Methodology of The Factory Farming Index

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1. Executive summary

World Animal Protection has developed the novel concept of a global Factory Farming Index (FFI) which presents data on the impacts of factory farming across animal welfare, human health, and the environment. The FFI allows its users to draw meaningful comparisons between the impacts of factory farming in different countries, identifying which nations need to make the greatest changes to their animal agricultural production systems in order to become more equitable, humane, and sustainable. The FFI enables researchers and policymakers to better appreciate and understand the connections between improved animal welfare and improved outcomes for human health and environmental integrity. With the FFI at their disposal, policymakers at national and international levels are able to see why achieving a paradigm shift in the way animal welfare is conceived and prioritised is also important for achieving the goals of promoting human health and protecting the environment.

In brief, the FFI focuses on three areas of concern related to factory farming. For each of these areas, four key issues were identified, each with a corresponding quantitative indicator. The FFI uses existing methodologies to create a metric which we call Healthy Years Lost. The units are the years of human and farmed animal life lost to premature death plus the number of years of life in reduced physical and/ or mental health. We use welfare ranges which weight farmed animal years of life lost differently based on the differing capacities of species for positive and negative welfare experiences.

We also separately report an environment-focused indicator – biodiversity loss – which quantifies the number of wild species lost to factory farming activity. This is unrelated to Healthy Years Lost and is designed to capture the effects of factory farming on the natural world. For this, we follow an established framework from Life Cycle Assessment – LC-IMPACT – to quantify biodiversity loss. We account for the effects of land use, climate change, water use, and eutrophication – caused by factory farming – on biodiversity loss.

We express these indicators at the total country level and on a per person basis in a country, which we call the *production perspective* and *consumption perspective* respectively. This results in a ranking, showing which countries perform better and worse in terms of the negative effects of factory farming. For users of the FFI interested in one particular area of concern, the dataset has been devised in such a way as to facilitate the comparison of countries either from the perspective of total Healthy Years Lost and biodiversity loss associated with factory farming or by examining each specific issue individually (e.g., how factory farming impacts climate change). As the FFI makes clear, the impacts of factory farming on animal welfare, human health, and the wider environment are far-reaching and interconnected.

2. Aims of the Factory Farming Index

The FFI has been developed with three main aims in view:

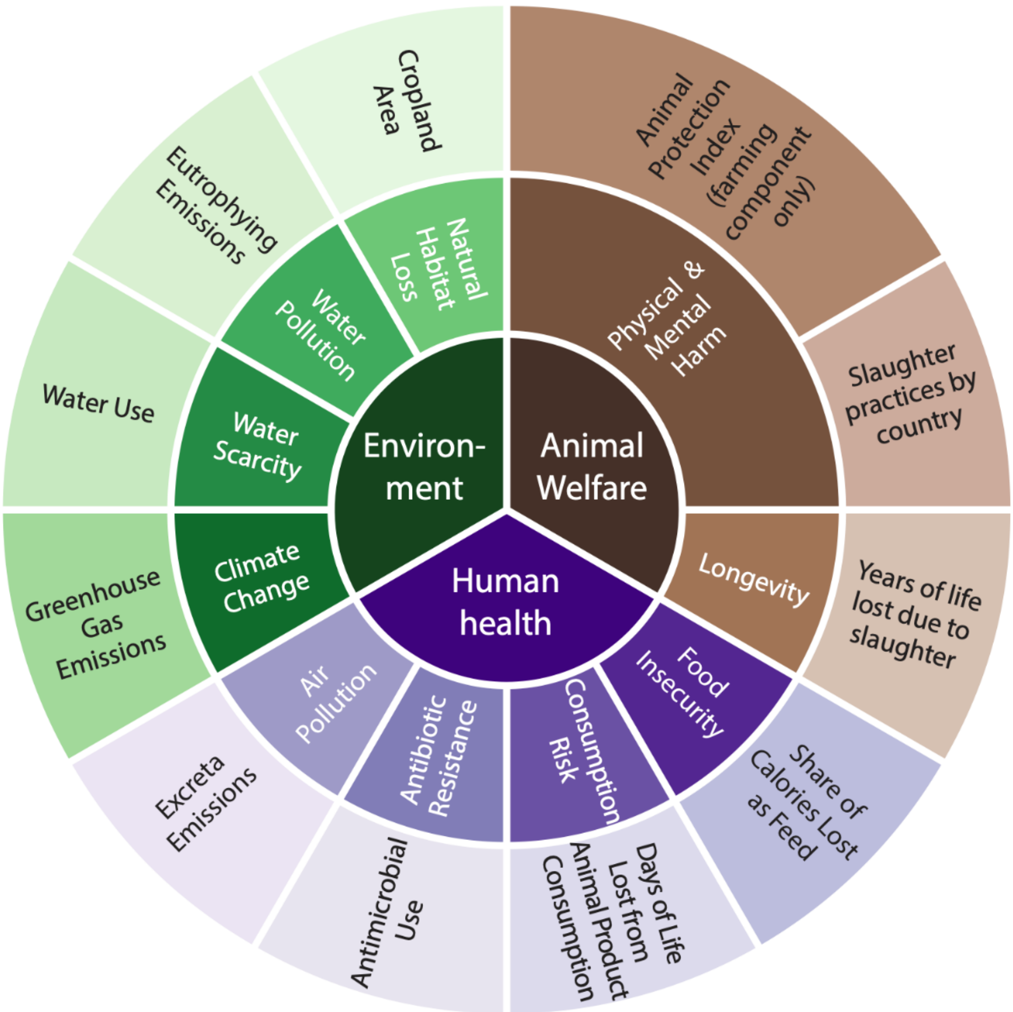
1. To explore the connections between enhanced welfare and legal protections of farmed animals and human health and environmental outcomes. Specifically, the FFI aims to deliver a fuller (though still incomplete) picture of the harms caused by factory farming across three areas of major concern.
2. To provide a robust empirical basis to identify poor performing countries on animal welfare, particularly those which benchmark badly against similar countries in socio-political and socio-economic terms. The purpose of identifying outliers is to motivate governmental and non-governmental efforts to improve animal welfare provisions and encourage longer-term food security strategies which give more holistic consideration to the impacts of factory farming.
3. To facilitate interdisciplinary and multi-stakeholder dialogue between potential users of the FFI. In particular, the FFI has been developed in the hope of enabling its users to identify new partners and allies to achieve a world where efforts to improve animal welfare, human health, and environmental outcomes are mutually supportive, as per the One Health framework discussed in Section 4.2 below. For example, although animal welfare is not an explicit feature of the UN's Sustainable Development Goals (SDGs), working towards improved animal welfare is consistent with, and may even contribute towards, achieving the SDGs (Keeling, et. al., 2022).

3. Methodological framework

3.1 Overview

The FFI looks broadly at the impacts of factory farming, from the harms inflicted on factory farmed animals, to the environmental impacts caused by factory farming, to the human health impacts. In Section 4 we detail each indicator in turn and how it is calculated. Here we present Figure 1 which gives an overview of the framework.

Figure 1. **Overview of the indicators of harm caused to factory farmed animals and of the harms caused to humans and the wider environment by the factory farming of animals.** In the centre of the wheel are the three areas of concern. Each area has four key issues, and each issue is quantified by an indicator. Water scarcity and climate change also contribute to human health impacts



The FFI captures the effects of factory farming in terms of:

1. The estimated reduction in human and farmed animal lifespans and the disability/welfare burden.
2. The estimated biodiversity loss caused by factory farming animals. This includes the effects of climate change, water scarcity, water pollution, and land conversion on biodiversity loss. This approach captures a range of environmental impacts and expresses them in terms of biodiversity, which is a widely used indicator of overall environmental health.

In Section 5 we justify the issues and indicators we focus on. However, there are many ways that factory farming could affect the environment and human health that we do not include. For example, factory farming leads to a concentration of power in a small number of businesses, potentially increasing income inequality, and creating human health and even social burdens because of this. Factory farming likely contributes to increased pesticide use due to the higher overall demand for crops to feed animals and the lower pesticide standards for animal feed vs food grade crops. These pesticides cause immediate health burdens to farmers and those nearby application areas etc. which we do not quantify here. We have sought to focus on some of the most critical issues, and future work should seek to expand this to make it more comprehensive.

What is Healthy Years Lost and how do we calculate it?

Healthy Years Lost includes both humans and farmed animals.

It quantifies the loss of animal life (*YLL*, or years of life lost) and the burden of disease and disability in the population (*YLD*, or years of life lived with disease, disability, or mental distress). It is analogous to DALYs (disability adjusted life years) which is a widely accepted concept for measuring the burden of disease in the human population, but here, we extend it to farmed animals.

Our approach builds on Scherer et al. (2018). Specifically, it is calculated for each country c as:

$$Healthy\ Years\ Lost_c = \sum_s (YLL_{c,s} + YLD_{c,s}) \times Welfare\ Range_s$$

Where s represents each species of farmed animal and also humans. $Welfare\ Range_s$ is a scaling factor which quantifies the difference between humans and farmed animals in terms of their capacity for experiencing positive and negative welfare. We discuss this in more depth later.

Considering only humans, where the *Welfare Range* = 1, this formula reduces to the normal specification of *DALYs:*

$$DALYs = YLL + YLD$$

For humans, *YLL* is calculated by quantifying the loss of life due to disease compared to reference life expectancies. *YLD* is calculated by multiplying years of life affected by factors for each possible disease or disability ranging from 0 (perfect health) to 1 (equivalent to death) to represent the severity of different health conditions. For example, the Global Burden of Disease (GBD) study assigns a factor of 0.049 to controlled diabetes, so living an entire life with this condition would, in theory, equate to 0.049 × expected lifespan. If the maximum reference life expectancy is 92 years, this results in about 4.5 DALYs. Our example is a simplification, because, in practice, age-specific life expectancies from standard life tables are used instead of a fixed maximum age. These tables adjust for the declining remaining life expectancy at older ages, making DALYs sensitive to both the timing and severity of health loss.

For farmed animals, we calculate *YLL* in country c for species s as the years of life lost to premature mortality (YLL) due to culling, on-farm mortality, or slaughter as:

$$YLL_{c,s} = Lifespan\ in\ Optimal\ Welfare\ Conditions_s - \ Actual\ Lifespan_{c,s}$$

We use lifespans in optimal conditions as the reference point, understood as conditions compatible with high standards of welfare in which animals can enjoy lives predominantly filled with positively valenced experiences. We do not use lifespans in the wild which are often shorter due to predation or disease, and this choice is a value judgement. We justify it in two ways. Firstly, *World Animal Protection* does not in principle oppose the farming of animals in every circumstance and therefore the goal is to reflect the extent to which we could improve farmed animal welfare conditions, which includes lifespan improvements (see further discussion in Section 5.1 below). Secondly, unlike wild animals, whose suffering from predation and disease is largely beyond human control, farmed animals exist in a human-made environment. This shifts the ethical reference point: we no longer compare their well-being to that of wild animals but instead consider the effects of our actions on their welfare. In this context, humans are not analogous to natural predators acting out of necessity, but moral agents making choices. Therefore, the avoidable harm caused by factory farming, which includes lifespan reductions, is a direct ethical concern.

