Exhibit B

DOUG GURIAN-SHERMAN, UNION OF CONCERNED SCIENTISTS, CAFOS UNCOVERED: THE UNTOLD COST OF CONFINED ANIMAL FEEDING OPERATIONS (Apr. 2008)

CAFOs Uncovered

The Untold Costs of Confined Animal Feeding Operations

Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

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The Untold Costs of Confined Animal Feeding Operations

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UNION OF CONCERNED SCIENTISTS
APRIL 2008

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The goal of the UCS Food and Environment Program is a food system that encourages innovative and environmentally sustainable ways to produce high-quality, safe, and affordable food, while ensuring that citizens have a voice in how their food is grown.

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EXECUTIVE SUMMARY

The livestock industry (including poultry) is vital to our national economy, supplying meat, milk, eggs, and other animal products and providing meaningful employment in rural communities. Until recently, food animal production was integrated with crop production in a balanced way that was generally beneficial to farmers and society as a whole. But livestock production has undergone a transformation in which a small number of very large CAFOs (confined animal feeding operations) predominate. These CAFOs have imposed significant—but largely unaccounted for—costs on taxpayers and communities throughout the United States.

CAFOs are characterized by large numbers of animals crowded into a confined space—an unnatural and unhealthy condition that concentrates too much manure in too small an area. Many of the costly problems caused by CAFOs can be attributed to the storage and disposal of this manure and the overuse of antibiotics in livestock to stave off disease.

The predominance of CAFOs is not the inevitable result of market forces; it has been fostered by misguided public policy. Alternative production methods can be economically efficient and technologically sophisticated, and can deliver abundant animal products while avoiding most of the problems caused by CAFOs. However, these alternatives are at a competitive disadvantage because CAFOs have reduced their costs through subsidies that come at the public's expense, including (until very recently) low-cost feed. CAFOs have also benefited from taxpayer-supported pollution cleanup programs and technological "fixes" that may be counterproductive, such as the overuse of antibiotics. And by shifting the risks of their production methods onto the public, CAFOs avoid the costs of the harm they cause.

In addition, the fact that the meat processing industry is dominated by a few large and economically powerful companies makes it difficult for alternative producers to slaughter their animals and get their products to market. This excessive market concentration is facilitated by lax enforcement of laws intended to prevent anti-competitive practices.

By describing several of the subsidies and other often hidden costs of CAFOs that are imposed on society (referred to as externalized costs or "externalities"), this report attempts to clarify the real price we pay—and can no longer afford—for this harmful system. These externalities are associated with the damage caused by water and air pollution (along with cleanup and prevention), the costs borne by rural communities (e.g., lower property values), and the costs associated with excessive antibiotic use (e.g., harder-to-treat human diseases). Subsidies have included payments to grain farmers that historically supported unrealistically low animal feed prices, and payments to CAFOs to prevent water pollution.

The United States can do better. In fact, there is a new and growing movement among U.S. farmers to produce food efficiently by working with nature rather than against it. More and more meat and dairy farmers are successfully shifting away from massive, overcrowded CAFOs in favor of modern production practices. We offer a number of policy recommendations that would level the playing field for these smart, sophisticated alternatives by reducing CAFO subsidies and requiring CAFOs to pay a fair share of their costs.

CAFOs—Too Big for Our Own Good

Most of the problems caused by CAFOs result from their excessive size and crowded conditions. CAFOs contain at least 1,000 large animals such as beef cows, or tens of thousands of smaller animals such as chickens, and many are much larger—with tens of thousands of beef cows or hogs, and hundreds of thousands of chickens.

The problems that arise from excessive size and density (e.g., air and water pollution from manure, overuse of antibiotics) are exacerbated by the parallel trend of geographic concentration, whereby CAFOs for particular types of livestock have become concentrated in certain parts of the country. For example, large numbers of swine CAFOs are now located in Iowa and North Carolina, dairy CAFOs in California, and broiler chicken CAFOs in Arkansas and Georgia.

