GASL Paper

Animal health and welfare for sustainable livestock systems

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Preface

Milk, meat and eggs are not just agricultural commodities. The underpinning and diverse animal production systems, along with their market and trade contexts mean that livestock contribute to multiple development outcomes. Besides contributing to the UN Sustainable Development Goals, like poverty alleviation, food security and nutrition, health and wellbeing, gender equality, economic growth, responsible production and climate action, there are also strong social dimensions related to livestock.

Therefore, the Global Agenda for Sustainable Livestock has taken on a Livestock System-approach to address the economic, social and environmental livestock issues. This is a broad and inclusive approach and this publication focus on the Animal health and welfare dimension, that in turn has an impact on other sustainability domains: Food and nutrition security, Livelihoods and economic growth, and Climate and natural resource use.

There are multiple, and very different perspectives on the livestock sector around the world depending on geographies, economic setting, political and cultural traditions as well as the stakeholders´ role or relation to livestock systems. Sometimes there is a common view, but quite often there are different views or even controverses.

The Global Agenda for Sustainable Livestock was created in 2011 as a multistakeholder partnership that aims to foster dialogue, build consensus and support policy and practise change towards a more sustainable sector. The 121 member organisations represent the diversity of livestock systems and stakeholders and include public and private sectors, producers, research and academic institutions, NGOs, social movements and community-based organizations, and foundations.

In this publication the authors explore the diversity of livestock across the world...and highlight the synergies between good animal health and animal welfare and how those may positively impact animal productivity, economic growth and livelihood, human nutrition, food safety, reduction of the risk for zoonotic transmission, reduction of the need for antimicrobials, natural resource use efficiency, reduction of green-house gas emissions as well the adoption to climate change.

I congratulate the authors of this report for showcasing the important role of animal health and welfare in livestock systems towards achieving the UN Sustainable Goals.

Shirley Tarawali
Chair
Global Agenda for Sustainable Livestock

Key messages

Good animal health and welfare is requisite, and a key domain, for the sustainability of livestock. This domain comprises technical, social, ethical, economic and environmental aspects that are summarized below:

- Animal health and welfare interact and support each other; freedom from disease is a substantial share of welfare and good care; as well, good management is a prerequisite for raising animals that are robust and resistant to disease.
- Good animal health and welfare support the productivity of animals; sick or stressed animals under poor management grow more slowly and produce less.
- Poor animal health and welfare threaten food security by reducing access to highly nutritious animal-source foods because of impaired productivity.
- Poor animal health and welfare may also jeopardize the livelihoods of farmers and the economies of large producers.
- Livestock systems with poor animal health and welfare are less efficient, draw more heavily on natural resources and emit more greenhouse gases per unit of produce.
- In the One Health perspective healthy animals are less prone to spread zoonotic disease - including those with pandemic potential and food-borne pathogens. Also, well managed and healthy animals do need less antimicrobials.
- Technical innovations and organizational improvements for better animal health are abundant, but unevenly distributed in the world. Research and development on animal diseases, for example, are far better resourced in high-income countries than they are in lower- and middle-income countries.
- Regulations might not always be the best way to stop the mis-use and over-use of antibmicrobials or to improve animal welfare; capacity to enforce regulations and control compliance is weak in many countries. Instead, “soft law”, such as guidelines, positive incentives and awareness campaigns, may be more effective at changing practices in some settings.
- The major trade-off for good animal health and welfare is the cost to the farmer or producer; the necessary resources may not be available or they may not be regarded as worthwhile. This balance depends on several factors, such as wealth, policy and regulatory environment, market access, international trade and the specific demands made by consumers and retailers.

1 Introduction

Trends and disruptors to livestock systems

Over the last 30 years, the consumption of meat, milk and eggs in low- and middle-income (LMICs) countries has more than doubled (FAOSTAT, accessed 28/5/21). Population growth, urbanization, income gains and globalization continue to fuel the growth. Many people in LMICs do not have sufficient high quality protein in their diets (FAO *et al.*, 2020); a problem that could be rectified through improved access to animal-source foods. Many in high-income countries (HICs), conversely, eat too much animal-sourced foods. Policies and information campaigns should promote healthy diets for all.

Growing demand does also offer business opportunities for many livestock producers. Under a business as usual scenario, demand for meat in LMICs will increase (from 2012) by a further 40 percent by 2030 and by over 65 percent by 2050, according to the latest FAO projections (FAO 2018a). Livestock systems are increasing production to meet this demand and adapting to satisfy the changing food preferences of an increasingly affluent and urbanized population in a globalized economy.

Such rapid growth in production and trade does not just mean opportunities – it also entails risks. Growth is not evenly distributed, with most occurring in intensive systems and with relatively little contribution from smallholder producers. The risks include concerns over food and nutrition security, livelihoods and equity, animal health and welfare and the environment.

Livestock systems are also exposed to less predictable, disruptive influences, which are often more localized.

Consumers in many HICs are becoming increasingly concerned over animal welfare, health and the environment and, based on a perceived risk that animal husbandry poses to these domains, several are moving away from animal-sourced proteins, towards more plant-based diets.

Consumer demand tends to drive rapid innovation, creating new opportunities for expansion of the agri-food system. Cellular agriculture – where animal proteins and whole cells are generated in bioreactors – is developing quickly. It may be some time before replica meat cuts can be made economically, but alternatives to powdered milk, powdered eggs and ground beef for the agri-food industry seem already to be in reach.

Emerging and re-emerging diseases can also disrupt livestock systems. The emergence and spread of highly pathogenic avian influenza (HPAI) in 2004–5 and African swine fever in Asia more recently has called for adjusting production systems that includes improved biosecurity.

The coronavirus disease (COVID-19) pandemic highlights the interrelationship between human and animal health. Most emerging infectious diseases in humans originate from wildlife. Livestock can serve as a bridge between wildlife and humans (which may be the case for HPAI). Or the infection can be directly transmitted from wildlife to humans (which is the case for Ebola and SARS, and likely for COVID-19). These two transmission patterns underline both the importance of biosecurity (reducing the interface between wildlife and livestock and between humans and livestock) and the need to regulate the sale of wildlife at food markets.

Regardless of its origins the pandemic poses a threat to food security and has caused a shock to the production and marketing of animal-sourced foods, with disruptions to supply chains and the temporary disappearance of markets such as restaurants changing the patterns of demand. The medium- and possible long-term impacts of the pandemic remain to be seen.

Photo: **Karel Prinsloo - FAO**

Figure 1 Drought in the Sahel

Climate change both affects livestock production and is affected by it. A changing climate affects the availability of feed and water, the prevalence of pests and diseases, and the suitability of land for grazing and growing fodder. Livestock systems are major contributors to greenhouse gas emissions, responsible for almost 15 percent of anthropogenic greenhouse gases (Gerber *et al.* 2013). This means the sector can and must make an important contribution to reducing overall emissions. Countries committed to the 2016 Paris Agreement on climate change are under growing pressure to mitigate livestock emissions. Practical actions for mitigation identified by the Food and Agriculture Organization (FAO) (FAO 2019a) include: improving the efficiency of livestock agri-food systems; strengthening the circular bio-economy; capturing carbon in livestock systems; striving for healthy, sustainable diets and accounting for protein alternatives; and creating incentives to reduce livestock emissions through appropriate policy and institutional reforms.

Much progress has already been made in a number of countries, shifting livestock systems towards environmental sustainability. But much remains to be done.

Shaping the future of livestock

Such trends and disruptors reveal the complexity and vulnerability of livestock systems, globally, and highlight concerns over their sustainability. Recognizing this, the Global Forum for Food and Agriculture chose the topic *"Shaping the future of livestock"* for its 2018 ministerial meeting in Berlin (FAO 2018). This was organized around four interlinked domains relating to sustainability:

- Food and nutrition security
- Livelihoods and economic growth
- Animal health and welfare
- Climate and natural resource use.

The **Global Agenda for Sustainable Livestock** (GASL/Global Agenda) has adopted this framework. The 2019 meeting of the Global Agenda, held in Manhattan, Kansas, in collaboration with Kansas State University, focused on the theme of *"Innovation for sustainable livestock systems"*. Four papers, one on each domain, were commissioned to provide information to feed into the technical and policy debates. They were peer-reviewed before the meeting and have been further revised to reflect feedback during the meeting. The paper on the domain "Animal health and welfare" is the basis of this publication.

Global Agenda for Sustainable Livestock

The **Global Agenda for Sustainable Livestock** is a partnership committed to the sustainable development of the livestock sector. It aims to builds consensus on the path towards sustainability and to catalyse practice change through dialogue, consultation and joint analysis. It brings together a wide range of stakeholders: the public and private sectors, producers, research and academic institutions, donors, NGOs, social movements and community organizations, and intergovernmental and multilateral organizations.

www.livestockdialogue.org

In this publication

This publication focuses on the issues, opportunities and risks in animal health and welfare that stakeholders face in relation to the sustainability of livestock systems. It identifies innovations and policies that may help them take advantage of the opportunities and manage the risks, while still ensuring sustainability in other dimensions: food and nutrition security, livelihoods and economic growth, and climate and natural resource use.

Section 2 presents the diversity of livestock systems and outlines three broad livestock production systems: extensive, labour-intensive, and capital intensive.

Section 3 focuses on animal health and welfare and consists of 5 parts:

- A **summary** for policymakers to consider.
- An **introduction** outlining the topic.
- **Issues, opportunities and risks:** A brief description of the major issues facing the aspect under consideration, followed by outlines of the opportunities that stakeholders may consider and the risks that they may face.
- **Innovations:** Some suggestions on promising innovations in the fields of technology, organization or policy that may take advantage of the opportunities or address the risks discussed earlier.
- **Implications for policy:** Suggestions for policymakers to consider as they design policies that balance the various interests both within the livestock sector and beyond.

Section 4 explores the potential synergies and trade-offs, pulls together the different trends and interests and explores the potential synergies and trade-offs between them.

Section 5 contains the references used in this publication.

