Cost-effective control strategies for animal and zoonotic diseases in pastoralist populations

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Summary

Animal diseases and zoonoses abound among pastoralist livestock, which is composed of cattle, sheep, goats, yak, camels, llamas, reindeer, horses and donkeys. There is endemic and, periodically, epidemic transmission of highly contagious viral and bacterial diseases in Africa, Asia and Latin America. Pastoralist livestock is often multiparasitised with endo- and ectoparasites, as well as being affected by vector-borne viral and protozoal diseases. Pastoral livestock can be a reservoir of such diseases and can also, conversely, be at risk from exposure to wildlife reservoirs. Public and private animal health services currently underperform in almost all pastoral areas due to structural reforms and lack of income, as indicated in assessments of national Veterinary Services by the World Organisation for Animal Health. Control of infectious disease in industrialised countries has been achieved through large-scale public funding of control measures and compensation for culled stock. Such means are not available in pastoralist areas of most low- and middle-income countries (LMICs). While the cost-effectiveness and profitability of the control of animal diseases and zoonoses is less of a consideration for industrialised countries, in the experience of the authors, understanding the economic implications of a control programme is a prerequisite for successful attempts to improve animal health in LMICs. The incremental costs of animal disease control can potentially be shared using cross-sector assessments, integrated control, and regional coordination efforts to mitigate transboundary disease risks. In this paper, the authors discuss cost-effective animal disease and zoonoses control in LMICs. It illustrates frameworks and examples of integrated control and cross-sector economics, showing conditions under which these diseases could be controlled in a cost-effective way.

Keywords

Animal disease – Animal health service – Benefit–cost ratio – Disease control – Disease surveillance – Low-income country – One Health – Pastoralism – Public health – Transboundary disease – Zoonosis.

The burden of animal disease in pastoralist areas and measures for disease control

Livestock, mainly cattle, sheep, goats, llamas, camels, dromedaries, reindeer, horses and donkeys, sustain the livelihoods of several hundred million pastoralists worldwide. These livestock populations suffer from malnutrition (1) and many contagious diseases, including infectious viral (1, 2, 3) and bacterial (4, 5, 6, 7) diseases. They are also susceptible to multiparasitism (they can be parasitised by a number of ectoparasites and several endoparasites, including gastrointestinal nematodes and trematodes [8, 9]). Mobile pastoralists avoid periodic exposure to ticks by moving away from affected areas,

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and they thus avoid tick-borne diseases such as East Coast fever and arthropod-borne infections such as trypanosomiasis. The priority diseases in Asian, African and certain Latin American pastoralist areas are the highly contagious diseases of foot and mouth disease (FMD) and peste des petits ruminants (PPR), followed by contagious bovine and caprine pleuropneumonia, pasteurellosis, blackleg, Rift Valley fever (10), brucellosis (11), sheep pox, bovine tuberculosis (7) and, in certain areas, East Coast fever and anthrax (4). For certain diseases, such as brucellosis and bovine tuberculosis, wildlife reservoirs exist; for others, such as echinococcosis and leptospirosis, dogs or rodents serve as the reservoir. Since dogs are kept for herding or protection, dog rabies is also important. Extensive pastoral husbandry systems, especially mobile systems, may reduce exposure risks because they allow animals to be moved away from a risk area. For some infectious diseases, e.g. bovine tuberculosis and brucellosis, transmission is also reduced by lower animal densities (11).

Despite high animal disease burdens, pastoralists, and especially mobile pastoralists, are poorly served by animal health services (12), relying heavily on traditional and informal animal healthcare workers (13) and self-medication (14). With the privatisation of veterinary services following the structural reforms advocated by the World Bank (15), public animal health services were further reduced in pastoralist areas, especially in countries in sub-Saharan Africa. In some of these countries, governments attempted to motivate private veterinarians to serve pastoralist areas using 'sanitary mandates', which authorised them to carry out interventions on behalf of the government, but the practice did not become widespread due to the high logistic costs. The high cost of disease control in pastoralist areas remains an obstacle for effective control of transboundary and endemic diseases in these areas and, indirectly, across the world. Finding solutions for more effective control of animal diseases in pastoralist areas is a priority for the World Organisation for Animal Health (OIE). The OIE has developed a tool to evaluate the Performance of Veterinary Services (PVS Tool) (16) and Member Countries can request an evaluation should they so wish, but the Organisation has not yet established a mechanism that enhances animal health delivery in remote pastoralist areas. This brief discussion paper addresses options for cost-effective control of animal disease and zoonoses in pastoral areas, as well as for disease surveillance and the financing of animal health services. Many of the issues discussed are not specific to pastoralist areas, but they are all of significant relevance to pastoralist livestock production in low- and middle-income countries (LMICs), which are the countries that are most underserved by public services.