We need to be concerned about these excessively large feeding operations because they have become the predominant means of producing meat and dairy products in this country over the past few decades. Although they comprise only about 5 percent of all U.S. animal operations, CAFOs now produce more than 50 percent of our food animals. They also produce about 65 percent of the manure from U.S. animal operations, or about 300 million tons per year—more than double the amount generated by this country's entire human population. For the purposes of this report, there are approximately 9,900 U.S. CAFOs producing hogs, dairy cows, beef cows, broiler chickens, or laying hens.

Better Options Exist

CAFOs do not represent the only way of ensuring the availability of food at reasonable prices. Recent studies by the U.S. Department of Agriculture (USDA) show that almost 40 percent of medium-sized animal feeding operations are about as cost-effective as the average large hog CAFO, and many other studies have provided similar results. Medium-sized and smaller operations also avoid or reduce many of the external costs that stem from CAFOs.

If CAFOs are not appreciably more efficient than small and mid-sized operations, why are they supplanting smaller farms? The answers lie largely in farm policies that have favored large operations. CAFOs have relied on cheap inputs (water, energy, and especially feed) to support the high animal densities that offset these operations' high fixed costs (such as buildings). Feed accounts for about 60 percent of the costs of producing hogs and chickens and is also an important cost for dairy and beef cows, and federal policies have encouraged the production of inexpensive grain that benefits CAFOs.

Perhaps even more important has been the concentration of market power in the processing industry upon which animal farmers depend. This concentration allows meat processors to exert considerable economic control over livestock producers, often in the form of production contracts and animal ownership. The resulting "captive supply" can limit market access for independent smaller producers, since the large majority of livestock are either owned by processors or acquired under contract—and processors typically do not contract with smaller producers. Federal government watchdogs have stated that the agency responsible for ensuring that markets function properly for smaller producers is not up to the task.

Hoop barns and smart pasture operations

Although there is evidence that confinement operations smaller than CAFOs can be cost-effective and produce ample animal products, studies also suggest that sophisticated alternative means of producing animal products hold even greater promise. For example, hog hoop barns, which are healthier for the animals and much smaller than CAFOs, can produce comparable or even higher profits per unit at close to the same price.

Research in Iowa (the major hog-producing state) has also found that raising hogs on pasture may produce animals at a lower cost than CAFOs. Other studies have shown that "smart" pasture operations such as managed intensive rotational grazing (MIRG) can produce milk at a cost similar to confined dairy operations, but with added environmental benefits.

Properly managed pastures, for example, require less maintenance and energy than the feed crops (such as corn and soybeans) on which CAFOs rely. Healthy pastures are also less susceptible to erosion, can capture more heat-trapping carbon dioxide than feed crops, and absorb more of the nutrients applied to them, thereby contributing less to water pollution. Furthermore, the manure deposited by animals onto pasture produces about six to nine times less volatilized ammonia—an important air pollutant—than surface-applied manure from CAFOs.

The Many Hidden Costs of CAFOs

Feed grain subsidies

CAFOs have been indirectly supported by huge taxpayer-funded subsidies that compensated grain farmers for excessively low prices. Because feed makes up such a large part of CAFOs' costs, lower grain prices can have a big impact on the total cost of production.

Over the past few decades, federal farm bills have progressively moved toward policies that let grain prices fall—often below the cost of production—and compensated farmers for much of the difference. Without such subsidies, grain farmers would not have been able to continue selling their product at such low prices, which benefit CAFOs.

This so-called indirect subsidy to hog and broiler CAFOs amounts to hundreds of millions of dollars per year. When extended to include the dairy, beef, and egg sectors, low-cost grain was worth a total of almost $35 billion to CAFOs from 1996 to 2005, or almost $4 billion per year.

Farms that raise animals on pasture and those that grow their own grain do not usually receive as much of a subsidy as the CAFO industry. Pastures themselves are not subsidized at all, so the sustenance that livestock derive from pastures receives no government support.

During the past few years, grain prices have approached or even risen above the cost of production. Under these conditions, CAFOs no longer benefit from grain subsidies, but the problem of increasing concentration in the processing industry persists. This may make it difficult for CAFO alternatives to gain substantial market share without changes in U.S. policy.