YLD is calculated as the sum of the duration that animals live in factory farms multiplied by a factor representing the level of physical and mental harm they suffer, plus the duration of the slaughter period multiplied by a factor representing the physical and mental harm caused by the slaughter process. For farmed animals, *YLD* does not capture the years lived with a disability or disease as straightforwardly as in the case of humans. For the purposes of the FFI, we have assumed that factory farmed animals experience disease, disability, or mental distress proportionate to their welfare conditions. As such, *YLD* for farmed animals is more a reflection of welfare than it is a reflection of disease/ disability *per se*, but, nevertheless, it seems reasonable to assume a strong correlation between reduced welfare and increased disease, disability, or mental distress. This is important because we lack global data on the burden of disease, disability, and mental distress for animals in factory farms, but do have global data on welfare.

$$YLD_{c,s} = \left(Actual\ Lifespan_{c,s} - Slaughter\ Duration_s\right) \times Farm\ Welfare\ Reduction_c + Slaughter\ Duration_c \times Slaughter\ Welfare\ Reduction_c$$

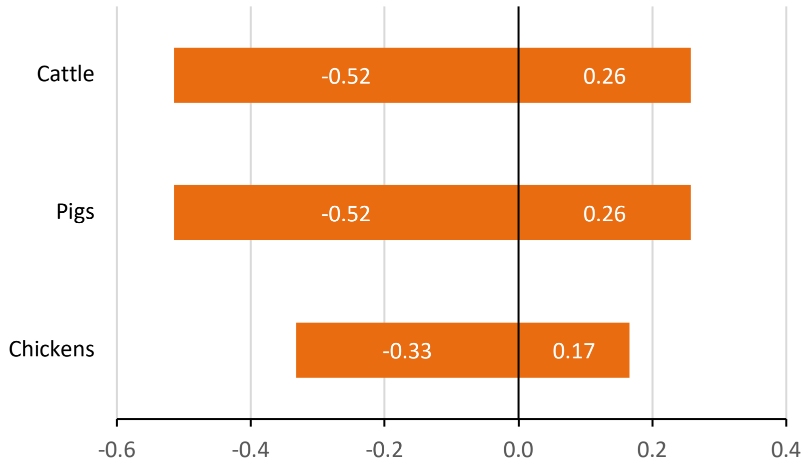
We provide further justification and detail our data sources in Section 5.1 below.

The FFI has been constructed in such a way that countries cannot improve their Healthy Years Lost number without first implementing welfare changes which would bring their Animal Protection Index (API) ranking up to 'A.' This means that, although the FFI recognises reduced lifespan as an animal welfare issue, it does not fall into the error of suggesting that extended lifespans for factory farmed animals would constitute substantial improvements to animal welfare. Indeed, for animals farmed in the worst welfare conditions, it is reasonable to assume that death may be a preferable state. Nevertheless, we do not include the idea of a life worse than death (negative welfare) in the concept Healthy Life Lost, and follow the established methods from the DALYs approach by setting the lowest welfare standard to 0 (equivalent to death), rather than worse than death [1].

The use of welfare ranges allows users of the FFI to evaluate the impacts of factory farming on different species of animal (including humans) on a single metric. Welfare ranges represent a farmed animal's capacity for experiencing positive or negative welfare relative to a human's capacity for welfare. For the purposes of the FFI, we adopt the welfare ranges generated by the work of Rethink Priorities as part of their Moral Weight Project (MWP) (Fischer, (ed.) 2024). However, we make one important modification to the welfare ranges as proposed by the MWP, namely we alter the assumption that the welfare range of farmed animals is symmetrical around the neutral point. Instead, we assume that the MWP is correct in its quantification of the negative part of the welfare range but that it is questionable whether symmetry in the positive part of the welfare range is plausible (i.e., we question whether factory farmed pigs can experience positive welfare states about half as intensely as human beings). We assume this based on the fact that animals on factory farms have drastically reduced lifespans. A significantly reduced lifespan has implications for quality of life. With too little time, farmed animals lose opportunities to meet basic needs such as resting, roaming, or foraging. They are also deprived of higher needs: to explore and learn; to form social bonds; and to exercise autonomy in making choices, expressing themselves, and even taking risks. Therefore, to err on the side of caution, we adopt the negative part of the welfare range proposed by Rethink Priorities but downscale the positive part of their proposed welfare range by 50%.

[1] Including negative welfare is possible in a QALY (Quality-Adjusted Life Years) framework, which accounts for both positive and negative aspects of health-related quality of life. In the QALY model, higher scores represent more years lived in good health, while lower scores (including negative values) reflect years lived in states worse than death. However, our focus is specifically on quantifying (and reducing) the negative effects of factory farming in terms of loss of physical and mental health and lifespan. Therefore, we follow the DALY (Disability-Adjusted Life Years) approach, which quantifies health and life loss. However, we do include an option in the underlying Excel model which allows users to explore what including negative welfare may do to Healthy Years Lost.

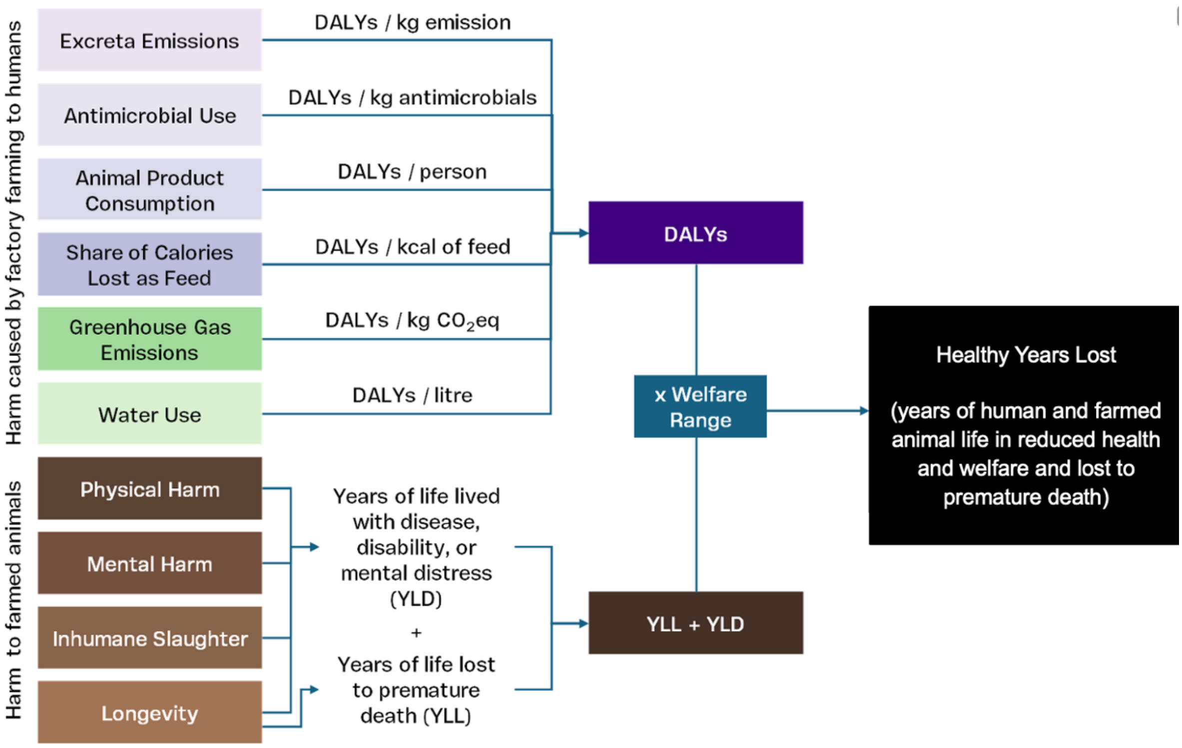
Figure 2. Welfare ranges used in the FFI. The welfare ranges are non-symmetric. While cattle, pigs, and chickens have half to a third of the intensity of negative experiences as humans, they have around a quarter to a fifth of the capacity for positive welfare experiences relative to humans.



More information about the existing research into welfare ranges we have drawn on for the FFI is available in Section 4.4. We note the welfare ranges used in the FFI give higher weight to farmed animals than prior work (e.g., Scherer et al., 2018) but we note that prior work has considered very simple indicators of the capacity for welfare (e.g., neuron counts alone) and it is well established that these simplistic indicators are not good proxies for overall welfare capacity (Fischer, 2024). The MWP is a recent project, considering a much larger number of indicators of welfare, and we think it provides far better proxies for welfare capacity than other assessments.

We call the final indicator Healthy Years Lost to distinguish it from DALYs which has a primarily human usage so as not to dilute the important usage of this term, but we also construct it in a comparable way to highlight the huge burden on farmed animal lives if viewed through the same lens as the human health burden. We also use a different term as there is criticism of the word “disability” in DALYs. This has been criticised because it puts lower value on the lives of people with certain disabilities which are argued by disability rights campaigners not to compromise human health in the way DALYs suggests. In fact, disability in DALYs is used to mean health loss more broadly, and we think there is a case for using new language to better position the concept.

Factory farming is both a direct and indirect cause of human DALYs. For example, there are direct links between the consumption of animal products and premature death and/ or years of life lived with disability or disease. Factory farming also indirectly causes human-DALYs by contributing to issues such as climate change. Climate change then causes premature death and/ or years of life lived with reduced physical and/ or mental health. We quantify these pathways where we have data and where estimates of DALYs are, or could be, established (Figure 2).



What is RAW and why do we report it?

In addition to reporting the overall Healthy Years Lost numbers for each country, the FFI also reports RAW numbers for each country, where RAW represents *reduced animal welfare* associated with factory farming. Unlike Healthy Years Lost, which captures the harmful effects of factory farming on both human and non-human animals, RAW exclusively captures the harms of factory farming on the welfare of farmed animals (i.e., the sum overall species included in the FFI, except humans, $s \in N$).

$$RAW_c = \sum_{s \in N} YLD_{c,s} \times Welfare\ Range_s \tag{5}$$

Another important point of difference between Healthy Years Lost and RAW is that whereas Healthy Years Lost captures the combined effects of reduced animal welfare and reduced lifespans, RAW exclusively captures the effects of reduced welfare of farmed animals. Although the FFI includes shortened lifespans amongst the harms factory farmed animals can suffer (and indeed includes longevity as an indicator of animal welfare *as per* Figure 1), we also acknowledge the difference between experiencing the loss of a good life and the experience of enduring physical and mental harm.

