Assessing the economics of animal trypanosomosis in Africa—history and current perspectives

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ABSTRACT

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Finding appropriate ways of dealing with the problem of tsetse and trypanosomosis will be an important component of efforts to alleviate poverty in Africa. This article reviews the history of economic analyses of the problem, starting with the use of cost to guide choice of technique for tsetse control in the 1950s, followed by work in the 1970s and 1980s linking these to the impact of the disease on livestock productivity, and in the 1990s to its wider impact. In the current situation, with limited resources and a range of techniques for controlling or eliminating tsetse, the cost implications of choosing one technique or another are important and a recent study reviewed these costs. A novel approach to assessing the potential benefits from removing trypanosomosis by creating 'money maps' showed that high losses from animal trypanosomosis currently occur in areas with high cattle population densities on the margins of the tsetse distribution and where animal traction is an important component of farming systems. Given the importance of the decisions to be made in the next decade, when prioritising and choosing techniques for dealing with tsetse and trypanosomosis, more work needs to be done underpinning such mapping exercises and estimating the true cost and likely impact of planned interventions.

INTRODUCTION

Africa's nations entered the 21st century facing the monumental challenge of combating poverty in a continent which contains almost all of the world's poorest nations, and where over half of the world's total deaths in children under five take place. The problem of trypanosomosis, affecting both human and animal health, "lies at the heart of Africa's struggle against poverty" and dealing with this disease has the potential to impact on all eight Millennium Development Goals—of the 37 countries with tsetse infestations, 21 are among the world's 25 poorest (PAAT 2008).

HISTORICAL OVERVIEW

Underpinning today's analyses of the economics of dealing with tsetse and trypanosomosis are over five decades of research and experience. At this historic moment, celebrating the centenary of the Onderstepoort Veterinary Institute, it seems appropriate to review this work and how it informs the present day dilemmas and decisions. All the more so, since the first large-scale successful tsetse eradication took place here, with the elimination of *Glossina pallidipes* over 11 000 km^2 from what was then Zululand (Du Toit 1954).

Thus, from the late 1940s onwards into the 1950s and 1960s, the economic component of tsetse control work consisted of meticulous recording of the costs of operations. By this time, a number of approaches had been tried and tested for controlling or eliminating tsetse populations. Describing bush clearing Wilson (1953) records: "The total cost therefore for the clearing done in both 1949 and 1950 over most of the blocks was £200 per mile. The cost of continuing this method of eradicating *Glossina palpalis* was obviously prohibitive." They then turned to "the use of 5 per cent DDT sprays on the fringing vegetation along 20 miles of the Mbogo river" which "gave dramatic results and *G. palpalis* was eradicated at a cost of £42 per mile". Thus, by 1950, costs were being analysed in order both to inform choice of technique and to improve tsetse control methods. More systematic cost analyses began in the 1970s with consideration of full overheads and comparison of techniques. Thankfully, the tsetse control methods used have changed: Jahnke (1974) cites a "grand total of animals shot" between 1944 and 1970 in Uganda of 161 867, a figure which is only marginally mitigated by the fact that the number shot per km^2 ranged from 2–16 animals. Furthermore, seen strictly in terms of government expenditure, game clearance came out better, at roughly half the cost of ground-spraying. The most detailed and comprehensive cost study was undertaken during the late 1980s and early 1990s by Barrett (1997) in Zimbabwe, where so much ground-breaking research work into tsetse control methods was being undertaken. During this period a uniquely wide range of techniques was being used there: ground-spraying, aerial spraying, targets and insecticide-treated cattle (ITC). Barrett's study emphasized the fact that for each technique costs varied greatly depending on terrain, fly species and the presence of cattle and quantified how these variables affected cost. The cost studies all highlight the difficulties of calculating tsetse control costs in a manner which enables comparisons to be made across ecosystems, tsetse species, project duration, currencies, tsetse control unit administrative structures and therefore countries and locations.

