Interpretation and utility of the Animal Health Loss Envelope as part of the Global Burden of Animal Diseases (GBADs) analytical process

W. Gilbert [1, 2]

(1) Global Burden of Animal Diseases (GBADs) Programme, Institute of Infection, Veterinary and Ecological Sciences, University of Liverpool, 146 Brownlow Hill, Liverpool, L3 5RF, United Kingdom (https://animalhealthmetrics.org)

(2) Institute of Infection, Veterinary and Ecological Sciences, University of Liverpool, IC2 Building, 152 Brownlow Hill, Liverpool, L3 5RF, United Kingdom

E-mail: w.gilbert@liverpool.ac.uk

Summary

The Global Burden of Animal Diseases (GBADs) programme follows a multistage process to produce disease burden estimates in livestock and farmed aquatic animal production systems. The GBADs programme has broad goals of inclusivity, transparency and rigour. Meeting those goals means providing users of all levels of technical expertise with a clear explanation of the programmes output. In this way, we seek to ensure that the meaning and limitations of those results are clearly understood, minimising the risk of misinterpretation.

The first published estimates of disease burden have been calculated at farm-level using a model called the Animal Health Loss Envelope. This model estimates the cost of lost productivity and expenditure on disease control for profit-maximising producers by comparing current system performance to a hypothetical ‘ideal health’ scenario. This ideal is a farm-specific concept and is critically different from an ideal health state when physiologically defined. The model and its key concepts are described in this article.

Keywords

Disease – Economics – Expenditure – GBADs – Loss – Methodology.

Introduction

Recognising the economic purpose for farming animals and the incentives facing producers operating with disease, the Global Burden of Animal Diseases (GBADs) programme describes disease burden in economic terms at farm level by examining the impact of disease on animal and consequently farm productivity. The existence of disease is commonly described by a triangle made up from the three-way interaction of host organism, pathogen and environment [1]. This is the fundamental relationship for which the GBADs programme seeks to describe the economic consequences. Beginning with a description of the populations of the world's major farmed food-animal species, the resources consumed and outputs generated by livestock farming are described in a farm economic model. The effects of disease on farm productivity are then fed into set of economic models to broaden the scope of analysis. The burden of disease at animal level is thereby connected via farm modelling to sector and trade models, nationally and internationally, and to models of societal outcomes such as greenhouse gas emissions, animal welfare, antibiotic use and zoonotic disease burden in humans.

Understanding the method behind the farm-level model of disease burden aids interpreting GBADs results. This paper gives an overview of that method, which contains some novel concepts.

The GBADs farm-level burden model is conceptually similar to the methods that have preceded it and are regularly applied in animal health policy making, such as cost-benefit analysis. These predecessors typically involve the comparison of a baseline scenario, usually the *status quo*, with a modelled scenario based on a hypothetical event or counterfactual scenario. In this way, changes in health state (disease losses) are connected to the costs of disease management and compared between the scenarios to estimate the impact of disease on the productivity of the system. This analysis has previously typically done for a single disease at a time. The GBADs method is innovative in the domain of animal health in that it attempts to quantify all-cause burden at farm-level in a single calculation. This serves as a tool for comparative analysis between similar livestock systems over geography and time, and also as validation step when disease burden estimates are attributed to specific causes individually. This total estimate of farm-level burden has been called the Animal Health Loss Envelope (AHLE).

Current and ideal health at farm level

It is vitally important to make a distinction between the ideal health state for animals from a societal perspective, and the ideal health state from a farm perspective. If we use productivity parameters to measure health state, then a point of maximum health should coincide with peak milk and egg yield, and reproductive and growth rates. As a result, the absolute level of health of the animal is determined not only by the presence of pathogens and hazards, but also by the supply of ordinary inputs (land and feed, labour and capital) allocated to each animal.

The GBADs ideal health concept differs from this maximum point because it reflects the economic purpose for livestock keeping. Figure 1 illustrates this difference with an example of a dairy cow producing milk in response to increasing units of feed input. Assuming constant price per litre of milk, the revenue from milk sales will follow the yield curve directly. When feed is subject to diminishing marginal returns in milk yield due to the biological limits of the animal, a point may exist at which a profit-maximising farmer is no longer incentivised to purchase additional feed. If yield as a proxy measure of health maximises at a higher feed input, a gap will therefore exist between the economically ideal level of health from the farmer's perspective, and the ideal from a physiological perspective which is at the absolute maximum. Since GBADs is interested calculating monetary burden of animal disease at farm level, it is the former of these points that is our focus in this model.

