The economic impacts of endemic diseases and disease control programmes

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Summary
The authors discuss the evaluation of the economic impacts of endemic livestock diseases, and economic issues in control of these diseases. Particular attention is focused on helminths and endemic vector-transmitted infections (particularly ticks and tick-borne diseases). Decisions relating to disease control have to be made by government and by the producer. Government requires information on the level of control to adopt, the extent of involvement needed, and how to fund animal health programmes (particularly how to share costs between taxpayers and livestock producers). Individual producers require information as to how much effort to invest in disease control, including information collection effort, and how to design control strategies. Economics can shed light on these issues. However, experience suggests that animal health policies are particularly difficult to evaluate from an economic viewpoint, with complex relationships between animal health, production impacts, market access, and non-production benefits of livestock. While little information is available concerning the cost of helminth diseases, many estimates have been made of the costs of ticks and tick-borne diseases at a regional and national level, sometimes demonstrating that eradication is warranted.

Keywords

Introduction
The term endemic diseases covers an extremely wide range and the characteristics of these diseases differ greatly. In this paper, therefore, the example of parasites as a source of disease will be highlighted, taking helminths as examples of endoparasites and ticks as examples of exoparasites. Even with such a focus, the number of parasite species and diseases is large, and there is, therefore, a need to concentrate on individual cases.

Endemic parasites are a major source of economic loss in animal husbandry, especially in tropical areas and developing countries, but as discussed later, the extent of those losses has yet to be accurately specified, and knowledge about the economics of treatment of these diseases is inadequate, mostly because the damage functions, and in addition, the response functions to treatment are imperfectly known. The response functions should be specified in relation to economic variables of importance (e.g. depending on the situation, weight gain, reproduction rates, lactation of mammalian livestock), rather than just clinical effects. Co-operation between veterinarians and economists is needed at an early stage if information of economic relevance is to be collected by veterinarians.

Extra cost is incurred in the collection of extra veterinary data of economic relevance, however, without this additional step, little progress will be made in the economic evaluation of diseases. This point cannot be over emphasised, and is supported in the conclusion of a recent paper (36). Economic impacts of parasites of livestock may be divided into two groups - direct and indirect impacts. Direct impacts are those attributable purely to the presence of the parasite, e.g. reduced economic productivity of the livestock or economic loss due to mortality. Indirect impacts occur because some parasites, such as ticks, are also disease vectors, and the vector-borne diseases, if transmitted to a livestock host, often result in much greater economic loss than the presence of the parasite. Furthermore, by weakening the host
the presence of a parasite may make the animal much more susceptible to infection and adverse impact from other diseases, or to environmental stresses such as food deficits (18).

The range of parasites of livestock is very large. Helminth parasites belong to three phyla of invertebrates: platyhelminths (flatworms), acanthocephalans (spiny-headed worms) and nematodes (roundworms).

In addition to ticks, ectoparasites include mites, lice, fleas, leaches, mosquitoes and flies of various kinds. However, as mentioned earlier, to deal with the full range of these parasites in this article would be impossible, and the focus here is limited to helminths and ticks. This article first considers general issues involved in the evaluation of the economic impact of endemic diseases and the economics of disease control. Subsequently, these issues are considered specifically for helminths and then for ticks and tick-borne diseases, and general conclusions are drawn.

Evaluation of the economic impact of endemic diseases and the economics of disease control

Evaluation of the economic impact of endemic diseases

Endemic diseases cause large economic losses but few precise estimates of the magnitude of these losses have been made, mainly because the amount of information required is large and the cost of obtaining the information is high. Furthermore, as mentioned earlier, veterinary research effort is not always sensitive to the data needs of economic evaluation. Economists can only make progress with economic evaluation if veterinary data is provided in a required form so that it can be combined with economic data and the appropriate economic analysis can be undertaken (30).

Economic evaluations can be undertaken for a variety of target groups, or geographical areas, for example:

- an individual livestock holder
- a region
- a nation
- for the global situation.

Different types and amounts of information are required for these different levels of coverage.

In collecting information on economic impact, the coverage required must be determined (this depends on the target group), but in addition, the purpose for which the information is to be used must be taken into account. For example, a common objective in relation to disease control is to estimate the total economic loss caused by the prevalence of disease. But what is the purpose of this? True, it provides an indication of the economic benefits to be had if an inexpensive method could be found to reduce substantially the incidence of the disease. However, such relative losses from diseases are a poor guide to the allocation of research funds, because the likelihood and cost of making new discoveries concerning the control of a disease and the economics of remedies discovered must also be considered (30).

Information regarding whether the full economic potential from remedying a disease is being obtained, given existing knowledge about disease control, is useful from several points of view. It is important to determine the scope which exists for increasing economic benefits from the use of existing veterinary knowledge. For an individual livestock holder, the scope for this will be equal to the difference between the economic gain using the current control practice and the economic gain using an optimal economic control strategy. As discussed later, such an approach has been adopted by several researchers (1, 27, 30). Similar estimates can be made regionally, for a nation or globally. However, accurate estimates cannot always be obtained by merely aggregating economic gains for individual livestock owners considered in isolation. For example, this will be true if an increase in supply of livestock products, as a result of disease control, reduces the market price of these products (18), or if a favourable environmental health spillover (externality) is generated by the disease control measures adopted by individual farmers. In some cases, measures taken by individual farmers to control livestock diseases also reduce the likelihood that the livestock of other farms will contract the disease. Where a difference exists between potential and actual net economic benefits from disease control practices, stockholders may be encouraged by government extension services to change control strategies.

Optimal economic strategies are not always the same for all stock owners and may vary with environmental conditions. This provides challenges for government extension services, which cannot, as a rule, target individual clients, and must focus on broad groups of clients. Therefore, government advice is generally based on average situations, and one has to decide how finely to structure this advice for target clients in different regional and environmental situations. To some extent this involves economic choice – the extra economic benefit for more structured and specifically directed advice must be weighed against the additional cost (4, 44). Improvement of advice is only socially desirable up to the point where the extra economic benefits generated equal the extra cost.
Economics of control of endemic diseases

The economics of control of endemic diseases is complex since the epidemiology of most is complicated and disease prevalence often changes radically with alterations in environmental conditions. In particular, the occurrence of parasitism seems to be greatly influenced by environmental conditions. This means that simple models of the economics of control of diseases can often only be applied to particular endemic diseases if considerable modification and further development is undertaken.

Livestock holders often fail to control endemic diseases in an economically optimal manner and convincing individuals to change this behaviour can be difficult. For example, particularly in developing countries, the presence of such diseases is often recognised or considered 'normal', and is thus fatalistically accepted by livestock holders. For example, although the occurrence of bovine fasciolosis is a major problem in Indonesia (42), control attempts are uncommon because the extent of the problem is largely unrecognised by farmers (the disease is common and unspectacular, and the main clinical signs of failure to thrive and reduced exercised tolerance are similar to those of poor nutrition or regarded as 'normal'), modern anthelmintics are expensive and there is no reliable information on the benefits of control (42).

This raises a further aspect, namely that the economics of control of a disease may vary from country to country and from region to region. The occurrence of endemic diseases can be greatly influenced by cultural practices - both agricultural practices and wider practices. For example, attitudes to the keeping and handling of dogs influence the occurrence of hydatidosis in humans. Treatment of animal manure by humans can influence whether the life-cycle of some helminths is assisted or thwarted. If cow dung is composted at high temperatures, before being returned to the field, or burnt for fuel, as in parts of the Indian subcontinent, the eggs of some species of helminths will be destroyed, thereby reducing these populations (37).