Pollution prevention subsidies

Another farm bill program, the Environmental Quality Incentives Program (EQIP), provides CAFOs with another important subsidy. Beginning in 2002, CAFOs were no longer explicitly excluded from EQIP funding (which was originally intended to help smaller farming operations reduce their pollution), and the maximum funding level for individual projects has increased dramatically to $450,000. Several criteria used to prioritize projects such as manure disposal actually favor CAFOs over pasture-based operations. Extrapolation from the available data suggests that U.S. CAFOs may have benefited from about $125 million in EQIP subsidies in 2007.

State-level EQIP projects can also favor confinement operations. California, the state with the most dairy CAFOs, spends $10 million of its allocated EQIP subsidies each year to address dairy manure issues. Georgia, the state with the most broiler chicken CAFOs, uses EQIP funds to support the transportation of chicken manure from that part of the state where broiler CAFOs are primarily located to areas with enough cropland to accept this manure. The distance involved would often not be economically feasible without subsidization.

Water pollution from manure

Disposal of CAFO manure on an insufficient amount of land results in the runoff and leaching of waste into surface and groundwater, which has contaminated drinking water in many rural areas, and the volatilization of ammonia (i.e., the transfer of this substance from manure into the atmosphere). Several manure lagoons have also experienced catastrophic failures, sending tens of millions of gallons of raw manure into streams and estuaries and killing millions of fish. Smaller but more numerous spills cause substantial losses as well.

Remediation of the leaching under dairy and hog CAFOs in Kansas has been projected to cost taxpayers $56 million—and Kansas is not one of the country's top dairy- or hog-producing states. Based on these data, a rough estimate of the total cost of cleaning up the soil under U.S. hog and dairy CAFOs could approach $4.1 billion.

The two primary pollutants from manure, nitrogen and phosphorus, can cause eutrophication (the proliferation and subsequent death of aquatic plant life that robs freshwater and marine environments of the oxygen that fish and many other aquatic organisms need to survive). For example, runoff and leaching from animal sources including CAFOs is believed to contribute about 15 percent of the nutrient pollution that reaches the Gulf of Mexico, where a large "dead zone"—devoid of fish and commercially important seafood such as shrimp—has developed. CAFO manure also contributes to similar dead zones in the Chesapeake Bay (another important source of fish and shellfish) and other important estuaries along the East Coast. The Chesapeake Bay's blue crab industry, which had a dockside value of about $52 million in 2002, has declined drastically in recent years along with other important catches such as striped bass, partly due to the decline in water quality caused in part by CAFOs.

Although it is difficult to account for all of the social benefits (such as fisheries and drinking water) lost due to CAFO pollution, it is reasonable to assume the losses are substantial. One indirect way of estimating such costs is to calculate the cost of preventing some or all of the pollution caused by CAFOs. The USDA, for example, has determined how much it would cost to transport manure to enough crop fields or pastures to comply with new Clean Water Act rules governing the distribution of manure on fields. Based on a nitrogen-limited standard and realistic estimates of the rate at which farms will accept manure, the annual cost of adequate manure distribution in the Chesapeake Bay region alone would total $134 million per year. Using a phosphorus-limited standard and an unrealistically high manure acceptance rate, the cost would be $153 million annually. Considering that net returns for the animal industry in this region amount to $313 million, compliance with such standards could comprise between 43 and 49 percent of net returns.

Air pollution from manure

Airborne ammonia is a respiratory irritant and can combine with other air pollutants to form fine particulate matter that can cause respiratory disease. And because ammonia is also re-deposited onto the ground, mostly within the region from which it originates, ammonia nitrogen deposited on soils that have evolved under low-nitrogen conditions may reduce biodiversity and find its way into water sources. Ammonium ion deposition also contributes to the acidification of some forest soils.