In the early 1970s, benefit-cost studies became a mandatory component of all donor-funded and government projects. Meanwhile, these difficulties in comparing costs across localities and projects with different objectives, led to people becoming increasingly aware that decision-making in the tsetse and trypanosomosis field would need to include a benefit component. The first published benefit-cost study on the subject was Jahnke (1974), which looked at ground spraying and game clearance in relation to benefits from ranching in Uganda, and concluded that given the costs of tsetse control by these methods plus land clearance for development, these schemes barely broke even. Since then, numerous benefit-cost studies were undertaken throughout Africa, both in advance of work being undertaken and retrospectively following successful control or elimination. Some of these are summarised in Shaw (2004). They demonstrate that most interventions to deal with tsetse yield respectable benefit-cost ratios of around 3:1, provided that they are undertaken in areas where trypanosomosis seriously constrains cattle production and that they are sustained.

By the 1980s it had become clear that the demands for benefit-cost studies needed to be underpinned by serious field work looking at the direct impacts of the disease on livestock productivity. A large number of studies were undertaken, comparing key parameters (herd structure, mortality, birth rates, mass gain and milk yield) in infected and non-infected individuals, herds and in locations with different levels of tsetse challenge, mostly studying cattle. These consistently showed that the disease has an impact on productivity, but the impacts vary hugely, even across similar locations. The results were summarised in Swallow (2000) and updated in Shaw (2004), with the following broad conclusions. Calf mortality rates were 6–10 % higher in infected populations, but the difference could be up to 20 %. Death rates in older animals were 2–8 % higher, but the difference can be negligible if trypanocides are used effectively (Doran 2000). Annual calving rates were typically 7% lower in infected populations. The effect on milk yields was particularly difficult to measure, with impact ranging from a reduction of 2–26%. In terms of its impact on agriculture, the disease's impact on the use and effectiveness of draught power is crucial, but there is, in fact, very little numerical data on this. Swallow (2000) estimated oxen in a high-risk area in Ethiopia to be 38 % less efficient. Throughout Africa, farmers probably treat draught oxen more than any other category of livestock. For example, in the Eastern Province of Zambia, Doran (2000) reports them as being given nearly ten times as many curative trypanocide treatments as bulls and over 50 % more than cows.

During the 1990s more work was done on the indirect effects of the disease on land use. In contrast to the 'direct' effects of the disease on livestock health, 'indirect' effects occur where the presence of tsetse affects people's production methods by limiting their use of draught power, making it difficult to upgrade livestock breeds, avoiding grazing or settling in certain areas. Again, the studies undertaken showed very variable responses to the challenges posed by tsetse infestation (Reid & Swallow 1998; Doran 2000). For example, in some cases tsetse removal accelerated in-migration by farmers and livestock keepers; in others in-migration preceded tsetse control or took place despite the presence of tsetse. Thus, following the Sahel droughts of the early 1970s and 1980s zebu cattle keepers migrated southwards in large numbers, for example increasing cattle numbers six-fold in northern Ivory Coast and five-fold in the Central African Republic (Shaw 2004). Despite the presence of tsetse, draught power is extensively used in West Africa, southern Africa, Ethiopia and Uganda, but at a high cost in terms of trypanocides, lowered productivity and increased mortality.

CURRENT PERSPECTIVES

Faced with the closing of tsetse control departments, a gradual reduction in funding and interest, not just in tsetse control and animal trypanosomosis, but overall in livestock, African scientists set up the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC). This was endorsed by the African Union Heads of State in their historic declaration in 2000 in Lomé, which committed their countries to finding ways of dealing with the problem of tsetse and trypanosomosis. Thus, the new millennium began with this Pan-African initiative and with it a renewed need for economic inputs in order to analyse where, when and how best to intervene.

Refining the costs

In order to inform choice of technique in this context, a study was undertaken based on the options for Uganda (Shaw, Torr, Waiswa & Robinson 2007). This updated the approach used by Barrett (1997), siting the estimates in Uganda and using as a basis the control approaches being examined by PATTEC for tsetse elimination, including field studies and an administrative structure. The four methods were trapping at various intensities, insecticide-treated cattle (ITC) with insecticide applied by pour-on or by spraying, aerial spraying using the sequential aerosol technique (SAT) and the use of the sterile insect technique (SIT) following suppression using SAT or SIT. The gradual elimination of tsetse with the use of each technique was modelled using a tsetse population dynamics model (Vale & Torr 2005; http://www.tsetse.org/). The results for a selection of scenarios are given in Fig. 1.