Whilst Healthy Years Lost is the overall metric we use to capture the harms associated with factory farming as fully as possible, we also include the RAW numbers as a subset of Healthy Years Lost. We do this, specifically, because one of the purposes of the FFI is to equip animal advocacy groups with an effective tool for identifying – and applying pressure on – countries which perform poorly in terms of animal welfare (i.e., countries which subject factory farmed animals to the worst physical and mental harms whilst on farms and at the point of slaughter). Given that years of life lost dominates the Healthy Years Lost calculation for farmed animals – because all countries perform badly in terms of reducing the life expectancies of factory farmed animals in comparison to animals farmed in optimal farming conditions – we have separately reported RAW numbers so that animal advocacy groups can focus their attention on either encouraging measures which would increase lifespans in some countries (i.e., those with an API ranking of ‘A,’ which, at present no country has obtained for farmed animals), or which would improve welfare conditions in other countries.

By reporting RAW as a subset of Healthy Years Lost, the FFI remains sensitive to the kinds of welfare reforms advanced by animal advocacy groups in a way that would be unachievable if only Healthy Years Lost were reported. To give an example, whilst measures such as banning gestation crates for pigs or ending the use of cages for factory farmed chickens would make a comparatively insignificant difference to the Healthy Years Lost number, by including RAW numbers the FFI can identify countries with higher standards of welfare and incentivise other countries to adopt similar practices. For, even though welfare reforms do not address the harm caused by radically curtailing animal lifespans, they nevertheless can make huge differences to an animal's quality of life.

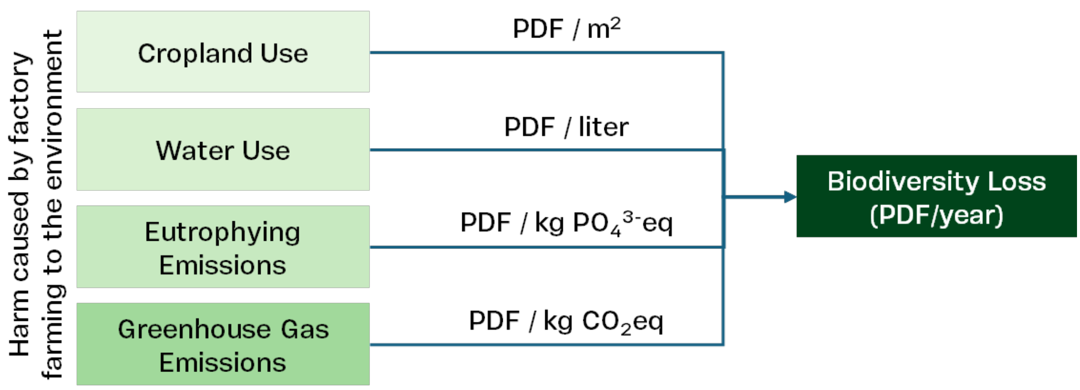
3.2 How is biodiversity loss due to factory farming calculated?

We estimate the effects of factory farming on biodiversity loss by quantifying the number of wild species of plants and animals that become destined to extinction using the metric PDF (Potentially Disappeared Fraction of species). We focus on four environmental pressures, about which we have good global data, and which represent some of the most significant environmental problems. We use the LC-IMPACT model, which reports relationships between these pressures and biodiversity loss.

- **Cropland use:** the LC-IMPACT model assesses how occupying or converting land destroys or degrades natural habitats, linking the area affected and the type of land use to the potential disappearance of species native to that region.
- **Water use:** LC-IMPACT quantifies how much water consumption reduces water availability for local ecosystems, thereby stressing aquatic and terrestrial species that rely on those water sources.
- **Eutrophication:** biodiversity impacts are calculated by relating the quantity of excess nutrients (like nitrogen and phosphorus) released into water bodies to the subsequent harm caused, such as oxygen depletion (hypoxia) which kills off sensitive aquatic species.
- **Greenhouse gas emissions:** these cause climate change, which in turn shifts climate zones, alters habitats, and increases the risk of extreme weather events. This forces species either to adapt, migrate, or go extinct.

For each pathway, LC-IMPACT translates the magnitude of the pressure (e.g., area of land, volume of water, mass of nutrient/GHG) into a quantified potential biodiversity loss expressed in PDF (Potentially Disappeared Fraction of species) units, often considering regional differences in species vulnerability. The calculations use simple linear relationships (e.g., one more/less unit of pressure leads to a proportional decline in biodiversity, but this is a simplifying assumption; in practice, adding more of a pressure could lead to higher biodiversity loss such as when last remnants of forest hosting endangered species are cut down, large species loss may occur). Given the simplicity of these calculations the results should be treated with caution, but we are using some of the best modelling currently available given the data that we have.

Figure 4. **Overall quantification of biodiversity loss.**



3.3 Producer and consumer versions of the FFI

There are two versions of the FFI, reflecting the harms associated with factory farming in every country from both production and consumption perspectives.

For the production perspective, we consider the total impacts of factory farming caused by animal production in a country. Countries rank higher (i.e., perform worse) if they produce more animals in factory farming systems and/ or their systems cause more harm to human or farmed animals. If a country were to produce no factory farmed animals, its score would be 0. Larger countries with many animals tend to rank higher.

For the consumption version, we calculate the total impacts of factory farmed animals consumed on average per person, considering animals imported as well as those produced and consumed domestically. Countries rank higher (i.e., perform worse) when larger numbers of factory farmed animals and animal products are consumed on average per person, and when the harm caused by that production is high.

3.4 Species included and excluded

The FFI includes data on three of the most commonly farmed terrestrial species: chickens (including chickens raised for meat and layer hens), pigs, and cows (including beef and dairy cattle). Their meat, milk (including dairy products), and eggs contribute 85% of human animal-source protein production (FAOSTAT, 2024). They represent 92% of the number of terrestrial animals farmed per year (FAOSTAT, 2024) excluding insects. These species have been selected as *World Animal Protection*'s priority species, but the FFI could certainly be strengthened by the inclusion of additional species which are also subjected to variable, and all too often very poor, welfare conditions globally.

Indeed, many aquatic animals are farmed each year, and including these, the species covered by the FFI only represent 9% of animals farmed (FAOSTAT, 2024; FishCount, 2025). We have two main reasons for currently not including aquatic animals. Firstly, there is a lack of available data on farming practices in aquaculture systems worldwide, particularly related to welfare. To include aquatic animals would therefore require significant updates to the API which is the main indictor we use for assessing animal welfare. Although the API ranks countries in terms of whether their laws recognise animal sentience and the strength of their laws protecting farmed animals, it is noteworthy that, globally, the scope of laws pertaining to aquatic animal protection is limited. For example, only as recently as 2021 were invertebrate aquatic animals such as lobsters, crabs, and octopuses included in the UK's Animal Welfare (Sentience) Bill, affording them legal protections which they had not hitherto enjoyed. Given how widespread the lack of laws protecting aquatic animals is, it seems likely that the API would not differentiate much between different countries. A picture would therefore emerge of different countries – some with higher animal welfare standards for terrestrial animals – having fairly similar standards for aquatic animal welfare. However, it is unclear how accurate a picture this would be. Indeed, whilst legal changes can often drive improved animal welfare, it is also the case that the adoption of best practice and attitudinal shifts towards animals can be a driver of legal change. Hence, the inclusion of aquatic animals in the FFI will require us to improve, or look beyond, the API as a data source for evaluating the welfare of non-terrestrial animals.

Secondly, because aquatic animals are farmed on such an enormous scale (on some estimates as many as 2.5 trillion fish are caught/ farmed annually), including aquatic animals in the FFI would effectively mean that the animal welfare segment would be entirely dominated by considerations of aquatic welfare. Hence, the FFI would become largely ineffective as a tool for evaluating the best means of improving the welfare of terrestrially farmed animals. To avoid this situation – where considerations of terrestrial animals are dwarfed by considerations of aquatic animals – we propose developing another FFI in the future, specifically covering the harms of aquatic factory farming not just to aquatic animals but also to human health and the environment.

None of this is to deny the moral significance of aquatic animal welfare. On the contrary, the sheer scale of production, combined with the largely unregulated treatment of aquatic animals, should motivate further work in this area.

3.5 The number of animals in farms

FAOSTAT provides data on the stocks of animals in a country at a point in time in a year. However, because many farmed animals, in particular pigs and chickens raised for meat, live less than a year on average in farming systems, many more animals are farmed in a year than the stock at one point in time. FAOSTAT also provide data on the number of animals slaughtered each year. However, many milk and egg producing animals do not go on to be slaughtered in a year, hence using number slaughtered is also likely an underestimate of the number of animals on farms. Further, many animals are culled (e.g., male chicks) or die from illness or disease, and these animals are not included in the number slaughtered and may not be included in stocks.

Here, to estimate the total number of animals farmed per year, we look at the ratio of the stock of animals to the number slaughtered per year. If this ratio is less than one, we use the number slaughtered per year as the basis of our calculations. If this ratio is greater than one, we use the stock of animals as the basis of our calculations. We then apply corrections for mortality and culling where relevant. Table 1 below shows the approach used and lists the data sources.

Table 1. Ratio of farmed animal stocks to slaughtered animals. Percentiles are across countries.

<table>
<tr><th rowspan="2">Animal type</th><th colspan="3">Stock / Slaughtered</th><th rowspan="2">Estimate of total farmed animals per year based on</th><th rowspan="2">Sources</th></tr>
<tr><th>5^{th}</th><th>50^{th}</th><th>95^{th}</th></tr>
<tr><td>Cattle</td><td>1.6</td><td>4.7</td><td>18</td><td>Animal stocks</td><td>FAOSTAT (2025)</td></tr>
<tr><td>Chickens (broilers)</td><td rowspan="2">0.2</td><td rowspan="2">0.3</td><td rowspan="2">1.3</td><td>Animals slaughtered plus pre-slaughter mortalities</td><td>FAOSTAT (2025), GLEAM-i (2023)</td></tr>
<tr><td>Chickens (layers)</td><td>Animal stocks plus culled male chicks</td><td>FAOSTAT (2025)</td></tr>
<tr><td>Swine / pigs</td><td>0.4</td><td>1.0</td><td>4.4</td><td>If stock/slaughter > 1, animal stock; else animals slaughtered plus pre-slaughter mortalities</td><td>FAOSTAT (2025)</td></tr>
</table>

We assume that chicks are born with a ratio of 50:50 male: female, and that all male chicks in egg laying systems are culled in all countries. Germany and France were two of the first countries to make culling of male chicks illegal in 2022 and 2023 respectively, but this comes after our reference period of 2020, and hence we do not correct for that here. In some countries, where egg laying hens also produce meat, we may be double counting male animals which go into meat production and are then counted in the number slaughtered. However, given our focus on factory farming where male chick culling is standard practice, we assume this is not the case. However, global data on chick culling practices is unavailable (Our World in Data, 2023) and we are unable to improve this estimate at present. We also did not find a global dataset of culling rates of male dairy calves and were unable to include these animals.