Control strategies for endemic diseases which are economically feasible in developing countries often differ from those which are economically optimal in more developed countries. This is because farmers in developing countries usually only keep a small number of livestock, and often use communal water and feed sources, capital is usually in short supply, and agricultural activities differ from those in developed countries, with specialised farming being more the exception than the rule. In addition, cultural differences between countries can influence practical control policies. To be relevant, economic advice must be varied to take account of all such considerations. In addition, the objective of keeping livestock may vary from society to society and from group to group: the purpose is not always to earn the largest stream of net cash income, as seems to be the basic motivation in developed countries. Economic advice needs to be formulated by considering the differing objectives of target groups and the different cultural practices and habits of these groups, especially those relevant to the farming and grazing activities of livestock holders. Nevertheless, fundamental factors can be identified which are relevant to most analyses of the control of endemic livestock diseases.

For example, one needs to know the relationship between possible disease control strategies and the benefit expected by livestock holders or other targeted groups. It is necessary to determine what attributes of the livestock are valued and how much value is placed on each to obtain an objective function. The problem is a holistic one and calls for an interdisciplinary approach.

Ideally, the aim should be to recommend a specific disease control strategy which maximises the objectives of the client. Mathematically, the problem can be considered as a constrained maximisation problem - to maximise the objective or utility function of the client, subject to the resource and other constraints faced by the client and taking into account the possibilities generated by the available disease control strategies.

A simple form of this approach (which is particularly relevant to developed countries and increasingly to less developed countries as they become more market-oriented) is as follows: a) the objective of the livestock holder is to maximise net monetary income (or net discounted cash flow)
b) this depends on the quantity and quality of saleable products produced by or attributable to having livestock in the farming enterprise as well as the prices of these products
c) allowance is made for financial outlays on account of these livestock, which include any outlays on disease control.

In considering this problem, one of the important points for attention is the relationship between strategies for control of a disease and the impact of these strategies on the quantity and quality of the saleable livestock products. In essence this means that a production function response or relationship needs to be estimated (30).

To take a simple case, suppose that a farmer wishes to maximise annual net income and that, for livestock, the only attribute of relevance is the weight of meat of the livestock. Suppose that preventive treatment for the relevant livestock disease is available which can be administered with varying intensities. Intensity, for example, may be the number of times per year that the stock are drenched to control helminth infestations. Additions to meat weight may increase with the number of preventive doses per year, but at a decreasing rate. In stationary conditions, a functional relationship exists between the number of doses and meat weight gains, which in principle can be determined scientifically.
The following procedure can be adopted to determine the economically optimal number of annual doses of the treatment to administer: increase the number of doses as long as the additional revenue (which equals extra weight of meat in kilograms multiplied by price paid per kilogram for this meat) exceeds the cost of an extra dose of the treatment, e.g. additional drenching. As a rule, the net income maximising dose rate will be the highest dose rate for which the above condition is satisfied. The optimal number of doses can be expected to vary with factors such as the price of meat and the cost of dosing the animals.

In practice, the situation will be much more complicated. More than one livestock product may be affected by a disease, and the economics of treatment may vary with environmental conditions, which may be relatively unpredictable. Thus, the economic decision to control a disease may have to be made in uncertain and variable conditions. Therefore, attitudes to risk and instability must be taken into account. In animal health economics, sensitivity analysis is usually used to measure these variables (10, 30). Sensitivity analyses specify outcomes for different possible scenarios or states of nature. The likelihood of these may also be indicated. Depending upon the attitude of the decision maker towards the bearing of risks and income variability, he or she can adopt a particular strategy. Essentially, this was the approach adopted by Meek (27) in analysing the economics of alternative strategies for the control of ovine fascioliasis in Australia.

The problem becomes more complicated when alternative techniques of parasite control exist, since these need to be compared to decide which are the most economic, including possible combinations of these techniques (43). More detailed analysis of animal health economics is provided by Dijkhuizen and Morris (10).

The main purpose of this sub-section is to emphasise that the economics of control of endemic diseases is especially complicated. This is particularly true of diseases related to parasitism because of the high degree of sensitivity of these (and of the economics of control) to variable environmental conditions. Furthermore, especially in the case of helminths, cultural factors and the often complicated helminth life-cycles add extra dimensions to difficulties of determining the economics of control.

**Helminthiasis: economic impact and economics of control in livestock**

**Economic impact of helminthiasis**

Many qualitative statements can be found in the literature which indicate that the economic impacts of helminth infections are substantial, but few quantitative estimates of these impacts exist. The opening section of a major FAO-sponsored review of helminth diseases states: 'Helminthiasis infections of food animals cause significant economic losses. The effect of the infection is determined by a combination of factors of which the varying susceptibility of the host species, the pathogenicity of the parasite species, the host/parasite interaction, and the infective dose are the most important. The economic losses are closely associated with the extent to which the pathogenic effect of helminth infections influences the production of the individual host. This may vary considerably from clinical disease including mortality to chronic production losses which may appear as, e.g., reduced growth rate, weight loss and/or reduced fecundity or it may go unnoticed' (35).

A further cost arises in that some helminths can be transmitted to man. Many parasitic helminths can in fact be transmitted between vertebrate animals and man (i.e. these helminths are zoonoses) and 'about 20 species are of public health importance causing severe or fatal infections. In many parts of Africa parasitic helminths are responsible for enormous economic losses, hampering rural development programmes and reducing the pace of economic growth' (25).

Bain and Urquhart estimated that the economic loss from stomach worm in British cattle in the mid-1980s would have been approximately £45 million annually if parasitic gastroenteritis had been completely uncontrolled (2). This potential loss would show a several fold increase if the figure were to be scaled up to cover the whole of Europe. The research was mostly concerned with the economic impact of the most pathogenic of the stomach worms in cattle in Europe, *Ostertagia ostertagi*. Estimates of financial loss are based on mortalities in young cattle and the failure of cattle to reach potential normal weights (weight loss). These are assumed to vary according to the severity of infection. In the absence of parasitic control, it is assumed that 5% of cattle will be severely infected, 20% moderately so, 45% will have sub-clinical infections and the remainder will not be affected. Only the severely infected group is assumed to suffer mortality; 24% of this group are supposed to die annually, involving a loss of £200 per dead animal on average. Weight loss per calf is assumed to decline as the degree of infection declines, being 35 kg for severely infected animals, 20 kg for the moderately infected and 10 kg for sub-clinical cases. Each kilogram loss is supposed to reduce the value of a calf by £1.20. The estimated annual production of calves in Britain was 3.2 million over the period in question and consequently the estimate of a £45 million annual loss can be easily obtained.

In this analysis, no account has been taken of any possible impact on prices of livestock nor of the possibility of a reduction in the milk yields of older cattle. In addition, no estimates have been made of profits forgone by not adopting the most economic methods of control of stomach worms of
cattle, that is economic gains which could be made by adopting superior available methods of control of stomach worms. Therefore, this exercise appears to be of limited value. Nevertheless, it resulted in Zinsstag et al. (45) proclaiming that 'In Africa such estimations are not available, but losses are expected to be even higher due to poor nutrition, which substantially enhances the pathogenic effect of parasites (15)'.

In an early study of the economics of control of helminthiasis in weaned lambs (1), it was estimated on the basis of experimental evidence in Victoria, Australia, that if all young sheep in the high rainfall area of Australia were given the critical treatment scheme (anthelmintics at the most appropriate time) rather than being treated for clinical parasitism only, the additional net benefit would be approximately AUS$6.7 million annually at 1970-1971 wool prices. In comparison to traditional drenching schedules, the extra net benefit to wool growers from the critical scheme would amount to AUS$5.4 million. These economic gains increase with wool prices. The precise figures are not very important for this article; what is more important is that owners of sheep could have considerably increased their incomes by adopting a superior available strategy for heminth control.