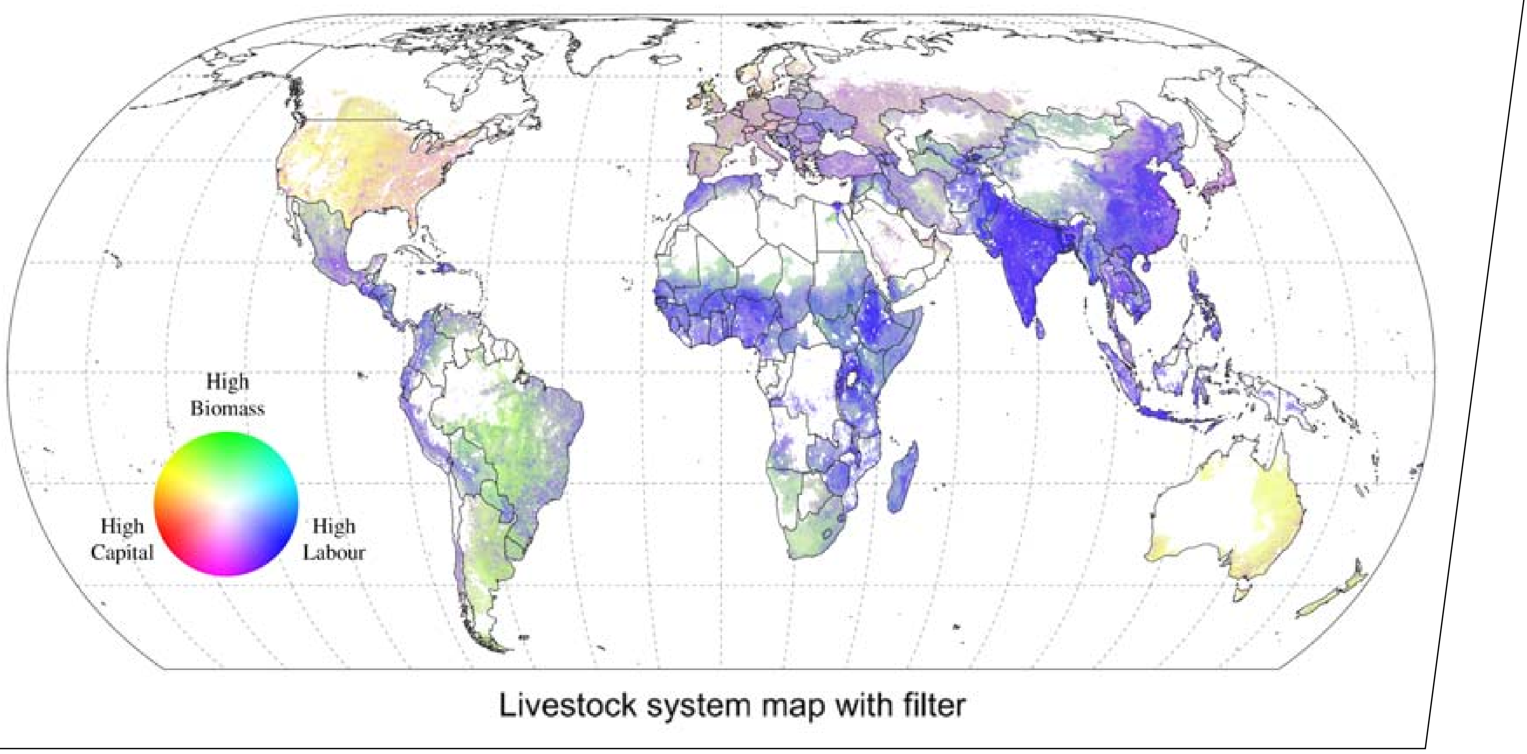
Livestock agri-food systems are highly complex and diverse. It is not possible to generalize, nor to be exhaustive in coverage. The examples presented in this publication are necessarily selective and illustrative. Policymakers and practitioners should bear this in mind as they design solutions to the issues faced in their countries.

2 The diversity of livestock systems

While humanity relies on just a handful of animal species for the vast majority of its meat, milk and eggs, the world's livestock production is nonetheless stunningly diverse. Livestock are kept in a wide range of production systems and environments. Production systems can be intensive or extensive, large- or small-scale, and involve huge amounts of land, labor and capital – or very little of one or more of these "factors of production". Livestock are found in the most crowded of cities, in sheds containing thousands of animals, or grazing in high mountains, baking deserts and icy tundra.

Livestock also play very different roles in the economy and society. Farmers and pastoralists who raise livestock mainly to feed their families have different concerns from those who sell to highly competitive, international markets. In moving towards sustainable livestock agri-food systems, we need to understand their diversity and the motivations of livestock keepers and other actors in the system, including those that operate upstream (such as genetics, feed and health services suppliers, for example), and downstream (for example aggregators, transporters, processors, distributors and retailers). It is also important to understand the public policy and institutional environments that confront the different actors across systems, regions and countries. Consumers, competitors and market conditions defined and framed by cultural and economic conditions all influence the sustainability of the sector in terms of the four domains discussed above. Understanding the production, distribution and marketing environments in which the sector operates in the different regions must precede the development of innovative solutions that can lead to sustainable livestock systems, globally.

Source: **Steinfel *et al.* (2018)**



Map 1 / Extensive (green to pale blue), labor-intensive (blue to magenta) and capital-intensive (red to yellow) livestock production systems. Color intensity represents the number of livestock

Types of production systems

We can broadly classify livestock systems (and agricultural systems more generally) in terms of the relative availability and cost of the classical production factors: land, labour and capital (Ruttan and Hayami 1984; Ruttan *et al.* 1980; Hayami and Ruttan 1971). For livestock systems, which include landless production, livestock biomass is more relevant than land area, so the **land** production factor is better represented by the average biomass of livestock per agricultural person than by agricultural land area. The density of the population engaged in agriculture represents **labor** and per-capita GDP represents **capital**.

Using this approach, Steinfeld *et al.* (2018) defined three broad livestock systems (Figure 1).

- **Extensive systems** use a lot of land but have low labor and capital inputs and generally occur in marginal habitats. They appear in Figure 1 as green to pale blue, generally representing pastoral and agro-pastoral areas.

- **Labor-intensive systems** are typically smallholder farms with low returns and a surplus of labor, often constrained by scarcity of both land and capital. They are shown as dark blue to magenta in Figure 1.

- **Capital-intensive systems** are usually associated with highly modified environments where land and labor inputs have been substituted by capital investment through intensification and mechanization. They are shown as red to yellow in the figure; the yellow areas typically being rangelands in higher income countries – therefore a hybrid of extensive and capital-intensive systems, with low inputs of labor.

Photo: **Marag, ILRI**

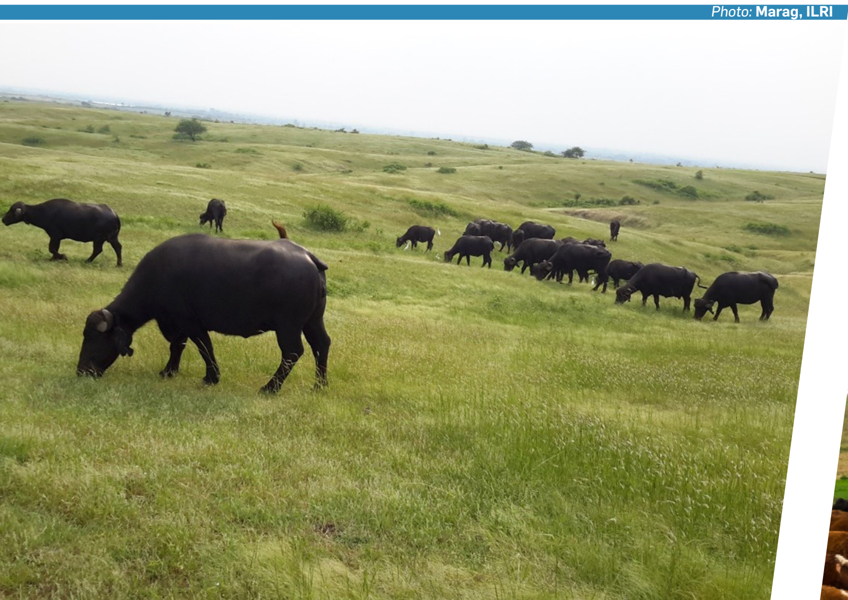


Photo: **FAO**

Figure 2a and 2b Two extensive livestock systems: Buffalos on rangeland, India and cattle herding in Uruguay

Extensive systems

Extensive livestock systems use small quantities of labor and external inputs. These systems are common in lightly managed areas that are unsuitable for crop production, therefore they do not compete with food crops. Extensive livestock systems here refer mainly to the dry rangelands of Africa and Latin America and to the steppes of Central Asia, where capital inputs are low. Livestock are often integral to the social fabric of societies living in these areas, so benefits extend well beyond food and livelihoods to fulfil many social and financial roles. Already living at climatic extremes (arid, semi-arid and cold environments), livestock keepers in these systems are vulnerable to climate change, with extreme weather and extended droughts cutting productivity, killing animals or making them ill. This type of livestock-raising directly uses natural vegetation, but its relatively low productivity means that greenhouse gas emissions are fairly high per unit of output.

In principle, grazing systems are closed: the waste products of manure and urine are returned directly to the system. If well managed, this does not present a burden on the environment. However, resource degradation, especially of land and biodiversity, is a widespread problem. For the most part this is occurring where, as a result of external pressures, traditionally well-managed common lands have become open access areas (de Haan *et al.* 1997). Problems of restricted access and movement of livestock also lead to concentration and overgrazing in certain areas but to abandonment of other areas. This problem of access can result from changing land tenure, conflicts or lack of infrastructure (such as boreholes in Africa and roads to summer pastures in Central Asia). In such open access situations, degradation is most severe. With appropriate management, however, grazing systems can offer potential for ecosystem services and biodiversity enhancement (Janzen 2010, Teague *et al.* 2013). If degraded grazing systems are restored to health, they hold considerable potential to sequester organic carbon in the soil (Paustian *et al.*, 2016; Lal, 2004).

Labor-intensive systems

Labor-intensive systems are typically smallholder-based and occur mainly as part of mixed crop-livestock farms. As well as arable crops, such farms may include aquaculture and tree crops. They are typified by the smallholder systems of Central America, Africa and Asia. The majority of labor-intensive systems are family farms with a focus on producing staple foods for subsistence, with surpluses sold or exchanged locally. However, in some cases – such as smallholder dairy production in East Africa and South Asia – they are well organized and linked to national and international markets.

Photo: **Andrew Nguyen, ILRI**

Figure 3a and 3b Two labor intensive livestock systems: family pig keeping in Viet Nam and dairy in Tajikistan

Photo: **Elisabeth Rajala, SLU**

Of about 400 million poor people who depend on livestock globally, most are in these systems. For such farming families, livestock are an important source of nutritious food and fulfil social and other functions, such as conferring status, payment of bridal dowries and supplying communal feasts. Livestock also provide an important source of food for people outside farming households, particularly dairy production in LMICs, where smallholders produce by far the largest share of the milk. They also ensure employment through associated agro-industries.

If measured simply by yield gaps, livestock production in these systems is generally inefficient compared to extensive or capital-intensive systems (e.g., Herrero *et al.* 2013, Steinfeld *et al.* 2018). However, other efficiencies must be accounted for, particularly in relation to nutrient cycling, using crop residues, providing draft power and manure, and capturing carbon.