Production with disease

An additional step is required to describe the relationship between production and the presence of disease-causing pathogens and hazards. Figure 2 depicts the disease triangle representing the *status quo* or current health state of a livestock system. The presence of disease affects the productivity of the system, that is, the rate at which the animals are able to use the ordinary inputs they are provided with (such as feed, labour, housing) to yield a given quantity of a desired product [2].

Farmers are able to respond to the effects of hazards by applying mitigating interventions, which come at a cost [3]. If we consider familiar disease control interventions we can see that these can be broadly divided into two types, those that modify the internal environment of the animal (i.e. veterinary interventions), and those that modify the external environment (biosecurity, hygiene, housing etc.). Where the cost of prevention or treatment is less than the loss to disease, farmers are incentivised to shift the burden toward the cost of intervention; where the marginal cost of intervention is too high the opposite incentive exists, in this way, disease impact is spread between lost animals and productivity per animal, and additional expenditure on prevention and treatment of disease [4]. It is important to note that this relationship is dynamic as prices and markets change, and therefore input-output efficiency and expenditure on control should be assessed together to get a complete picture of on which side of this balance burden lies.

The ideal health state models the hypothetical case in which disease-causing pathogens and hazards are removed from the system. Much as hypothetical disease outbreaks can be modelled and compared to a disease-free baseline without necessarily addressing the pathway leading to that outbreak, the ideal health state reverses this paradigm. In so doing it poses the question, what would the system look like if there were no hazards or pathogens present? This can be visualised as the removal of the upper section of the triangle in Figure 2, removing pathogens hazards as well as all expenditure on their control through biosecurity and veterinary interventions.

To further clarify what the ideal health scenario models, we may refer again to Figure 2. Since it represents the removal of negative effects rather than the addition of positive ones, the animals themselves and their management remain unchanged in their nature under ideal health, while the effects of exogenous hazards are removed. The total burden of disease can then be calculated by modifying each parameter on which disease has impact mortality, productivity per animal, expenditure on control as measured under the current scenario to simulate farm system performance in this hypothetical state. The performance of the animal in biological terms improves relative to the resources it consumes (land and feed, labour, capital, time), while the mortality and expenditure on control are proposed, to be zero. The summed monetary value of the change across each of these areas of impact is being termed the AHLE [5].

Calculation of the Animal Health Loss Envelope

Further constraints can be placed on the ideal health scenario to frame total health burden relative to desirable societal outcomes. For example, total product output can be fixed at current levels, thereby framing all disease burden through its impact on cost of production. For example, a single kilogram of meat from an ‘ideal health’ chicken might be found to be 15% cheaper to produce than the current cost per kilogram. This kind of measure is consistent with approaches being taken in modelling productivity change and greenhouse gas emissions [6] and associating them with animal health state [7]. A simplified output-constrained AHLE calculation is provided in Figure 3 to illustrate.

Alternatively, the system can be constrained on a particular input resource, for example grazing land. In such a way an ideal health population may make more efficient use of the land already under grazing, increasing output yield without increasing total grazing area. Exactly which constraints are the most appropriate for the GBADs programme is a question which is still to be answered through a process of needs assessment and user engagement. The first GBADs case study has simulated an unconstrained system, and user feedback on this is being given careful consideration. These constraining scenarios are an important step in addressing that feedback, and a standard set of scenarios will be developed for use in future case studies.

The work conducted so far has also allowed the exploration of the data landscape and some conclusions to be drawn with respect our ability to devise a representative production system classification, and the likelihood of being able to populate production system models in a globally complete manner with existing datasets. This has put renewed focus on imputation models to fill data gaps, and methods of quantifying the uncertainty resulting from variation in data quality and presenting it in a transparent manner. The way in which these challenges are being tackled is the subject of other papers published in this issue and forthcoming elsewhere.

The AHLE in context

The ideal health scenario and the AHLE calculation are a means of describing total disease burden for all causes simultaneously in a standardised manner, devised as a methodological step toward attributing burden to specific causes without double-counting. As a whole, the AHLE also provides a measure of disease burden which can be used for comparative analysis. The purpose of the ideal health model is not to map out an intervention pathway to be followed, since there is no pathway to disease-free status built into the model scenarios.

The AHLE is intended to be interpreted alongside, or as a denominator to, other measures of disease burden which are oriented toward practical decision-making. This includes providing a context for the burden attributable to specific causes which are to be the central output of the GBADs programme. For those interested in how GBADs may assist practical decision-making for farm-level interventions, it is the burden estimates attributed to cause that will be of greatest interest. At the point at which cause and burden are associated, a pathway to viable intervention strategies becomes possible to map out.

