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Mapping the benefit-cost ratios of interventions against bovine trypanosomosis in Eastern Africa

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ABSTRACT

This study builds upon earlier work mapping the potential benefits from bovine trypanosomosis control and analysing the costs of different approaches. Updated costs were derived for five intervention techniques: trypanocides, targets, insecticide-treated cattle, aerial spraying and the release of sterile males. Two strategies were considered: continuous control and elimination. For mapping the costs, cattle densities, environmental constraints, and the presence of savannah or riverine tsetse species were taken into account. These were combined with maps of potential benefits to produce maps of benefit-cost ratios.

The results illustrate a diverse picture, and they clearly indicate that no single technique or strategy is universally profitable. For control using trypanocide prophylaxis, returns are modest, even without accounting for the risk of drug resistance but, in areas of low cattle densities, this is the only approach that yields a positive return. Where cattle densities are sufficient to support it, the use of insecticide-treated cattle stands out as the most consistently profitable technique, widely achieving benefit-cost ratios above 5. In parts of the high-potential areas such as the mixed farming, high-oxen-use zones of western Ethiopia, the fertile crescent north of Lake Victoria and the dairy production areas in western and central Kenya, all tsetse control strategies achieve benefit-cost ratios from 2 to over 15, and for elimination strategies, ratios from 5 to over 20. By contrast, in some areas, notably where cattle densities are below 20 per km^2, the costs of interventions against tsetse match or even outweigh the benefits, especially for control scenarios using aerial spraying or the deployment of targets where both savannah and riverine flies are present. If the burden of human African trypanosomosis were factored in, the benefit-cost ratios of some of the low-return areas would be considerably increased.

Comparatively, elimination strategies give rise to higher benefit-cost ratios than do those for continuous control. However, the costs calculated for elimination assume problem-free, large scale operations, and they rest on the outputs of entomological models that are difficult to validate in the field. Experience indicates that the conditions underlying successful and sustained elimination campaigns are seldom met.

By choosing the most appropriate thresholds for benefit-cost ratios, decision-makers and planners can use the maps to define strategies, assist in prioritising areas for intervention, and help choose among intervention techniques and approaches. The methodology would have wider applicability in analysing other disease constraints with a strong spatial component.

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1. Introduction

The importance of the spatial dimension in planning interventions against African trypanosomosis is linked, in both animals and humans, to its cyclical transmission by an insect vector—the tsetse fly (Genus: *Glossina*)—whose geographic distribution is closely related to the presence of suitable climate, hosts and vegetation. Over the last two decades, advances in remote sensing, geographical information systems (GIS) and spatial statistics have triggered the development of modelling approaches to tsetse distribution mapping (Rogers and Randolph, 1993; Robinson et al., 1997) and (Rogers and Robinson, 2004). Turning to the disease, the human form (sleeping sickness) is characterized by a pronounced focal nature, with the distribution of endemic foci remaining remarkably stable over the last century (Simarro et al., 2010) with a few notable exceptions (e.g. Fèvre et al., 2001). Recently, systematic data collation and mapping have made it possible to represent the current distribution of human African trypanosomosis with high accuracy (Cecchi et al., 2009; Simarro et al., 2010) and to assess the population at risk (Simarro et al., 2012). In domestic animals, although the prevalence of the disease varies between populations and localities, trypanosomosis generally presents as an endemic disease, with a widespread presence in livestock populations across the tsetse-infested area of sub-Saharan Africa. The use of GIS and satellite imagery to map animal trypanosomosis has been explored (Hendrickx et al., 2000; de La Rocque et al., 2005; Bouyer et al., 2006) and recently work has begun on mapping the distribution of animal trypanosomosis as well as tsetse at a continental level (Cecchi et al., 2014, 2015).

Alongside spatially explicit data on the vector and the parasite, decision-making in the field of trypanosomosis control and elimination also requires other factors to be considered. In a number of studies in Zambia (Robinson, 1998; Robinson et al., 2002;) and Uganda (Gerber et al., 2008), a variety of GIS and decision-support approaches has been used to combine proxies for disease risk—usually the probability of tsetse presence—with other criteria, including human population and poverty, cattle density, land use and land tenure, agricultural potential and environmental fragility. Ultimately, these approaches have been addressing the same question: where are the benefits of intervention likely to outweigh the costs; be they financial, environmental or social? The present analysis addresses this question from an economics perspective.