Resource use in mixed farming is often highly self-reliant as nutrients and energy flow from crops to livestock and back. Where animals are kept for productive purposes, such as a closed system offers positive incentives to compensate for environmental effects, making them less damaging or more beneficial to the natural resource base.

Capital-intensive systems

Capital-intensive systems mainly produce beef, dairy, pork and poultry products. In contrast to extensive systems and integrated crop-livestock systems, these systems are almost exclusively dedicated to food production, as a response to growing demand for animal protein domestically and for export. Intensive beef production is typified by the feedlots of the southwestern United States. Mega-dairy farms – which are highly mechanized and extremely productive – are also becoming more prevalent. Half of the milk in the United States of America comes from farms with over 1,000 cows, and this proportion is growing each year. Pigs and chickens in particular lend themselves to industrial production and are often produced under vertically integrated systems where a single large company controls all the production stages, from breeding to production (sometimes with the involvement of external growers), to processing and retailing.

Photo: **Jenny Svennås-Gillner, SLU**

Figure 4a / Capital intensive system: Loose housed dairy cattle in in the barn,Sweden

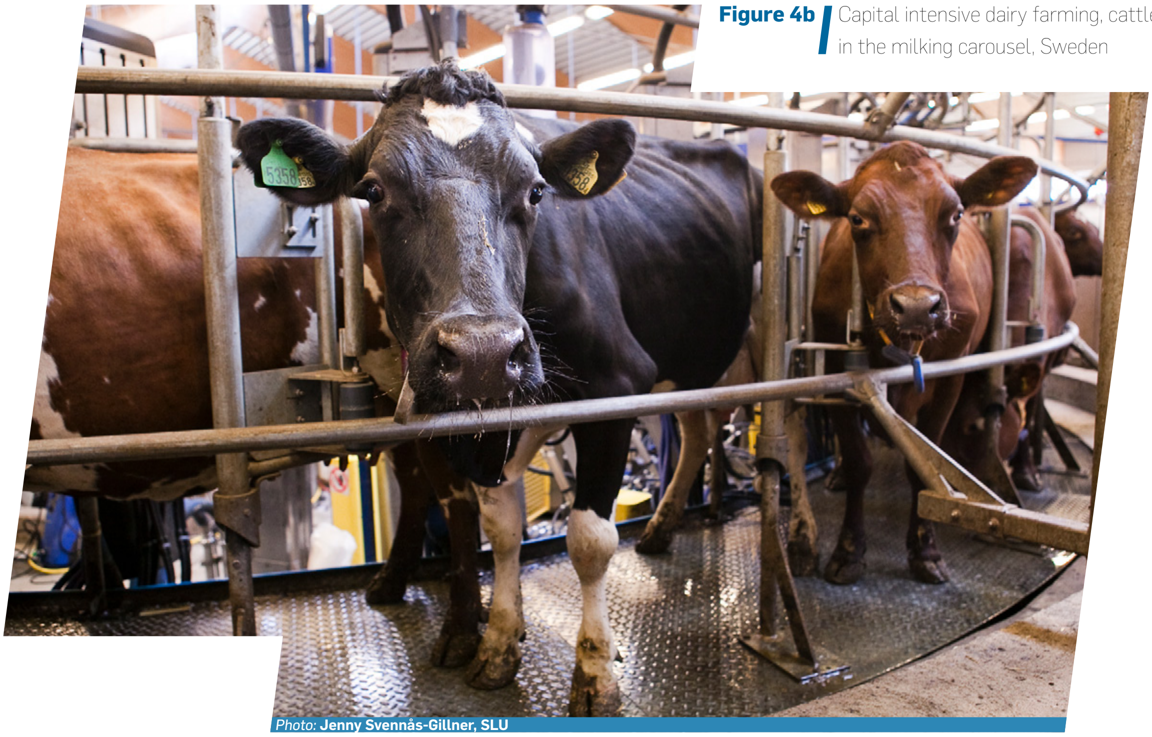


Figure 4b | Capital intensive dairy farming, cattle in the milking carousel, Sweden

Photo: **Jenny Svennås-Gillner, SLU**

These systems are the mainstay in HICs but are becoming more prevalent LMICs as well, where they contribute to feeding growing urban populations. Few people are employed directly as farmers from these systems, but many consumers benefit from a regular supply of clean, affordable, nutritious food.

Capital-intensive livestock systems are highly efficient despite relying on large amounts of inputs. In particular, feed is often grown far from where the livestock are kept. This can result in effects such as deforestation, the disruption of nutrient cycles, and pollution with pesticides and chemical fertilizers in feed-producing areas.

Capital-intensive systems also include systems such European beef and dairy herds, whose production is largely grassland-based, but where investment in inputs such as animal health, genetics, housing and feed supplementation is still relatively high.

Emission intensities are often relatively low in these systems, but with so many animals in such high densities, dealing with manure is a challenge and a major source of soil and water pollution. Capital-intensive systems use large amounts of antimicrobials and foster ideal conditions for the emergence of microbes that are resistant to available drugs and therefore hard to treat.

These systems are more uniform in terms of the technology and practices than are mixed and grazing systems. They rely on externally sourced feeds that are nutritionally optimized to promote growth. For cattle, this means fattening the animals on grain-and oilseed-based feeds in feedlots during the last few months before slaughter. In intensive pork and poultry production, the animals are exclusively fed purchased feeds. Farmers also use selective breeding to optimize for size, high productivity (e.g., milk yield) and rapid growth. The animals are kept in controlled, confined settings, often indoors. Capital-intensive systems use large amounts of feed and other external inputs, but also produce higher yields per unit of input than do extensive or labor-intensive farming systems.

3 Animal health and welfare

Summary

- Base the design of control and mitigation measures on a knowledge of each disease and its epidemiology in a given setting. Diseases, livestock systems and economic settings differ considerably. There is no one-size-fits-all.
- Combine tools such as biosecurity, vaccination and disease surveillance to prevent, detect and control disease outbreaks.
- Design interventions that are economically viable and provide incentives to producers. Education and organization are as important as technological solutions.
- Improve food safety through monitoring and control measures both pre- (animal production, health and humane transport and slaughter) and post-production (processing, storage, retail and consumption).
- Improve animal husbandry, biosecurity and vaccination to reduce the need for antimicrobials and mitigate the emergence of antimicrobial resistance.
- Promote animal health and welfare and food safety through a combination of minimum standards, compliance incentives, guidance and recommendations, and market incentives.
- Evaluate welfare beyond health to clearly identify associated opportunities and risks for welfare, health and productivity. Animal health is a key component of animal welfare, but animal welfare is broader than health alone.

Introduction

Good animal health and welfare are central to sustainable livestock production as they promote high productivity, adequate animal care and the efficient use of natural resources. Good animal health and welfare can lower greenhouse gas emissions per unit of output. They reduce the need for antimicrobials and protect farmers and consumers from food-borne diseases and other zoonoses. They help ensure farmers' livelihoods and food security, and increase consumers' trust in the livestock sector. They support all four sustainability dimensions of livestock adopted by GASL (FAO 2018) and are relevant in all types of production systems.

Reasons for not implementing good animal health and welfare practices may be due to a lack of resources, a lack of opportunity to develop the competence of producers or authorities, poor access to animal health services, traditions and cultural issues, or doubts about whether they contribute to increased profit. This section discusses four aspects of animal health: animal diseases, zoonoses and pandemics, food-borne diseases, antimicrobial resistance; and the role of animal welfare.

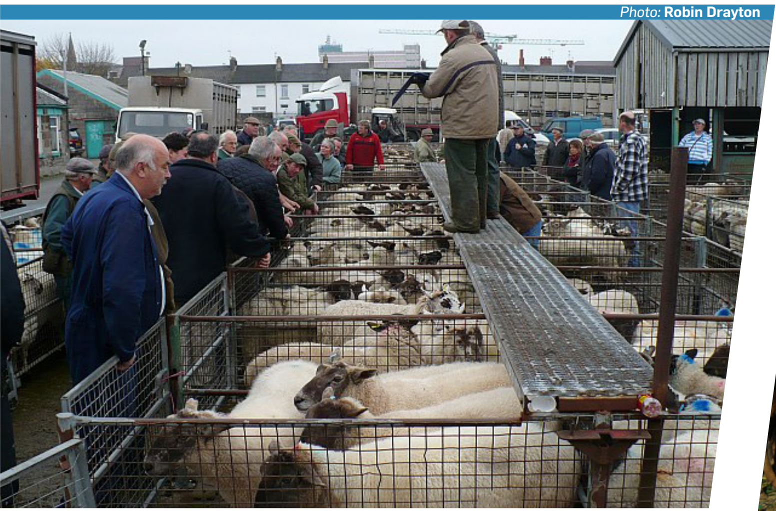


Photo: Robin Drayton

Figure 5a and 5b / Livestock markets in the UK and in Afghanistan

Photo: Farshad Usyan, FAO

Issues, opportunities and risks

Animal diseases

Huge range of diseases. A huge variety of diseases and other ailments afflict various forms of livestock. The World Organization for Animal Health (WOAH) lists 117 animal diseases, infections and infestations as being notifiable: 82 for livestock and another 35 for bees and aquatic animals (OIE 2020). These are the more serious problems; a host of other, less prominent afflictions also threaten the health and welfare of animals and the productivity of livestock systems.

Diseases may be caused by viruses, bacteria, parasites, fungi, prions. They may be magnified by poor management. Each has its own transmission mechanism: insects, ticks, mites, droplets, contaminated objects, feed, and so on. Some are highly contagious; others spread only slowly. Some are endemic to livestock populations in large regions; others are local in scope. Some have their origins in wild animals, which often provide a natural reservoir for reinfection (Jones 2014, Woolhouse 2005). For some, animals can develop immunity; for others, this is not the case. Some can spread like wildfire through a population, decimating stocks and destroying livelihoods.

Prevention and treatment methods vary according to the disease in question. Animals that are well-fed and well-housed are less likely to fall ill (so animal welfare is a health consideration as well as an ethical one). Vaccines help animals resist diseases, while veterinary treatments aim to cure them. Some diseases (such as foot-and-mouth disease) exist as several strains, each requiring its own vaccine. That makes it very important to select the right type or combination of vaccines (Diaz-San Sequndo *et al.* 2017).

Biosecurity measures aim to prevent the animals from becoming exposed to pathogens; however, they must cover all potential entry points, including animal movements, people and equipment involved in production, as well as feedstuffs (Dee *et al.* 2016). Different innovations are needed for different livestock systems, for example, to increase biosecurity, reduce occupational health risks, and prevent and control contagious diseases.