This shows that costs vary widely, both within techniques and across techniques. Where sufficient cattle are present for ITC to be used and the insecticide is applied by spraying, this can be the cheapest technique. Aerial spraying is more expensive but can be effective within the shortest time period. Where SIT is considered a necessary component of a programme, following suppression of the tsetse population by another method, the costs increase substantially. The cost of traps is relatively high, because of the organisation and manpower required to deploy them and is dependent on the density required, itself largely a function the *Glossina* species being targeted. In general terms, costs for elimination, in a straightforward situation of an isolated tsetse population, would thus range from 200–1,500 US\$/km^2. Once non-isolated populations are considered, barriers against reinvasion are needed and costs increase. For example, maintaining barriers for 5 years with reinvasion pressure on one of four sides of a block would add between 20 % and 60 % to costs. If barriers are needed over a larger area, for a longer period, or if reinvasions occur, costs would increase further.

These tsetse elimination scenarios need to be compared to the ongoing costs of controlling either the disease or the vector. Fig. 2 shows a selection of these costs, estimated over a 20-year period and using the standard practice of discounting (cf. Shaw *et al*. 2007) whereby monetary amounts received or spent in the future are weighted relatively lower than those spent or received in the present. These control approaches would obviously not eliminate the disease, so that some losses would still persist. For the use of trypanocides, the emergence of drug resistance remains a concern. The number of doses per km^2 per year would be a function of the cattle population density and the number of doses being given—for example, 1.5 per head per year on average in Eastern Zambia (Doran 2000). For this costing of control options, the costs of ITC are all using sprays with the additional option of using spraying in restricted application (RA) to the legs and belly of cattle (Bourn, Grant, Shaw & Torr 2005). This method retains the efficacy of the other ITC application methods while being substantially cheaper. Like other ITC methods it can also have an added beneficial effect in reducing tick burdens and the incidence of tick-borne diseases. Therefore, in terms of decision-making it can be seen that in many situations effective levels of tsetse control, even if maintained over a long period, can be cheaper, or as cheap as, attempting to eliminate the fly.

Mapping the benefits

The numerous benefit-cost studies had, over the years, demonstrated that for all the techniques developed, sustained tsetse and trypanosomosis control was profitable in specific localities. But, with the more global approach fostered by PATTEC, it has become necessary, *firstly*, to be very clear about where the priority areas for intervention are and,

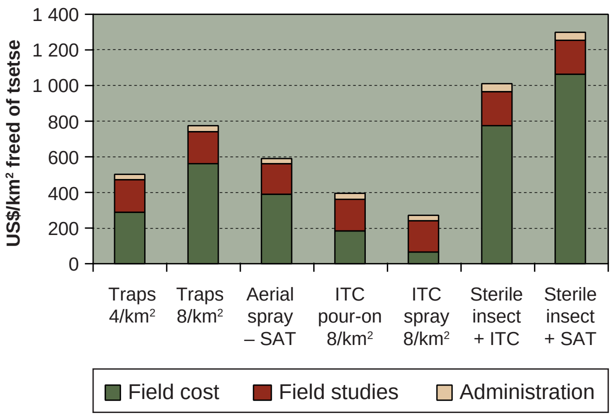

FIG. 1 Cost comparisons for tsetse elimination

Source: Adapted from Shaw *et al.* 2007 and based on prices in Uganda in 2006

Note: SAT: sequential aerosol technique; ITC: insecticide-treated cattle. Future costs are discounted at 10 % per annum

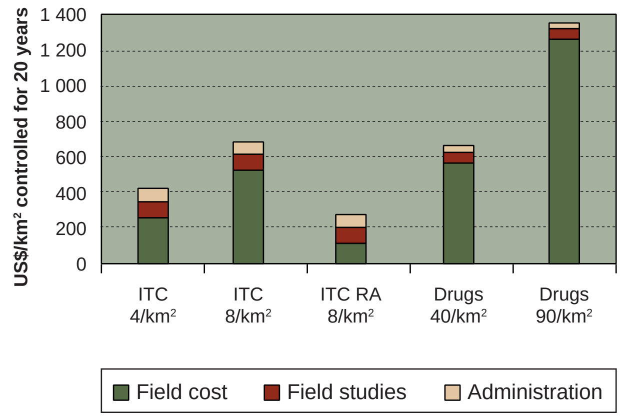

FIG. 2 Cost comparisons for ongoing control of tsetse and trypanosomosis at varying intensities