Unfortunately, the review by Over et al. (35) of helminth diseases of livestock in developing countries sheds little light on the economic impact of these diseases. Data such as infection rates of livestock and rejection rates of offal at abattoirs due to helminth infections provide a restricted basis for estimating economic impacts. Furthermore, no indication is given of economic benefits which are unrealised due to failure to adopt appropriate available control techniques.

**Economics of control of helminthiasis**

**Social and private perspectives on control effort**

The economics of helminth control may be viewed from a government or social perspective, or from the perspective of the individual producer. The government needs to take account of externalities, such as trade impacts and effects on public health. The individual producer is concerned with maximising private goals of revenue, stock quality and other objectives, within the resource limitations and regulatory framework.

Government wishes to determine the optimal control expenditure, including public and private sector expenditure. The social cost-benefit analysis framework generally accepted for evaluation of animal health programmes involves making estimates of all socially relevant costs and benefits, including both market and non-market items, and hence deriving 'incremental cash flows'. However, when expenditure levels vary between alternative disease control policies, it has been argued that benefit-cost criteria do not rank alternatives correctly, and that a loss-expenditure tradeoff curve provides a better indication of optimal control effort (21, 22, 23). This takes the form of a concave tradeoff curve between disease cost (C) and control expenditure (E) as illustrated in Figure 1. The points along the loss-expenditure frontier may be taken to represent the capitalised value, or discounted sum, of disease and expenditure costs over a number of years. This curve represents the set of choices available to a country in terms of effort on disease control. With no control expenditure, disease cost, c*, is high. As control expenditure is increased, disease cost first decreases rapidly, the C-E tradeoff curve being almost vertical. But with increasing expenditure the curve flattens as the marginal rate of improvement with respect to cost declines. If the disease can be eradicated, control expenditure may fall to zero or to some low amount representing the cost of preventing new outbreaks.

**Fig 1**

The McInerney loss-expenditure tradeoff model

Since both axes are expressed in dollars terms, and a dollar in disease cost is regarded as equivalent to a dollar in control costs, the line with slope -1 represents combinations of equal cost to the country, i.e. an isocost line. One such line is drawn in Figure 1; this is the line which is tangent to the C-E curve. Any C-E combination to the right of this line would represent greater overall cost; any point to the left is not achievable. Hence e* is the optimal expenditure level and is associated with a disease cost c* (total cost c* + e*). For this formulation, the disease cost variable would need to include all relevant items including non-market costs (e.g. environmental impacts, animal welfare changes).

The distribution of costs between government and livestock producers is a further issue. There is increasing emphasis on 'user pays' policies, and this could be applied to animal health research, disease control, inspection for export and so on. However, it is notable that measures which reduce livestock producer costs may lead to greater benefits for consumers than for producers. On the other hand, measures which enhance export markets may impose a cost on consumers, to the benefit of producers and traders (middlemen).
Issues in evaluating control economics

The economics of control of helminthiasis tends to be complicated because the life-cycles of helminths can be complex and are dependent on environmental conditions which can vary considerably. Furthermore, in most cases, the life-cycles of helminths depend on multiple hosts. Schwabe (40) suggests that helminths show unusual biological complexity and points out that 'broadly adapted to causing disease in other species, parasitic nematodes, cestodes and trematodes undergo successive stages of development, often as quite dissimilar forms, including in their feeding and other habits'. Four types of zoonosis cycle exist:

- direct zoonoses can be perpetuated by a single vertebrate reservoir, e.g. trichinosis
- cyclo-zoonoses require more than one vertebrate species to complete a life-cycle, e.g. echinococcosis
- meta-zoonoses require both vertebrate and invertebrate host species, e.g. schistosomiasis
- sapro-zoonoses require a non-animal reservoir or development site to complete a life-cycle, e.g. some species of nematodes (40).

Knowledge of such cycles is essential for the sound economic and epidemiological control of helminths. For instance, as Zinsstag et al. (45) point out: 'The precise knowledge of the biology and seasonability of the (gastrointestinal) parasite and the groups at risk in the various agro-ecological zones are prerequisites for any economically and epidemiologically sound approach to the control of gastrointestinal parasites'.

Even in the case of direct zoonoses involving a single vertebrate reservoir, the question is raised of what is the best stage in the life-cycle of the parasites to target for economic control (e.g. the eggs or a later stage in the life-cycle), and at what time to target these stages. Some anthelmintic treatments are ineffective if the parasites enter a dormant stage (2). If a parasite has more than one host (e.g. liver flukes depend on snails as hosts as well as vertebrates), the question arises of whether it is economic to control this reservoir in order to reduce infection in the end-host. Furthermore, can livestock be economically excluded from sources of environmental contamination with parasites or excluded from these at critical times? To this end, and for the control of particular helminth diseases, strategic rotational grazing of livestock or strategic cropping and grazing cycles can be practised.

Usually, a wide range of possible strategies are available for the control of helminths, but only a few of these alternative strategies are explored from an economics point of view. Some may be excluded on a priori grounds because they are clearly uneconomical. Those explored often reflect the particular expertise of the researcher. Some of the available studies of the economics of control of helminthiasis are considered below.

Anderson et al. (1) and Morris et al. (29) explored the economics of anthelmintic drenching of sheep, based on the results of experimental work in Victoria. The main helminths of concern were Ostertagia and Trichostrongylus spp. The economics of four alternative control strategies were compared:

- treatment 1: no preventive treatment
- treatment 2: traditional preventive treatment as indicated by surveys of farmers
- treatment 3: varied prophylactic treatment based on critical periods in the life of the helminth species involved

The studies found that both treatments 2 and 3 were economic, with treatment 3 being the most profitable when administered either to weaned lambs (1) or to breeding ewes (29). Fortnightly treatment was more profitable than traditional treatment.

These results were based on partial budgeting. Sensitivity analysis was applied and the profitability of the fortnightly treatment was shown to be particularly sensitive to wool prices. In the case of breeding ewes, it was concluded on the basis of the economic evidence presented that 'there is no merit for the farmers in considering the option of either the 'traditional' treatment scheme or 'two-weekly' treatment scheme in preference to the 'critical' treatment scheme, since the latter was the most financially rewarding under all circumstances evaluated' (29).

While the above contribution is a significant one, the study is based only on a small experimental sample on one farm, of limited numbers of sheep and results over one year. Further testing at other locations and other replications would be desirable to test the robustness of the results. When experimental research on the control of animal diseases, including field experiments, is performed, some doubt must arise regarding the extent to which the results can be generalised to a wider population. An interesting social science question raised by this research (but not explored) is why farmers used the traditional method rather than the more profitable one? Is it because of lack of information or for some other reason?

In northern Victoria, Australia, an analysis of the economics of control of ovine fascioliasis was undertaken in sheep grazing on irrigated and non-irrigated pasture (27, 30). A model was developed to analyse infections of sheep by Fasciola hepatica, taking into account environmental factors, the life-cycle of F. hepatica, and the impact of ovine fascioliasis on wool production (and value of wool sold) and value of sheep sold. Parameters in the model were specified using scientific literature, expert opinion and two experiments designed to
supplement this information. Using simulation techniques, the economics of control were examined for the following:
- five alternative anthelmintic strategies
- the use of a molluscide to destroy snail hosts
- rotational grazing.