Mortality data are taken from GLEAM from the FAO, which provides the only global dataset to our knowledge on mortalities. Mortality data are reported by system, and we use the "Industrial" system in GLEAM for pigs, the "Broiler" system in GLEAM for meat chickens, and the "Mixed" system for cattle, which are the closest proxies for factory farming.

3.6 The number of animals needed to meet consumption demand

Some countries import substantial amounts of animal products and live animals, which requires the production of animals in different countries. Other countries export substantial quantities. To calculate the number of animals consumed, we first calculate the total quantity of meat consumed in a country from FAOSTAT (using the quantity available for domestic consumption, which also includes food waste). We also get the average slaughter weight for each animal type in that country in kilograms per head from FAOSTAT. We divide meat consumed by the slaughter weight to get to the number of animals consumed. This assumes slaughter weights in a country are the same as the country the meat is imported from. We checked this assumption by comparing the total number of animals consumed to the total produced and find a 0.3% difference between the two values, suggesting this was a reasonable assumption. We assume eggs are produced domestically and therefore use the stocks number here. We assume all dairy animals are eventually slaughtered and that the meat numbers therefore include these animals.

3.7 Definition of factory farming

"Factory farming" is a fraught concept with no single, universally agreed upon, definition (Ritchie, 2023a). *World Animal Protection* understands factory farming to be systems of agriculture in which animal husbandry practices do not reflect or respect the sentience of the animals farmed and where negative animal welfare, environmental, social, and health impacts are significant yet not considered when calculating the costs of production. The factory farm business model is characterised by concentrated and highly corporatised management, streamlined processes, high production volumes, and a strong focus on cost minimisation. Intensive livestock operations, industrial farming, and concentrated animal feeding operations (CAFOs) are other terms used to characterise this type of animal production.

Given the lack of a single widely accepted definition of factory farming, for the purposes of the FFI we have identified factory farms by considering three important features:

1. stocking densities
2. farm size
3. the extent to which animals have access to outdoor space

We consider stocking density data to be the most useful for identifying factory farms since (at least until a certain threshold where there are increased risks of disease outbreaks) higher densities are simultaneously associated with lower cost and lower animal welfare. Hence, where data is available on stocking densities, we use that information to capture the share of factory farms within a country.

In real terms, the FFI defines chickens farmed for meat as being factory farmed if their stocking density indoors is over 13 chickens per m^2, and they have access to less than $10m^2$ of outdoor space per bird. We reach this definition by looking at the UK government's guidance on poultry meat marketing standards (DEFRA, 2024) and the EU Council Directive 1999/74/EC. For chickens used for egg production (layer hens), the FFI defines them as being factory farmed if there are more than 9 hens per m^2 indoor and they have access to less than 4 m^2 of outdoor space per hen. This definition is reached by considering how free-range eggs are defined in EU legislation (EU Commission Regulation, 2017) and EU Council Directive 1999/ 74/ EC). The FFI defines pigs as being factory farmed whenever a pig has access to less than 12 m^2 of outdoor space. This definition has been reached by looking at how the RSPCA understands free-range pig production (RSPCA, 2016, p. 17). Unlike for chickens and pigs, we have been unable to identify minimum space requirements/ stocking density thresholds by which we can discern whether a cow is factory farmed. Hence, for cows, we rely on data about farm size to determine whether they are factory farmed.

Where stocking density data are unavailable, we turn next to information about the size of farms. Whilst we recognise the theoretic possibility of mega-farms stocking animals in low densities, in practice there is little evidence to show that this occurs. We adopt the US Environmental Protection Agency's definitions of small, medium, and large CAFOs and define factory farms as those housing animals in equivalent or greater numbers than medium sized CAFOs (EPA, no date). Whilst a case could be made for describing even small CAFOs as factory farms (which, for chickens used for meat means a farm with fewer than 37,500 individuals), we adopted a more conservative approach.

Lastly, where neither data about stocking density nor farm size is available, we rely on data about animal husbandry practices focused on outdoor access. If we know what proportion of farmed animals are free-range or grass-fed (two major outdoor practice systems), then we calculate the share of factory farmed animals in a country as the difference between 100% and the % share in free-range or grass-fed systems.

To reiterate, to build our database on the share of animals in factory farms, we prioritise data sources with information on stocking density. Where this is not available, we prioritise data sources with information on farm size and, lastly, if these are not available, we seek out data sources using practice or standards-based information (Table 2).

Table 2. **Definitions of factory farming used per type of animal.**

	Broiler (Meat) Chickens	Layer Hens	Pigs	Dairy Cattle	Beef Cattle
Density Based Definition	More than 12 chickens per m^2 indoor, and access to less than $1m^2$ outdoor space per bird.	More than 9 hens per m^2 indoor, and access to less than $4m^2$ outdoor space per bird.	Access to less than $12m^2$ of outdoor area per pig.	None	None
Farm Size Based Definition	Over 37,500 chickens	Over 25,000 hens	Over 750 pigs	Over 200 mature cattle	Over 300 cattle or cow/calf pairs
Outdoor Practice Based Definition	Not certified using an outdoor related practice (e.g., free range).	Not certified using an outdoor related practice (e.g., free range).	Not certified using an outdoor related practice (e.g., free range).	Not certified using an outdoor related practice (e.g., grass fed).	Not certified using an outdoor related practice (e.g., grass fed).

Our primary data sources were government reports, the FAO GLEAM database, Eurostat, and peer reviewed articles. The sources are detailed in the accompanying Excel tool, in the "Share in Factory Farms" sheet.

3.8 Reference year

The FFI is created for the year 2020, and all reference data are collected for this year or the closest year possible. Factory farming is a rapidly growing sector worldwide, and future work should seek to recognise and quantify changes in the sector.

4. Conceptual foundations

4.1 The "five domains" model of animal welfare

For the purposes of the FFI, animal welfare is framed according to the "five domains" model, initially proposed by Mellor and Reid in 1994 and most recently updated to reflect developments in the science of animal welfare in 2020 (Mellor and Reid, 1994; Mellor et al., 2020). On this view, an animal's welfare is determined by whether their physical health, nutritional, environmental, behavioural, and experiential needs are met. The "five domains" model reinforces the idea that animal welfare is a multi-dimensional concept, encompassing both physical and psychological wellbeing. Whilst the external conditions in which animals live are inextricably linked to their welfare states, there is an irreducibly subjective element of welfare which can only be understood by evaluating an animal's mental state.

The "five domains" model is just one among many competing conceptualisations of animal welfare, each with their own strengths. We have selected the "five domains" model for several reasons, including the fact that we consider it an improvement on the more basic model of animal welfare according to which animals should be able to enjoy the "five freedoms": freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury, and disease, freedom to express natural behaviour, and freedom from fear and distress. Whereas the "five freedoms" model largely conceives of animal welfare in terms of conditions animals should be free of (i.e., in negative terms), the "five domains" model is built on the idea that there are goods animals are capable of enjoying and should have access to in high welfare systems (i.e., in positive terms). We have also adopted the "five domains" model as this model is endorsed by *World Animal Protection*.

Nevertheless, the FFI is compatible with a broad range of animal welfare theories and is not wedded to the "five domains" model to the exclusion of alternative theories. In fact, the FFI only loosely draws on this model and at times goes beyond the remit of the model itself to capture elements of animal welfare we consider important. A particular example of this is the FFI's inclusion of longevity as an issue pertinent to animal welfare. Whereas the "five domains" model focusses on the hedonic experiences of an animal during their lifetime, by including longevity as a relevant factor, the FFI considers reduced lifespans to be a serious harm inflicted on factory farmed animals. This is a controversial idea within the field of animal welfare science but is not without support. Indeed, there are moral arguments for including longevity as relevant to animal welfare. Expressed in basic terms, these include the fact that by depriving an animal of life, all future opportunities for enjoying high welfare are automatically removed and the animal's fundamental – and intrinsic – interest in continued existence is thwarted (Richter et al., 2024).

4.2 One Health

The FFI has been constructed on the premise that the One Health paradigm, according to which "the health of humans, domestic and wild animals, plants, and the wider environment... are closely linked and interdependent," provides both a powerful set of insights and a practicable approach to integrated problem-solving on some of the most pressing issues facing contemporary society (World Health Organization, no date).

Despite facing criticism from some quarters – either because the concept of One Health fails to establish that the health interests of the three distinct components of humans, animals, and environment are always in harmony, or because the notion of health itself is an opaque and evolving concept (Selter and Salloch, 2023) – for the purposes of the FFI these ambiguities can be seen as strengths rather than as weaknesses. Indeed, the evolution of the idea of health as encompassing more than the mere absence of disease and including positive states of wellbeing is in fact consistent with developments in the concept of animal welfare, as reflected in the "five domains" model. Similarly, the fact that the interests of humans, animals, and environment are not always perfectly aligned arguably demonstrates the need for critical engagement with the question of how to weigh and balance these interests (as per the FFI) rather than a repudiation of the One Health paradigm in its entirety.

Finally, it is important to note that drawing on the One Health concept to explore the harms caused by factory farming does not imply an unwavering or total commitment to this paradigm to the exclusion of all others. That is, rather than interpret other conceptualisations of the relationships between human, animal, and environmental well-being (e.g., One Welfare, Ecohealth, or Planetary Health accounts) as competitors to One Health, such holistic accounts of health may be best viewed as complementary. Indeed, as the originator of the One Welfare framework, Pinillos, writes: "The purpose of One Welfare is not to create a parallel structure, separate from One Health, but instead to complement and amplify its benefits within the least developed and known areas of animal, human and environmental collaborative approaches" (Pinillos, 2018, pp. 7-8). Hence, even if it transpires that the One Health paradigm is eventually supplanted with another model, it has at the very least been provisionally helpful for encouraging policy makers and healthcare providers to contextualise and weigh immediate human interests alongside long-term environmental and animal interests. As such, One Health marks a positive step forward from pre-existing models of health.

4.3 Understanding animals and welfare in terms of "units"

For the purposes of the FFI, animals are thought of as "units." The FFI calculates the amount of harm caused *to* factory farmed animals and caused *by* the factory farming of animals. Such calculations necessitate a conceptualisation of animals as "units" adjusted according to the welfare ranges of the different species. None of this is to deny that there are limitations in viewing sentient beings as "units" and it would be a mistake to imagine that animals are reducible to mere "units." Indeed, *World Animal Protection* is committed to the view that animals also matter as individuals, as beings possessed of their own inherent value and dignity. Hence, for this reason, we advance the FFI as just one of the many important tools and information sources which should inform the development of equitable, humane, and sustainable food system policies.

Nevertheless, by viewing animals and welfare as "units" the FFI reflects the fact that, all else being equal, countries subjecting higher numbers of animals to factory farming will achieve a worse ranking than those subjecting fewer animals to factory farming. The FFI treats all factory farmed animals as equal in terms of sentience whilst also recognising that different species have different welfare ranges. Critically, the welfare range captures "the relative peak intensities of different animals' valenced states at a given time" and does not in itself tell us anything about the relative moral value of different species (Fischer, 2023).

