Estimating livestock biomass across diverse populations and data ecosystems

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Summary

Estimates of livestock biomass can be used as a denominator in disease burden estimates, as well as informing assessments of resource use and environmental impacts. This paper explores the challenges of accurately estimating biomass across different scales and data ecosystems, with a particular focus on the use of biomass in the Global Burden of Animal Diseases (GBADs) Programme. The biggest challenge is a lack of breed and class (age, sex)-specific data on populations and liveweights at sub-national level. This can be overcome through the use of global datasets and generic estimates of liveweight for each species, though this approach fails to account for the diversity of livestock systems.

Keywords

Biomass – Disease burden – GBADs – Liveweight – Population.

Introduction

The Global Burden of Animal Diseases (GBADs) programme aims to estimate, compare, and attribute the burden of animal disease across diverse livestock production systems, providing vital insights for effective investments in animal health [1, 2]. For example, outputs from GBADs could be used to help prioritise investments to provide the greatest societal or production benefits, or for *ex-post* evaluation on the effectiveness of previous investments. The use of a consistent methodology across countries and case studies to estimate the burden of disease allows for comparisons between countries and multiple species.

One of the challenges faced by the GBADs programme is how to compare disease burdens between different species. Given the substantial differences in body sizes and corresponding resource requirements among species, direct head-to-head comparisons may lack fairness. In this context, livestock biomass, representing the aggregate liveweight of a given livestock population, emerges as a more equitable variable. It functions as a normalisation factor for comparing inputs, outputs, and production losses per unit across varying species, production systems, and countries. Livestock biomass is most frequently used in the assessment of natural resource use (especially grazing, [3]) and environmental impacts [4], and in the reporting the use of veterinary antimicrobials [5]. It can also be used as an indicator for gauging livestock development and food security, providing a benchmark for monitoring progress and trends in these domains [6].

However, despite its utility, there are no standardized methods for calculating animal biomass, and different approaches often provide widely varying estimates [7, 8]. This is perhaps driven by the evolution of different approaches in response to specific research questions or data availability. In this paper, we explore the challenges inherent in estimating livestock biomass at different scales, focusing on the liveweight of current livestock populations. We also provide guidance on the selection of methodologies for biomass estimation depending on the type and granularity of data available.

Challenges in estimating livestock biomass

The computation of livestock biomass involves aggregating the liveweights of individual animals. In an ideal scenario, this would include accurate liveweight data for each animal, capturing differences due to species, breed, class (e.g. age, sex), health status and production system factors. However, acquiring such data is constrained by the labour-intensive nature of individually identifying and weighing livestock in a population, especially since the liveweight of individuals changes over time. It is therefore necessary to use average values for a given population and time period, wherein the average liveweight of an individual within a population is multiplied by the total number of animals, yielding the aggregate biomass. This can be done for either an entire species population, or for specific livestock classes in cases where liveweight and population data for specific age/sex groups are available. While the latter implies greater accuracy, this is impacted by the inherent variability in liveweights across subgroups, as discussed below.

There is substantial variation in the liveweight of animals within a species based on breed and sex [4, 9]. This is illustrated in Ethiopia using data from the Domestic Animal Diversity Information System (DAD-IS), which catalogues around 35 cattle breeds kept for beef, dairy and draught power [10]. Among the 14 breeds with reported liveweight values, the average liveweight is 271 kg, and ranges from 153 kg (female Abergelle cattle) to 400 kg (male Fogera cattle). On average, males are 20% heavier than females (Figure 1).

Within breeds, liveweight is influenced by genetics, age, management, physiological status, and climate [11, 12], with these variables driving much of the differences in liveweight between different countries and production systems. For example, Fordyce *et al.* [13] reported average liveweight of mature *Bos indicus* cross cows in northern Australia ranging from 351 kg (non-pregnant cows, Northern Forest region) to 518 kg (pregnant cows, Central Forest region). Similar variation was also reported for heifers and first lactation cows, and between lactating and non-lactating animals. Data at this level is most often reported in the literature stemming from research projects and local surveys. However, the liveweight of animals in different age groups can be estimated based on known adult liveweights using growth curve formulas [14].