The GBADs burden estimation method makes investment appraisal, such as cost-benefit analysis, more accessible to users looking to plan interventions. The production system models developed for the AHLE calculation will be published and freely available. This will allow interested parties to devise scenarios for animal performance that focus on their area of interest. This customisability can be used to explore the marginal benefits of incrementally improving health in any kind of intervention scenario. This kind of customisable model provides a means of quantifying the benefit side of an investment appraisal, such as a standard cost benefit analysis. The data gathered to populate the AHLE calculation model also contain much of the same data needed for this kind of analysis, in terms of input and output prices and quantities.

The relationship between ideal health and performance benchmarking

The ideal health state, as a hypothetical concept, is not the same as the benchmarking metrics often used to compare performance between producers in the same system. Relative measure of productivity, so-called because performance is measured between farms relative to each other rather than against a fixed point outside of the data, are a useful tool for producers looking to make immediate improvements in their management with interventions already being used by their peers. Ranking producers according to a particular outcome, profit for example, allows users to make inferences about the factors contributing to their rank. This has shortcomings as a measure of absolute disease burden, since even the best producers will experience some disease, the extent of which will be variable between populations. This kind of data does have important application in developing quantitative associations between specific health hazards and performance as part of cause attribution. This data is also being explored as a means to setting single performance parameter values for the ideal health state. A useful output of the GBADs process will also be the gathering of farm-level data suited to developing benchmarks within the GBADs informatics database.

As the volume of data in the GBADs system increases in terms of the geographies, systems and time periods covered, new avenues of analysis will be opened up which will make the AHLE more valuable as an analytic tool. It is anticipated that between the total burden that is attributed and the total AHLE, a gap will remain. This will represent the limit of what is known about the hazards present and completeness of the measures of their impact. The relative size of this gap when compared across jurisdictions, being an indicator of information scarcity, may be a means of identifying gaps in animal disease surveillance and diagnostic capacity at a global level. This is a goal of interest, for example, to those interested in pandemic threat assessment [8,9].

The gap between the ideal health performance and a best performer benchmark, when compared across similar production systems, may shed light on country level effects which constrain the farm-level disease control options to producers. In an open and stable society, it can be hypothesised that producers are likely to have sustained access to a more diverse range of effective veterinary and other health interventions than in less open or politically unstable regions. There is evidence that inequalities in drug access are commonplace and providing information that supports public and private sector initiatives to address this issue in an unbiased manner would be welcomed [10].

Conclusions

In summary then, the AHLE provides a means of estimating farm-level disease burden when animal keeping being an economic activity for which the farm-level costs and benefits can be quantified in monetary units. It is a methodologically important step toward various other metrics which have practical application. While the GBADs programme remains at an early stage, the AHLE has been presented in a transparent manner for criticism by the audience of potential users. It has also been used to generate farm-level productivity changes to parameterise partial and general equilibrium models for estimating economic impact beyond the farm, with publications forthcoming on those. The same models (AHLE and economy) can be repurposed to look at single disease issues, producing partial attributions of the AHLE as disease specific information is gathered, reviewed and analysed. It is at the end of this process that information relevant to intervention planning will come to the fore.

Acknowledgements

The author acknowledges all GBADs colleagues whose perspectives have helped shape the content of this document.

This publication was supported by the Bill and Melinda Gates Foundation and the UK Foreign, Commonwealth and Development Office. The findings and conclusions contained within are those of the authors and do not necessarily reflect positions or policies of the Bill and Melinda Gates Foundation or the UK Foreign, Commonwealth and

Development Office. The funders had no role in study design, data collection and analysis, publication decision, or manuscript preparation.

References

[1] Scholthof K.-B.G. (2007). – The disease triangle: pathogens, the environment and society. Nat. Rev. Microbiol., 5(2), 152-156. https://doi.org/10.1038/nrmicro1596

[2] Morris R.S. (1988). – The effects of disease on productivity and profitability of livestock: how should it be assessed? Proc. N.Z. Soc. Anim. Prod., 48, 117-125. Available at: https://www.nzsap.org/system/files/proceedings/1988/ab88026.pdf (accessed on 11 September 2023).