Frameworks for evaluating the economic efficiency of animal disease control

Farmers whose livelihoods depend on pastoralism carefully evaluate the economic efficiency of controlling disease to ensure that the benefits, in terms of livestock production, outweigh the costs (benefit–cost ratio above 1) (17, 18). In the public health sector, the cost-effectiveness of an intervention is expressed as the cost per averted *disability-adjusted life year* (DALY), i.e. the cost of saving a year of 'healthy' life; for example, it costs about US $25 to save one year of life for a person suffering from tuberculosis. Similarly, one can consider cost-effectiveness in animal health as cost per animal life saved or added value in productivity, but the authors do not propose to further adapt the DALY concept to livestock (19).

Animal diseases cause losses in terms of animal numbers (asset value), income from animal products such as meat, milk and hides, and expenditure in reaction to the disease (20). To justify animal disease control interventions, the cost of disease control should be less than the losses from animal disease. Understanding the cost of disease requires an understanding of the effect of diseases on the demographic composition of the herd (through increased abortion or mortality rates) and on off-take rates (lower milk and meat production), as well as an understanding of the cost of treatment. Standard packages such as the Livestock Development Planning System (21), or generic demographic matrix models using Monte Carlo simulations which consider price variability and the uncertainty of productivity parameters, are suitable tools to estimate the losses due to livestock disease (22, 23). However, such assessments are limited by a lack of knowledge on how diseases reduce productivity parameters (24) or even knowledge on normal herd composition. In many cases, we must rely on very old estimates, since no current data exist, e.g. for bovine tuberculosis (25). Through the control of disease, some losses can be avoided. Economic analyses help to evaluate whether the costs of extra resources needed for disease control are outweighed by the avoided losses resulting from a disease. In most cases, the effects of disease control are dynamic non-linear processes, so mathematical models of disease transmission are needed to simulate interventions. Such models allow for simulation of disease frequency with and without interventions and enable analyses of the economic efficiency of interventions (26, 27).

In the case of zoonoses, in addition to the costs resulting from disease in animals, costs of disease in human health also arise, and cross-sectoral methods have been developed to analyse these costs simultaneously (28). Such cross-sectoral analyses assess the societal cost of disease and

show under which conditions interventions in human and/or animal health are cost-effective. For example, for dog rabies control in N'Djamena, Chad, it can be shown that, after 10–15 years, the mass vaccination of dogs is less costly than the post-exposure prophylaxis of humans (29). Mass vaccination of pastoral livestock against brucellosis in Mongolia is not profitable if we consider only the benefits for the public health sector; however, if benefits for livestock production and human health are pooled as societal benefits, mass vaccination of livestock becomes largely profitable to Mongolian society (27). Examples from joint human and animal health service provision for mobile pastoralists are described by Schelling *et al.* (30).

Consequently, disease control efforts involving closer cooperation between human and animal health (a 'One Health' approach) have great potential for the provision of cost-effective interventions in pastoralist areas (31). While bovine tuberculosis (BTB) has been eliminated in some industrialised countries, it persists worldwide, particularly in Africa. In Ethiopia, BTB is prevalent in pastoral livestock (32, 33) but has not been demonstrated in wildlife (34), and only a few cases have been found in humans (7, 35). Control of bovine tuberculosis in pastoral areas requires a better understanding of the cost of disease. A recent study on the cost of BTB to urban and rural cattle production in Ethiopia estimated an average annual loss of US $1 per cow per year, which is lower than the cost of tuberculin testing. Therefore, in the case of BTB in pastoral areas of Ethiopia, disease control is not currently justifiable on the basis of any measurable financial losses (through reduced productivity or lost livestock assets), but control of BTB may be justified on other, non-economic, grounds (22).

