Agricultural Pollution
Livestock Wastes

Figure 1: Farm Animals in Tight Quarters

Sources: fowl: © blickwinkel / Alamy Stock Photo; cows: Don Despain / Alamy Stock Photo; pigs: © Edd Westmaccott / Alamy Stock Photo

Why Care about Livestock Wastes?

The livestock sector is a major and growing source of pollution across the world as rising global demand for animal products including beef, pork, poultry, and dairy products is leading livestock operations to not only expand their output, but also to concentrate spatially, intensify, and separate from plant agriculture. Although livestock system outputs are growing faster than their spatial footprint—as managed grazing is giving way to confined, grain-based feeding—this pattern of development has major drawbacks and this note focuses on those related to animal wastes.[1] In parts of both the developed and developing world, animal wastes have become a leading source of surface and ground water pollution as they are a major vector of unwanted nutrients, and also carry pathogens, antibiotics, hormones, heavy metals, other minerals, and pesticides. Through the release of particulate matter and other air pollutants, they are also a cause of foul odors, haze, acid rain, a loss of soil fertility, and air quality-related disease, while their potent greenhouse gas emissions contribute to climate change.

Looking forward, if the world remains on course to roughly double meat and dairy consumption relative to 2000 levels by mid-century, livestock production will continue to industrialize and expand. Thus faced with the rise and transformation of the livestock subsector, policy makers need to be aware of the following. First, changes in management practices can make a significant difference when it comes to controlling pollution within different livestock systems, and certain technical solutions can be adopted cost-effectively or with public sector support. Industrialization, in this respect, opens new possibilities for monitoring, regulatory control, and the adoption of technology. Second, while demand for animal products reflects diverse sociocultural realities such as food preferences and social signaling (for example, prestige), high levels of consumption are neither desirable for public health or the environment, nor an inevitability.[2] There is room to shape this growing sector in a way that modulates its breadth, its geographic concentration, and its intensity.

Nature and Magnitude of the Problem

Livestock systems occupy roughly one-third of the planet's ice-free terrestrial surface area and, as of 2014, supplied 17 percent of available food calories and accounted for over half of global agricultural GDP. Far from being static, the sector is rapidly gaining ground in the developing world—particularly Asia and Africa—where it is among the fastest growing subsectors of the agricultural economy (see Figure 2).

1 Looking beyond animal wastes, the expansion of livestock production—in both extensive and intensive systems—is the leading cause of deforestation worldwide and a major contributor to land degradation. In Latin America, both grazing and field crops are encroaching into sensitive ecosystems, including the Amazon Forest.

2 From a health perspective, while some studies show that the introduction of animal products into diets can palliate protein and vitamin deficiencies, and others note that animal products provide important nutrients, the consumption of animal products (animal protein, fats, hormones, and so on) is also associated with increased risk of cardiovascular disease, diabetes, and certain leading forms of cancer. For this reason, nutritional guidelines consistently recommend higher intakes of whole, plant-based foods, while some recommend lower intakes of animal-based ones. In addition, livestock products are susceptible to pathogen contamination and can vehicle zoonotic diseases. See multiple citations in references.

This note was written by Emilie Cassou. Full references and acknowledgments are available online.

Box 1. Livestock Sector Overview

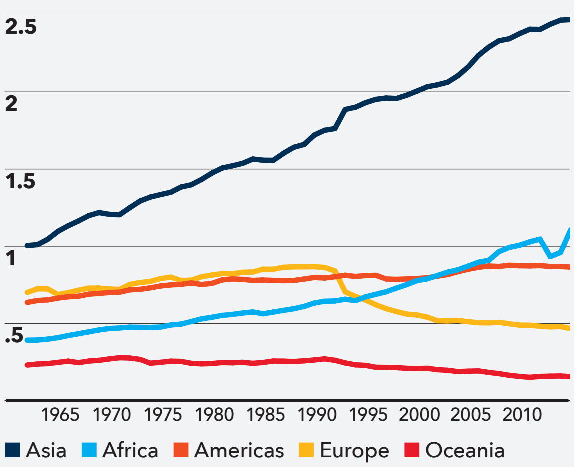
The livestock sector produces a variety of products from domestic, terrestrial animals. Though ovines, bovines, and swine (that is, sheep and goats, cattle and buffalo, and pigs) dominate the sector by far in terms of population size, livestock also include a rapidly rising number of poultry birds, (chickens, ducks, turkeys, geese, and guinea fowl), and large numbers of horses, mules, asses, camels, rabbits, bees, and silkworms among others (see figure 3). The sector's outputs include both food products–mainly meat, dairy, eggs, fats, and honey–and non-food products such as wool, silk, hair, hides, fur, bone, wax, and so forth. Livestock are also used as draught animals and for recreational purposes.