Therefore, all else being equal, if two countries consume the same number of kilograms of factory farmed animal products, the country that farms more animals to achieve this level of consumption will rank worse than the country that farms fewer animals to achieve the same level of consumption (assuming similar welfare ranges for the different animals farmed). In theory, due to the slightly lower welfare range of chickens compared with pigs and cattle (respectively 0.3 and 0.5), a country could shift its production practices away from pigs and cattle and towards chickens and, in fact, produce more animals yet still retain the same ranking in the FFI. In practice, however, the FFI tends to rank countries producing higher numbers of factory farm animal products worse than countries producing smaller numbers of such products, assuming comparable levels of welfare and lifespan.

The FFI also considers welfare itself as expressible in terms of "units." There are a number of ways a country could improve its ranking in the FFI by increasing the amount of welfare animals experience. One option would simply be to improve conditions on farms and at the slaughterhouse so that animals experience reduced levels of physical and mental harm. This approach would lead to clearly improved RAW numbers but may have little impact on the overall Healthy Years Lost number.

Another option, which would have greater effects, would be to combine these measures with extending the lifespans of factory farmed animals. Animal advocacy groups may worry that an unintended consequence of the FFI would be to incentivise the extension of animal lifespans whilst neglecting efforts to incentivise improved animal welfare: could more "units" of welfare be achieved simply by extending lifespans? However, in practice, countries would have little incentive merely to extend lifespans without simultaneously improving welfare conditions. This is because: (a) there are both environmental and economic costs associated with extending lifespans such that these would have to be factored into the FFI itself, where countries might consequently perform worse in terms of the environmental harms linked to their factory farming practices, and into broader economic decisions; and (b) extending lifespans for animals in countries with an API score of less than 'A' would in fact worsen their Healthy Years Lost calculation because – until welfare is optimised – simply granting factory farmed animals longer lives would amount to subjecting them to longer periods of time in sub-optimal welfare conditions in which they experience physical and mental harm.

Instead, the only means by which countries can effectively improve their Healthy Life Lost score would be to first address the issue of poor animal welfare (and achieve a ranking of 'A' in the API) and only subsequently address the issue of reduced animal lifespans.

By reporting both RAW and Healthy Years Lost, the FFI allows its users to identify, broadly speaking, which changes would be most effective at increasing units of welfare on a country-by-country basis. At present, because no countries achieve an API ranking of 'A,' all countries have the same pathway for improving Healthy Life Lost: improve welfare standards, then extend lifespans. In the future, however, if a country were to achieve an API ranking of 'A,' the most effective way of improving its Healthy Years Lost score would be to simply maintain welfare standards whilst extending lifespans. Again, we reiterate that, in practice, the environmental and economic trade-offs associated with extending animal lifespans are such that the most effective way to improve Healthy Years Lost would likely be to transition away from factory farmed products.

4.4 Welfare ranges

The FFI uses the idea of "welfare ranges," a concept developed by Rethink Priorities as part of their Moral Weight Project (MWP) (Rethink Priorities, 2022). The MWP aims to capture the "moral weight" of 11 of the most commonly farmed species globally. These species include pig, chicken, carp, salmon, octopus, shrimp, crab, crayfish, bee, black soldier fly, and silkworm. Cows are excluded from the MWP's list because, in terms of the number of *individuals* farmed, their numbers are comparatively low. For the purposes of the FFI, we have assumed that the "moral weight" of cows is equivalent to the "moral weight" of pigs. Although this is an imperfect assumption, we believe the advantages of using the idea of "moral weights" outweigh the disadvantages of not having exact "moral weights" for all the species covered in the FFI. The MWP and the FFI also share core philosophical and valued-based assumptions, and it is therefore relatively straightforward to apply the insights of the MWP to the FFI. Most importantly, the MWP and the FFI are guided by utilitarian principles and both projects aim to do the greatest good (morally) and assume that this can be objectively measured. Another shared principle is the idea of unitarianism, or the idea that welfare can be expressed in terms of units and that, regardless of whose welfare is at stake, one unit of welfare counts just as much (morally) as another unit of welfare.

The MWP understands an individual's moral weight in terms of that individual's "capacity for welfare" i.e., as a measure of how much welfare animals of different kinds can potentially "realise, produce, or generate" (Rethink Priorities, 2022). It is important to note that the concept of "moral weight" differs from the concepts of moral status or moral importance. The MWP does not make assertions about the relative value of different species, or about how much different animal species matter compared to humans. Instead, it aims to capture information about "the relative peak intensities of different animals' valenced states at a given time" (Fischer, 2023).

In other words, to say that a pig has approximately 0.5 of the "welfare range" of a human in the negative part of the welfare range is not to say that two pigs are of equal moral value to one human. Rather it is to say that the worst experiences a pig can have are approximately half as *intense* as those a human can have. Again, to say that a pig has about 0.25 of the welfare range of a human being in the positive part of the welfare range is not to say that four pigs are of equal moral value to one human. Instead, it is to say that the best experiences a pig is capable of enjoying are about a quarter as *intense* as the best experiences a human can have. The MWP defines the "best" human experiences in terms of what an average person in good health can experience, rather than the absolute limits of human potential. This distinction ensures that comparisons are grounded in realistic, everyday experiences rather than extreme or rare events.

Rethink Priorities reached its conclusions about the relative "moral weight" of the 11 species under its consideration by identifying numerous traits which could plausibly serve as proxies for variation between species with respect to the evolutionary function of valenced experiences. They conducted a literature review for traits which could indicate "conceptual or representational complexity, decision-making complexity, and affective richness, involving over 100 qualitative and quantitative proxies across 11 species" (Fischer, 2024). For the purposes of the FFI, we have erred on the side of caution and altered the assumption that the welfare range of farmed animals is symmetrical around the neutral point. Whilst it seems plausible to assume that the physical and mental harms suffered by factory farmed chickens, pigs, and cattle could be experienced, respectively, as 1/3 or 1/2 as intensely as the physical and mental harms a human could endure, it seems less plausible to imagine that these species can experience positive welfare states 1/3 or 1/2 as intensely as human beings, given the significantly reduced lifespans of factory farmed animals, which in turn has implications for quality of life, and opportunities to meet basic needs and higher needs essential to positive welfare states. Rethink Priorities has published the **full list** of traits considered as part of determining the respective "moral weights" of different species, but some illustrative examples include:

- Tool use
- Understanding of object permanence
- Ability to engage in mental time travel
- Understanding the concept of death
- Displaying cooperative behaviours
- Problem solving
- Associative learning from pain
- Emotional contagion (i.e., mirroring the emotions of others or transferring emotions across individuals)
- Playful behaviour
- Fear-like or boredom-like behaviour
- Maternal response to offspring distress

These traits were chosen because they reflect key needs of animals. For example, many relate to purpose and cognitive fulfilment – the ability to learn, grow, follow curiosity, and derive satisfaction from improving. Social animals (such as chickens, pigs, and cattle) require connection, affiliation, affection, cooperation, and companionship. Animals also need autonomy – the freedom to make choices, express themselves, dissent, and even take risks. Finally, animals require rest and recreation – space to play, relax, enjoy themselves, and seek stimulation.

After having identified an extensive list of relevant traits, the MWP team then aggregated their results to arrive at the moral weight of each species considered.

The "moral weight" only captures the welfare range of an animal at a given moment. It can therefore only provide a snapshot of the relative intensity of an animal's valenced state compared to that of a human.

5. Rationale for each issue and indicator

In this section, we explore the rationale behind the selection of each issue and indicator in the FFI. It is important to acknowledge from the outset that not every important issue and indicator is included in the FFI. This is partly because of the practical constraints involved in building such an index, but also because in some instances the data simply is not available for enough countries to allow for sufficient global comparisons. To give one example, available research suggests that the physical and mental health impacts on factory farm workers and meat processors can be severe (including death from injury, and chronic mental illnesses such as post-traumatic stress disorder and post-injury stress syndrome) (Human Rights Watch, 2004). Minority and/ or socially marginalised communities are disproportionately impacted by factory farms which further exacerbates the challenges of delivering justice, health care, and opportunities in under-privileged regions (Cappiello, 2021). Had the data been available on a global scale, inclusion of these issues in the FFI would have been valuable. Indeed, the fact that such data is not available arguably confirms the extent to which the rights and interests of particular racial and social groups are unjustly overlooked.

Nevertheless, since the FFI aims to facilitate global comparisons on the impacts of factory farming, the process of selecting which issues and indicators to focus on necessarily began by determining whether global data were available.

5.1 Animal Welfare

5.1.1 Physical and mental harm in factory farms

Justification

The capacity of animals to feel, and to interpret physical and mental harms as negative experiences is now a firmly established scientific fact. The capacity, known as sentience (derived from the Latin word *sentire*, meaning 'to feel'), means animals can experience subjective states like pain, pleasure, fear, joy, and anxiety. Although experiences of suffering are necessarily subjective, leading biologists and animal welfare experts now accept that, taken in combination, the physical health, physiological signs, and behaviours of animals can provide a sufficiently "objective" means for measuring welfare (Stamp-Dawkins, 2006, p. 36).

Whilst our understanding of what constitutes high animal welfare standards continues to evolve, it is important to note that freedom from physical and mental harm forms the bedrock of animal welfare. In extending the concept of animal welfare beyond the idea of a mere absence of physical or mental harm to encompass the concepts of "a life worth living" and even a "good life" (conceived as a life in which positive experiences predominate), animal welfare theorists affirm the importance of providing a holistic package of measures for animal welfare (Mellor, 2016). These measures are needed across the "five domains" of physical health, nutrition, physical environment, behavioural interactions, and an animal's mental state (Mellor et al., 2020).

The risk of suffering physical and mental harm is particularly acute for animals during their time spent in factory farms. When animals are viewed primarily as units of economic value – rather than as sentient beings with inherent value – providing for their physical and mental welfare may sometimes come at costs which cannot be recouped. Hence, whilst there are strong *moral* reasons to ensure the highest possible standards of animal welfare and to ensure that animals do not suffer unnecessary physical or mental harms in factory farms, economic reasons may not always be forthcoming. It is therefore flawed to think of animals *exclusively* as commodities or economic "units" whose welfare can be sacrificed for the sake of profit, (see Section 4.3 above on the uses but also the limitations of viewing animals as "units").

Countless undercover investigations into conditions on factory farms (conducted by animal protection organisations and activists around the world) reveal some of the worst instances of animal abuse. Crucially, even leaving aside cases of intentional cruelty, it is important to recognise that factory farmed animals suffer significant physical and mental harms in the implementation of standard (and in some cases "best") practice. To give just a single example, the practice of tail docking remains extremely widespread amongst pig farmers (with research suggesting that up to 77% of pigs have their tails docked in Europe) (De Briyne et al., 2018). This is despite the fact that European legislation prohibits the routine use of tail docking, allowing it only as a last resort when measures to prevent tail biting (which is often the result of chronic boredom and frustration) have not proved successful. This painful procedure is routinely performed without the use of anaesthetics and is known to cause ongoing pain throughout a pig's life in cases where neuromas (i.e., clusters of nerve endings) develop.