Integrated approaches to animal disease control

In pastoral areas of LMICs, available resources are so limited that any effort to reduce the incremental cost of control in order to increase the benefit–cost ratio of interventions is attractive. This increasingly includes integrated efforts to prevent a set of prevailing livestock diseases rather than just one single disease. It is important to note that the efficacy and safety of new combinations of vaccinations against several diseases, such as FMD combined with brucellosis, are not documented, and industrialised countries could make a contribution in this area. There are numerous examples of ways in which several diseases and conditions could be treated simultaneously using an integrated approach. In pastoral areas near the south-eastern shores of Lake Chad, cattle vaccination against anthrax (4) could be combined with deworming against *Fasciola gigantica* (9). Dogs could be vaccinated against rabies at the same time. In areas such as Sidi Kacem in Morocco, where there is concurrent bovine tuberculosis in cattle, echinococcosis and brucellosis in small ruminants, and rabies and leishmaniasis in dogs (36), an integrated control package could be applied. An animal health worker visiting a household could vaccinate dogs against rabies, deworm them for adult *Echinococcus granulosus*, and fit them with a repellent collar against sandflies. The sheep could be vaccinated against brucellosis, and cattle could be tested for bovine tuberculosis.

Such integrated control strategies require advanced knowledge about the epidemiology of the prevailing diseases. The planning and shaping of such multi-disease interventions requires the involvement of authorities, disease control experts, and communities. They should all be included in a participatory way to achieve local ownership and avoid negative effects on minorities (31, 37, 38, 39). The authors are not aware of any published economic analyses of such integrated control packages, but it seems reasonable to assume that the incremental cost of controlling several diseases at once would be lower, and the overall profitability higher, than the cost of controlling individual diseases. In public health, the World Health Organization's Expanded Programme on Immunization already uses several vaccines to immunise children during the same session. However, in animal health, such approaches do not exist on a large scale and require contextual adaptation. Fixed costs to enhance levels of public services and maintain the infrastructure for supportive health services require higher-level planning. Integrated disease control packages may be of particular interest in the case of diseases that are not considered a priority, e.g. dog rabies in pastoral areas. Mass rabies vaccination of dogs could be piggybacked onto priority interventions such as FMD vaccination of cattle (40, 41) or with conservation activities (42). To ensure that pastoralists adhere to such integrated approaches, additional services could be offered during the same operation, such as delivery of official birth certificates for children. An important issue to address is the fact that some pastoralists look after the animals of many different owners, many of whom are absentee owners, and they cannot all be contacted to find out whether or not they are willing to pay for these integrated interventions. One Health service provision to pastoralist communities could provide vaccination services for women and children at the same time as carrying out mass livestock vaccination (43), as further described by Abakar *et al.* (44).

In addition to integrated control approaches, regional coordination between countries is essential for transboundary diseases, including major zoonoses. Hampson *et al.* describe synchronous cycles of dog rabies transmission across East African countries (45), also highlighting the importance of regional efforts to eliminate dog rabies in Latin America. A classic example of the effectiveness of regionally coordinated livestock disease control efforts is the successful Pan-African Rinderpest

Control (PARC) campaign, which contributed towards the elimination of rinderpest in Africa (46, 47). Regional governance bodies, such as the African Union–Interafrican Bureau for Animal Resources, the Pan American Foot and Mouth Disease Center in Latin America and the Association of Southeast Asian Nations, play a very important role in animal health diplomacy.

Disease surveillance and animal health education

Effective disease control efforts require functional, timely monitoring and surveillance systems. The global community's slow response during the Ebola epidemic in West Africa in 2014–2015 is a warning that ineffective health systems and surveillance, late understanding of the social context and late implementation of global response mechanisms delay detection of emerging pathogens and cause unnecessary suffering and loss of life, possibly also wasting limited resources (48). In most pastoralist areas of LMICs, animal disease surveillance is too slow for rapid detection of emerging outbreaks. Sentinel herds in high-risk areas are frequently not maintained due to costs, and routine data are not available in a timely manner or are of poor quality. Most often, before the information reaches decision-makers, biological samples are no longer viable for processing. Future disease surveillance in pastoralist areas should make use of mobile communication and other modern technologies. A proof of concept for the use of mobile phones in integrated health and demographic surveillance of humans and animals in mobile pastoralist communities has already been published by Jean-Richard *et al.* (49). Such systems could be refined to develop a near real-time, community-based syndromic surveillance and response system that uses drones and mobile communication combined with geographical positioning systems; it might also be possible for these systems to be integrated into the existing INDEPTH network (a network of health and demographic surveillance systems across the developing world). The field for technical and disease control innovation is currently wide open in pastoral areas which have thus far been hard to reach. Beyond all technical improvements, it is investments in information, education and communication for pastoralists, across all ages and both genders, which are the foundation of community-based surveillance, creating a first line of surveillance for poor health in animals and humans in pastoral areas (3, 23, 50). Better surveillance, coupled with appropriate responses in terms of herd-level interventions (e.g. ring vaccination), provides an important basis for strengthening general health systems, but its cost should also be factored into the overall economics of disease control.