Animal agriculture is the major contributor of ammonia to the atmosphere, and the substantial majority of this ammonia likely comes from confinement operations, since manure deposited by livestock on pasture contributes proportionately much less ammonia to the atmosphere than manure from CAFOs. Up to 70 percent of the nitrogen in CAFO manure can be lost to the atmosphere depending on manure storage and field application measures. Over the past several decades, the amount of airborne ammonia deposition in many areas of the United States with large numbers of CAFOs has been rising dramatically, and may often exceed the capacity of forests and other environments to utilize it without harm.

The USDA has estimated the total U.S. cost of controlling air and water pollution through manure distribution onto farmland—in quantities that comply with the Clean Water Act—at $1.16 billion per year under high manure acceptance rates. However, the standard applied in this calculation would only reduce airborne ammonia pollution from CAFOs by about 40 percent. And if lower, more realistic manure acceptance rates were used, the manure would have to be transported unacceptable distances. Therefore, proper manure disposal from CAFOs at current farmer acceptance rates would in all likelihood exceed these values considerably.

Harm to rural communities

CAFOs are sited in rural communities that bear the brunt of the harm caused by CAFOs. This harm includes the frequent presence of foul odors and water contaminated by nitrogen and pathogens, as well as higher rates of respiratory and other diseases compared with rural areas that are not located near CAFOs.

One study determined that each CAFO in Missouri has lowered property values in its surrounding communities by an average total of $2.68 million. It is not possible to accurately extrapolate this value nationally due to the many differences between localities, but as a very rough indication of the magnitude of these costs, multiplying by 9,900 (the total number of U.S. CAFOs as defined for this report) would yield a loss of about $26 billion.

Antibiotic-resistant pathogens

Estimates have suggested that considerably greater amounts of antibiotics are used for livestock production than for the treatment of human disease in the United States. The massive use of antibiotics in CAFOs, especially for non-therapeutic purposes such as growth promotion, contributes to the development of antibiotic-resistant pathogens that are more difficult to treat.

Many of the bacteria found on livestock (such as *Salmonella, Escherichia coli,* and *Campylobacter*) can cause food-borne diseases in humans. Furthermore, recent evidence strongly suggests that some methicillin-resistant *Staphylococcus aureus* (MRSA) and uropathogenic *E. coli* infections may also be caused by animal sources. These pathogens collectively cause tens of millions of infections and many thousands of hospitalizations and deaths every year.

The costs associated with *Salmonella* alone have been estimated at about $2.5 billion per year—about 88 percent of which is related to premature deaths. Because an appreciable degree of antibiotic resistance in animal-associated pathogens is likely due to the overuse of antibiotics in CAFOs, the resulting costs are likely to be high. Eliminating the use of antibiotics for growth promotion (the majority of which occurs on CAFOs) could cost CAFOs between $1.5 billion and $3 billion per year.

Conclusions and Recommendations

The costs we pay as a society to support CAFOs—in the form of taxpayer subsidies, pollution, harm to rural communities, and poorer public health—is much too high (Table ES-1, p. 6). For example, conservative estimates of grain subsidies and manure distribution alone suggest that CAFOs would have incurred at least $5 billion in extra production costs per year if these expenses were not shifted onto the public. The figure would undoubtedly be much higher if truly adequate manure distribution was required. Although we do not have good national data for other costs quantified in Table ES-1, and some that have not been quantified (such as water and energy use and water purification costs), they could amount to billions of dollars more per year.

Technological solutions to specific CAFO problems have been proposed, such as feed formulations that would reduce manure nitrogen, lagoon covers that would reduce atmospheric ammonia, and "biogas" capture and production that would reduce methane emissions from manure, but these are only partial solutions and would generally add to the cost of production. None of these technologies solve antibiotic resistance, loss of rural income, or the ethical treatment of animals. By comparison, sophisticated CAFO alternatives can provide plentiful animal products at similar prices, but with much fewer of the problems caused by CAFOs.