The accuracy of biomass calculations is also impacted by population data, and liveweight of different classes of stock is not useful without equivalent data on herd structures. Official country statistics and international databases commonly house reported livestock population figures. These statistics predominantly stem from surveys, owing to the impracticality of directly counting every animal within a country. However, this approach introduces potential errors and bias. For example, Fordyce *et al.* [15] used a static herd modelling approach to validate reported Australian cattle population data generated from surveys. They found that national statistics likely underestimate the national cattle population by a substantial amount, largely due to a combination of low survey return rates (possible selection bias) and consistent under-reporting of herd size by individual businesses (measurement errors). National surveys may also exclude certain farm businesses, particularly smallholder, informal and backyard production systems. Again, drawing on the Australian example, the Australian Bureau of Statistics rural environment and agricultural commodity survey used to estimate livestock populations only includes farms registered with the Australian Tax Office and where the estimated value of agricultural operations is greater than AUD $40,000 [16], excluding an unknown number of farms and livestock. Due to the logistical challenge in conducting regular livestock population censuses or surveys, national data on livestock numbers is also not always available for every country every year. As such, global datasets such as FAOstat report 'imputed', 'estimated' or 'unofficial' population data for some countries and species [17].

The detail of population reporting varies between data sources. For global datasets, population data is usually limited to the total number of each species type. National statistics are more likely to include data for subgroups based on breeds, sex, and age, though this varies between countries. National statistics are also more likely to provide geographical disaggregation of populations, but this is usually based on political boundaries (e.g. state borders) rather than production systems. This is important in the context of GBADs because differences in animal liveweights and production losses associated with disease are associated with production systems.

For both liveweight and population data, the challenge of accessing accurate information are likely to be greatest for animals kept in informal and/or extensive production systems, and those with limited presence within a country. In comparison, detailed data on populations and liveweight is often collected for intensive and integrated industries such as pork and poultry production. However, this data is not readily shared, and incentives may be required to facilitate access to this information.

Data and methods for estimating livestock biomass

As indicated above, data on livestock weights and populations are available from a range of sources, including international databases, national statistics, industry data, and the literature, and availability of this data varies between countries and production systems. These sources differ in the specificity, and therefore accuracy, of their information, and their suitability for calculating biomass at different scales (Table I). In response, the GBADs programme has adopted methodological Tiers to guide the selection of different methods for estimating livestock biomass. This aligns with the IPCC tier approach for calculating greenhouse gas emissions, where a tier represents a level of methodological complexity; Tier 1 is the basic method, Tier 2 intermediate, and Tier 3 the most demanding in terms of complexity and data requirements.

For biomass calculations, Tier 1 methods rely on coarse estimates of livestock populations (e.g. global data from FAOstat [17]) and generic liveweight values. These methods can be used to estimate biomass at a global scale or in countries without national data. Where country-specific data on liveweight is not available, livestock conversion units such as Tropical Livestock Units (TLU) [18] may be used. A TLU (250 kg liveweight) is based on the average weight of a camel, with conversion ratios for common terrestrial livestock species shown in Table II. For a given species, livestock weight is estimated as 250 kg multiplied by the appropriate conversion factor. For example, the average liveweight of cattle estimated using this method would be 175 kg, while a chicken would be 2.5 kg. These conversion ratios provide a convenient way to estimate the average liveweight of a species and are not specific to breeds, production systems or countries.

Despite providing easy estimates of liveweight for different species, caution is advised when utilizing TLUs. TLUs are typically based on the metabolic energy requirements of different livestock species and used to estimate grazing pressure. Although TLUs have been used elsewhere to estimate livestock biomass [6], this is a deviation from their intended application and may under or over-estimate the liveweight of some species. They are also often regionally specific, with the TLU unit and conversion ratio based on African production systems. Thus, application of these units outside their intended geography may lead to errors [18]. Application of similar units such as Livestock Units (LSU, [20]) and Adult Equivalents (AE, [21]), which were designed to calculate equivalent liveweights of different classes of stock, face similar limitations.

Tier 2 methods use country-specific data on livestock populations and liveweight, and where sufficient data is available, this method may be scaled to provide continental or regional estimates of livestock biomass. Country-specific liveweight data may be sourced from national statistics or the FAO Technical Conversion Factors for Agricultural Commodities [19].