Methodology

Due to a lack of outcomes-based animal welfare data (i.e., data capturing the on-the-ground realities of welfare standards applied in factory farms) on a multi-national scale (Scherer et al., 2018), the FFI uses data from the *World Animal Protection* Animal Protection Index (API) which captures information about the legal status of animals in 50 countries (World Animal Protection, 2020).

The API captures how well countries perform in the provision of legislative measures designed to protect animals, including whether animal sentience is recognised in law. The API also ranks countries depending on whether governmental bodies are held accountable specifically for ensuring animal protection and whether the laws and policies of a country reflect commitment to animal welfare standards outlined by the World Organisation for Animal Health (WOAH).

The FFI assumes that the countries covered by the API comply with the laws governing how farmed animals may be treated but, of course, it is not possible to say exactly how strictly these laws are complied with.

The API uses a scoring system from A to G, where A represents optimal welfare conditions and G represents non-existent or limited welfare legislation and institutional support. We convert this into a quantitative indicator of *Farm Welfare Reduction* as:

- A: welfare reduction of 0% (no physical or mental harm)
- B: welfare reduction of 25%
- C: welfare reduction of 50%
- D: welfare reduction of 75%
- E: welfare reduction of 90%
- F: welfare reduction of 95%
- G: welfare reduction of 100% (highest degree of physical and mental harm)

This is a simplifying approach. For example, even without legal protection, animals may experience reasonable welfare conditions. Further, the grading system in the API is not linked to any quantification of physical or mental harm outcomes and we must assume here that it is both linked and linearly correlated. This is a critical area for future improvement of the FFI and merits substantial further consideration.

Five subcategories of the API are used as these are particularly linked to factory farming. They are "Sentience is recognised in legislation", "Laws against causing animal suffering", "Protecting animals used in farming, "Government accountability for animal welfare", and "OIE animal welfare standards." An average score of these five is taken.

Only 50 countries are included in the API. However, these are most of the major countries globally, and they represent 90% of global farmed animal production in 2020. For the countries where data are missing, we calculate a regional API average and apply them to each country in the region where data are missing. The regions we use are Africa, East Asia Pacific, Europe, Central Asia, Latin America/Caribbean, Middle East, and South Asia.

The fact that the years of life lost component dominates the FFI's overall Healthy Years Lost calculation may engender questions about the purpose of including physical and mental harms as core indicators to begin with: if reduction in lifespan is the main driver of a high Healthy Years Lost number, why not focus exclusively on extending lifespans rather than also seeking to address reductions in welfare? The answer is multifaceted. Firstly, for countries with poor API scores, extending lifespans alone does little to improve the Healthy Years Lost number. Instead, countries with poor API scores must first take steps to improve welfare conditions on farms and at the point of slaughter (i.e., reduce the harmful effects of their practices on animal welfare) and then extend lifespans. Only by taking both of these measures can a poorly performing country achieve tangible improvements to their Healthy Years Lost number. The second reason for including welfare indicators in the FFI, and not focusing exclusively on animal lifespans, is that the conditions farmed animals endure matter *morally* in and of themselves. For example, even if the overall Healthy Years Lost calculations change little as a result of measures like increased cage space for factory farmed animals, these measures are nevertheless important for achieving more humane farming systems in which the lived experiences of the animals themselves are not overlooked. At the same time, because lifespans do dominate the Healthy Years Lost calculations, the FFI introduces an alternative perspective about the value of incremental welfare improvements for the lives of factory farmed animals – whilst alleviating the suffering associated with the worst conditions is morally important, it would be a mistake to characterise these improvements as huge victories for animals who, nevertheless, may still only be living out 4% of the time they might expect to live in optimal farming conditions. It is for this reason that the RAW numbers are presented as a subset of the Healthy Years Lost numbers. In other words, whilst improving animal welfare is certainly important, the idea that animals living such curtailed lives as factory farmed animals are living "good" lives is an illusion which the Healthy Years Lost number helps to dispel.

Other approaches in the literature

There are many approaches in the literature which seek to create quantitative indicators of farmed animal *welfare reduction* which could be considered comparable to the disability factors approach used in the DALYs framework for humans. Here we briefly review some of the key approaches and justify why we chose a welfare reduction approach based on the API.

- Scherer et al. (2018) use some components from the Welfare Quality® framework to construct a welfare reduction. However, they are unable to use the full Welfare Quality® framework as this would require on farm data collection which is not feasible at the global scale and no databases currently exist on key metrics (e.g., the number of animals with lameness per farm). For example, for cattle, they only use the number of days spent on pasture to quantify welfare. The API considers a much larger range of criteria than this, and legal data are more available globally. We think that the more comprehensive assessment that the API provides outweighs the benefits of the narrower focus used in Scherer et al.
- Teng et al., (2018) propose a metric called welfare adjusted life years (WALYs) and estimates disability factors for different diseases (effectively the same approach as DALYs). However, their data are limited to dogs and there is no global data (to our knowledge) on disease and disability prevalence in farmed animals.
- Bartlett et al. (2023) use all components from the Welfare Quality® framework, account for lifespans, and also allow for both negative and positive welfare. However, using the full Welfare Quality® framework is not feasible for the FFI, as such data do not exist at a global scope.

5.1.2 Inhumane slaughter

Justification

In addition to the physical and mental harms experienced during their lives in industrial farming complexes, factory farmed animals face the risk of inhumane slaughter (i.e., physical and mental harm at the point of slaughter). What happens to an animal in the moments immediately preceding, and at the moment of, death matters morally. Animal advocates are critical of the concept of "humane slaughter," arguing that the term itself is oxymoronic, and questioning the sense of describing any intentional and unnecessary act of killing as "humane" (Gen V, 2019). Those critical of the concept also point out that, too often, the measures designed to ensure animals experience a (relatively) painless death free from suffering and distress (e.g., measures such as being rendered unconscious through stunning), are far from failproof.

Nevertheless, even if "humane slaughter" cannot in principle be achieved, clearly some methods of slaughter are more/ less humane than others. In other words, regardless of one's general stance on the moral permissibility of killing animals, there is a consensus on the importance of minimising suffering and distress at the point of slaughter. According to a 2003 report by the UK's Farmed Animal Welfare Committee (now the Animal Welfare Committee), the welfare of an animal at the point of slaughter requires "an effective process which induces immediate unconsciousness and insensibility or an induction to a period of unconsciousness without distress and a guarantee of non-recovery from that process until death ensues" (FAWC, 2003, para 8, p. 2).

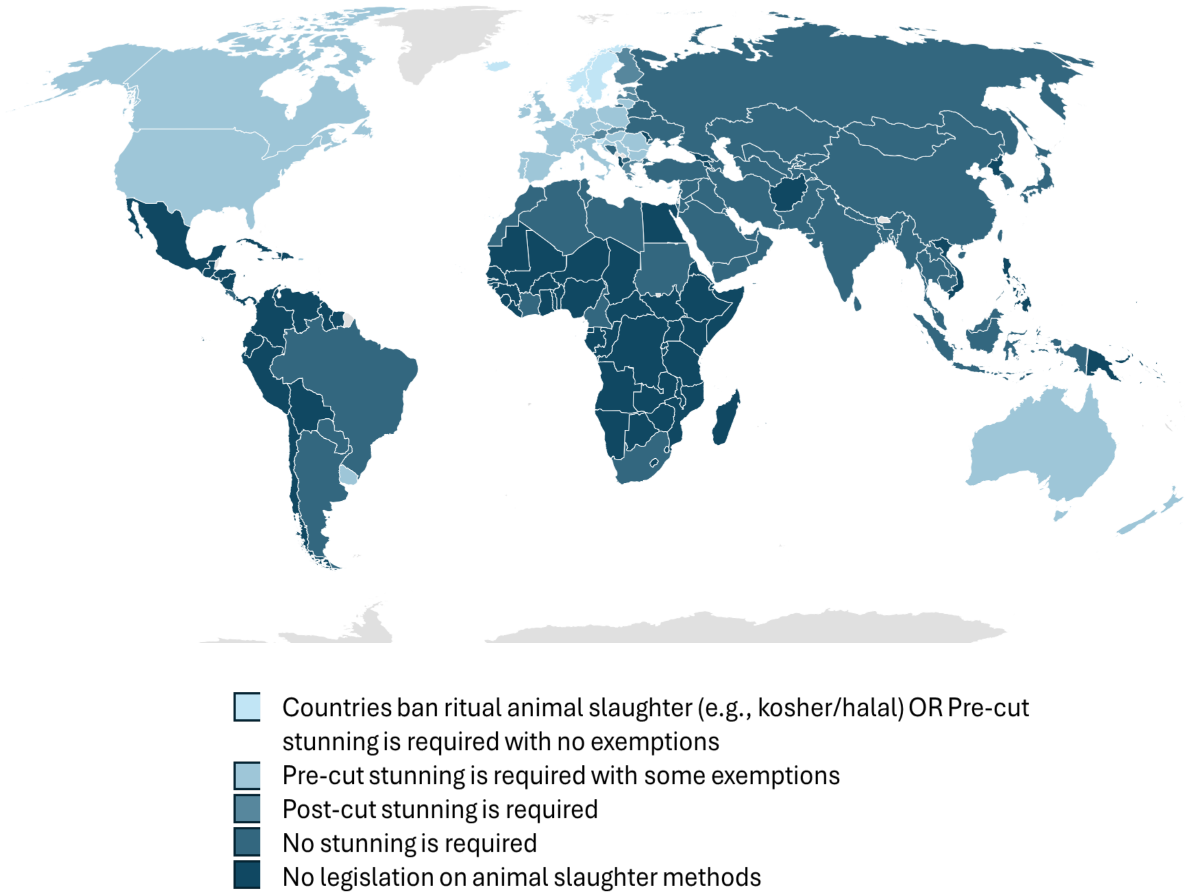
In full acknowledgement of the practical challenge of ensuring these measures are implemented, for the purposes of the FFI, the indicator used to assess how different countries perform in preventing the inhumane slaughter of factory farmed animals considers legislation surrounding the need to stun (and render animals irrecoverably unconscious and insensible) before slaughter. Countries which do not permit exemptions on grounds of religious/ cultural reasons (e.g., in the production of halal or kosher animal products) attain a better animal welfare score than those which permit such exemptions.

Methodology

We quantify *Slaughter Welfare Reduction* based on public data on stunning requirements per country in the following way:

- 0% = Countries ban ritual animal slaughter (e.g., kosher/halal) OR Pre-cut stunning is required with no exemptions
- 25% = Pre-cut stunning is required with some exemptions
- 75% = Post-cut stunning is required
- 100% = No stunning is required
- 100% = No legislation on animal slaughter methods

Figure 5. **Global legal slaughter requirements (generated using Kimi-K2 in July 2025 which searched all national legislation on animal slaughter; sense checked manually).**



We justify assigning a 100% reduction in cases of no legislation because incentivising countries to include provisions for animal welfare at slaughter in law is a critical step.