In capital-intensive systems, biosecurity is usually very high and the risk of introducing contagious diseases is low. However, once an infection enters a farm it may spread quickly, causing production losses and fatalities, and requiring control and eradication measures. These may harm animal welfare and result in severe economic costs to the farmer. As most such farms are in HICs, there is likely to be little or no effect on food security.

In small-scale extensive livestock systems in rural areas, biosecurity is generally low. Such farms often have several livestock species, which is a way for the farmer to mitigate risks. If such farms are affected by a disease, the impact on the individual farm may be severe, including livelihoods and food security

The most challenging situation from epidemiological perspective appears on small-scale commercial farms with poor biosecurity in LMICs, as in the case with HPAI (FAO/OIE 2008). Contagious diseases may spread quickly on such farms, as well as to other farms through direct and indirect transmission, especially if they are in close proximity, as is often the case in urban or peri-urban areas. These farms are thought to be important for the emergence of new influenza viruses due to the contact risk with wild birds. The economic impacts can be devastating for individual farmers affected.

Economic impact. The economic impact of diseases can differ widely. Some diseases have a debilitating effect on production, reducing productivity and output, or precluding livestock raising altogether. Others cause drastic drops in production, either through the disease itself killing animals (as with Newcastle Disease in poultry), or through widespread culls of livestock and trade restrictions imposed to try to contain the disease (as in the 2001 foot-and-mouth disease outbreak in the United Kingdom (Thompson *et al.* 2001)).

A disease outbreak may not affect all actors in a livestock production system in the same way. In the 2013 outbreak of porcine epidemic diarrhea virus (PEDV) in the United States of America, production losses were probably outweighed by price increases caused by the decline in supply (Schulz *et al.* 2015). Pig producers as a whole may actually have benefited, while those further down the chain – packers, processors, distributors, and retailers – experienced losses, and consumers paid higher prices for their pork. Price changes in one type of meat also affect the prices of other types of meat, influencing those food systems too.

Figure 6a and 6b / Veterinary services in South Sudan and in Sweden

Veterinary services. These are mainly organized in four main categories: private practices, government services, in-house veterinarians working for large livestock companies, and research (in universities and pharmaceutical companies) and teaching. In HICs, individual private veterinary partnerships have been consolidating into larger, commercially owned companies. Professionals are often more attracted to small-animal practices serving pet-owners than to large-animal practices serving farmers. In many LMICS, veterinarians are scarce, especially in remote rural areas and in semi-arid regions with mobile pastoralists. While the number of agrovet vendors is growing, they are still rare in many areas.

Animal health care companies produce pharmaceuticals, hygiene and diagnostic products, equipment and software. Some are (or have been) subsidiaries of companies focusing on human medicines; others are independent.

Opportunities

Opportunities to control and reduce the risk of livestock diseases tend to fall into five categories: technology, breeding, organization, regulation and market.

Technology. Better diagnostics make it possible to detect and treat diseases (including new diseases) more quickly and sometimes also directly at the farm. New vaccines and treatment methods improve control. Traceability measures (ear-tags, databases) make it possible to track an animal from birth to abattoir to the supermarket shelf. Information and communication technology can be used to ease disease reporting and response, and also to advise farmers in remote areas. It should be noted though that there is a general skewness in investment in research and new technologies in that far more is invested in animal issues relevant for HICs than those relevant for LMICs only.

Breeding. It has been difficult to breed animals for resistance to specific diseases but some traditional breeds have valuable genetic traits that confer hardiness and more general disease resistance. It is important to raise these breeds in situ to maintain and further develop these traits, and to conserve their germplasm in gene banks.

Organization. The organization of livestock keepers into interest groups, cooperatives and marketing groups makes it easier to manage the incidence of diseases. Allying with human health professionals, training and collaborating with traditional healers and community animal health workers, and the provision of mobile clinics make it possible to extend animal health services to more livestock keepers in underserved and remote areas.

Regulation. Governments are becoming more aware of the need to control diseases, and they are becoming more adept at doing so. They impose biosecurity measures such as quarantines and movement restrictions, and order the culling of infected animals and the vaccination of animals surrounding an outbreak area.

Markets. In HICs, the livestock industry is controlled by a few large actors at key stages in the value chain: animal genetics companies, feed suppliers, livestock processors, and supermarkets. A similar trend is taking place in LMICs. The powerful actors in the chain impose demands on and make requirements of producers in terms of product standards, health, biosafety and traceability. In these large complex systems, it is important that there is continued improvement in the balance between high production, animal welfare, and the use of other technologies like antimicrobials.

Risks

Highly contagious, deadly diseases pose the biggest risk in areas with large numbers of livestock raised for subsistence. In Viet Nam, for example, an outbreak of African swine fever, first reported in February 2019, had by April spread to 24 provinces and cities, leading to the culling of nearly 90,000 pigs (FAO 2019). The transport of animals and their products over long distances and international borders increases the risk of diseases spreading rapidly within countries and across the globe. The costs of an infection may be huge. If African swine fever were to enter the United States of America, for example, it would cost the pork industry an estimated USD10 billion (Swine Health Information Center, 2019)

Figure 7 | A wild boar interacts with domestic outdoor-kept domestic pigs in the UK

Disease transmission is especially a risk during transport and at markets and water points. In LMICs, the introduction of purebred and crossbred animals that are poorly adapted to local conditions makes them more susceptible to diseases. Such animals may require greater investment in facilities, feed and medicines than hardy local breeds do.

If there are not proper governmental compensation schemes in place, stamping out procedure (culling of infected livestock or livestock at risk) may destroy the economy and livelihoods of farmers and force them out of business. Hence, this may lead to livestock owners not contacting veterinary services. Instead they may sell or cull infected animals to gain some economic revenue.

Efforts to clear infected animals from an area are often not completely successful. And if the clearance is successful, the remaining animals cannot develop immunity to the disease if an effective vaccine is not readily available. Both situations leave open the possibility that the disease may reappear and spread rapidly.

Many diseases, especially those affecting the tropics and subtropics, still lack adequate control measures such as vaccines. Pharmaceutical companies are reluctant to invest in developing solutions to ailments where most farmers are poor and unable to pay for prevention and treatment. Universities and national and international research organizations are inadequately equipped or underfunded to fill the gap.

As the climate changes, the distributions of diseases and their vectors (insects, ticks, mites, etc.) may also change. Diseases can be expected to move into new areas and into livestock populations that lack resistance or tolerance to them, and where livestock keepers and veterinary professionals lack the experience and resources to deal with them. Growing global trade in livestock may also facilitate the spread of diseases (FAO 2013).

Globally, government veterinary agencies are often inadequately staffed and resourced, leading to a lack of inspections, lax enforcement and periodic outbreaks of animal and food-borne diseases. In many LMICs, effective veterinary medicines are in short supply, available only in a few locations, or prohibitively expensive for poor, small-scale producers. Medicines may be falsified, adulterated or out of date, and are sold by unregulated vendors. Many livestock keepers use the wrong dosages or apply the wrong medicines to treat their animals' diseases. Livestock owners often do not get advice about treatment from qualified veterinarians but more likely from suppliers such as the owners of agrovet shops and kiosk.

Modern, high-yielding livestock breeds are the result of selection for specific traits, often with the use of biotechnologies. The use of artificial insemination means that a single male can sire a hitherto impossible number of offspring. This has dramatically reduced the risk of spread of sexually transmitted diseases and increased the speed of the genetic progress but has also narrowed the genetic base of some livestock breeds, especially dairy cattle, pigs and chickens and at some occasions contributing to the spread undesired genetic traits.

» Zoonoses and epidemics

About two-thirds of human infectious diseases are zoonotic (transmissible between animals and humans) and account for a significant global health burden (Woolhouse *et al.* 2005; Jones *et al.* 2008; Havelaar *et al.* 2015). Livestock serve as a reservoir for many of these zoonoses, but may also serve as intermediate hosts for zoonotic diseases that have originated in wildlife. The close contact between humans and livestock means that pathogens have ample opportunity to jump species barriers.

Zoonoses such as brucellosis, leptospirosis, Rift Valley fever and Chikungunya are frequent in LMICs (Halliday *et al.* 2015). In HICs, such diseases are kept in check by various biosecurity measures and control or eradication programmes, except in cases where consuming products such as unpasteurized milk are popularized by misinformation, but in LMICs they are widespread in domestic animal populations and readily infect humans who care for or come into contact with animals or who consume poorly cooked animal products. Symptoms from such diseases may be un-specific and are thus often misdiagnosed or go untreated.

Zoonoses with high epidemic potential – like various corona virus infections, Ebola, Zika and influenza – originate in wildlife. They may be transmitted directly to humans (Ebola), or via an intermediate host like pigs or poultry (influenza) or via an insect vector (Zika). Some of these zoonoses, primarily viruses, are highly contagious and do actually, like SARS-CoV-2 and influenza type 1, cause pandemics. Because humans do not have immunity to such novel zoonoses, they can spread rapidly across the globe – through human-to-human transmission aided by international travel, as well as the global trade in livestock and food of animal origin.

The economic impact of zoonotic outbreaks is substantial: it is estimated that 6 major outbreaks of highly fatal zoonoses between 1997 and 2009 caused economic losses of at least USD 80 billion (World Bank 2012). The public-health restrictions imposed to control COVID-19 have caused massive economic losses worldwide.

If the pathogen is novel (it has newly mutated or jumped the species barrier to humans), it is necessary and urgent to identify and characterize the causal organism, the disease symptoms and transmission methods in order to design control or eradication methods. For all pathogens tracing the source(s) of infection is of utmost importance.

The COVID-19 outbreak has shown the risks of misleading information spreading rapidly via the internet and social media – as so-called "infodemic". This danger is magnified if governments themselves are a source of misleading information. Governments may also try to conceal information or restrict its spread in an effort to avoid criticism, preserve export markets, remain in favor with its electorate, or maintain public calm.

Figure 8 Mongolian farmers handling their sheep

Photo: FAO

Opportunities

For both epidemic and endemic zoonoses, control and containment measures in livestock are very much the same as for other infectious livestock diseases. However, zoonotic diseases – especially those that cause epidemics or pandemics – usually get more attention from the public and authorities, so more financial and organizational resources are put in place to control them. It is generally more cost-efficient to invest in surveillance and control of zoonoses in animals – "at source" – than in humans (World Bank 2012). The control of other infections in livestock may benefit from such resources, as in the case of HPAI.

Widespread connectivity and the popularity of social media present both risks and opportunities to spread awareness and information.