While traditional livestock systems are far from being impact-free, the industrialization of animal agriculture—a phenomenon observed across regions—is a game changer. With it, animal wastes tend to go from being a valued agricultural resource—a bearer of soil fertility—to a costly waste stream and multi-hazard pollutant. Concentration in particular makes it more likely for fecal nutrients to exceed local capacity to safely absorb these, for fecal pathogens to cause disease, and for pesticides and antibiotics to be used preventively to ward off houseflies, other pests, and diseases. The polluting effects of industrialization are usually directly attributable to poor livestock waste management practices such as the flushing of untreated waste or the collection of manure in leaky or open-air lagoons, as well as to operations' geographic siting. In many developing country contexts, animal rearing activity has formed rings around cities, causing major pollution problems by virtue of their geographic concentration and proximity to urban dwellings, even though these operations, taken individually, can be small to mid-size and moderately intensive in nature. From a big picture perspective, industrial livestock systems are contributing to the global imbalance in nitrogen and phosphorus cycling, two domains in which human activity is testing the planet's biogeochemical boundaries.[3]

Impacts

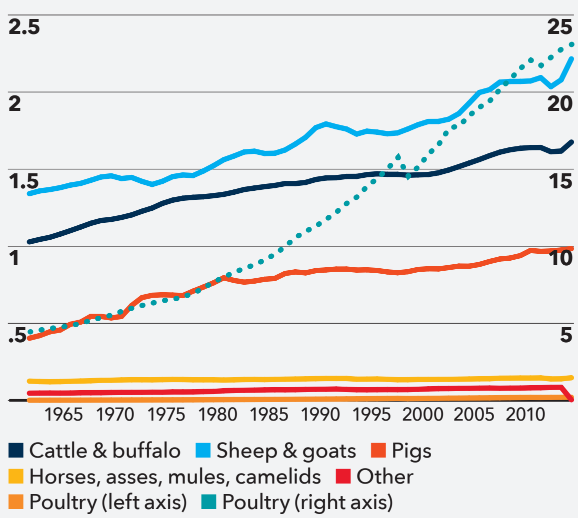
Under current management practices, livestock wastes are contributing—often in high proportion—to water, soil, and air pollution, and concentrated operations are generating especially acute problems in their vicinity. These include the eutrophication of surface waters, the contamination of drinking water, antimicrobial resistance, particulate pollution, and a loss of soil fertility, leading to ecosystem disruption, a loss of farm productivity, heightened food safety risk, and disease. A full 86 percent of global effluent (in kilograms of fecal pollution per year) is attributed to livestock, and in surface waters, the flow—or deposition—of fecal nutrients (mainly

Figure 2: Live Animals by Region, 1961–2014



Source: Based on FAOSTAT data.

Figure 3: Live Animals by Type, 1961–2014



3 The cycling of phosphorus occurs on a geological timescale, such that the mining of phosphorus—80 percent of which is used to make fertilizer—is drawing down known reserves of the mineral and contributing, through accumulation in aquatic environments, to widespread eutrophication. In the case of nitrogen, organic waste management practices that inhibit plant and animal nitrogen from feeding their regrowth, and the addition of nitrogen into the food chain in the form of synthetic fertilizer, are energy-intensive and sources of both air and water pollution.

ammonia, organic nitrogen, and phosphorus) is a major cause of eutrophication. This phenomenon can lead to the spread of toxic algae and hypoxic zones in which nothing can live. In China, where these are growing problems, 38 percent of nitrogen and 56 percent of phosphorus in surface waters are attributable to livestock. In the United States, livestock manure is second only to fertilizer use as a source of Mississippi Basin nitrogen, which (with phosphorus) is fueling the dead zone that now stretches across 16,800 km^2 of the Gulf of Mexico. Livestock manure and poultry litter account for about half the nutrients entering the Chesapeake Bay, a major U.S. estuary. In addition to harming human health and biodiversity, eutrophication can prove costly to the utility, beverage, tourism, and fishing industries.

