availability, cost, usage etc
2. Actively collect, store and analyse data on TBD control and related studies for dissemination within the region.
3. Develop decision-support information systems for small holder farmers.

Applied research

1. Design and conduct strategic studies to evaluate delivery systems to target clients (e.g. cost/benefit and socio-economic impact studies).
2. Continue evaluation of vaccine efficacy in the field, particularly in relation to characterisation of challenge parasite populations.

Standardisation

Standard methods of TBD vaccine delivery should be adopted particularly in relation to vaccine storage, resuscitation, dilution, animal inoculation etc

Evaluation methods

1. Develop standard minimum guidelines for evaluating effectiveness of delivery of TBD control.
2. Minimum information for monitoring should include:
   - number of animals in target area;
   - number of adopters (sales, vaccine doses etc); and
   - changes in morbidity/mortality.
3. Assessment through smaller, more detailed studies should include:
   - changes in productivity;
   - changes in income; and
   - consumers' response.

Training

1. Training of veterinarians and socio-economists is required for characterising target areas in terms of risk assessment, impact analysis, market surveys, delivery strategies etc
2. Training is also required in evaluation methods for delivery systems.

Priorities

1. Coordinate delivery of control strategies through national TBD steering committees/working groups and through linkages with broader smallholder dairy development programmes.
2. Establish standard delivery methods. Once established, assist national working groups with training in the appropriate methodologies.
3. Set up applied research studies to evaluate delivery systems in order to develop standard minimum criteria for evaluation, and apply these through national working groups who report to directors of veterinary services.

Theme 3. Measuring impact of immunisation against TBDs on livestock productivity

Specific needs for improving the measurement of impact were identified as follows:

Impact assessment

1. Development of standardised methodologies for impact assessment (data collection and analysis).

- identifying farmers’ perceptions and including their priorities; and
- minimum data set requirements.

2. Make provision (including appropriate funding) for impact assessment in all programme/project planning.
3. Explore funding possibilities for impact assessment in current projects.
4. Training in impact assessment is needed for staff involved in national projects and the Regional Programme.
5. National short courses in collaboration with universities could be conducted in impact assessment.

Collaboration

1. Promote collaboration with epidemiology units in national research institutions/universities.
2. FAO should play a catalytic role in promoting exchange and dissemination of information.
3. Enhance sustainability of information collection and dissemination by development of national databases.
4. Develop strong linkages with production systems research and development groups within countries.
5. Closer collaboration is needed with research institutions in validation and evaluation of new technologies being applied in the field.

Research priorities

1. Improve the database on the impact of *Theileria parva* infection on milk production.
2. Applied research to develop improved strategies for tick control after immunisation.
3. Development and evaluation of impact assessment models and decision-support systems.

General recommendations

Needs and priorities in the epidemiology of TBDs and their control

Linkages

A key requirement in improving epidemiologic support is to strengthen linkages to improve communication and information exchange between the key players in TBD control, research and development. The linkages required include:

Within countries

1. Improved linkages between TBD control programmes and broader smallholder livestock development programmes.

2. Improved linkages between national agricultural research and extension systems (NARES), universities and non-governmental organisations (NGOs).
3. Establishment and effective operation of national steering committees for tick and TBD control to foster these linkages and serve as the coordinator for linkages between: national bodies, other countries in the region, and regional and international TBD control programmes.

Within the region

4. Improved linkages and information exchange between national TBD programmes, regional programmes and international research centres (e.g. ILRI) or internationally funded TBD projects. The FAO Regional Programme should play an important role in developing and fostering such linkages.

Standardisation

1. For all three workshop themes (assessment of efficacy; delivery systems; impact of TBD control), a strong need was expressed for standardising information recorded and agreeing minimum standards for:
   - vaccination procedures and post-vaccination monitoring;
   - diagnostic tests used;
   - procedures for responding to vaccine break-downs and breakthroughs;
   - sampling methods, data recording and data bases; and
   - tick control following vaccination.
2. It was recommended that a working group be established through the FAO Regional Programme to develop such standards.

Research

Four important epidemiologic research topics were recommended as being of highest priority:

1. Optimal tick-control strategies to be adopted following immunisation against ECF.
2. Changes in parasite populations post-immunisation.
3. Effect of theileriosis and other TBDs on livestock production, particularly milk production.
4. Development of decision-support systems on the efficacy and impact of TBD control (particularly immunisation) so that information can be presented in a form useful to decision makers.

Training

1. Training programmes with NARES and universities in individual countries should be conducted on:
   - efficacy and impact assessment, particularly of immunisation and control programmes;
   - the inclusion of impact assessment in project planning; and

- improved diagnostic methods to characterise TBD risk and conduct surveillance programmes.

2. With the future focus on improving delivery of vaccination programmes, there is a strong need to improve training at national and local levels in the handling and delivery of vaccines, and the subsequent monitoring and follow-up of vaccinated animals.