The bottom line is that society is currently propping up an undesirable form of animal agriculture with enormous subsidies and a lack of accountability for its externalized costs. Once we appreciate the role these subsidies—along with government

Table ES-1. **CAFO Costs Underwritten by U.S. Taxpayers**[1]

	Cost of Pollution or Pollution Avoidance	Cost of Subsidy
Cost to Distribute and Apply Manure to Fields	$1.16 billion/year[2]	
Reduction in Property Values	$26 billion (total loss)[3]	
Public Health Costs from Overuse of Antibiotics in Livestock	$1.5 billion – $3.0 billion/year[4]	
Remediation of Leakage from Manure Storage Facilities (Swine and Dairy)	$4.1 billion (total cost)[5]	
Grain Subsidies for Livestock Feed		$3.86 billion/year[6]
EQIP Subsidy		$100 million – $125 million[7]

[1] Numbers are rough estimates of current or recent costs and are presented only to indicate the magnitude of these costs. See the text for details.
[2] SOURCE: Aillery et al. 2005.
[3] SOURCE: Mubarak, Johnson, and Miller 1999. Extrapolation from Missouri data based on national CAFO numbers.
[4] SOURCE: NRC 1999. Extrapolation based on U.S. population of 300 million.
[5] SOURCE: Volland, Zupancic, and Chappelle 2003. Extrapolation from Kansas data based on national swine and dairy CAFO numbers.
[6] SOURCE: Starmer 2007. Data averaged over the period 1996–2005.
[7] SOURCE: NRCS 2003. Calculations based on NRCS projections for 2007 (yearly values increase from a low in 2002 to a high in 2007).

policies—play in shaping the way our food animals are raised, we can also see the environmental, health, and economic benefits to be gained from redirecting agriculture toward smart pasture operations and other desirable alternatives.

Public policies that support CAFOs at the expense of such alternatives should be eliminated, and policies that support these alternatives should be implemented. Needed actions include:

- Strict and vigorous enforcement of antitrust and anti-competitive practice laws under the Packers and Stockyards Act (which cover captive supply, transparency of contracts, and access to open markets)
- Strong enforcement of the Clean Water Act as it pertains to CAFOs, including improved oversight at the state level or the takeover of responsibilities currently delegated to the states for approving and monitoring and enforcement of National Pollution Discharge Elimination System (NPDES) permits; improvements could include more inspectors and inspections, better monitoring of manure-handling practices, and measurement of pollution prevention practices
- Development of new regulations under the Clean Air Act that would reduce emissions of ammonia and other air pollutants from CAFOs, and ensure that CAFO operators cannot avoid such regulations by encouraging ammonia volatilization
- Continued monitoring and reporting of ammonia and hydrogen sulfide emissions as required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly referred to as the "Superfund") and the Emergency Planning and Community Right-to-Know Act (EPCRA)
- Replacement of farm bill commodity crop subsidies with subsidies that strengthen conservation programs and support prices when supplies are high (rather than allowing prices to fall below the cost of production)
- Reduction of the current $450,000 EQIP project cap to levels appropriate to smaller farms, with a focus on support for sound animal farming practices
- Revision of slaughterhouse regulations to facilitate larger numbers of smaller processors, including the elimination of requirements not

appropriate to smaller facilities, combined with public health measures such as providing adequate numbers of federal inspectors or empowering and training state inspectors

- Substantial funding for research to improve alternative animal production methods (especially pasture-based) that are beneficial to the environment, public health, and rural communities

INTRODUCTION

Although our milk cartons still portray contented cows and chickens on pastures in front of bright red barns, these bucolic scenes are far from the current reality in which food animals are produced. Food animals today are predominantly raised in very large facilities called CAFOs (confined animal feeding operations), which contain thousands of animals and are geographically concentrated in several regions of the country. Although consumers pay a relatively low price for meat, milk, and eggs produced in CAFOs, society in general pays a high price for such products in the form of taxpayer subsidies and damage to the environment, public health, and rural communities. This report examines some of the often hidden costs of CAFOs to arrive at a meaningful accounting of their true costs.

The U.S. Environmental Protection Agency (EPA) estimates that there are approximately 15,500 CAFOs in the United States, as defined by Clean Water Act regulations (EPA 2003), including about 9,900 large CAFOs containing the types of animals that are the focus of this report[1] (EPA 2002). Although large CAFOs make up only 5 percent of all animal feeding operations (AFOs), they contain 50 percent of all animals and produce 65 percent of livestock[2] manure (Ribaudo et al. 2003).