Although most attention is given to anthelmintic strategies, the economic study is more comprehensive than most because other control possibilities are also considered. The economic benefit from anthelmintic treatment is shown to depend on stocking rates and percentage of the paddock (used by sheep) occupied by snail habitats. The most intensive strategy for anthelmintic treatment (drenching approximately every eight weeks) was shown to give the highest financial return. The research provides a valuable holistic framework for studying the economics of control of ovine fascioliasis (27). In this regard, this study is a relatively unique contribution to the veterinary economics of the control of helminthiasis.

The case studies mentioned above concern a relatively developed country. Similar case studies for developing countries are scarce, but the need for economic evaluation is often crucial, as is evident from recent research on strategic gastrointestinal nematode control in cattle in The Gambia (45). Significant weight loss from nematodes was demonstrated in cattle, but financial analysis of the recommended control measures was not completed.

An interesting economic evaluation of the economic returns from vaccinating cattle in the Sudan against *Schistosoma bovis* has been completed (18). *Schistosoma bovis* vaccine has proven to be effective in experiments in the White Nile province of the Sudan in reducing mortality and weight loss (or growth delay) from *S. bovis* infection. The results of these experiments are used together with other data to estimate the economic return to be expected from an *S. bovis* vaccination campaign in the Sudan extending over a five-year period.

For the purpose of estimation, the Sudan is divided into three areas — central, western and southern. The area divisions reflect judgements on the probabilities of infection and vaccine coverage that could be reasonably expected under the conditions in the different provinces (18). Returns for vaccination in each of the areas are estimated for high and low levels of production losses avoided as a result of *S. bovis* vaccination. The estimated benefit-cost ratios and internal rates of return are set out in Table I. Benefits exceed costs in all areas except southern Sudan where low levels of production losses are avoided. For central Sudan, estimated economic benefits are especially high, being well in excess of costs in all circumstances considered, with internal rates of return varying from a low of 43% to a high of 328%, depending on whether low or high productivity losses are avoided.

The methods used to estimate bovine schistosomiasis losses in the Sudan and the costs of the vaccination programme, and to estimate the value of losses avoided are clearly described in the research (18). For the purpose of the exercise, the study concentrates on sales of meat and takes into specific account two factors: mortality from *S. bovis* and growth delay weight loss. It is recognised that additional factors could be considered, such as losses in production from reproduction inefficiency and condemnation of livers at abattoirs. However, reliable data was not available concerning increased reproduction inefficiency, and losses due to liver condemnation are small.

While the estimates in this study rely on various assumptions, the systematic framework provides a solid basis for economic evaluation. The model can be easily reworked for changed assumptions or conditions. In addition, scope exists for adapting the model to estimate the economic returns from control of other animal diseases. However, the model evaluates one method of control only, whereas comparative economic analysis of different methods and techniques of control would be desirable.

The level of subsidy or the extent to which farmers would have to pay for vaccination of cattle in the Sudan against *S. bovis* is unclear. Even when returns from an investment are high, individual farmers in less developed countries (LDCs) may fail to undertake this investment because of lack of finance or because of suspicion of new techniques. Farmers in LDCs often face different economic constraints to those in developed countries. As highlighted by Roberts and Subardono (38), control measures for animal diseases which are economic in developed countries may be uneconomic in less developed countries or prevented from being adopted by cultural practices. Therefore, the development of different strategies for controlling helminths in LDCs may be necessary. In relation to the control of fasciolis in ruminants in LDCs, the following observations have been made: 'Anthelmintics are not affordable. Recent observation of a major fasciola resistance gene with substantial dominance in Indonesian Thin Tail sheep infected with *Fasciola gigantica* suggest that parasite control by breed substitution, or cross-breeding and selection, are feasible. Such control should be inexpensive to implement and sustainable' (38).

<table>
<thead>
<tr>
<th>Area and coverage assumed</th>
<th>High production loss avoided</th>
<th>Low production loss avoided</th>
<th>B/C</th>
<th>IRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central (50%)</td>
<td>22.7</td>
<td>1.5</td>
<td>328</td>
<td>1.2</td>
</tr>
<tr>
<td>Western (50%)</td>
<td>5.7</td>
<td>1.2</td>
<td>209</td>
<td>1.5</td>
</tr>
<tr>
<td>South-east (50%)</td>
<td>4.0</td>
<td>0.7</td>
<td>157</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: based on McCauley et al. (18), p. 738
a) Benefit-cost ratio based on net present values of benefits and costs
b) Internal rate of return

Table I: Benefit-cost ratios and internal rates of return for a five-year vaccination programme against bovine schistosomiasis in the Sudan.
Breed substitution is in fact often used as a mechanism for coping with parasites, even in developed countries, including Australia. Bos indicus cattle are often substituted for Bos taurus in tick-infested areas because the former species has superior resistance to ticks. However, such substitution can involve economic costs, for example if the market value of products from the substituted breed is less than the alternative. Roberts and Suhardono also suggest that some simple changes to agricultural cultural practices in LDCs may entail low cost and provide some control of fasciolosis, however, an economic study was not undertaken (38). The study is nevertheless significant in that the importance of relating research on the control of animal diseases to the social and economic context in which this research is to be applied is emphasised. To complicate matters, it might also be added that social and economic conditions are rarely stationary. Changes in the direction of research and in the type of advice given to client groups are generally required as circumstances change.

It should be noted that in undertaking social evaluation of methods of disease control, as opposed to the calculation of private economic benefits, factors additional to those mentioned above should be taken into account. For example, the use of molluscides to destroy snails which are hosts for a helminth may destroy other biota of value. All externalities and environmental spillovers should be taken into account in a social evaluation. Furthermore, more frequent administration of anthelmintics may accelerate resistance of helminths to these chemicals, so the more immediate economic benefits must be balanced against loss of economic benefits in the longer term. In addition, some anthelmintics (and other chemical means of controlling parasites) result in chemical residues in meat or milk which can limit the marketability and suitability of the product for human consumption. This restricts the economic and social value of the use of such chemicals.

Thus, it can be seen that the economics of control of helminthiasis is complex, partly because of the complex epidemiology involved. A sound knowledge of both biological and economic relationships is needed to evaluate disease control strategies involving helminths. That few in-depth economic studies of the control of helminthiasis have been completed is therefore not surprising. However, the authors are surprised to find that no substantial studies in the area seem to have been published since 1984.

**Tick and tick-borne diseases: economic impact and control economics**

Ticks and tick-borne diseases are accepted as major causes of economic loss to livestock industries in tropical and sub-tropical regions of the world. In particular, these losses occur in the ruminant industries. According to McLeod and Kristjansson (24): 'Tick-borne diseases severely constrain cattle production in Asia, Africa and Australia. The diseases theileriasis, babesiosis, anaplasmosis and heartwater can cause mortality, reduced milk and beef production, depressed manure production and reduced animal draft power. The distribution of these diseases is dictated by the presence of specific tick vectors for each of the diseases. Anaplasmosis and babesiosis are primarily transmitted by ticks of the genus *Boophilus*, found throughout Africa, Asia and Australia. Heartwater (cowdriosis) is vectored by *Amblyomma* spp. in Africa. Theileriosis, called tropical theileriosis in Asia and northern Africa is vectored by ticks of the genus *Hyalomma*. It is known as East Coast fever (*Theileria parva*) in Central and Eastern Africa where it is transmitted by the tick *Rhipicephalus appendiculatus*.'