This work builds on two recent studies. On the benefit side, a methodology was initially developed for West Africa (Shaw et al., 2006) and subsequently extended and adapted to eastern Africa (Shaw et al., 2014), including the mapping of livestock production systems (Cecchi et al., 2010). The methodology enabled the mapping of the potential economic benefits to livestock keepers from removing bovine trypanosomosis from the eastern African region. Results showed considerable geographical variability in the potential benefits, ranging from less than US$ 10 to over US$ 12,500 per km^2.

However, the maps of benefits only tell part of the story. Should a benefit of US$ 500 per km^2 over 20 years be considered low or acceptable? Is US$ 5000 per km^2 high or just about justifiable? In order to address this type of questions, the costs of intervening against tsetse and trypanosomosis need to be factored in. Costs for different interventions against tsetse and trypanosomosis, based on a hypothetical area of 10,000 km^2 in Uganda were provided by Shaw et al. (2013a). Since then, new information on costs has emerged from a number of recent field interventions (Adam et al., 2013; Bouyer et al., 2014).

The present analysis takes into account these recent cost data, and maps the costs in such a way that they can be compared to the mapped benefits for eastern Africa, thus enabling regional benefit-cost maps to be produced.

2. Materials and methods

The study area includes all tsetse- and trypanosomosis-affected countries in the Intergovernmental Authority on Development (IGAD) region, namely Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda. For these countries, cattle production systems and the impact of trypanosomosis were previously analysed in Shaw et al. (2014). For costs the present analysis follows the framework developed in Shaw et al. (2013a) for Uganda. Costs were refined and updated to 2013 levels by incorporating knowledge from recent publications and research and adjusting for inflation. The comprehensive set of prices and costs calculated for Uganda were taken as a basis, after validating them against those of the other study countries. The inflation rates were based on the Uganda Consumer Price Index for non-food items (UBOS, 2014) and Ugandan Shillings were converted to US dollars (US$) using the historical rates given by FX Oanda (http://www.oanda.com/currency/historical-rates-classic). On this basis, by 2013, prices had increased by 27.1% since 2006 and 11.2% since 2009, the reference years used in Shaw et al. (2013a, 2014) respectively. A discount rate of 10% was applied to all benefits and costs. This relatively high discount rate was selected as reflecting both the higher returns expected from investments in the livestock sector (when compared for example to human health interventions) and the economic growth rates and real interest rates in the study region which are higher than those currently experienced in Europe and North America. The African Development Bank currently applies 12% as the opportunity cost of capital for its projects in the region. The twenty-year time horizon used in Shaw et al. (2013a, 2014) was retained for both benefits and costs; a preparatory year was 0 added to the costs and benefits were assumed to start in year 1. This long period enables control and elimination scenarios to be compared.

2.1. Interventions

Two possible intervention strategies were considered: sustained control and the creation of permanently tsetse-free zones (here and after referred to as 'control' and 'elimination', respectively). Four control options (prophylactic use of trypanocides, targets, insecticide-treated cattle (ITC) and aerial spraying) and four options for elimination (targets, ITC, aerial spraying and the sterile insect technique (SIT)) were considered. For a comprehensive discussion of the strengths and weaknesses of the different techniques, which is beyond the scope of this paper, readers are referred to Maudlin et al. (2004). The elimination scenarios were costed as taking place on a large scale, as described in Shaw et al. (2013a) and being protected from tsetse reinvasion by barriers, whereas the continuous control operations were envisaged as being undertaken on smaller scales and subject to constant reinvasion pressure.

2.1.1. Trypanocide prophylaxis

For the continuous control scenarios, the cost of systematic use of chemoprophylaxis was estimated as an alternative to tsetse control. Trypanocides in Africa are widely used by cattle keepers, both curatively and prophylactically (Holmes et al., 2004). For comparison with other control interventions, the cost of blanket administration of four doses of trypanocide per bovine per year was estimated. This would emulate the use of isometamidium chloride, which is primarily prophylactic, and is effective for about 3 months depending on the breed of cattle and level of tsetse challenge. In rural areas, its current price is estimated at US$ 1.93 for a 300 kg adult dose or US$ 1.35 for the average bovine (210 kg) (personal communication, Dennis Muhanguzi, 2014). At current prices, delivery costs are US$ 0.65 (updated from Shaw et al., 2013a and personal communication, Dennis Muhanguzi, 2014) bringing the cost per dose to US$ 2.00 and thus US$ 8 per year per bovine if