Risks

Pandemic and epidemic zoonoses. The public health risks of epidemic zoonoses may be considerable, as we have been reminded by the current COVID-19 pandemic. Pandemics **Figure 9** may cause enormous human suffering and economic and social dislocation. This is worsened if the authorities initially try to conceal the nature and extent of the disease. Governments may be reluctant to impose restrictions (on livestock production and trade, and on human movements and social interactions) needed to control the disease. Efforts to do so may face substantial political, social and economic resistance. Social media may spread falsehoods, making it still harder to contain the disease.

Apart from the public health risks, the risks related to zoonoses with pandemic potential are very similar to those of other non-zoonotic transboundary diseases. They include trade restrictions, direct production losses and indirect losses resulting from control measures, such as the culling of non-infected animals. These may result in severe effects on the producers' economies and livelihoods, especially in countries that provide little or no economic compensation for such losses. In LMICs, fighting pandemic zoonoses may harm food security. Livestock production may be stigmatized as a biohazard, as with pig production in Malaysia during the Nipah outbreak in the 1990s (Chua 2013).

Endemic zoonotic diseases. The endemic zoonotic diseases are often overlooked as being among the background hazards of livestock keeping. This is especially the case if there are no dramatic effects on the livestock, just poor production performance, as with endemic brucellosis in LMICs. Other endemic zoonoses that pose risks to public health, but have little or no negative effect on animal health, are campylobacteriosis in poultry and Shiga toxin-producing *Escherichia coli* in cattle. For these diseases, farmers may have few incentives to take control measures, unless these are demanded by public health and food agencies, or by actors in the food value chain.

For all types of zoonoses, farmers and their families in LMICs are often at most risk as they tend to live close to their livestock and have limited resources to contain the disease.

Figure 9 Pork at the wet market in Vietnam

Photo: **Nguyen Ngoc Huyen, ILRI**

Food-borne diseases

Some of the most important food-borne diseases originate from livestock, for example campylobacteriosis and salmonellosis (Havelaar *et al.* 2015). This reflects the importance of animal health, welfare and management systems that prevent the spread of food-borne diseases. The burden of food-borne diseases is estimated at 33 million Disability Adjusted Life Years (DALY), a similar magnitude to those of major communicable diseases HIV/AIDS, malaria and tuberculosis (Havelaar *et al.* 2015). The highest burden falls on Africa, particularly on children below the age of five. There are also high economic and societal costs associated with food-borne diseases, including direct costs of the healthcare sector, as well as indirect costs such as absence from work, permanent or long-term disability, and premature mortality.

An outbreak of a food-borne disease can trigger measures that disrupt the supply chain, such as the destruction of animal products suspected to be contaminated, the closure of abattoirs and processing facilities and food recalls. If consumers lose confidence that a product is safe, they stop buying it. Demand and prices fall, reducing income for everyone in that food system, from retailers back to livestock keepers and input suppliers.

Food-borne diseases may originate in the animals themselves (see *Zoonoses and pandemics* above), or may be introduced during processing and marketing. Unhygienic slaughtering and processing facilities may contaminate meat and milk. Products may be poorly conserved, for example, if they are not adequately cooled during storage and transport. Products kept beyond their shelf life may become unfit for consumption. There are particular challenges in LMICs where the majority of poor people buy their food at local wet markets. At these markets there are food safety risks related to absence of cooling facilities, lack of clean and running water, and poor food hygiene.

Traditional food chains are simple: they may have just one step (farmer sells direct to consumer) or even none (subsistence farmers consume what they produce). But the global consumption of animal-sourced foods is increasing (Steinfeld and Gerber 2010). Food chains have been getting longer and more complex: they have been turning into intricate webs with many stages in processing, and numerous actors in different locations each performing a separate task. Processed foods typically contain multiple ingredients, each of which must fulfil food-safety requirements. The risks of contamination have multiplied accordingly (Boqvist *et al.* 2018).

While food-borne diseases mainly threaten consumers in LMICs, they also affect HICs. A scandal in Germany in 2019 involving sausages contaminated by listeria exposed shortcomings in both the processing factory and in the government system for inspecting such facilities (Schulz 2019). The European Union's ban on chlorine-washed chicken to mitigate campylobacter reflects concerns that it may compensate for poor hygiene standards both at production level and at processing. The ban has halted virtually all imports of chicken meat from the United States of America, where the process is generally used in chicken-processing plants (Schraer and Edgington 2019).

››› Opportunities

Improving animal health will improve public health as healthy animals are less likely to carry and pass on zoonotic food-borne pathogens. Fewer contaminated food products on the market will boost consumer trust, increase access to markets for producers, and benefit them and other actors in the food system.

The spread of supermarkets in LMICs is improving sanitary standards in the food-supply chain, as retailers introduce refrigeration and packaging and place strict quality controls on their suppliers (see *Animal diseases* above). Such requirements cascade back through the chain to producers. In many LMICs where the informal wet market is prevalent, guidance and recommendations to improve hygiene may improve hygiene, prevent cross contamination and storage, thereby improving food safety.

Repeated, high-profile food scandals put pressure on retailers, processors and producers to improve their standards, and on governments to introduce and enforce more effective controls. New technology might facilitate tracing of food products in food borne outbreaks involving several countries. Social media can help spread information on outbreaks of food-borne diseases.

››› Risks

As living standards improve, the consumption of meat, milk and eggs increase. Consumers thus face a larger risk of being exposed to diseases from these foods, especially in systems with poor animal health and management.

While the shift towards supermarkets in LMICs promises to raise food-safety standards, it also carries the risk of larger-scale crises. Inspection and enforcement systems are not as robust as in HICs. A problem in the supply chain may lead to more widespread problems than in a marketing system dominated by small-scale, local, wet markets.

As food chains are getting longer and more complex it becomes more difficult to trace food products associated with food borne outbreaks due to the large number of actors involved and because food products may be processed in several different countries. The challenges to monitor and control these complex chains also enables food frauds. One well known fraud is the "horse-meat scandal" in 2013, where beef burgers were found to contain undeclared horse meat (Food safety authority of Ireland, 2013).

Increased livestock production may put more people at risk of exposure to both zoonotic and food-borne diseases if animal health and management is poor and biosecurity insufficient. Pathogens may be transmitted in various ways, including through direct exposure to excreta, unsafe foods, contaminated drinking water and poor personal hygiene. There may be food safety risks also associated with smallholder production for the same reasons mentioned above.

Figure 10

Photo: Ami Vitale, FAO

Figure 10 / Family dairy production in Turkey

Antimicrobial resistance

Antimicrobials (antibiotics, antifungals, antivirals) and anti-parasitics are used in four ways in livestock keeping: to treat diseased animals (treatment); to control the spread of a disease in a herd or flock (when a disease has been detected); to prevent the animals from becoming ill (prophylaxis); and to put in feed in low doses to enhance growth rates (growth promotion). In some farming systems, antimicrobials are mixed with the feed or drinking water for prophylaxis and growth promotion. However, the practice of using antibiotics for growth promotion is nowadays banned in many countries since it drives development of antimicrobial resistance (AMR). The regular use of antimicrobials for prophylaxis is also restricted in some countries.

Bacteria and other microbes naturally develop resistance to antimicrobials. But this process is greatly enhanced through the extensive use – and overuse – of antibiotics and other antimicrobials in livestock production (as well as in human medicine). Hitherto effective antimicrobials used to treat major diseases of both humans and animals are becoming ineffective. The emergence of AMR is currently the greatest threat to progress made in human health and well-being as well as animal health, welfare and production over several decades. It has been estimated that AMR will contribute to millions of human deaths per year in the world and the production in the livestock sector in low income countries is at particular risk with an estimated livestock production loss of 10 percent by 2050, if the emergence and spread of AMR is not curbed (O'Neill, 2016; World bank, 2017).

To maintain the efficacy of antimicrobials, it is vital to reduce their use by limiting it to medically rational use. The livestock sector is a large user of antimicrobials and contributes significantly to the global pool of resistant microbes (Van Boeckel *et al.* 2015). Except for cases where farm workers have been infected with resistant bacteria from livestock, the importance of the sector as a contributor to resistant microbes to the human population as a whole is however not known (Tang *et al.* 2017). Even so, for the sake of maintaining the efficiency of antimicrobials for veterinary use, and to reduce the risk of transmission of resistance to humans, it is reasonable to reduce the use of antimicrobials in the livestock sector (e.g. Robinson *et al.* 2016).

The availability of antimicrobials varies widely from one country to another, and from place to place within a country. In some locations, they are expensive and hard to find; in others, they are more affordable and easily available, even without prescription. There is also great variability in use between farming systems: most food animal antimicrobials are used in intensive poultry and pig systems (Van Boeckel *et al.* 2015).

Countries differ considerably in their regulations on the use and supply of antimicrobials, as well as in capacities to enforce such regulations. Falsified and substandard drugs are common in many LMICs (Kelesidis and Falagas 2016). Also, the public awareness and attitudes towards the use of antimicrobials in the livestock sector varies.

Photo: **Theodoros Ntallaris, SLU**

Figure 11 Treating a cow with a narrow spectrum antibiotics, Sweden

Opportunities

As awareness of the danger of AMR increases, governments are imposing greater restrictions on the types, amounts and uses of antimicrobials. The European Union, for example, banned the prophylactic use of antimicrobials in livestock in 2015. This has led to a drop in the quantity of such medicines used in the European Union (European Commission 2015, European Medicines Agency 2019). Globally, more countries are now banning the use of antimicrobials as growth promotors (OIE, 2019), which may lead to similar reductions in use in these countries.

Antimicrobials are in several cases used to compensate for shortcomings in animal management. Investment in preventive animal health and animal welfare reduces the need for antimicrobials (Magnusson *et al.*, 2019; FAO, 2020). Conversely, restricting the use of antimicrobials may force producers to upgrade their husbandry and biosecurity, vaccination programmes and standards of animal welfare.

Risks

Despite a global trend with more regulations restricting the use of antimicrobials, substantial demand for such products may still exists from some large-scale producers. Compliance to these regulations may in some settings be poor and inspection services underfunded and understaffed. Also, veterinarians are in some jurisdictions allowed to sell antimicrobials to farmers; a practice that does not promote restrictive use (Magnusson 2020). Some veterinarians earn huge profits by dispensing large quantities of medication to livestock producers (Klawitter 2012; Hucklenbroich 2011).

In some LMICs, antimicrobials are available from unregulated agrovet stores and kiosks, and are sold in the absence of professional animal health advice (Magnusson *et al.*, 2021). Thus, they may be applied without a proper diagnosis, used to treat the wrong diseases or applied at the wrong doses. Falsified, substandard and expired drugs are also common (Kelesidis and Falagas 2016). All these problems may lead to inappropriate and excessive use of antimicrobials that drives the development of AMR.