[3] Hennessy D.A. & Marsh T.L. (2021). – Economics of animal health and livestock disease. In Handbook of Agricultural Economics (C.B. Barrett & D.R. Just, eds). Elsevier, Amsterdam, the Netherlands, 4233-4330. https://doi.org/10.1016/bs.hesagr.2021.10.005

[4] McInerney J.P., Howe K.S. & Schepers J.A. (1992). – A framework for the economic analysis of disease in farm livestock. Prev. Vet. Med., 13(2), 137-154. https://doi.org/10.1016/0167-5877(92)90098-Z

[5] Torgerson P.R. & Shaw A.P.M. (2021). – A simple metric to capture losses: the concept of an animal health loss envelope. Bull. Panorama, 2021-1, 3 pp. https://doi.org/10.20506/bull.2021.1.3259

[6] Chang J., Peng S., Yin Y., Ciais P., Havlik P. & Herrero M. (2021). – The key role of production efficiency changes in livestock methane emission mitigation. AGU Adv., 2(2), e2021AV000391. https://doi.org/10.1029/2021AV000391

[7] MacLeod M., Eory V., Wint W., Shaw A., Gerber P.J., Cecchi G., *et al.* (2018). – Assessing the greenhouse gas mitigation effect of removing bovine trypanosomiasis in Eastern Africa. Sustainability, 10(5), 1633. https://doi.org/10.3390/su10051633

[8] Aborode A.T., Hasan M.M., Jain S., Okereke M., Adedeji O.J., Karra-Aly A., *et al.* (2021). – Impact of poor disease surveillance system on COVID-19 response in Africa: time to rethink and rebuilt. Clin. Epidemiol. Glob. Health, 12, 100841. https://doi.org/10.1016/j.cegh.2021.100841

[9] Lasley J.N., Appiah E.O., Kojima K. & Blacksell S.D. (2023). – Global veterinary diagnostic laboratory equipment management and sustainability and implications for pandemic preparedness priorities. Emerg. Infect. Dis., 29(4), 1-12. https://doi.org/10.3201/eid2904.220778

[10] Jaime G., Hobeika A. & Figuié M. (2022). – Access to veterinary drugs in sub-saharan Africa: roadblocks and current solutions. Front. Vet. Sci., 8, 558973. https://doi.org/10.3389/fvets.2021.558973

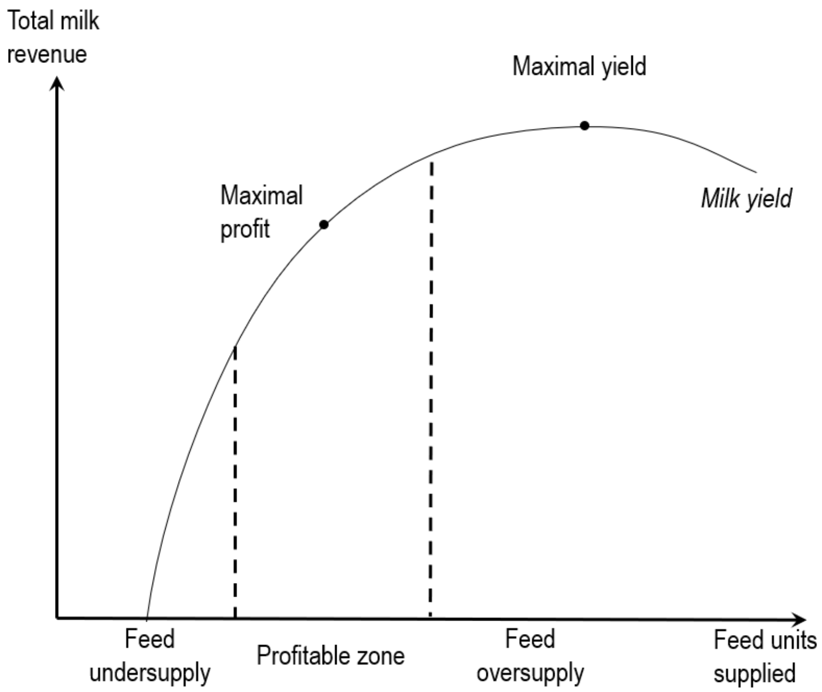

Figure 1

The difference between ideal health from a purely physiological perspective when compared to an economic perspective

Diminishing response to additional feed units mean profits are maximised where total revenue is furthest from the total cost of production. Assuming total yield is directly proportional to health, in this case the point of maximum profit occurs at a lower feed allocation point than required to produce maximum 'health'. As a result, an additional health gap exists above the economic ideal