We generated this map under time constraints and used AI (Kimi-K2 in July 2025) to search national legislation. Further work is required to validate the map. The map has an approximate reference year of 2025, but further validation is needed here.

Nevertheless, we note that slaughter practices have a relatively small impact on the overall Healthy Years Lost calculation because slaughter durations are assumed to be 1 day for all species (Scherer et al., 2019) which is relatively small compared to the number of days on farms. Of course, for factory farmed animals experiencing the greatest reduction in lifespan (i.e., chickens), the impacts of inhumane slaughter are greater than for animals experiencing less of a reduction in lifespan (i.e., cows), since 1 day constitutes a greater proportion of their lifespan. We also do not currently account for animal transport, which can deliver major welfare reductions, and this should be considered for future work.

5.1.3 Longevity

Justification

The selection of longevity as an issue pertinent to animal welfare requires explanation. After all, length of life cannot in and of itself give an indication of quality of life. In the case of farmed animals living lives "not worth living" (i.e., lives where irredeemably negative experiences predominate), a longer life may be worse than a shorter life of higher quality (Mellor, 2016; and discussion above). Nevertheless, if animal welfare is understood in terms of the "five domains" model in which an animal's behavioural/ social interactions and overall mental state are considered, then longevity gains relevance.

If the highest welfare standards can deliver a "good" life for animals, then it makes sense to suppose that sufficient opportunities are available for enjoying the experiences a "good" life consists of. Meaningful social interactions between animals (e.g., bonding experiences, satisfaction of maternal instincts, and group playfulness) and the expression of a full range of rewarding normal behaviours (e.g., environmental exploration, establishment of group hierarchies, freedom to make choices, and dissent) requires significantly longer lifespans than factory farmed animals typically have. To take pigs as an example, the average age at slaughter is nine and a half months but in optimal conditions we could expect them to live to as old as 15 years.

If animal welfare refers not just to the animal's present-moment subjective experience but also to their wellbeing over time, then considerations of length of life are relevant. Moreover, it is important to acknowledge the specific welfare concerns arising from the agricultural industry's efforts to maximise profits by achieving slaughter weights as quickly as possible. In the EU, for example, 95% of broiler chickens are "fast-growing" breeds, selected to grow rapidly and achieve slaughter weight in just five to six weeks. "Fast-growing" chickens suffer specific problems associated with unnaturally quick weight gain such as lameness, skin lesions (caused by prolonged periods of sitting), and heart failure. Research suggests that "slower growing" chickens experience 80% less "excruciating" pain (defined as "intolerable" and "impossible to conceal") than "fast-growing" chickens (Ritchie, 2023 b). Hence, whilst *length* and *quality* of life are distinct concepts, in the context of factory farmed animals they are inevitably interconnected.

Methodology

Following formula (4) above, we use FAOSTAT data to calculate the life expectancy of animals in farming conditions in each country and use the lifespans. The average age at slaughter can be calculated by dividing the animal stocks by the total number of animals slaughtered of each meat producing animal and multiplying that value by 365. To illustrate this, if there are 5000 animals alive at any point in time (a stock) and 10,000 animals are slaughtered each year, this implies that on average, each animal lives for 0.5 years.

We use data from Scherer et al., (2018) to define natural lifespans of farmed animals in optimal conditions. Specifically, cattle, pigs, and poultry can live on average 20, 15, and 7.5 years respectively in optimal conditions. We estimate that, against this reference point, on average globally, factory farmed cows are slaughtered after living 27% of their potential life expectancy, factory farmed pigs are slaughtered after living 5% of their life expectancy, whilst factory farmed chickens are slaughtered after living just 4% of their life expectancy.

For countries with an API ranking of lower than "A," the FFI is constructed such that Healthy Years Lost will worsen if lifespans are expanded without first improving welfare conditions to "A". "A" represents the best welfare conditions with a 0% reduction in welfare and "G" represents the worst welfare conditions with a loss of welfare of 100% (equivalent to death). Moreover, given that extended animal lifespans would require more animal feed and would lead to more excreta, there may be increased impacts on both human health and the natural environment such that, at least for countries which such low API scores, the improved Healthy Years Lost number produced by extending lifespans may be offset by other harms. Therefore, in order for extending lifespans to deliver significant improvements to a country's overall Healthy Years Lost number, this measure would need to be accompanied by improvements to animal welfare standards on factory farms and at the point of slaughter.

5.2 Human health

5.2.1 Particulate emissions from excreta management

Justification

Intensive animal farming often involves the management of excreta which cause particulate air pollution which substantially damages human health. Total particulate emissions from all outdoor sources are responsible for around 4.2 million deaths worldwide (Wyer et al., 2022).

Methodology

Direct particulate matter emissions with a diameter of less than 2.5 micrometres (PM2.5) emissions, and ammonia (NH_3) and NO_x (the sum of nitric oxide and nitrogen dioxide), which create indirect PM emissions from manure management, are taken from the EDGAR database (European Commission, 2025). These are then divided by the number of animals produced (in Population Correction Units or PCU equivalents) to get to the emissions per PCU and then multiplied by the number of factory farmed animals. The PCU correction is done because these emissions are primarily driven by quantity of excreted animal manure, which is driven by dietary N intake, which is driven by body size. Finally, to calculate DALYs we multiply the emissions by the factor of 0.16 DALYs per tonne of NH_3, 0.08 DALYs per tonne of NOx, and 0.63 DALYs per tonne of PM2.5 from GLAM (2024). This leads to a total estimate of 1.3 million DALYs lost globally due to factory farm excreta management emissions.

EDGAR does not differentiate manure management emissions by factory farmed and non-factory farmed animals. It is possible that factory farmed animals have higher manure emissions. Additionally, many factory farms are located near to humans, meaning the DALYs per tonne of emissions are likely higher than the average factors we use here (Wyer et al., 2022).

5.2.2 Premature deaths related to animal product consumption

Justification

Red and processed meat consumption is linked to heart disease, stroke, cancers, and diabetes, contributing to millions of premature deaths per year.

Methodology

Here our indicator is the percentage reduction in premature mortality achieved by substituting animal products for plant-based alternatives in each country. These data are drawn from an analysis by Springmann et al., (2020). We then scale this down by the share of animal products derived from factory farmed sources in each country to approximate the effect of consuming factory farmed meat, eggs, and dairy on human health.

This indicator is calculated from the WWF Planet Based Diets report (WWF, 2020) originally drawing on data from Springmann et al., (2020). Results are calculated by comparing the estimated number of premature human deaths under the current diet in a country to the estimated number of premature human deaths under an animal product free diet. We convert this to DALYs avertable by country by multiplying the number of premature deaths in that country due to diet change relative to the total global premature deaths due to diet change, by the total global DALYs due to red and processed meat consumption linked dietary risks from the Global Burden of Disease of 19.9 million DALYs in 2020. We then multiply it by the share of meat from factory farming per country, giving 12.2 million DALYs related to factory farming in 2020.

The data does not discriminate between the human health impacts of factory farmed and non-factory farmed meat; the health impacts are the same however it is produced under the methods here. This indicator simply reflects the effects of high red and processed meat consumption in human diets.

This indicator reflects food consumption in a country and is not a food production indicator. To calculate the effects of producing factory farmed meat on diets, potentially in different countries, we simply multiply the consumption-based indicator by the ratio of factory farmed meat produced to consumed. Ratios above one mean more meat is exported, and more health burdens are created abroad.

5.2.3 Antibiotic resistance

Justification

High stocking densities and confined spaces in factory farms create an environment that supports disease transmission. To combat this, antimicrobials are used widely. This antibiotic use can cause increased antimicrobial resistance, posing a significant threat to both animal and human health. Overall, bacterial antibiotic resistance caused 4.7 million deaths in the year 2020, representing a major human health burden (Naghavi et al., 2024).

While antibiotic resistance already causes millions of deaths annually, a major challenge is the long-term systemic risks it poses. Growing antibiotic resistance could destabilise modern medicine which depends on the effectiveness of antibiotics. This would make routine surgeries, cancer treatments, and even minor infections far more dangerous. However, we are unable to quantify these future risks here and instead focus on the current human health burden.

Methodology

Mulchandani et al. (2023) used national surveys of antimicrobial use for 42 countries to compile standardised data on consumption of antimicrobials for cattle, chickens, pigs, and sheep for the year 2020. They then extrapolated these data to create estimates of antimicrobial use in farmed animals for all countries globally. The authors did not report usage for each species separately, and we were unable to remove antimicrobial use in sheep (not part of this study) from their estimates. In Fig. S3 of the article, sheep appear to represent around 15% of global antimicrobial use, and we therefore downscale our estimates by this factor.

The analysis also does not make available data by intensive and extensive systems available (despite calculating them); therefore, we use the factors from a report by the Alliance to Save our Antibiotics (2021) to disaggregate into intensive and extensive systems. These factors are limited by being specific to the UK, and by comparing organic to conventional systems; nevertheless, they allow us to make this correction given the lack of global and representative data.

Table 3: Data on antimicrobial use in the UK for the year 2019 by organic and non-organic system.

	Non-organic (mg/PCU)	Organic (mg/PCU)
Dairy Cattle	22.5	10.7
Beef Cattle	24.5	7.2
Pigs	110	1.4
Meat Chickens	17	3.0
Layer Hens	0.7	0

For our calculations, we use standard values for weight per animal from the EMA (2023) guidelines to calculate population correction units (PCUs). PCUs are a combined sum of all animals corrected for weight differences that are used when assessing antimicrobial use in animals.

Table 4: **Standard liveweights per animal used to calculate PCUs.**

	Standard Liveweight per Animal (kg)
Dairy Cattle	425
Beef Cattle	425
Pigs	65
Meat Chickens	1
Layer Hens	1

From the original 99,000 tonnes of antimicrobial use in farmed animals estimated by Mulchandani et al. (2023) in all systems, we estimate that 65,765 tonnes of antimicrobials are used in factory farming systems. This is higher than the prior estimate by World Animal Protection of 41,323. This is due to our use of newer estimates of factory farmed shares and more recent antimicrobial data.

To estimate total human DALYs lost to antimicrobial resistance, we follow methods from the World Animal Protection (2023) report, updating the DALY total using new Global Burden of Disease data, which reports 187 million DALYs for the year 2020 (average of 2019 and 2021) associated with antimicrobial resistance (Naghavi et al., 2024). This is three times higher than the previous estimate used in World Animal Protection (2023).

We also use a new estimate of total human antimicrobial use of 32,200 tonnes, for the reference year 2012-15 (Macedo et al., 2025). We assume this value grows by the rate of human population growth to reach 34,600 tonnes in 2020.