The effects of these agents can be devastating as evidenced by the outbreak of East Coast fever in southern Africa at the beginning of this century, which decimated the cattle industry. In addition, the consequences to an individual producer can be high when naive cattle are introduced into an area where these diseases occur, or where the vector transmitting a disease is introduced to a new area. The latter may occur either as a result of changes in seasonal conditions (for example warmer, wetter conditions, favouring tick development and reproduction) or due to changes in tick control methods. Therefore, the problem confronting decision makers is not whether the diseases are important, but when the disease should be controlled and which method or combination of methods is most appropriate.

Tick-borne diseases provide many difficulties in determining the most economically efficient approach to control. Problems arise due to the complexity of the system, including both the large number of tick species present and of diseases transmitted by the ticks, and the interactions between animals, ticks and disease agents.

Disease control involves a number of activities in various combinations and is not an all-or-nothing event. In addition, disease or vector control activities often affect other vectors or diseases, providing benefits (and in some cases costs) not directly related to the original disease control programme. In addition, control methods for ticks and tick-borne diseases can be difficult to use and are not always effective. For example, vaccines are usually live and although of low virulence, can have side effects requiring close monitoring of livestock for signs of vaccine reactions and need for treatment.

Tick control can have additional side effects: the most commonly applied method (the use of chemical acaricides) produces residues in meat if animals are slaughtered within the prescribed withholding period. Environmental contamination and erosion of areas around dip tanks can also occur.
The factors outlined above, in association with the interactions that occur between vector ticks and the diseases produced, make decisions about tick and tick-borne disease-control complex on a technical and economic basis. For example, treatments to control one species of tick will affect other species of ticks, and the introduction of one programme such as dipping, for tick control, may require introduction of another programme involving vaccination against tick-borne disease (due to reduced immunity). These flow-on effects need to be considered in the analysis. The complexity of animal health systems, in particular, the large number of interactions, calls for the development of simplified models to enable the important factors in the system to be determined and considered in the analysis.

**Economic impacts**

The effects of disease on livestock production

Disease has a variety of biological effects on animals that are exhibited as production losses. Disease affects the ability of an animal to survive, grow and reproduce. In addition to the effects of disease on individual animals, herd effects are also seen, including adverse modification of the herd structure (26).

Close clinical observation, physical measurement and laboratory examination of specimens is often required to determine the effect of a disease on the productivity of an animal (30). The effects of a disease on animal production are difficult to estimate because of the large number of variables that are affected, such as age, breed, production status and condition of the host, pathogenicity of the disease-causing organism and environmental factors (16). Because information is limited on the effects of diseases on production, estimates must usually be made using a combination of published data and expert opinion (11, 33).

The effects of parasitic infestation (which can produce a chronic disease) on animal production have been widely reported (1, 14, 27, 30). A system has been developed to outline the information needed to determine the effects of a disease on livestock production (30). The system uses a combination of experimental studies and expert opinion to determine the effects of a disease on animal production.

In the case of sporadic or exotic diseases there is much less certainty about disease occurrence. To perform a field experiment or observational study would either involve artificial infection of a group of animals or the use of a large number of sites, which would be expensive. In addition, the large number of variables which could not be controlled in an observational study would lead to the need for unacceptably large sample sizes (17). Under these conditions, the use of a modelling approach is appropriate to estimate the effect of the disease on production. This is especially true under extensive grazing conditions where the effects of disease on individual animals are difficult to measure. However, for modelling to be carried out successfully, an understanding of the potential effects of disease on the productivity of affected animals is essential.

Although systems for the assessment of the effects of chronic diseases, in particular internal parasitism, are well documented, techniques to assess the effects of acute infectious diseases on animal production under grazing conditions are not. Extensive production of livestock differs significantly from intensive production, for example, animals are rarely observed closely, animal health information is therefore scarce, inputs are considerably lower per head and feed intake is difficult to measure.

Few studies have been carried out to assess the effect of disease on animal production in extensive areas in Australia. The costs of outbreaks of bovine ephemeral fever have been assessed using crude estimates of disease incidence and the effect of disease on production (39). In addition, the benefits of using an improved vaccine against tick-borne diseases in Australia (3) have been estimated, as well as the costs of bovine pestivirus infection in extensively grazed cattle (20). However, none of these studies examined in detail the loss in production due to the disease compared with the loss avoided when the disease was controlled. No field studies comparing the effect of various disease control measures on animal production have been carried out in extensively grazed areas of Australia.

**Effects of disease on livestock productivity**

Morris and Meek divide the effects of chronic disease on the productive performance of livestock into two categories, namely, apparent alterations in efficiency and real reductions in efficiency (30). This conceptual framework is expanded by Morris and Marsh, who have defined apparent alterations in efficiency as changes in production caused by animals eating less food (31). In some cases, appetite suppression may be due to a direct and specific effect on appetite, while in others the effect may be indirect due to the reluctance of the animal to forage due to pain or discomfort associated with movement or prehension, caused by the disease.

Real reductions in efficiency are defined by Morris and Meek as being due to depression of feed digestibility or of feed conversion efficiency (30). The estimation of real reductions in efficiency is complicated by interactions between these two factors because the level of feed intake can affect the efficiency with which feed is used.

The differentiation between a reduction in feed intake and a true reduction in productive efficiency is important because if a reduction in feed intake is the factor causing the lost production, an increase in stocking rate will increase production as an alternative to controlling the disease (30). Often, the dividing line between apparent and real effects is not clear, and if feed intake cannot be measured, as occurs in
extensively-raised cattle, the two effects cannot be
differentiated (31).

The effects of acute disease contrast with those of chronic
disease because acute disease is short-lived and affected
animals usually either recover rapidly or die. In addition,
animals that have recovered from acute infectious diseases are
often not susceptible to a second attack of that disease,
whereas in the case of diseases such as mastitis and internal
parasitism, recurrent infections or infestations occur.

Categories of livestock production affected by
disease
While the effects of a disease on animals are extremely
variable, a simplified approach must be taken to enable the
examination of these effects. The production loss in grazing
animals due to diseases can be divided into the following
categories:
- death
- weight loss
- reproductive loss
- lactation effects.

A description of each of these factors is given below.

Production loss due to death
The death of animals due to disease can have several effects on
herd production. Deaths result in a reduced number of
animals available for sale and a modification in the herd
structure. In extensively grazed animals, production loss due
to death is difficult to assess.

Production loss due to weight loss
The final effect of weight loss, due to disease, on production
will depend on several factors, the most important of which are:
- the amount of weight lost due to the disease
- the composition of that weight loss (i.e. body fluid, gut
  content, muscle or fat)
- the rate at which the weight is recovered (this is affected by
  compensatory growth, the level of nutrition and the
  composition of the weight loss).

Considerable information is available on the effects of the
restriction of nutrition on the subsequent growth and
development of cattle (34). Much of this information is
contradictory but there is general agreement that several
factors are important in determining if compensatory growth
occurs and if it does, how much compensatory growth occurs.
These factors are as follows:
- breed
- age, liveweight and maturity
- stage of growth and condition (ratio of fat:lean meat:bone)
- severity and duration of restriction
- type of feed
- level of nutrients in the feed (34).

Although clinical disease does cause weight loss, little work
has been done to measure the amount and variation in the
amount of weight lost, the type of weight lost and the ability of
animals under various conditions to recover the weight lost.

Production loss due to product quality
Ticks and tick-borne disease can cause downgrading of live
animals at sales, and of meat, offal, and hides.

Production loss due to effects on lactation
Disease can vary both the quantity and the quality of the milk
produced. The effects on quantity can vary from a mild
temporary reduction to a total cessation of milk production.
The effects vary depending on the stage of lactation at which
the disease occurs and the severity of disease. In beef cattle,
the main effect of a reduction in lactation is on the growth and
survival of calves.