The improper management of animal wastes also bears responsibility for the contamination of drinking water with nitrates, pathogens, hormones, and sometimes pesticides. These can also taint food products directly, affecting food safety and detracting from agricultural trade. Pathogens and zoonotic diseases such as E.coli, listeria, salmonella, giardia, influenza, foot and mouth disease, bovine spongiform encephalopathy, and others, are known for their acute and sometimes lethal effects. Other pathogens and growth hormones, by contrast, can provoke cancers, endocrine disruption, and other ailments with a late onset or chronic pattern that can sometimes blur the agricultural origins of these. Pesticide effects fall into both categories. Meanwhile, the prophylactic administration of antibiotics to animals held in tight and sometimes unsanitary quarters, particularly when practiced on a wide scale, paves the way for hazardous and costly antibiotic resistance. In the United States, livestock consume some 87 percent of antibiotics. In 2016, the United Nations recognized antimicrobial resistance as one of the biggest threats to global health, and elevated the issue as it has HIV, Ebola, and non-communicable diseases in the past.

Turning to air pollution, animal wastes, when they are stirred up or decompose—particularly when they are concentrated—release a range of noxious gases and fine particles (or precursors to these) that do more than cause unpleasant smells and haze. Manure accounts, for example, for around one-third of global emissions of ammonia, a precursor to acid rain and particulate pollution. And though animal wastes are not their primary cause, both have clear links to respiratory, cardiovascular, and other forms of disease, accelerate building and infrastructure corrosion, and harm soil fertility. Manure management also results in significant emissions of nitrous oxide and methane, powerful greenhouse gases linked to climate change. Particulate pollution, for its part, can accelerate near-term and local climate change.

From a crop farming perspective, the concentration of manure sources is creating problems related to both its overuse and underuse. Although manure is a natural

Figure 4: Backyard Pigs Amidst Homes in Peru

Source: © Pilar Olivares/Reuters.
Note: Pamplona Alta shantytown in Lima, Peru, on September 30, 2011.

fertilizer, its over-application leads to soil acidification, as do its gaseous contributions to acid rain. Together with the build-up of heavy metals used in feed, its excessive use or mismanagement can lessen land fertility (increasing fertilizer use and pollution). Manure being heavy and costly to transport to increasingly distant crop fields, however, it is progressively being foregone as a source of soil organic matter, even as soil—a virtually nonrenewable resource—is being mined unsustainably.

Drivers

The emergence of livestock waste as a pollution problem in a widening part of the world is closely intertwined with urbanization, income growth, and the rising demand for animal products that has accompanied this development pattern. Industry has effectively risen to the task of delivering ever-larger quantities of (affordable) animal-based foods to urban dwellers by concentrating geographically around cities and industrializing in order to realize economies of scale and minimize transportation costs. Indeed, transportation costs loom large in an industry that needs to move bulky feed inputs and highly perishable products—often relying on underdeveloped or aging transportation infrastructure in emerging economy contexts. The weak enforcement or absence of regulations pertaining to farm siting, intensity, or waste management, meanwhile, have generally allowed private investment in this growing subsector to discount the costs of negative, pollution-related externalities. Manure management can represent a significant share of operating costs (for example, 10–15 percent in Northern Europe), and improving these from an environmental perspective can weigh on producers' bottom line.

What Can Be Done?

While the industrialization of livestock operations is creating and magnifying certain waste-related pollution problems, it is also opening new avenues for pollution control. Industrial systems, particularly as they increase in size and consolidate, are more easily traced and controlled than small, dispersed, and informal (that is, backyard) activities—though their influence over regulators may also grow. And from technical and financial standpoints, they may have greater options and capacity when it comes to adopting mitigation technology (or even improving efficiency). This is namely due to economies of scale in manure management.

One path to mitigation involves **the pursuit of livestock system efficiency** within concentrated systems. This may mean selecting breeds, feeding practices, housing conditions, or cleaning protocols that maximize feed conversion efficiency and reduce effluent per unit of milk or meat. This approach can marginally improve the environmental performance of existing industrial systems and align well with business motives. It can be supported through investments in research, extension, and infrastructure, and indirectly through water pricing or other incentives that encourage resource-use efficiency. Such policies can be nearsighted, however, if by encouraging further concentration they increase overall pollution.

Still within industrial systems, a second approach involves **the adoption of pollution control practices and technologies** and the phase-out of those which are most polluting. Examples of mitigation technologies include the use of buffer crops or holding ponds to absorb nutrients and filter out water pollutants; the adoption of lagoon covers to contain volatile compounds; anaerobic digestion with methane capture and use; ammonia recovery and sale as fertilizer; and biological conversion of nitrogen to less reactive forms. Other measures include changes in feed that reduce nitrogen and heavy metals in manure, and the construction of animal quarters that require less antibiotics to control outbreaks. This approach generally requires site-appropriate technologies to be developed and absorbed into operations.