Animal health financing and global solidarity

Animal disease control in pastoralist areas is hindered by lack of sensitive disease surveillance, insufficient diagnostic capacity, inadequate service provision and, importantly, a lack of funding. Institutional donors are reluctant to invest in high-risk interventions without a stringent framework for monitoring success (51). A new concept using Development Impact Bonds (DIBs) has evolved from initiatives in social financing (51). DIBs allow for the sharing of investment risks between private investors and institutional donors within a 'payment on result' framework. However, the modalities of purchasing and refunding such bonds are still a matter of debate for animal disease control. Currently, one of the first DIBs for animal disease control aims to eliminate *Trypanosoma brucei rhodesiense* (the parasite responsible for zoonotic sleeping sickness) in Uganda (52).

The financing of the above-mentioned successful PARC campaign is an example of international solidarity in animal disease control. International animal disease control efforts should also learn from the Global Fund, which is a partnership of governments, civil society, the private sector and disease-affected communities that aims to control tuberculosis, HIV/AIDS and malaria. It builds on the principle of making diagnostic capacity, essential drugs and management strategies for these diseases available to eligible countries through international donations (53). The risk from infectious diseases such as avian influenza, FMD, PPR, African horse sickness and African swine fever justifies global solidarity and the promotion of freedom from transboundary diseases as a global public good. A globally coordinated control effort, especially in pastoral areas, should be much more cost-effective than separate disease surveillance and control programmes run by national governments. The improved cooperation of the OIE, the Food and Agriculture Organization of the United Nations and the World Health Organization is encouraging and crucial for such globally coordinated efforts.

Concluding remarks

Cost-effective animal disease control in pastoralist areas requires information, education and communication efforts in order to develop locally adapted community-based disease surveillance that can identify disease frequency and the causative agents of outbreaks in near real-time. Knowledge about the cost of disease and, ideally, the profitability of disease control should be assessed prior to undertaking mass interventions and herd-level decision-making. For zoonoses, the societal benefits, across all involved sectors, should be assessed and costs of

intervention assigned proportionally to the different sectors – and, if possible, the human health benefits should be expressed as averted DALYs. Based on these profitability assessments, a prioritisation of interventions is possible, analogous to that used in public health (54, 55). Integrated approaches, combining human and animal health as One Health interventions, have great potential in pastoralist areas. Depending on the prevailing diseases, disease control should be packaged and aim to control several diseases simultaneously, further reducing incremental costs. There has never been better global coordination between animal and public health, and this should be harnessed to work towards global solidarity for freedom from animal diseases in the poorest countries of the world and in pastoralist areas in particular.

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Stratégies efficientes au regard de leur coût pour lutter contre les maladies animales et les zoonoses dans les populations pastorales