Source: Based on estimates in Shaw *et al*. 2007 and Bourn *et al*. 2004

Note: ITC: insecticide-treated cattle; RA: restricted application; drugs refer to the total number of doses of trypanocide given to cattle per year per km^2. Future costs are discounted at 10 % per annum

secondly, what levels of expenditure are justified by the losses due to trypanosomosis in different locations. The development of geographic information systems (GIS) alongside remote sensing has dramatically increased the extent to which spatial variables can be analysed, linked and mapped. These techniques have much to offer epidemiology and animal health and more specifically in decision-support in the fields of tsetse and trypanosomosis (Gilbert, Jenner, Pender, Rogers, Slingenbergh & Wint 2001; Hendrickx, Biesemans & De Deken 2004). The provision of maps of cattle populations and updated tsetse distributions already highlighted priority areas for intervention. Accordingly a study was undertaken (Shaw, Hendrickx, Gilbert, Mattioli, Codjia, Dao, Diall, Mahama, Sidibé & Wint 2006) to try and bridge this gap, by producing a 'money map' of the impact of animal trypanosomosis for West Africa. This study had three components. *Firstly*, a new map of the main cattle breeds and production systems was produced. *Secondly*, for each of the four main systems identified, the herd dynamics were modelled for 'with' and 'without' trypanosomosis scenarios and the differences in monetary output were calculated and projected over a 20-year period. These differences in output represent the losses imposed by the disease, or the potential benefits from its removal. They were then expressed as dollars per bovine currently present in the area. *Thirdly*, a spatial expansion model was used to project where 'with' and 'without' trypanosomosis cattle populations would migrate over the 20-year period, in relation to the carrying capacity of the land. Combining production systems, benefits per bovine and the expansion of cattle populations made it possible to produce a map showing the potential monetary benefits per km^2, over 20 years, if trypanosomosis were removed. A section of this map is reproduced in Fig. 3.

This shows the potential benefits in US$/km^2 ranging from under $500 to over $7,000 over 20 years (as with costs, benefits have been discounted at 10 %). This big range reflects, *firstly*, the cattle distribution and, *secondly*, the work oxen distribution. The highest levels of benefits, shown in dark green, are in the areas on the northern boundary of the tsetse distribution and there is a strong association with the cotton growing areas where there is intensive use of draught cattle, often partly trypanotolerant crossbred stock. Further to the south, in the 'red' zones on the map, cattle population densities are much lower, many of the breeds are trypanotolerant so that although trypanosomosis does affect them, the disease usually presents in a less acute form. Cattle are kept mainly as a store of wealth and not used as intensively for draught or milk production as they are further north. Closer to the West African coast, around the major conurbations, meat prices are higher and there is a substantial demand for milk from urban populations, so that cattle, including some trypano-sensitive zebu breeds, are kept on a more commercial basis, and thus the losses im-