The large numbers of animals in CAFOs produce mountains of waste—more than 300 million tons per year, or twice the amount produced by the entire human population of the United States (EPA 2003). Unlike the majority of human waste, however, livestock waste is not treated to reduce pollutants and pathogens, but is applied untreated to land and allowed to pollute the air and water. Animal manure is often temporarily stored in facilities such as pits or "lagoons," but instead of frogs, fish, and water lilies, these lagoons hold foul-smelling liquid waste. Typically, the waste from CAFOs is ultimately applied to nearby crop or grass fields in amounts that may not be fully absorbed by the land.

Because CAFOs contain many animals in a relatively small area, the waste they produce becomes a major disposal problem unless ample cropland is available nearby. Unfortunately, such cropland is often too distant to be accessed without considerable expense. And although manure is intrinsically valuable as fertilizer if applied to crops, it also represents an important source of pollution if its components make their way into our air and water. This pollution contributes to large areas of oxygen-depleted coastal waters that are now devoid of fish (as in the Chesapeake Bay and Gulf of Mexico), and exacerbates the spread of pathogens and disease. Spills from manure storage facilities into streams and rivers have killed millions of fish and increased water purification costs for downstream communities. Furthermore, the odor from CAFOs has hampered life and lowered property values for nearby homeowners.

The Rise of the CAFO

The increasing size of animal farms and the geographic concentration of CAFOs have not always been part of the picture of animal farming in the

1 The number of CAFOs as defined by the EPA includes some medium-sized operations that are not the primary focus of this report. The number of large CAFOs to which we refer excludes operations that produce sheep and horses exclusively (which are not covered in this report).

2 The term "livestock" is often used to refer to large farm animals such as cattle and pigs, but for the sake of simplicity, this report also includes poultry under the definition of livestock.

United States. Poultry industry concentration has been increasing for more than 50 years, but the concentration of pig and cattle production has only increased dramatically in the last few decades. Overall, the number of animals on small to medium-sized farms decreased substantially between 1982 and 1997, while animals on CAFOs increased by 88 percent (Kellogg et al. 2000). In addition, many animal farmers have ceased being independent and diversified producers of crops and livestock, and have become contract farmers for huge animal-product processors.

What accounts for this enormous change in the way we raise livestock? One might assume that the transformation of animal agriculture in the United States and elsewhere reflects a process of increasing modernization and efficiency, and that the relatively low prices we currently pay for meat, milk, and eggs could only be maintained by continuing to raise animals in such systems.

This assumption is, at best, a half-truth. As will be seen in this report, the existence of CAFOs can be attributed only in part to efficiencies of scale and technological advances that reduce production costs. When examined in detail, economies of scale largely disappear for CAFOs. A more important factor is processor-driven vertical integration and coordination,[3] and the resulting accumulation of market power in the hands of large processors.

This trend is facilitated by a wide array of subsidies—both direct and indirect—paid for by the public. For example, taxpayers have supported CAFOs through crop subsidies that most of the public is unaware of and would not connect to animal production. And because CAFOs are not held accountable for the environmental and health damage caused by their pollution (leaving the public to foot the bill), CAFOs are essentially being subsidized in this regard as well. A full accounting of the cost of animal products reveals that CAFOs are anything but efficient—consumers are actually paying a very high price for this type of production.

The history and highly subsidized nature of CAFOs suggest that these operations are not an inevitable and essential form of animal agriculture, but the result of specific government policies. Although CAFOs are entrenched, other systems can also produce plentiful and—from a perspective in which all the costs are taken into account—reasonably priced meat, milk, and eggs.

Considering the Alternatives

The purpose of this report is to illuminate some of the important hidden costs of CAFOs. By doing so we can make a more informed decision about whether this form of animal agriculture represents the path to a sustainable way of producing livestock, or a temporary diversion from that path.