Information support

Given the limited resources of countries in the region, great emphasis was placed on the need to share results and other information at regional level. Information could include:

- directory of different projects with their objectives, staff and results to date;
- details on the availability, price, efficacy studies, and registration status of TBD vaccines; and
- informal copies of project reports or summaries.

Project planning and funding

1. Projects need to apply (through consultancy if appropriate) cost-effective methods to obtain baseline data for establishing target areas or groups for immunisation.
2. Impact assessment studies should be included and the costs be built into future project plans for all national and local TBD-control projects.
3. Most of the above recommendations have funding implications. Appropriate funds should be built into project budgets to cover these needs.

Specific country needs

On the basis of the above conclusions and recommendations, countries were invited to identify their specific priorities for studies, support, assistance and collaboration within the epidemiology of TBDs and their control, and the role that the FAO Regional Programme might play in this context.

Ethiopia

The major interest was on research on the risk and impact of *Cowdria* infection and dermatophilosis. Specific needs expressed were:

1. Provision of assistance to the national TBD steering committee.
2. Estimation of the effect of TBDs on milk production.
3. Surveillance for *T. parva* infections along the southern and western borders.

Kenya

1. Research and recommendations on tick control post-immunisation against ECF.

2. Establishment of linkages between FAO and other regional and national programmes.
3. Collaboration on the wider dissemination of information.
4. Standardisation and implementation of methods to assess efficacy, delivery and impact of TBD control.

Malawi

1. Research and recommendations on tick control post-immunisation against ECF.
2. Training in the assessment of efficacy, impact and delivery of TBD control.
3. Standardisation and implementation of methods to assess efficacy, delivery and impact of TBD control.
4. Establishment of linkages between FAO and other regional and national programmes.
5. Estimation of the effect of *T. parva* infection on milk production.

Mozambique

1. Assistance in surveillance and estimation of tick and TBD risk and impact in main livestock areas and production systems in the country. No recent baseline data are available.
2. Establishment of linkages between FAO and other regional and national programmes.

South Africa

1. Establishment of collaboration with a number of existing research programmes.
2. Collaboration on economic impact assessment with FAO and ILRI.
3. Onderstepoort can offer diagnostic methods, training, vaccine sales, delivery expertise.
4. Onderstepoort would like to be represented on standardisation committees and would participate and support any recommendation from these committees.
5. Linkages with FAO and other regional and international programmes.

Swaziland

1. Training in tick identification and TBD diagnosis.
2. Improvement in communications between TBD control projects and epidemiology units at national and regional levels.
3. Assistance with epidemiological and impact assessment studies.

Tanzania

1. Research and recommendations on tick control post-immunisation against ECF.

2. Standardisation and implementation of methods to assess efficacy, delivery and impact of TBD control.
3. Research on the effect of *T. parva* infection on production.
4. Linkages between FAO Regional Programme and NARES and university epidemiology units.
5. Training, particularly in assessing and responding to immunisation breakthroughs.
6. Recommendations on standardised delivery methods.
7. Assistance on including provision for impact assessment in all phases of project planning.

Uganda

1. Research and recommendations on tick control post-immunisation against ECF.
2. Standardisation and implementation of methods to assess efficacy, delivery and impact of TBD control.
3. Training in impact assessment methods.
4. Linkages between FAO Regional Programme and NARES and university epidemiology units.
5. Training in assessing efficacy of delivery systems.

Zambia

No specific priority areas were identified or requests presented.

Zimbabwe

1. Development of standard methods for impact assessment.
2. Research and recommendations on tick control post-immunisation against theileriosis.
3. Training, particularly in assessing and responding to immunisation breakthroughs.
4. Research into impact assessment methods for tick control.
5. Linkages between FAO Regional Programme and NARES and university epidemiology units.

Epidemiology component of the FAO Regional Programme

Recommendations on functions of the epidemiology component of the FAO Regional Programme

1. Establish strong linkages and provide epidemiological support and advice to national TBD steering committees and smallholder livestock development programmes.
2. Coordinate the development and adoption of standard methods to assess efficacy, delivery and impact of TBD control.
3. Provide interim guidelines for tick control post-immunisation based on current information, and coordinate research on tick-control strategies post-immunisation within the region.
4. Collaborate with international and national research institutes focusing on TBD control and smallholder livestock development in establishing research programmes for the assessment of efficacy of delivery systems and their impact; decision-support systems; and the impact of TBDs on milk production.
5. Develop epidemiological training programmes and materials, particularly on risk and impact assessment, in collaboration with NARES and national universities.
6. Assist national programmes/projects in the design and establishment of standardised data recording and information systems relating to TBD impact and control in the region, and in the communication and dissemination of epidemiological information.
7. Explore and assess alternative delivery systems for TBD control in collaboration with national TBD steering committees, NARES and smallholder livestock development projects.
8. Assist in advising national programmes on prioritising project formulation needs with regard to impact assessment of TBD control, particularly the need for initial baseline data.

In order for the FAO Regional Programme to fulfil these functions, the workshop urged that the proposed post of epidemiologist be filled as soon as possible.

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