Production loss due to reproductive loss
Diseases can have several effects on reproduction. These
effects on reproduction are firstly examined for females and
then for males. The effects of disease on female reproduction
vary according to the time that the disease occurs in relation to
the reproductive cycle of the individual. The system of
management, either controlled seasonal breeding or
continuous breeding, will influence the proportion of females
at each stage of the reproductive cycle at different times of the
year, and therefore the effect of a disease on reproduction in
the herd.

Diseases can affect reproductive efficiency in the following
ways:
- silent oestrus periods
- prevention of fertilisation
- early embryonic loss
- loss in mid gestation
- abortion in the last trimester of pregnancy
- birth of dead, weak, or deformed calves which die soon
  postpartum
- delays in heifers breeding due to body weight and
  condition being below optimal.

The effects on male reproduction are more restricted and
relate to the ability of the male to seek, mate with and fertilise
receptive females. The effects of a disease in males can be
summarised as follows:
- reduced mobility, with the consequence that affected
  animals are not able to seek and mate with receptive females
- reduced libido
- temporary or permanent infertility due to direct effects of a
disease on spermatogenesis
- temporary infertility due to effects on spermatogenesis and
  sperm survival due to pyrexia associated with a disease.
Temporary effects are especially important if a disease outbreak occurs during or just before the breeding season.

Indirect production effects and non-production effects

Disease can mask genetic differences, making herd improvement difficult, and can be an impediment to introducing more intensive systems of livestock production (12, 28).

Apart from impacts on livestock products, tick-borne diseases can impose costs in terms of reduced consumer surplus, adverse impacts on human health, reduced draught and transport services in countries where cattle and buffalo are used for these purposes, and impose adverse effects on animal welfare. Reduced reproduction can lead to lower stock numbers, where stock ownership is a measure of wealth, a status symbol, source of creditworthiness, or provides other social values. In general, the literature overlooks these costs, with disease costs defined in terms of production and control costs only, as described, for example, by Mukhebi (32).

Costs of ticks and tick-borne diseases

There is no shortage of reported estimates of regional and national costs of ticks and tick-borne diseases. Often these estimates are made to assist in evaluation of tick eradication proposals. A number evaluations in various countries have been reviewed by Davis (8, 9), some examples of which follow:

a) The Bureau of Agricultural Economics (BAE) estimated the annual cost of cattle tick to producers in Australia (including production loss, chemical purchases, capital works, mortality and hide damage) at £9.5 million (about AUS$90 million at current prices) (6).

b) The cost of *Boophilus microplus* to beef producers and government in Australia (including research, loss of production, tick fever vaccinations, labour, dip maintenance and chemicals) was estimated by the Cattle Tick Control Commission to be AUS$41.27 million (over USS$250 million at current prices) (7). Indirect costs due to tick fever deaths or illness were approximated by assuming 1% mortality. No estimates were made for the dairy industry. The estimated cost to Queensland in this study was approximately AUS$140 million at current prices, considerably higher than found in the BAE study (6).

c) McLeod and Kristjanson noted that 120 scientists have been involved in preliminary estimation of tick-borne disease costs in South Africa, Kenya, Tanzania, Zimbabwe, Thailand, China, India, Nepal, Indonesia, the Philippines and Australia (24). As an example, the cost estimates for Australia for US$37 million in 1997 (approximately US$38 million at current prices), are shown in Table II.

d) In the United States of America (USA), an eradication campaign for *B. microplus* and *B. annulatus* was successfully completed in 1947, at a cost of US$53.5 million (at 1953 prices). A retrospective economic analysis (5) estimated a benefit-cost ratio of the eradication of 140:1.

e) In Argentina, the cost of tick infestation was estimated at US$154.6 million for weight loss, death and hide damage, and US$34.9 million for the cost of tick control and tick fever vaccine (41).

jf) The global cost of ticks and tick-borne diseases was estimated in 1979 at US$7 billion (over AUS$26 billion at current prices) (19).

The above studies suggest there are major variations in cost estimates, e.g. AUS$90 million and AUS$140 million for Queensland, and AUS$250 million and AUS$60 million for Australia. In addition, the cost of ticks and tick-borne diseases in Australia is generally agreed to have fallen sharply with the wider use of *Bos indicus* cattle.

Control economics

Control economics from a social perspective

The optimal level control effort for ticks and tick-borne diseases may be viewed in terms of the loss-expenditure tradeoff curve. In this context, Mukhebi (32) views immunisation in terms of the tradeoff curve developed by McInemey (21, 22). However, often the decision faced will not be to decide the optimal amount of control, but rather to decide whether to continue current practice or introduce an eradication campaign, on a local, regional or national basis. In fact, for developed countries engaging in intensive livestock production, tick eradication may be the optimal policy. However, this will be true only for a very few countries (such as those in the Caribbean where the USA wishes to prevent the introduction of *Amblyomma* into the USA). Often eradication will be favoured where the process is moderately easy technically, e.g. areas of low rainfall or low temperatures. In some cases, eradication will proceed incrementally, as individual districts work towards and achieve eradication. The Cattle Tick Control Commission noted essential conditions for successful eradication: ability to muster all tick hosts; adequate treatment facilities; effective industry co-operation; reasonable prospects of avoiding reinfection; efficient weapons of control; and adequate funding (7).

### Table II

**Annual cost of ticks and tick-borne diseases, Australia, 1997 (US$ million)** (24)

<table>
<thead>
<tr>
<th>Cost category</th>
<th>Tick worry</th>
<th>Anaplasma and Babesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- chemicals</td>
<td>4.2</td>
<td>0.0</td>
</tr>
<tr>
<td>- labour</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>- vaccines</td>
<td>12.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Productivity loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mortality</td>
<td>0.0</td>
<td>15.1</td>
</tr>
<tr>
<td>- milk production</td>
<td>0.7</td>
<td>0.06</td>
</tr>
<tr>
<td>- live weight</td>
<td>3.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>20.8</td>
<td>15.9</td>
</tr>
</tbody>
</table>
Where livestock production systems are more extensive (such as in Australia, South America or Africa), the economics of eradication becomes questionable. Here the payoff from eradication is lower, ticks do not represent an acute problem, managing a full muster may be difficult, and more wild hosts are likely to be present, making eradication more difficult.

If eradication is warranted, the issue arises as to how the cost is shared between government and private sector. Davis suggests that this may be through consolidated revenue, charges on producers, or joint funding, noting that in voluntary tick eradication programmes in Queensland, government met 50% of the cost, and had representation on a corporatised local management committee (9).

It has been argued (13) that in the case of disease (or vector) eradications, a different form of tradeoff curve is relevant, as illustrated in Figure 2. Substantial overhead costs ($c_1$) may be incurred in setting up a tick eradication programme, which in themselves do not achieve any reduction in disease cost. In addition, even at a moderate level of variable expenditure ($c_2 - c_3$), little progress may be achieved towards eradication. At a high level of control expenditure, collapse of the tick population may take place. If the C-E curve is of this shape, then the choice is one of either eradication or non-eradication, and not an intermediate point.