Photo: **Jenny Svennås-Gillner, SLU**

Figure 12 Sow in the farrowing pen with straw

Animal welfare

Concern about animal welfare has been growing strongly globally, for example regional strategies for animal welfare are now available across continents (e.g. African Union, 2017). For farm animals, welfare encompasses a broad range of issues relating to the health and well-being of livestock on farms, during transport and at slaughter.

Livestock production in LMICs is dominated by smallholders. They typically devote much greater individual attention to their animals than is possible in larger systems. Welfare problems instead come from scarce feed and health resources, or an absence of knowledge, not an absence of care (Godfray and Garnett 2014; Abubakar *et al.* 2018). In large scale animal production, animal welfare challenges are related to confinement, behavioral restrictions, and extreme levels of production and intervention.

Animal welfare considers the health, nutrition, housing and behavioral needs of animals, and how they are managed. It is linked to the pillars of sustainable agriculture (Broom 2010; Appleby and Mitchell 2018). FAO's vision for sustainable livestock production treats animal welfare as a priority (FAO 2018). The welfare of livestock and working animals directly relates to eight of the UN's Sustainable Development Goals (Doyle *et al.* 2018; World Horse Welfare and The Donkey Sanctuary 2018; Keeling *et al.* 2019)

Many livestock enterprises are responding to changing consumer preferences, including welfare sensibilities. Some can charge a higher price for products produced in a way that is mindful of animal welfare; or penalties for non-compliance to animal welfare standards may emerge.

Better animal welfare may incur costs: it may be necessary, for example, to convert production facilities, replace equipment, reduce the number of animals, allocate more space per animal, or switch to alternative sources of feed. But it also brings benefits for farmers by allowing them to target higher-value markets and by cutting losses, wastage and animal mortality. It is often more environmentally friendly than conventional production. It is good for worker satisfaction too, as well as for occupational health, food safety and food security. These trade-offs need to be identified and managed, and synergies built upon.

Sensitivity to and standards for animal welfare varies from one country to another. This may cause problems in trade. In 2011, for example, Australia temporarily banned exports of live cattle to Indonesia, its largest market, because of the lack of safeguards against the inhumane slaughter of animals (BBC 2011).

Opportunities

The scope for improvements in animal welfare to enhance sustainability is huge. The connection between animal welfare and other components of sustainability means that welfare-focused innovation gains can be made at the same time as other sustainability improvements.

Animal and human health and welfare go hand in hand. Poor animal welfare causes stress for animals and humans alike. It contributes to food-borne diseases caused by zoonotic bacteria such as *E. coli*, *Salmonella* and *Campylobacter* (European Food Safety Authority 2012). Improved welfare practices on farm and afterwards can improve productivity, meat quality and food safety, reduce risks to human health, and lead to economic benefits (Appleby and Mitchell 2018).

During disease outbreaks, humane management of sick animals and culling for control can ease animal suffering and the psychological stress on the farming families and animal health workers (Hall *et al.* 2004, FAO 2009, Whiting and Marion 2011). As an example, the 2019 outbreak of African swine fever in parts of Asia saw the death and culling of almost five million pigs (estimates from December 2019, FAO, 2019), often not meeting international standards of animal welfare (OIE, 2019a).

Risks

As animal welfare concerns increase, they influence consumer behaviour, government processes and international expectations. A failure to take these concerns into account could result in lower demand for livestock products, harming the viability of production systems.

Without genuine improvement of animal welfare, many of the Sustainable Development Goals will not be realized (Euro Group for Animals 2018) and livestock systems, the people that rely on them, and the animals will suffer.

In many countries there is a wide gap between regulation and implementation, which makes welfare improvements, specifically the phasing out of unacceptable practices, difficult to achieve. Commitment to implement changes, broad stakeholder involvement in the development of regulations, and investment to support changes in practices (e.g. through raising awareness, education, or developing skills) are ways that this gap can be narrowed.

Short term vision for production poses risks to animal welfare when animals are in poor health and welfare but are still counted as ‘productive’. Lame cows still produce milk, but yields eventually decline, and cull rates increase (Oltenacu and Broom, 2010); broiler flocks with high rates of digital dermatitis still can be used for meat, but the chances of *Campylobacter* contamination after slaughter are higher (Bull *et al.*, 2008); working equids often continue to be used for work when chronically ill, creating significant, costly health issues to address that have long recovery periods (Pritchard *et al.*, 2018). In these situations, proactive welfare interventions would reduce these long-term, high impact losses as well as enhance the welfare of the livestock involved, in both the short and the long term.

Innovations in animal health and welfare

Good animal husbandry and welfare

Clean and comfortable housing, nutritious feed, free access to clean drinking water, good air quality and optimal temperature are the basis for keeping animals healthy so they can remain free of stress and resist infection.

Improvements in the availability of feed and water, veterinary medicines and services and farmers' education, and investments in transport, infrastructure, markets and slaughter facilities are making it possible to ensure animal health. Better access to markets and improved consumer awareness strengthen the incentives for farmers and processors to raise healthy animals and to improve hygiene and handling so they can sell livestock, meat, milk and eggs.

Figure 13 Poultry farming in Uganda

Photo: **Olivia Graaf Bjöersdorff, SLU**

Biosecurity

Better knowledge of how diseases are transmitted makes it possible to reduce the risk of animals becoming ill and also prevent food borne diseases. Increased biosecurity measures are widely applied in HICs. They cover the management of animals and the movement of animals and humans within and between farms. Measures to prevent infection include avoiding livestock markets, using artificial insemination and embryo transfer for breeding, strict quarantine measures, limiting the mixing of young animals from different farms, reducing livestock–human interactions through increased automation of procedures such as milking, and preventing livestock from coming into contact with wildlife. Adequate biosecurity also implies good farm hygiene to prevent survival, multiplication and transmission of pathogens, including food borne diseases.

Biosecurity measures are increasingly being applied in LMICs as a result of ambitions to increase productivity and demands from local supermarkets and consumers, government regulations, and the requirements of importing countries. In many countries, politics as well as economic pressures are forcing a shift away from small-scale and backyard livestock-raising to large, more intensive production units where biosecurity is easier to implement – though a disease may spread rapidly if it gains access to the facility.

Animal health services in remote areas

The expansion of vaccination programmes in LMICs has the potential to protect more animals from infectious diseases, especially in remote areas. Promising approaches include mobile vaccination teams and clinics to serve pastoralists, and combining programmes to vaccinate nomadic pastoralists and their livestock (Shelling *et al.*, 2007). Novel information and communication technology has the potential to improve reporting and response to outbreaks of infectious diseases, as well as providing livestock keepers with advice from qualified veterinarians.

Institutions and compliance

Changes in institutions may be just as important as improved technology in controlling diseases. Brucellosis in cattle is an example. This zoonotic disease was eradicated in Sweden in the 1950s based on the robust diagnostics available at that time (Cerenius 2010). This was made possible because communal grazing and mixing of herds were limited, engagement in farmers' organizations was strong, and the veterinary authority and service interacted closely with the farmers. These institutional factors made compliance with external biosecurity measures effective. The opposite conditions still apply in many countries where brucellosis is an issue (Plumb *et al.* 2013). In such cases, where animal productivity is generally low and where the disease is endemic and symptoms vague, farmers may be reluctant to invest in control measures such as vaccination. A lack of compensation for culled animals further increases resistance to control measures.

The development and strengthening of institutions, both state and non-state, in such areas are vital to improving control of livestock diseases. Stronger groups of livestock keepers make it easier for government organizations and veterinary services to interact with larger numbers of local people, learn about their opinions and needs, and provide them with the information and services they require. It also makes compliance with disease-control measures more possible (FAO, 2020).

Monitoring and surveillance

Advances in technology are making it possible to detect and respond to livestock diseases more quickly. Improved testing and control have made it possible to eradicate diseases such as bovine brucellosis and porcine pseudorabies in the United States (USDA 2019a, 2019b). For some diseases it is now possible to perform a rapid diagnosis on the farm itself. To be practicable, such tests must be cheap and quick. Currently, some "pen-side" tests and several basic laboratory tests are in common use in HICs.

Information technologies, including cameras, image-recognition software and sensors in equipment and in the animals themselves make it possible to gather performance-related data. Sensors can monitor and manage the temperature, air quality and ventilation in housing, and the feed consumption of individual animals, making it possible to detect infections early (Shi *et al.* 2019). Acoustic sensors can detect an increase in coughing of pigs and calves (Carpentier *et al.* 2018) as an indicator of respiratory infection. Data collection and record-keeping can become more efficient, as in the Individual Pig Care approach, which combines systematic observation with electronic records (Pineiro *et al.* 2014, van Looveren 2013). New technology can also be applied to increase traceability within complex food chains, one example being blockchain technology (Antonucci *et al.* 2019).

Smartphones, now common in most countries, offer the prospect of improved disease surveillance, especially for livestock-keeping in and around cities in LMICs (Roesel and Grace 2015). However, livestock production in the informal sector often escapes formal regulation, so conflicts of interest may arise when it comes to monitoring and surveillance. Smartphones may also be used to improve knowledge and awareness of diseases and their control among actors throughout the production system.

Antimicrobial use and resistance

The prospect of developing effective new antimicrobials for veterinary use is limited in the near future, as new antimicrobials will very likely be reserved for humans. In parts of Europe, restrictions on the use of antimicrobials, combined with better disease prevention, has significantly lowered the use of antimicrobials in the livestock sector, with no loss of productivity or profitability (Bengtsson and Wierup 2006). Such measures could be expanded and implemented elsewhere.

The three intergovernmental organizations, the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the World Organization for Animal Health (WOAH) have agreed to collaborate in fighting AMR. The United Nations Environment Programme (UNEP) has also joined this effort (WHO; FAO; OIE UNEP, 2022). Other global initiatives are taken by the World Bank (World Bank, 2019) and the CGIAR has established an AMR-hub focusing on reducing the risks of AMR associated with agriculture in LMICs (CGIAR 2019).

In several HICs it has been shown that it is possible to maintain good health and productivity when reducing the use of antimicrobials. In LMICs, a more medically rational use of antimicrobials would lead to lower use and may both improve animal health and increase productivity. Wholesalers, retail distributors, animal health professionals, livestock producers, policymakers, governmental agencies and academia must all strive to replace excessive and medically non-rational use of antimicrobials with good animal husbandry and disease-prevention measures.