Proxy data such as slaughter weight may be used where liveweight data is not available since slaughter data is often collected by national agencies. However, it should be noted that this approach introduces additional errors since slaughtered animals are probably not representative of the broader population. Firstly, in most countries, slaughtered animals are mainly adults, and the age/sex structure of the slaughtered animal group may differ from that of the same species on the farm. Secondly, the body condition, and therefore liveweight, may vary for slaughtered animals and those remaining on a farm. For example, slaughtered beef cattle from intensive commercial farms in the UK would have a higher liveweight than the average on-farm liveweight of beef cattle. Conversely, slaughtered cattle in Ethiopia are mainly the old cattle from small herds and may have lower body condition and liveweight compared to the growing and healthy cattle on a farm. Given that the source of slaughtered animals varies between countries, using slaughter weight as a proxy for average liveweight of a species would introduce positive or negative bias in estimating livestock biomass for different countries.

Finally, Tier 3 methods require data on population size and structure, and animal liveweight at sub-national levels. Estimates of biomass for each sub-group can be summed to calculate biomass at larger scales (e.g. production system or national level). This data is sometimes available in national livestock census reports (e.g. Central Statistics Agency of Ethiopia [22]) but may need to be supplemented with farm survey data or information from literature. Synthetic data on population structures and cohorts can also be generated using mathematical and population dynamics models, based on known reproduction, mortality, and offtake rates [23], with liveweights estimated from growth curve formulas if no other data exists.

Methods in practice – Comparing livestock biomass estimations using different data sources in Ethiopia

To illustrate the difference in the biomass estimations using different methods and data sources, the stock biomass of cattle in Ethiopia in 2018 was estimated using different methods (Table III). While some methods gave similar estimates, the overall range (11-16 billion kg) was large. Assuming the Tier 3 (most detailed) method provides the greatest level of accuracy, we see that using TLUs underestimates average cattle liveweight, while application of average values across a population over-estimates liveweight if there is a large proportion of young livestock in a country.

Conclusions

As illustrated above, due to the variation in availability and quality of liveweight and population data, no single method can be recommended to calculate livestock biomass. The choice of methodology, guided by tiers, is influenced by factors such as resource availability, the scope of analysis, and the desired level of accuracy. While Tier 3 methods may provide greater accuracy given the disaggregation of livestock population and liveweight data by class and locality, useful estimates can still be derived using less detailed data and Tier 1 or 2 approaches.

As such, the implementation of methods varies across the GBADs programme. For initial global estimates of biomass, Tier 1 methods utilizing FAOstat data are currently the only suitable approach, and this resolution is consistent with initial global estimates of disease burden. Within case studies, Tier 2 and 3 methods are being utilized, depending on the species and country of interest. These biomass estimates are being used as inputs into calculations of total economic value [24], to highlight potential areas of high resource use and risk of disease transmission for policy makers [25], and as a denominator for comparing estimates of livestock value [26] and disease burdens between production systems and species. As the GBADs programme evolves, biomass and disease burden estimates from individual countries will be combined to give regional and global estimates of higher accuracy. Consistent with this, the standardization of biomass estimation methodologies will be important in ensuring cross-study and cross-regional comparability.

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Table I

Different sources of liveweight data and their utility in biomass calculations

Data source	Differentiated by breed, age, and sex groups	Disaggregated by production purpose	Disaggregated by country	Accuracy	Data scale	Use in method Tiers	Pros for biomass estimation	Constraints for biomass estimation
Transformed biomass concepts such as tropical livestock units [18]	No	No	No	Poor	Can be applied at all scales, but may be regionally specific	1	Easily scalable for national, regional, and global analyses	Most of these units are based on energy requirements not liveweight. Intended for use in grazing systems only
Domestic Animal Diversity Information System database [10]	Disaggregated by breed and sex	Sometimes	Yes	Good	National; Global	1,2	Suitable for regional and national analysis	Incomplete data for many breeds. Not all countries are represented in dataset
Slaughter weight from Food and Agriculture Organization of the United Nations [19]	No	No	Yes	Poor	National; Global	1,2	Suitable for national, regional, and global analyses	May overestimate the biomass of a species as not all individuals are slaughtered at adult ages
National statistics	Sometimes	Yes	Yes	Fair	National; Subnational	1,2,3	Suitable for subnational and national analysis; may support analysis by production system	Often not open access
Private industry data	Yes	Yes	Yes	Good	Farm or production system	1,2,3	High level of accuracy	Not publicly available
Literature	Sometimes	Yes	Yes	Variable	Subnational	1,2,3	Studies often focus on specific production systems; may support analysis by production system	Often small studies in which the representativeness of live body weights is arguable. Data from multiple studies will usually be required to scale up to national level