This allows us to estimate 1.4 DALYs per kilogram of antimicrobial use (187 million DALYs / (34,600 + 99,000 tonnes of antimicrobials)). We apply this DALYs estimate to data for each country and estimate 92 million DALYs lost globally caused by antimicrobial use in factory farming animals. This is three times higher than the previous estimate by World Animal Protection (2023), primarily caused by the higher estimates of DALYs used here.

5.2.4 Food insecurity

Justification

Factory farming diverts human-edible food (e.g., soy and maize) to animals as concentrate feed. These animals only convert a fraction of the protein and calories in that food into human-edible protein and calories (e.g., cattle convert just 15% of the energy in their feed into meat and dairy). This has a range of socially significant consequences. Countries with nutritional deficits, such as Myanmar or Indonesia, export millions of tonnes of animal feed each year and in so doing exacerbate national food insecurity problems. Within countries, for example in India, human-edible food is routinely sold out of poverty-stricken and nutritionally deficient regions to industrial animal units.

Methodology

The GBD reports that of the total DALYs associated with undernutrition (around ~255 million DALYs) around 11 million are associated with direct calorie/protein malnutrition. Here we assume that all of this is linked to the diversion of human-edible crops to animal feed. Nevertheless, this is a strong assumption (some crops may never make human food grade; some areas are only suitable for growing animal feed crops etc). More research is needed here. However, it is very clear that feeding crops to animals is a huge drain on the food available to humans. Cassidy et al. (2013) state "given the current mix of crop uses, growing food exclusively for direct human consumption could, in principle, increase available food calories by as much as 70%, which could feed an additional 4 billion people".

Our modelling here is relatively simple. We take the 11 million DALYs globally and apportion it to each country based on the quantity of potential human food fed to factory farmed animals based on our factory farmed shares and data from the FAO Food Balance Sheets. In total we estimate 2100 trillion food calories are fed to factory farmed animals, enough to feed around 2 billion people.

5.3 Environment

Justification

We discuss the four environmental issues and indicators together as they are related and use the same methodology. Campbell et al. (2017) identified the contribution of agriculture to each of the planetary boundaries. They identified climate change, nitrogen and phosphorus pollution of water, water scarcity, and land system change as issues which were transgressing planetary boundaries and substantially affected by agriculture. Hence, we focus on these indicators here. Factory farming likely contributes substantially to other environmental issues (such as pesticide toxicity, ozone depletion – through the N_2O pathway –, and deforestation) but we currently lack sufficient global environmental impact data to robustly quantify these issues for animal products specifically.

Methodology

We use data from Poore & Nemecek (2018) which provides the data for each animal product on their greenhouse gas emissions, eutrophication potential (water pollution), water scarcity, and arable land use (which we use as a proxy for land system change and biodiversity loss). We do not expect pastureland use to be substantially caused by factory farming, as factory farmed animals are primarily raised indoors or with limited grazing land, and we simply exclude this indicator. However, we note that in Australia (as well as some other countries) cattle are primarily raised outdoors, including those raised on feedlots, causing soil and environmental degradation.

We currently do not have specific data on the multiple environmental impacts of factory farmed animals specifically. Hence, we follow the previous methodology developed by *World Animal Protection* and use the global average environmental impact per kg for each animal product as a proxy for each country's environmental impact. We multiply that by the total amount of animal product production and multiply that by the share of animals in factory farms.

We justify using a global average impact for factory farming and not making further assumptions to split into factory farms and non-factory farms, for the following reasons. Firstly, factory farms are relatively homogenous globally, and their impacts are likely to be similar globally, hence why we use a global mean rather than a country specific value. Secondly, the existing evidence – for GHG emissions for non-ruminants – suggests that GHG emissions per kilogram of product are broadly similar across factory farming and non-factory farming systems, with only small differences observed in most studies.

Specifically, for poultry, there is no robust evidence for a difference in GHG emissions per kilogram of product between intensive and free-range/organic systems. The existing research, while somewhat dated and not comprehensive, supports the approach in the analysis not to differentiate emissions between systems:

- Leinonen et al. (2014): GHG emissions do not substantially differ between low and high welfare systems.
- Wiedemann et al. (2017): GHG emissions do not substantially differ between conventional and free range.
- Alig et al. (2012): GHG emissions may be slightly higher in organic and outdoor systems.
- Dekker et al. (2011): Organic systems have the lowest emissions, conventional systems have slightly higher emissions, while free range have slightly higher. In general, the differences were not substantially different nor were there enough data to detect significance (only 7 farms surveyed).
- Mollenhorst et al. (2006): No substantial difference in GHG emissions between systems.
- FAO GLEAM: No difference between "backyard" (3.6kg CO_2eq/kg meat) and "broiler" (3.5kg CO_2eq/kg meat) GHG emissions globally.

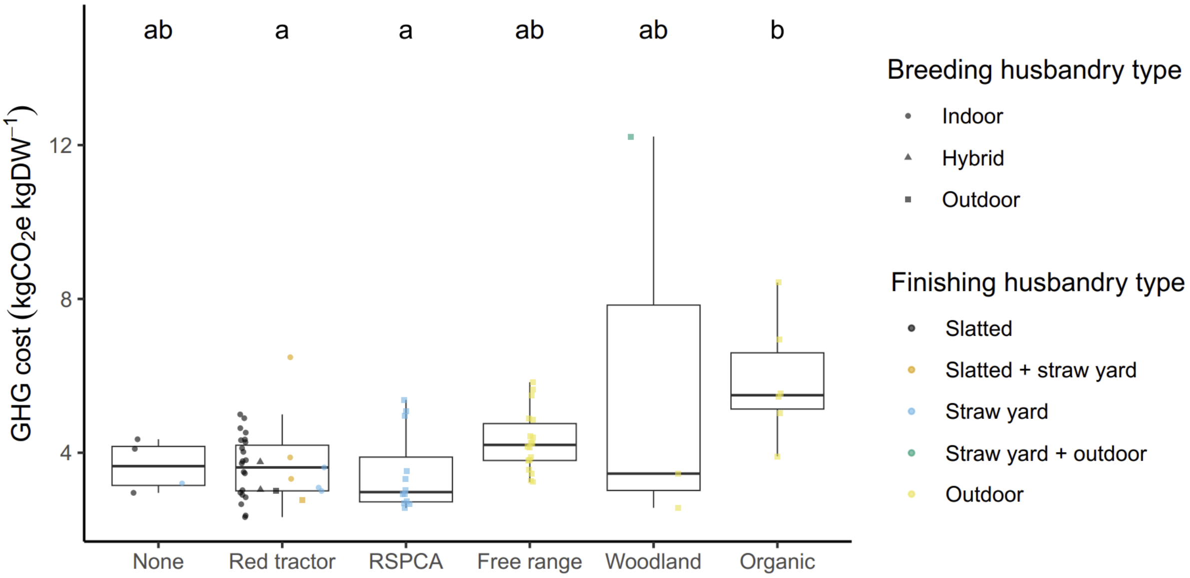
For pork, prior research found no substantial difference in emissions per kilogram of product between the systems:

- Williams et al. (2006): No substantial differences between systems.
- Alig et al. (2012): No substantial differences between systems.
- FAO GLEAM: No difference between "backyard" (5.6kg CO_2eq/kg meat) and "industrial" (5.6kg CO_2eq/kg meat) GHG emissions globally.

However, more recent work has found a significant difference:

- Bartlett et al. (2024): Organic and free-range systems have higher GHG emissions per kilogram of product than conventional ("factory farmed") systems. This is a good quality study with good sample sizes. However, not all extensive systems had statistically significantly higher emissions (e.g., "woodland"). Further, an improved welfare system ("RSPCA") had lower emissions. Overall, this study does point to the need to differentiate emissions factors for pigs, but on balance, given the UK focus and some results that do not support differences, we do not differentiate emissions factors here.

Figure 6. GHG emissions per kilogram of product across different animal production systems from Bartlett et al. (2024).



It is important to note that while factory farming poultry and chicken systems have similar GHG emissions per kilogram of product than non-factory factory farming systems, there is substantial variability (e.g., factory farming systems which are heavily reliant on deforestation linked feed can have higher emissions. By contrast, free-range and regenerative systems can have higher direct emissions per animal or per kilogram of meat due to slower growth, but their overall climate costs may be lower once land-use change, feed supply chains, and potential soil carbon sequestration are taken into account.

For ruminants, there is a lack of research that directly compares systems. What research there is, however, generally finds that intensive systems have *lower* GHG emissions per kilogram of product:

- Capper (2012): Intensive systems have lower GHGs than extensive, grass-fed systems.
- Huerta et al. (2016): Intensive systems have lower GHGs than extensive systems.
- FAO GLEAM: Substantial difference between "grassland" (7.6kg CO_2eq/kg meat) and "mixed" (4.4kg CO_2eq/kg meat) GHG emissions globally.

To recognise this, for GHG emissions from cattle only, we use emissions data from GLEAM describing their "mixed" system which is the closest to factory farming they report for cattle. We checked our approach by undertaking GHG emission reconciliations for key countries where agriculture is a high share of GHG emissions, and found that not correcting for the *lower* GHG emissions in factory farmed cattle led to unrealistic emissions (e.g., for New Zealand, the approach using Poore & Nemecek factors only gave 38,813kg CO_2eq for factory farming, roughly 2/3 of New Zealand's food system GHG emissions; while using GLEAM data for factory farmed cattle, we got 20,023kg CO_2eq, a substantial difference, roughly 1/3 of New Zealand's food system GHG emissions). We are unable to make corrections for other environmental impact indicators beyond GHGs due to a lack of data.

Nevertheless, the lack of data on factory farming environmental impacts means these data should be seen as first estimates. More work and better environmental impact data, differentiating farming systems, and providing country-level nuance, is much needed. The HESTIA project (https://hestia.earth/) for example is focusing on generating such data, but they are not yet publicly available. However, we feel our assumptions and approach are reasonable given the current data available.

An additional limitation is that environmental impacts per kilogram have decreased over time, primarily driven by increasing crop yields. Our environmental impact data have the reference year of 2010 for Poore & Nemecek (2018) and 2015 for GLEAM, whereas our production data have the reference year 2020. We have not been able to correct for this in the current version of the FFI, and we expect this will slightly bias up our environmental impact estimates. Further work should seek to correct for this and improve the estimates.

We discuss above how we calculate the biodiversity effects of climate change and water use above. To calculate the human health burden (DALYs) we use data from GLAM (2024). For water use, the DALYs represent the effects of water scarcity on hunger and malnutrition. For climate change, GLAM differentiate the DALYs into two scenarios: with adaptation and no adaptation. Here we assume adaptation will occur and use the factors including adaptation. Unlike DALYs derived from the Global Burden of Disease dataset, which represent the year 2020, these factors are an average over the next 100 years based on forecast climate scenarios. While our DALYs modelling approach is not entirely consistent here (as all DALYs would ideally represent the same time period), we feel it's a reasonable assumption to pool data like this – in the absence of better current data – to fully reflect the multiple pathways by which factory farming causes human health burdens.

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