The applicability of solutions will depend on the setting. They may include (European Commission 2015):

- Using only quality-assured medicines.
- Not using antimicrobials as growth promotors and avoiding regular preventive use of antimicrobials.
- Avoiding using highest priority, critically important antimicrobials for human medicine in livestock.
- Using antimicrobials only based on a diagnosis of the disease by a veterinarian or other animal health professional and only for authorized indications.
- Treating animals individually with the correct dose and duration, and avoiding the use of antimicrobials for group treatments, especially via feed.

Reducing the administration of sub-therapeutic antimicrobials (as well as hormones or steroids) may mean that animals do not grow as quickly. This can be addressed through changes in feeding. Major feed companies are exploring custom blends that reduce dependency on medicated feed and improve digestibility and gut health. It should be noted that for some antimicrobials used for growth promotion and disease control, such as the ionophores, there has been no demonstration of selection for resistant bacteria of either animal or human importance.

Enforcing strict compliance to withdrawal times (the time period between applying an antimicrobial and when the eggs, meat or milk may be marketed for human consumption) may incentivize a more limited use of antimicrobials. Effective monitoring and traceability along the food chain are needed to ensure this.

Figure 14 ▮ Live birdmarket in Cambodia

One Health

The importance of the One Health approach has – since the global spread of the highly pathogenic avian influenza in 2004 when WHO, FAO and WOAH joined forces – been fully recognized. These three major global organizations dealing with agriculture and human and animal health have agreed to collaborate to deal with health threats at the human–animal–ecosystem interface; UNEP has also now joined this effort (FAO, OIE and WHO, 2010).

The approach includes disciplines like food safety, public health, health economics, ecosystem health, social science and animal health. In the 1980s in the United Kingdom, an outbreak of bovine spongiform encephalopathy (BSE) in cattle lead to a parallel outbreak of its human equivalent, variant Creutzfeldt-Jakob disease (vCJD) in humans (Ducrot *et al.* 2008). Important aspects such as food safety, public health and the ability of the BSE agent to spread through the food and feed chains had been overlooked. It was only when the One Health approach was used that the disease's ability to spread, and the magnitude and severity of the epidemic were fully grasped. It is also widely acknowledged that the One Health approach is essential for successfully fighting the global AMR emergence (WHO, FAO,OIE UNEP 2022)

Animal welfare standards

The development of global standards is raising the bar for animal welfare, and welfare-assessment programmes are providing the tools needed to evaluate compliance. The WOAH (previously OIE) has developed codes for the welfare of terrestrial and aquatic animals (OIE 2004), including dairy, beef, chickens, pigs and working equids, and for post-farmgate transport and slaughter for food and for disease control. The codes are scientifically based. Consensus among the WOAH's member countries supports their adoption and makes them inclusive and accessible to all involved (Sinclair 2016).

Valid and reliable welfare indicators for sheep, goats, horses, donkeys, turkeys (AssureWel 2010, AWIN 2015) and broilers, laying hens, pigs, beef and dairy cattle (AssureWel 2010, Blokhuis *et al.* 2010), and working equids (Sommerville *et al.* 2018) have been well researched. While indicators need to be evaluated for different systems, particularly in LMICs, these tools allow comparisons to be made within and between systems and environments over time. These codes and indicators make it possible to gather evidence on animal welfare.

One way for consumers to understand what they are buying is via welfare labelling. Welfare labelling provides advice and information to the consumer, but it also comes with risks of mis-information, consumer distrust if not regulated, and can act as a barrier to trade (More *et al.*, 2017).

For example, in 2019, German supermarkets introduced a four-point labelling system for meat (*https://www.haltungsform.de/*) where 1 ("Stallhaltung" or stable management) is the lowest and 4 ("Premium") the highest score. A score of 4, for example, indicates that the animal has much more room than required by law and that it can go outdoors at least some of the time. Eggs sold in Germany have a coding from 0 to3 (where 0 denotes organic and 3 cage management; the opposite scoring system to meat). Some milk is marketed as "Weidemilch" (meadow milk) or "Heumilch" (hay milk), but these have no legally defined criteria (Verbraucherzentrale 2020). In addition, several environmental organizations have introduced their own certification and labelling schemes (NABU undated), and animal elfare groups have called for a compulsory, state-sponsored labelling scheme.

Figure 15 Free-ranging broiler chickens in the UK

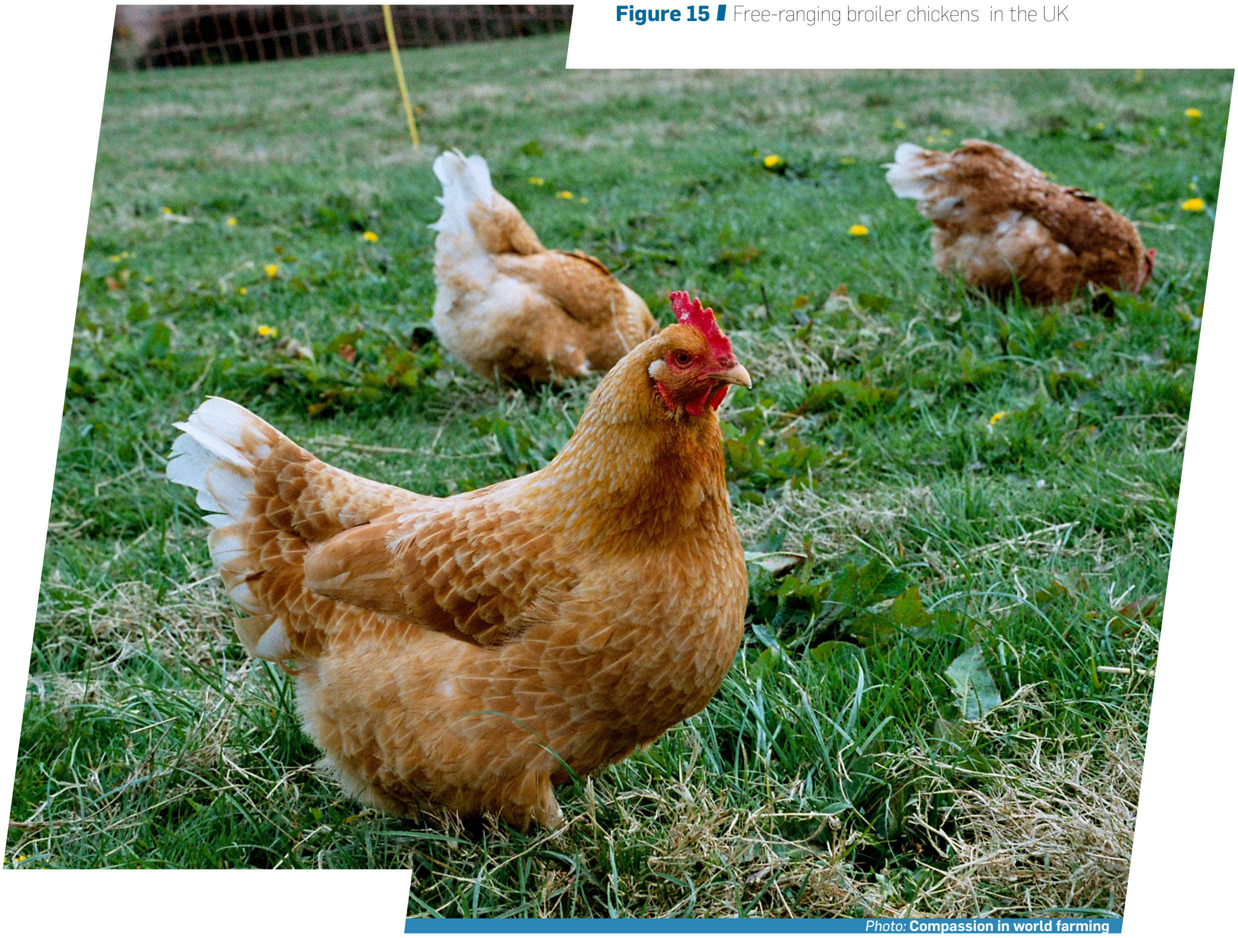


Photo: **Compassion in world farming**

Incentives for animal welfare

Improving animal welfare often involves costs for the farmers. That means that farmers need incentives to improve welfare. This can happen if they get a better price or a more reliable market for their output. UpTrade (*https://uptrade.org/*) is a start-up creating incentives for smallholder goat farmers in Pakistan to improve traceability, feeding and health management. Meat Naturally (*https://www.meatnaturallyafrica.com/*) provides livestock keepers with training, equipment and market access, if they agree to preserve rangelands and produce quality meat products that are produced in a sustainable fashion. In both examples, organizations connect farmers with higher-value markets that require them to invest time and resources in improved welfare.

Good animal feeding and integrated approaches to land use, such as silvopastoral systems, may improve feed efficiency, biodiversity, and human and animal welfare (Broom *et al.* 2013, Chará *et al.* 2018). They also permit the animals to behave in a natural way (Fraser 2008). Opportunities for integration of agroforestry and animal production systems may apply to both private and public lands, if managed appropriately.

Implications for policy

Healthy animals are more productive than unhealthy ones, so it is in the livestock keepers' interests to take care of their animals' health and welfare. However, it may not be obvious that an animal has a disease and in some cases the farmer may neglect optimizing the health and welfare of the animal for the sake of profit, despite lower productivity. Also, in some settings the farmers may be tempted to conceal an illness so animals can be sold or slaughtered.

Governments have a wider responsibility for controlling disease. They are tasked with protecting other livestock keepers, the industry and consumers from the effects of disease. Measures such as culling, movement bans and quarantines may be unpopular but necessary.

Governments are also responsible for protecting animal welfare. Governments must find positive incentives and practical, enforceable ways to ensure that animals are kept in a humane way. Public policy, however, is not solely the domain of government and different livestock sector actors; international organizations can also have roles to play in shaping the policy and institutional environment in which livestock systems operate. Policy instruments can take various forms – characterized as "sticks", "carrots", "maps" and combinations of these.

- **Command and control.** Regulations, operating through legal instruments and generally with sanctions in the event of breach. These include bans, quotas, restrictions, licenses, permits and compulsory standards. This is the equivalent of a stick (punishment if you do not comply with the rule).

- **Direct implementation.** This is where a government implements an activity itself. Examples are direct purchases of products, government-run extension services, and infrastructure such as markets, roads and ports owned and run by the government. This is the equivalent of the government pulling the cart by itself.

- **Taxation.** Where the government imposes additional costs, such as taxes and levies, on activities in order to raise revenues, make the activity more costly and less attractive, or to cover the costs of providing services. It is a stick.

- **Cross-compliance.** Regulation, where conditions are attached to direct payments at various points in the livestock and food system. This is a combination of a carrot (the promise of payments) with a stick (the reduction in payments if you do not comply with recommendations).

- **Support.** Where the government finances an activity that it deems desirable. This includes subsidies, funding of initiatives, purchases of products and lower tax rates. It is a carrot.