Table II

TLU conversion ratios [18]

Species	TLU conversion ratio
Asses	0.5
Camels	1
Cattle and buffalo	0.7
Goats	0.1
Horses	0.8
Mules	0.7
Pigs	0.2
Chickens	0.01
Sheep and goats	0.1

TLU: tropical livestock units

Table III

Total biomass of cattle in Ethiopia in 2018 using different methods and data sources

Data and method	Method tier	Biomass (billion kg)	Difference
National statistics on livestock populations [23] and liveweight by age/sex/breed	3	12.8	Reference method
National statistics on livestock populations [23] and mean liveweight (250 kg)	2	15.4	+20%
FAOSTAT data on populations [17] and liveweight data [19]	1	15.7	+23%
FAOSTAT data on populations [17] and the TLU conversion ratios [6]	1	11.0	-14%

FAOSTAT: Food and Agriculture Organization Corporate Statistical Database
TLU: tropical livestock units

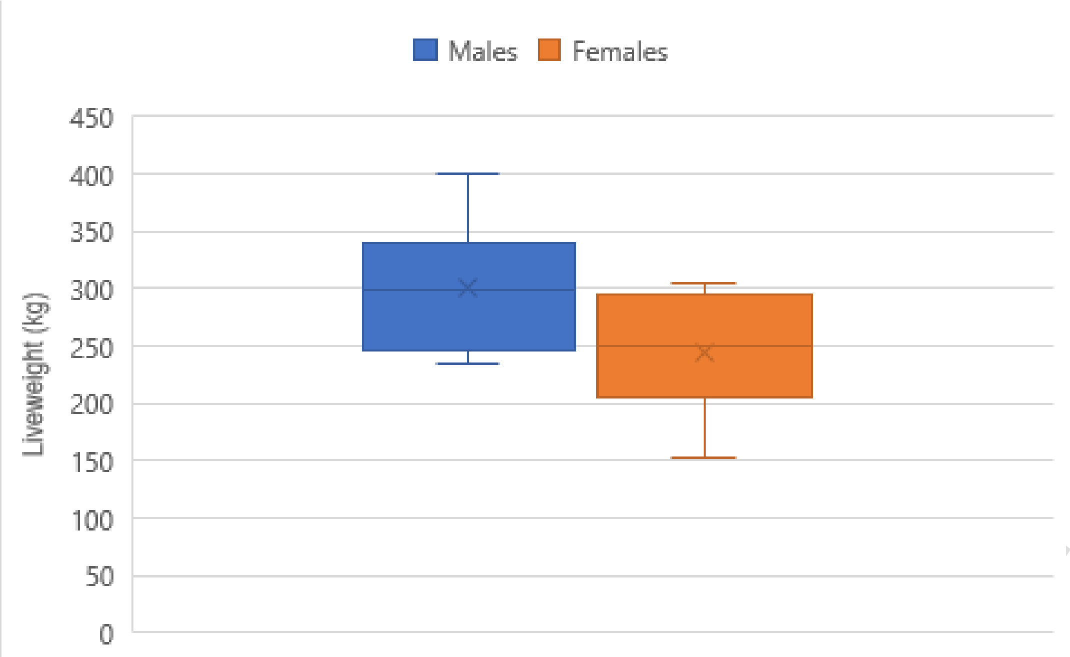

Figure 1

Distribution of average liveweights for male (blue) and female (orange) cattle of the 14 breeds of cattle in Ethiopia [10]