Meanwhile, their adoption can be stimulated by being required—explicitly or implicitly—by such things as **licensing, market access, certification and labeling, taxation or subsidies, and financing (for example, insurance, credit, and guarantees)**. Taxing the disposal of concentrated manure, its emissions, or other externalities, for example, can encourage farms to minimize these voluntarily; so can paying farms for these outcomes directly. This can be achieved by purchasing verified emission reductions (for example, methane), or paying a price premium for a labeled product (for example, growth hormone- and antibiotics-free). Similar outcomes can be expected if producers are legally or commercially barred from operating, activating insurance, or accessing given markets without adopting best available control technologies or performing in alignment with these. The Netherlands, for example, imposes limits on the amount of nutrients farms may generate and spread, and the number of heads they raise, per hectare of land. To limit ammonia emissions, it also requires farms to inject manure into the soil when applied to grasslands or maize fields. Subsidized loans and credit guarantees can encourage producers to upgrade their on-farm technology, as can performance-based incentives that facilitate maintenance and upkeep. For multiple years, the Dutch government financially supported farmers to invest in manure storage facilities and other waste disposal technologies. It also established a national manure bank to transport excess manure to crop farms where it could be used more safely.

The removal of counterproductive incentives, such as energy,[4] production and other subsidies which disproportionately benefit the most intensive or polluting systems, can be an another effective strategy in some cases. In many contexts, improvements can also come from better enforcement of existing standards, be they mandated or voluntary. Publicizing requirements and incentives can provide an opportunity to raise farmers' awareness of different technologies, management practices, and their impacts. These strategies are more likely to be effective, however, if they are designed with and around farmers' perceptions, constraints, and needs from the beginning. This can be seen in the relative success of Dutch flagship farms—real farms that exceed average environmental performance—which have been used to demonstrate what can be achieved and calibrate national environmental requirements.

A third and more transformational path to mitigation is based on changing the geographic distribution and concentration of animal agriculture, or in other words, engaging in spatial planning to use landscape resources more favorably. Livestock operations can be distanced from cities and fragile ecosystems, sited closer to plant agriculture (though this can lead to cross-contamination risk), dispersed in space, and limited in size or intensity—so long as this does not cause them to further encroach on natural landscapes. In this case, land-use planning and regulations including zoning rules can be put to task, alongside economic incentives and infrastructure investments. In Thailand, for instance, the dissuasive taxation of operations within a 100 km radius of Bangkok helped to spatially disperse these, as did the construction of a new slaughterhouse a few hundred kilometers outside the city. Though less direct, investments in road and logistics infrastructure can enable

4 Incentives for biogas energy, however, can act as an incentive for improved waste management.

more distant livestock farms to supply cities.

A complementary path to mitigation involves curbing production growth by **curbing the demand for livestock products** in food-secure contexts. This can be pursued through interventions focused on, *inter alia*:

- Changing social norms and preferences (e.g., through cultural and role model strategies such as the enlistment of celebrity Arnold Schwarzenegger to dissuade meat consumption in China,[5] U.S. "checkoff" program-style food marketing campaigns, social marketing);
- Raising consumer and medical professional awareness (e.g., broadcasting of dietary health guidance by government, insurance companies, health education non-profits);
- Habitual behavior (e.g., employer wellness programs, cafeteria choice architecture and other food environment changes studied by Cornell University's Brian Wansink, "Meatless Monday"-style campaigns, interventions to increase availability of and consumer access to fresh fruits and vegetables); and
- Economic incentives (e.g., food-related taxes and subsidies, other interventions that influence food prices, food safety nets and income support programs—or insurance and retailer reward programs—that privilege specific food spending patterns).

Growing evidence surrounding the health benefits and environmental co-benefits of whole food, plant-based diets are increasingly being incorporated into public dietary guidance (for example, in Brazil, the United States, and the Netherlands). In the United States, this has stimulated flows of venture capital into the development of cell-cultured meat and plant-based meat substitutes that are able to gain consumer acceptance (see figure 5). Regardless of the approach, robust monitoring of livestock systems practices, its pollutants, and their impacts are the starting point for mitigating these.

Figure 5: Venture Funding is Flowing into the Development of Meat Alternatives

Source: © Beyond Meat.

5 http://wildaid.org/news/james-cameron-arnold-schwarzenegger-speak-out-reduced-meat-consumption.