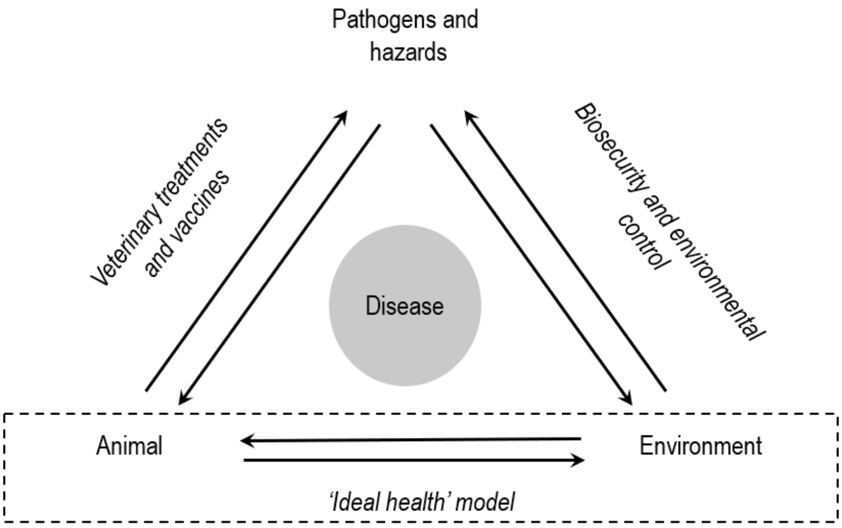

Figure 2

Disease 'triangle' illustrating the relationship between the occurrence of disease and possible management expenditure aimed at mitigating disease impact

Expenditure can broadly be summarised as either modifying the environment internal to the host through veterinary medical interventions, or externally through environmental modifications such as housing, temperature and humidity control, or biosecurity and hygiene practices. In both cases, treatment and prophylaxis are possible. The ideal health scenario describes the removal of the upper vertex of the triangle, with consequent removal of expenditure on disease impact mitigation activities

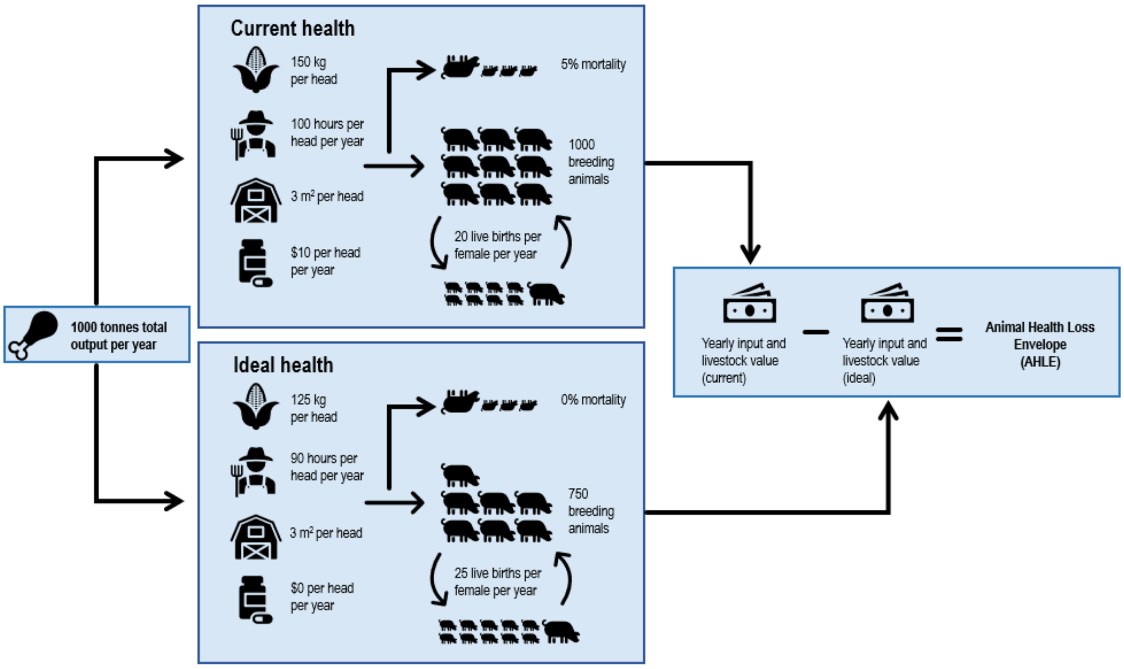

Figure 3

Output-constrained Animal Health Loss Envelope calculation for a simple production system using feed, labour, housing and veterinary inputs to produce 1000 tonnes of meat per year

Improvements in growth rate, feed conversion efficiency and fertility, and no mortality or expenditure on disease control combine to produce a total disease burden when the ideal health state is compared to the current health situation