- **The market.** Where consumers' concerns filter back through retailers and processors to producers. This is a carrot, where you get rewarded for meeting the market's needs, combined with a stick, where you lose market share if you do not.

- **Soft law.** In the form of guidance, recommendations on best practices, and voluntary standards from international organizations and other authorities, corporations, Non-Governmental Organizations (NGOs) or professional associations. This is like a map showing you the best way to get to a destination.

- → **Information, education and research.** This involves informing stakeholders in the value chain, from produces to consumers, about a topic. It may include information campaigns, training, guidelines, rating systems and networking, as well as research to generate information and new technologies. It is also a map.

Some of these options are best suited to governments and other better to non-government actors, such as the private sector and NGOs. For example, groups of private-sector retailers (or a single larger retailer) can set quality standards that their suppliers must follow. NGOs can implement some types of activity themselves (such as organizing producers into groups), or can run information campaigns to raise awareness about an issue.

Policy tools can influence the behavior of food system actors by impacting on supply and demand. Supply-side policy instruments act upon producers, processors and distributors by altering the conditions that determine prices and quantities supplied: quotas and subsidies, for example. Demand-side policy instruments affect the conditions of demand. Their role is largely under-explored within sustainable food policy. For instance, taxes on saturated fat are aimed at altering relative prices among food items; nutritional labelling aims at orienting consumers' choice.

›› Control movement of animals and animal products

Controlling the movement of livestock and animal products is vital to prevent the spread of certain diseases, including food borne diseases. Such controls may be imposed routinely on international trade or on movements within a country – such as between areas where a disease is endemic to areas that are disease-free. They may also be imposed on a temporary basis in response to a disease outbreak. In imposing such controls, it is necessary to balance between biosecurity and economic considerations: while the restrictions may be in the best interest of society as a whole, they may be against the short term and local economic interests of some parties. A mix of economic incentives and regulatory enforcement must be struck in such cases.

›› Overcome barriers to health innovations

The financial barriers to innovations in animal health are often substantial. Economic margins are typically narrow in livestock production. New technologies must be economically viable, but companies have little incentive to develop them, and farmers to adopt them. Governments can address this problem by supporting the costs of developing a solution to a problem where the value to society exceeds the value to the marketplace. Such an approach may apply to innovation in vaccines, diagnostic tests, and other disease-control measures. A similar logic may apply to deploying existing technologies to control diseases, such as through vaccination programmes for livestock in LMICs.

›› Improve control of infectious diseases, including zoonoses

For infectious livestock diseases not affecting humans, a mixture of command-and-control and soft laws may be appropriate, depending on the disease, the scale of losses, and public health risks. In countries with weak veterinary services, there are few control options for common endemic diseases. Farmers can be motivated by soft laws to implement simple biosecurity and management measures to control the spread of these diseases. Where a disease is less common, or if it is new in an area, command-and-control may be more appropriate to control or eradicate the disease. A well-functioning veterinary service and collaboration across institutions and sectors are required for this. It may be possible to start with soft laws to encourage voluntary actions and reduce the disease prevalence, followed by command and control for the final eradication. Notably, international trade agreements based on WOAH-standards are important determinants in how a country handles a livestock disease – in the absence of measures a country may not be allowed to export livestock or livestock products to the global market.

Managing zoonotic diseases is even more complex and requires collaboration across institutions and sectors. Command-and-control approaches covering both human and livestock health may be needed, especially for zoonoses with pandemic potential. HICs already use integrated control systems across animals, foods and humans but in LMICs controls are less effective and are not always integrated across the different sectors.

Pressure from the public health sector to control zoonotic diseases in livestock is of particular importance for diseases showing few or no clinical signs in livestock, such as campylobacteriosis. In these cases, it may be difficult to motivate farmers using soft law, instead a combination of cross-compliance, the market and command-and-control may be more effective.

Use One Health to control zoonotic and food-borne diseases

Zoonotic and food-borne diseases are best tackled using a One Health approach. Resources should be allocated where they most reduce the risk of zoonotic and food-borne diseases. Interventions must be based on knowledge of the socio-economic situations of farmers, food business operators and consumers. A combination of cross-compliance and soft law approaches may work best.

Improving animal husbandry and welfare is important for reducing the risks of zoonotic and food-borne diseases. Data on the occurrence of food-borne diseases and the disease burden in the human population are crucial to assess the costs and benefits of disease-control measures in the livestock production and processing systems. Postharvest interventions are also required to reduce the risk of the pathogens surviving, multiplying and contaminating food. In HICs, efficient control and monitoring of targeted diseases are needed by well-functioning regulatory bodies using command-and-control, cross-compliance and market approaches. In low-income countries, such approaches are less likely to be useful; there, soft laws in the form of recommendations and guidance will probably be more effective.

Reduce use of antimicrobials

Not all governments have the capacity to impose command-and-control measures to restrict antimicrobial use, and overly harsh regulations could jeopardize the profitability and livelihoods of livestock producers. It also risks pushing antimicrobial use into a poorly regulated black market dominated by sub-standard products that are administered inappropriately. The cross-compliance approach also requires the capacity to enforce regulations, and the market approach relies on consumers demanding food produced without excessive use of antimicrobials. Such approaches will probably work only in HICs. Soft law – guidelines and persuasion – along with education and information, also has a place in HICs, but may be the only realistic option in LMICs.

Promote animal welfare

Efforts to improve animal welfare include both creating and raising minimum standards for welfare, and enforcing accountability to improve practices. These must cover all stages in the production cycle: on-farm, transport and slaughter. A combination is needed of command-and-control regulation (from government), and cross-compliance and soft law (from industry and the supply chain), whereby actors must achieve a level of welfare in order to sell their products.

In many governmental and compliance systems, large gaps exist between policy, regulation and implementation. Policies that are not demanded by farmers or consumers but developed by experts and adopted in response to international pressure are especially likely to be ignored. Extension providers must be trained in animal welfare so they can guide producers. Industry actors and nongovernment organizations can often connect with farmers better than governments. Rather than imposing rules, dialogue is needed to raise awareness of animal welfare among producers and consumers.

4 Synergies and trade-offs

Synergies

Animal health and welfare interact and support each other; freedom from disease is substantial share of welfare and good care and management is a prerequisite for raising animals that are robust and resistant to disease. Here we focus on synergies between animal health and welfare, and the other livestock sustainability domains.

Negative externalities

The flip side of synergies are negative externalities: where a decline or failure in one domain leads to problems in another domain. Examples abound. Lower productivity (livelihoods domain) threatens the food security of livestock keepers (and of the population as a whole) and may forces them to over-exploit the natural resources, spend less on maintaining animal health, over-use of antibiotics, and pay less attention to animal welfare.

Trade-offs

Improvements in animal health and welfare may theoretically lead to losses in other domains. Such negative interactions - trade-offs - are sometimes difficult to spot, and it can be hard to agree on what the right approach should be: should the animal welfare be sacrificed in order to boost output, or to guarantee food security?

Animal health and welfare and Food and nutrition security

Synergies

Better food security, less food waste. Protecting animals against disease results in healthier animals that are more productive, and their meat, milk and eggs are less likely to be rejected for food-safety reasons.

Better production, improved nutrition. Animal-sourced foods provide high value nutrients critically important for children and women at reproductive age. Such foods are scarce for poor people living in LMICs and healthy animals that produce well contribute to larger amounts of these highly nutritious foods.

Trade-offs

Rejecting food. Strictly enforcing food-safety regulations leads to rejecting food that is regarded to be unfit for human consumption, contributing to food wastage. There is thus a trade-off between concern for food safety and strictly enforcing regulations on one hand and the availability of food on the other. This may also have a negative impact on availability and accessibility of nutritious animal-sourced foods.

› Animal health and welfare and Livelihoods and economic growth

››› Synergies

Protecting the effectiveness of antimicrobials. In some settings, especially in intensive systems in emerging economies, animal health is maintained under an umbrella of antimicrobials. Thus, to implement other disease prevention measures not based on antimicrobials, and to use antimicrobials in a medically rational and responsible way, can reduce the risks of spurring the emergence of resistant microbes, which may pose a threat to animal health and productivity as well as to human health.

Reducing the risk from zoonoses. Zoonotic diseases are common to both humans and livestock: indeed, the majority of infectious diseases in humans originates from the animal kingdom. Albeit the majority of these diseases originates from wildlife, livestock may serve as a bridge for transmission to humans and can serve as a reservoir for pathogens. Hence, controlling diseases in livestock can reduce the risk of infection in humans.

Higher productivity. Animals that are healthy and can perform their natural behaviors are more productive, boosting incomes and economic growth. While controlling animal diseases may be costly in the short term, it pays off in the long term for livestock keepers and others in the value chain through higher productivity and greater profitability.

Income rise and education. As incomes rise, livestock keepers become more able to afford animal health care and to ensure the welfare of their livestock. Better education, infrastructure and services also make it easier to maintain animal health.

Addressing consumer concerns. Concerns about animal welfare are growing globally. Such concerns may reduce demand for animal-sourced foods in some markets; trigger policy changes by government and action by stakeholders in the livestock sector to improve welfare.

››› Trade-offs

Costs of controlling animal diseases. It can be very costly to control livestock diseases. Measures such as inspections, trade bans, quarantines and depopulation are very much “command-and-control” in nature. The costs fall on the individual livestock keeper unless they are compensated by the government or by insurance schemes.

Rejecting food. As with above, strictly enforcing food-safety regulations can exclude certain producers from markets. There is thus a potential trade-off between concern for strictly enforcing food safety regulations on one hand and market access on the other.

Costs of improving welfare. For infrastructure-heavy animal production systems, the cost of introducing welfare changes can be incredibly expensive for producers to implement. Such additional costs may take time or be difficult to recover though increased profits alone, and so may need a substantial timeframe for phasing in such industry-wide changes.

Reduction of antimicrobial use. For many reasons, some livestock keepers make up for poor health management through the excessive use of antimicrobials. If a reduced use is not replaced by good animal health management, animal health and welfare may deteriorate.

Lower animal welfare. Capital-intensive systems can restrict natural behavior in animals and can be accompanied with genetic selection that can compromise health and welfare.

Animal health and welfare and Climate and natural resource use

Synergies

Lower emissions, less environmental degradation. Healthier animals produce output more efficiently than unhealthy animals, resulting in lower GHG emission intensities, and lower use of natural resources per unit of egg, milk or meat produced.

Trade-offs

Less feed and water. Climate change and environmental degradation may make nutritious feed scarcer and deplete water supplies resulting in more vulnerable animals and cause or exacerbate poor animal health and welfare.

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