Fig. 2
Disease cost-control expenditure tradeoff model for an infectious disease which requires a threshold protection level

### Control economics from a private perspective

As noted above, in intensive livestock production systems, the optimal policy is likely to be tick eradication. In extensive systems and in developing countries, choice of optimal control measures is more difficult, and strategies need to be compared in terms of expected profit or cost to the individual producer. The complexity of the economic evaluation may necessitate a form of modelling and simulation. From the viewpoint of the livestock owner, several questions arise with respect to disease control actions, as follows:

- does the control method work (what is the chance of the method failing)?
- will production be greater after the control programme is implemented?
- will the benefits derived exceed the costs (including opportunity costs)?
- can the control programme be put into practice within the constraints in which the livestock owner operates?

At the private producer level, decisions arise concerning the following options:

- to live with the disease, with little or no control measures
- to continue current practice, or standard practice in the district, e.g. spraying for ticks when numbers climb
- to adopt a regular vaccination schedule
- to increase control incidence, perhaps supported by information collection
- to attempt to achieve a disease-free herd or flock, with respect to particular diseases.

### Control measures

Davis (8) categorises control measures for the cattle tick species *B. microplus*, as follows:

- chemical control
- use of tick-resistant (*B. indicus*) cattle
- pasture rotation
- use of TickGARD, a cattle tick vaccine.

Davies notes that tick fever – *Babesia bovis*, the major indirect effect of the cattle tick – can be controlled by reducing cattle tick populations, selecting cattle which have natural resistance to tick fever (*B. indicus* cattle), and using tick fever vaccines. With constant tick populations, cattle will have an acquired resistance; vaccination is more critical where outbreaks occur only occasionally.

### Estimating the production loss avoided

In the simplest form, the production loss avoided due to disease control equals the reduction in the number of cases of disease due to disease control multiplied by the production loss per case. However, the production loss avoided will vary with the age and sex class of the animals and the severity of the disease. The calculation can be made more accurate if the production loss avoided is estimated as the sum of the production loss of each age and sex class of the animals in the herd and is weighted according to the different severities of disease.

Most control studies, models and programmes involve a combination of experimental studies, expert opinion, field studies and modelling and simulation. The complexity of the system means the level of knowledge about the biology of a
disease is limited. However, perfect knowledge of all interactions is not required to make an appropriate decision about control of the disease. Attempts to collect all information about the disease and control method before control is instituted will bear a cost and may be uneconomic. It is necessary that any analysis considers the likely consequences of action and inaction. Lack of information on the likely effects of disease control does not prevent an effective and detailed analysis being carried out.

The private use of animal health information

Information provides support for private decision makers. Any decision in livestock disease control involves uncertainty because the aim is to predict what may occur in the absence of a disease control programme and the effect that a disease control programme may have on disease occurrence. Decisions are therefore made using the imperfect knowledge that is available to the decision maker (in this case knowledge is defined as the sum of available information). However, perfect knowledge is not required for rational decision-making and the optimal decision-making usually involves imperfect knowledge and hence imperfect information (4).

The collection of additional data, which is processed into information, is one way to decrease uncertainty. However, the production of information requires the use of resources, and hence bears a cost. Because of these costs, it is often uneconomic to decrease uncertainty through the gathering of additional information. Alternatively, the effects of uncertain events can be reduced by, for example, maintaining flexible policies that enable a rapid response to change in animal health status. Examples are: preparation for immediate vaccination if cases of a disease occur in the district, or reduction of the hazard, as in the case of farming disease-resistant B. indicus cattle where there is a risk of disease caused by B. bovis infection. However, maintaining flexible policies will also bear a cost.

The effect on a decision of the collection of additional information, leading to increased knowledge, can be to change the decision, decrease the uncertainty in making the decision, or decrease the need for flexible policies.

The benefit gained by a farmer from collecting additional information will depend on the current level of knowledge. If, when using the information currently available, the level of knowledge of the producer is at a low level, then the collection of additional information will most probably bring a large increase in information for a relatively small expenditure. However, if the level of knowledge is high, the benefit from collection of additional information is much less per unit of expenditure. A farmer with a high level of knowledge would be expected to gain less benefit from the same expenditure on information collection than a farmer with a lower level of knowledge. A farmer with a high level of knowledge may gain little information from additional expenditure and the expenditure could exceed the value of the information.

Collection of information

Although collecting information is regarded as an essential part of economic analysis, the economics of obtaining additional information is not usually assessed when designing animal health programmes. Often, additional data must be collected and analysed before the presence of a disease problem and the possible benefits of controlling a disease are recognised (i.e. the efficiency gap is detected). The value of information will depend on the attitude of the farmer to using information and the degree of confidence the farmer has in the accuracy of the information. Disease control is often carried out because a severe disease outbreak in the past has stimulated producers to avoid similar losses in the future. Ellis and James (11) note the lack of use of available information on disease control by farmers, commenting on the slowness of farmers to commence new disease control measures which have been shown to produce financial rewards. Furthermore, it is suggested that this is due to the reluctance of farmers to spend money and effort to obtain a benefit that has not previously been obtained.

If a producer is already making the most appropriate decisions then the private benefit received from the improved animal health information will be small, and will depend on the value placed on the decreased uncertainty in relation to decisions and the reduction in the cost of maintaining flexible policies due to the decreased uncertainty. It is also possible that additional information will change a specific decision from the appropriate one to an inappropriate one, resulting in a negative pay-off from the additional information (though not in an expected pay-off sense). It will not be worthwhile for a producer to collect additional information on animal health unless the benefit gained from using that information exceeds the costs of collection.

The relationship between cost and value of additional information in private decisions

If a farmer decides to gather additional information on the occurrence of disease on the farm, there are many methods of collecting that information. While some of these methods will not be feasible, or will be prohibitively expensive, the farmer will generally have a choice. To select the method to be used, the farmer can compare the cost of the method and the value of the information likely to be produced. In most cases the method will not be an all-or-nothing method, and by increasing expenditure, the farmer will obtain increasingly accurate information. However, the relationship between the cost of collecting information and the value of that information to a private decision maker is almost certainly not a linear relationship and several possibilities exist for that relationship.
Specific scenarios for animal health decisions

The following sections examine the issues confronting individual producers in a variety of situations, with some examples of analysis for different production systems. A relatively simple situation will be examined first with more complex decisions considered in subsequent examples.

**Scenario 1: control of ticks and tick-borne diseases for an extensive beef producer in Australia**

Here, the major tick-borne disease is caused by B. bovis and tick control is often not practised on the property. The producer faces the decision of whether to vaccinate. The questions are whether the benefits from vaccinating exceed the cost, and how the net pay-off compares with alternative uses of the money, such as depositing it in a bank account or investing in shares. In addition to these financial concerns, the producer may wish to be perceived by other cattle producers as a good manager who maintains healthy stock, and by the community as someone who is concerned about the welfare of animals. Therefore, the producer will also want information on the effect of vaccination on morbidity and mortality in the herd.

How can this information be provided to the producer? Discounted cash flow analysis, including partial budgeting, can provide information on expected returns from vaccination. A variety of information is required to produce annual partial budgets. How extensive does the partial budget need to be, and how accurate must the data be? In its simplest form, the calculations might resemble the following:

- a) 500 cattle are to be vaccinated each year
- b) the vaccine costs AUS$1.50 per dose and administration costs AUS$0.50 per head (mainly for labour)
- c) the vaccine is effective and all animals that require vaccination are vaccinated
- d) cattle only need to be vaccinated once in a lifetime
- e) in the absence of vaccination, three cattle die as a result of B. bovis infection each year and each animal that dies has a value of AUS$400.

From these data, the partial budget would take the following form:

- **Vaccine costs:** 500 x AUS$1.50 = AUS$750
- **Administration costs:** 500 x AUS$0.50 = AUS$250
- **Total costs:** AUS$1,000.