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Résumé

D'abondantes maladies animales et zoonoses affectent le cheptel pastoral, qui est composé de bovins, d'ovins, de caprins, de yaks, de chameaux, de lamas, de rennes, de chevaux et d'ânes. Il existe une transmission endémique (prenant périodiquement une dimension épidémique) des maladies virales et bactériennes hautement contagieuses en Afrique, en Asie et en Amérique latine. Le polyparasitisme à endoparasites et ectoparasites est fréquent dans les troupeaux pastoraux, ainsi que les maladies virales à transmission vectorielle et les maladies dues à des protozoaires. Les animaux élevés par les pasteurs font également office de réservoirs potentiels pour ces maladies et sont à leur tour exposés aux réservoirs sauvages. Les services de santé animale tant publics que privés sont actuellement sous-efficients dans pratiquement toutes les zones pastorales en raison des réformes structurelles et du manque de moyens, comme l'ont révélé les évaluations des Services vétérinaires nationaux réalisées par l'Organisation mondiale de la santé animale. Dans les pays industrialisés, les maladies infectieuses ont pu être maîtrisées grâce à un financement public massif des mesures de contrôle et à l'indemnisation des éleveurs dont le bétail avait été sacrifié. Ces moyens ne sont pas disponibles dans les zones pastorales de la plupart des pays à revenus faibles et moyens. Alors que les pays industrialisés n'ont pas tellement à prendre en compte les questions de rentabilité et d'efficience au regard des coûts lorsqu'ils ont à lutter contre des maladies animales ou des zoonoses, il n'en va pas de même dans les pays à revenus faibles et moyens, où, d'après l'expérience des auteurs, la prise en compte des conséquences économiques d'un programme de lutte est une étape préalable de toute tentative fructueuse d'amélioration de la santé animale. L'augmentation progressive des coûts de la lutte contre les maladies animales peut être prise en charge de manière partagée grâce aux évaluations intersectorielles, à une stratégie de lutte intégrée et aux efforts de concertation à l'échelle régionale pour atténuer les risques de maladies transfrontalières. Les auteurs de cet article examinent les méthodes efficientes au regard de leur coût déployées par les pays à revenus faibles et moyens pour lutter contre les maladies animales

et les zoonoses. Ils présentent quelques cadres et exemples de lutte intégrée et d'approches économiques intersectorielles, en faisant ressortir les conditions qui permettent de contrôler ces maladies de manière efficace et à moindre coût.

Mots-clés
Lutte contre les maladies animales – Maladie animale – Maladie transfrontalière – Pastoralisme – Pays à faible revenu – Rapport coût-bénéfice – Santé publique – Services de santé animale – Surveillance des maladies – Une seule santé – Zoonose.

Estrategias rentables de lucha contra las enfermedades animales y zoonóticas en las poblaciones pastorales

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Resumen
Las enfermedades animales y las zoonosis son muy comunes en el ganado pastoral, formado por ganado vacuno, ovino y caprino, yaks, camellos, llamas, renos, caballos y asnos. En África, Asia y América Latina hay transmisión endémica (y periódicamente epidémica) de enfermedades víricas y bacterianas sumamente contagiosas. El ganado pastoral suele estar infestado por múltiples endo y ectoparásitos y padecer enfermedades víricas y protozoarias transmitidas por vectores. A veces ejerce de reservorio de esas enfermedades y también puede, a la inversa, verse expuesto al contacto con reservorios salvajes. Actualmente, en casi todas las zonas de pastoreo, los servicios zoosanitarios públicos y privados presentan un funcionamiento deficiente debido a las reformas estructurales y a la falta de ingresos, como se desprende de las evaluaciones de los Servicios Veterinarios nacionales realizadas por la Organización Mundial de Sanidad Animal. En los países industrializados, el control de las enfermedades infecciosas ha sido posible gracias a la financiación por el sector público de vastas y onerosas medidas de lucha y de indemnización por los animales sacrificados. Pero en las zonas de pastoreo de la mayoría de los países de ingresos bajos o medianos no existe la posibilidad de instrumentar tales medios. Mientras que los países industrializados prestan menos atención a la relación costo-eficacia y la rentabilidad de las medidas de control de enfermedades animales y zoonosis, en los países de ingresos bajos o medianos, a tenor de la experiencia de los autores, el éxito de toda tentativa de mejorar la sanidad animal pasa necesariamente por tener en cuenta la dimensión económica de los programas de lucha. Existe la posibilidad de compartir los costos adicionales de la lucha zoosanitaria recurriendo a evaluaciones transectoriales, a medidas integradas de control y a actividades coordinadas a escala regional para reducir el riesgo de enfermedades transfronterizas. Los autores examinan aquí sistemas eficaces en relación con el costo para combatir las enfermedades animales y zoonosis en los países de ingresos bajos o medianos, exponiendo principios de referencia y ejemplos de lucha integrada y de economía transectorial que demuestran en qué condiciones sería posible controlar esas enfermedades de manera eficaz en relación con el costo.

Palabras clave
Control de enfermedades – Enfermedad animal – Enfermedad transfronteriza – País de bajo nivel de ingresos – Pastoreo – Razón beneficio-costo – Salud pública – Servicio zoosanitario – Una sola salud – Vigilancia de enfermedades – Zoonosis.

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