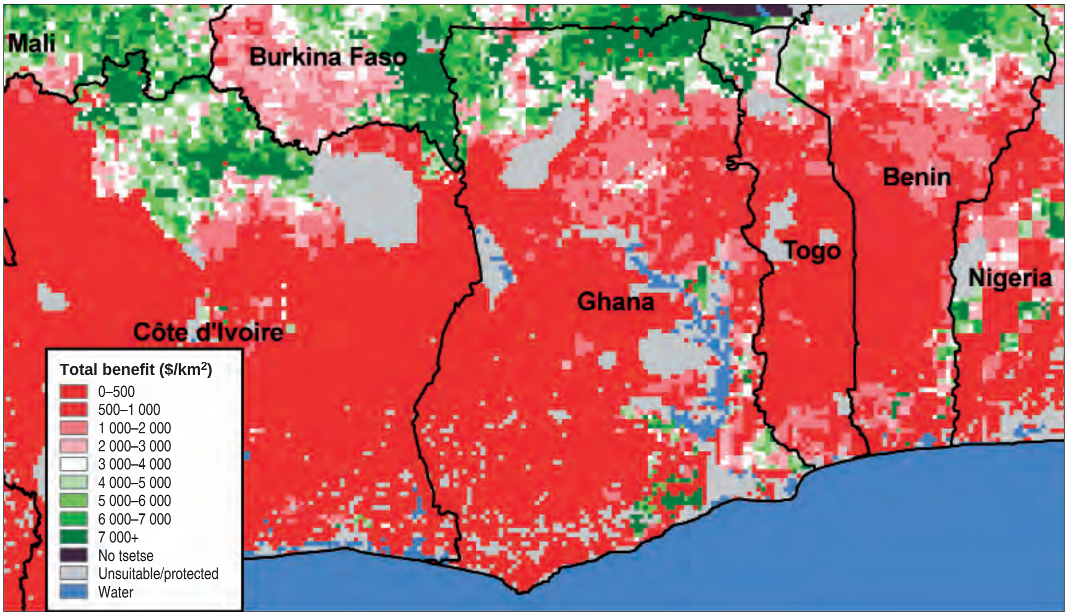

FIG. 3 Potential benefits from the removal of trypanosomosis in West Africa: US$ gained over 20 years
Source: Adapted from Shaw *et al.* 2006
Note: Future benefits are discounted at 10 % per annum

posed by disease are, therefore, again likely to be higher.

Implications for decision-making

These two recent pieces of work therefore provide basic figures for the key economic variables. While it is tempting simply to juxtapose the money maps and the costs of dealing with tsetse, this would be too simplistic. As in any economic analysis of this type, a number of assumptions had to be made alongside extrapolations from existing data, so that the figures give orders of magnitude rather than absolutely accurate amounts. Furthermore, the nature of the tsetse distributions—whether they are isolated, how many fly species are present—need to be considered, alongside other variables determining which techniques are feasible and sustainable (human and cattle population density, vegetation, terrain, etc.). With these caveats, it is possible to generalise along the following lines.

Looking at the West African money map, the red areas are primarily those with very low cattle population densities (five or fewer per km^2). In these areas, 20 years is far too short a time horizon for cattle populations to become established (and there may be constraints other than tsetse) so that investment to deal with tsetse on a large scale would currently be unprofitable. The green areas, where much higher cattle population densities prevail and there is high use of draught oxen, are those areas where the disease is causing the highest losses and should be priority areas. Here intervention to control tsetse is likely to be highly cost effective.

The focus of decision-making will need to be on identifying any areas where tsetse populations are sufficiently isolated to consider long-term elimination which could be sustained without the need to maintain long-term barriers and the attendant risk of reinvasion and increases in costs. In such areas, choice of technique will need to be guided by cost and appropriateness to the fly species, cattle population density and terrain. Where tsetse populations are not isolated and elimination is not currently considered feasible the presence of high numbers of cattle makes cheaper options for control, such as ITC, look very attractive. The areas in the middle range between the green and red range still offer high levels of potential benefits per km^2. These tend to be neither isolated nor on the fringes of the tsetse distribution, so that ongoing tsetse control using low cost sustainable methods alongside the judicious use of trypanocides would appear to be the best option.

LOOKING TO THE FUTURE

With the very welcome renewal of interest in and funding for tsetse and trypanosomosis control spearheaded by PATTEC comes a grave responsibility to ensure that funds are directed to those activities which are most likely to be successful, sustained, appropriate to the locality and most cost effective. Economic arguments will therefore continue to be important in guiding decision-making. Much information has been gathered over the past five decades, but today's decisions still rely on up-to-date field information appropriate to each country, socio-economic environment and tsetse/trypanosomosis interface. New tools, especially GIS, offer new insights and help to decision-making. The 'money mapping' approach has been welcomed by planners in the field of tsetse and trypanosomosis control and could be adapted to other diseases and production constraints. Currently, work is underway with the FAO Pro-poor Livestock Policy Initiative (PPLPI) to apply the 'mapping the benefits' concept to the tsetse-infested countries within the Inter-Governmental Authority on Development (IGAD) countries: Ethiopia, Kenya, Somalia, Sudan and Uganda. However, new data on livestock productivity and how it is affected by disease is urgently needed to underpin such modelling exercises. Similarly, on the cost side of the equation it is vitally important that accurate calculations are made of the true costs of interventions, not just to projects and governments, but also to those who actually have to deal with this disease on a day to day basis and invest their time and money in mitigating its effects—Africa's livestock keepers.

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