Benefits from preventing stock deaths:

- AUS$400 x 3 = AUS$1,200

Annual net cash benefit: AUS$200.

The farmer can see that if the estimate of three deaths is accurate, the gains will exceed the expenditure on disease prevention (by AUS$200/year), provided the vaccine is effective.

Many livestock producers carry out analyses similar to the one described above, to assist in decision making.

In some cases, a limited partial budget may provide the farmer with sufficient information to meet decision-making needs. However, the disease may also have effects such as reducing cattle growth rates and reducing reproductive efficiency. An approach to estimating the production loss avoided and financial benefit gained due to a vaccination programme to control B. bovis is provided by Ramsay (37) and a brief description is presented here. The approach illustrates several areas in which additional information may be of use and others where information may be of limited use to a decision maker.

The production loss is divided into loss due to deaths, weight lost and not regained by the time of sale, and reproductive loss. A simulation model is developed which is used to determine the production loss avoided for two vaccination programmes, for each of three herds containing cattle that are resistant, susceptible and of intermediate susceptibility to disease, following infection with B. bovis at high, medium and low levels of incidence of infection.

The model developed provides an effective method of examining the production benefits gained from adopting a vaccination programme. Simulations indicate that the major production benefit from B. bovis vaccination arises from deaths avoided. Considerably less benefit is predicted to be gained in the form of weight loss avoided due to prevention of clinical disease from which animals recover. The effect of B. bovis vaccination on reproductive efficiency is also predicted to be small.

As expected, the production benefits of B. bovis vaccination are predicted to be greatest in the susceptible cattle and least in disease-resistant cattle. The incidence risk of infection also affects the production benefits of B. bovis vaccination, with the loss avoided being highest where the incidence risk of infection is medium and least where the incidence risk of infection is high, as in these cases, herd resistance to B. bovis is also high.

Livestock producers in extensive grazing areas of Australia suffer from a shortage of animal health information. However, a rational decision can be made without perfect information and it will not be worthwhile for a producer to collect additional information on animal health unless the benefit of that information exceeds the cost of collecting the information. A clear understanding of the interactions between the disease incidence and production effects will enable the livestock producer to consider the decision to gather additional animal health information systematically and examine the potential returns. However, the benefits from collection of additional information need to be calculated for each individual situation.
The information above with respect to the effect of *B. bovis* on production demonstrates that collection of additional information to determine more precisely the weight loss due to disease caused by *B. bovis* will not be of great benefit to the decision maker, nor will be additional information on the reproductive effects of the disease. However, additional information on the number of animals likely to die following infection and on the incidence of risk of infection could be of use to the decision maker.

Before deciding whether to collect additional information, the livestock owner needs to determine if the benefit from collecting the information is sufficient to justify the costs of collection. The collection of additional information does not always result in a net gain. When the gain from collection of additional information is small, it is possible that the farmer would gain more by using the money elsewhere rather than collecting additional information. In the case of *B. bovis*, vaccine is relatively inexpensive in comparison to the cost of the collection of additional information, and provides long-lasting protection. Therefore, it is possible that money may be more effectively spent on the purchase of vaccine rather than on gathering additional information. If vaccination must be carried out annually, or a more expensive and less effective vaccine is used, the benefit from collecting additional information would be expected to be greater.

*Scenario 2: cattle producer in a country in Africa where multiple ticks and tick-borne diseases are present*

In the case of a large-scale beef producer the question to be asked may be ‘How should I control ticks and tick-borne disease on my property?’ The producer faces a number of decisions which can interact producing flow-on effects. For example, dipping practised to control ticks will also affect the exposure of stock to agents causing tick-borne diseases. If a producer is considering reducing dipping intensity what benefits will be obtained? The livestock might enter a higher priced market for chemical-free beef, and chemical and labour costs may be reduced. Environmental contamination on the property could be reduced since the producer is no longer using dip wash. In addition, the farmer may wish to protect the environment and farm in an ecologically sustainable manner. However, by reducing dip use, production could be reduced and greater morbidity and mortalities experienced.

In the case of a small-scale dairy or beef producer, the effect of losing a single animal may be much larger than for a large-scale beef producer. For example, a producer with three cows will lose a third of productive capacity if one cow dies. Therefore, this producer is more interested in reducing risk of loss of an animal rather than the average long-term effects of disease control. The producer may be prepared to spend relatively more on control of ticks and tick-borne disease because although the risk of loss of an animal to tick-borne disease may be low, the loss would have major economic consequences.

**Conclusion**

Economic study of endemic diseases and disease control is a complex area, with a large number of disease vectors and diseases, and complex relationships between treatment, environment and livestock performance to consider. While considerable technical study of these diseases has been performed, economic analysis of the effects and the control of the diseases remains a relatively neglected field.

Decision-making about livestock diseases needs to be viewed from both social and private perspectives. In making social decisions it is necessary to take a broader view than in making private decisions, and consider externality costs, optimal overall control effort, and sharing of costs between taxpayers and livestock owners. Individual producers face complex decisions about disease control effort, including whether to invest in obtaining further information before making decisions.

Major differences in livestock systems and in optimal disease control programmes arise in developed and developing countries, between intensive and extensive production systems, and even between properties, due to differences in environment, resources and objectives of livestock owners. Non-production costs of diseases can be important, but typically are not adequately taken into account in disease cost studies.

While little information is available on the cost of helminth diseases, many estimates have been made of the costs of ticks and tick-borne diseases at regional and national level, sometimes demonstrating that eradication is warranted. Introduction of more tick-resistant cattle appears to have substantially reduced costs associated with ticks and tick-borne diseases.
Impact économique des enzooties et des programmes de prophylaxie

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Résumé

Les auteurs évaluent l’incidence économique des enzooties et les enjeux économiques liés à leur prophylaxie. Ils s’intéressent en particulier aux helminthiases et aux infections transmises par un vecteur endémique (notamment les tiques et les maladies qu’elles transmettent). Les décisions relatives aux mesures de prophylaxie doivent être prises à la fois par les pouvoirs publics et par le producteur. Les pouvoirs publics ont besoin d’informations sur le niveau de prévention nécessaire, sur l’importance de la participation requise et sur les modes de financement des programmes zoosanitaires (notamment sur la répartition des coûts entre contribuables et éleveurs). Quant aux producteurs, ils doivent être informés sur les efforts qu’ils auront à fournir pour la prophylaxie, notamment en ce qui concerne la collecte des données, et sur la manière de concevoir des stratégies de lutte. L’économie peut apporter un éclairage sur ces questions. Toutefois, l’expérience montre que les politiques zoosanitaires sont particulièrement difficiles à évaluer d’un point de vue économique, d’autant qu’il existe des relations complexes entre la santé animale, les effets sur la production, l’accès au marché et les bénéfices non productifs liés aux animaux. Il existe peu d’informations sur le coût des helminthiases, mais de nombreuses estimations réalisées sur celui des tiques et des maladies qu’elles transmettent, aux niveaux régional et national, montrent qu’une éradication peut parfois se justifier.

Mots-clés
Animaux d’élevage — Économie — Helminthiase — Maladies animales — Maladies transmises par les tiques — Prophylaxie.
complejidad de los vínculos existentes entre sanidad animal, efectos sobre la producción, acceso a los mercados y beneficios no productivos que procura el ganado. Aunque no existe mucha información sobre el coste de las enfermedades helminticas, sí abundan las estimaciones de los costes que entranan, a escala tanto regional como nacional, las garrapatas y las enfermedades que transmiten. Esas estimaciones demuestran a veces que la erradicación puede justificarse.

**Palabras clave**

**References**