The scope of the report is domestic rather than international, and is not intended to be comprehensive in terms of the subsidies discussed. We have looked at three major categories: direct taxpayer subsidies (payments made directly to CAFOs for actions they take to reduce pollution, such as manure transport to crop fields), indirect taxpayer subsidies (payments made to others, such as farmers who produce grain for animal feed, thereby lowering CAFOs' operating costs), and the "virtual" subsidies represented by the costs society pays for environmental and health damage caused by CAFOs.

We were unable to quantify costs that CAFOs impose on society, such as air pollution, except in a preliminary way, but have included numbers where we could find them. Some data are better than others, and we focused most of our attention on several calculations at the national level because of their larger scale than local subsidies. Nevertheless, local and state subsidies may add up to large cumulative national costs. Finding enough of these costs to

3 Vertical integration is the ownership by a single company of several stages of production, such as the production, processing, and marketing of chicken meat. Vertical coordination is the control by a single company of several stages of production (for example, through the production contracts that processors often require of meat producers).

draw precise conclusions was beyond the scope of this report, but even when limited to the available national data, a glimpse of the large scale of CAFO subsidies is possible.

Alternatives to CAFOs are many and diverse. They include smaller feeding operations; pasture-based cattle, swine, and poultry; and swine hoop barns. Even these alternatives receive some subsidies; in particular, systems that use feed grain may have received some of the indirect grain subsidies that CAFOs have received. However, some alternatives have not received these subsidies, and most have received proportionately less than CAFOs. Alternatives do not receive several important direct subsidies (e.g., for manure transport), and they do not produce the degree of water pollution, air pollution, antibiotic-resistant organisms, health costs, or harm to rural communities that CAFOs do, thus greatly reducing the costs the public must bear.

Depriving CAFOs of their subsidies could help level the playing field, but would not necessarily ensure the success of alternative systems. In many ways subsidies are appropriate in agriculture—provided the public gets the desired benefits in return for its investment.

Chapter 1

PRODUCTION COSTS OF CAFOs AND ALTERNATIVE SYSTEMS

CAFOs are distinguished from other ways of raising livestock by their size, high-density confinement of livestock, and grain-based diet, which requires bringing feed to the animals rather than allowing the animals to graze or otherwise seek their food. Other ways of raising farm animals may include some of the features of CAFOs, such as a predominantly grain-based diet or some degree of confinement, but CAFOs have all of these features.

CAFOs are primarily associated with the production stages of livestock. For example, beef cattle enter CAFOs after weaning and early growth, and remain until they are ready for slaughter. The earlier stages of beef cattle production, so-called cow-calf operations, often involve much smaller numbers of cattle than CAFOs and occur on widely dispersed range or pasture. On the other hand, broiler chickens typically enter CAFOs within a few days of hatching.

Definitions of CAFOs differ in terms of the minimum number of animals a facility has on site. This report uses the U.S. Environmental Protection Agency (EPA) definition, which considers 700 dairy and 1,000 beef cows as the lower limit for cattle CAFOs (EPA 2003). Chicken CAFO sizes depend on the waste system and product: 30,000 broilers for wet-manure systems, 125,000 broilers for dry-litter[4] systems, and 82,000 laying hens for egg-producing operations. For hog-finishing operations, the lower limit is 2,500 hogs.[5]

The EPA definition has been criticized for lack of equivalence in manure production for the different animal types. However, the EPA uses these thresholds in its regulatory programs under the Clean Water Act, and other agencies including the U.S. Department of Agriculture (USDA) also use them in their calculations. Data and analyses by the EPA and USDA are of major importance in this report, and therefore the EPA definition is convenient for these purposes. It should be kept in mind, however, that cited literature may use other definitions.

Animal feeding operations (AFOs) that confine animals at a high density but are smaller than CAFOs are called small or medium-sized AFOs. Other operations such as hoop barns[6] for pigs (Gegner 2004; Honeyman and Harmon 2003) generally confine animals to a main building, but at a lower density and with more freedom of movement than hog CAFOs. The high geographic clustering of many CAFOs is also an important feature of the system that dominates today's agriculture.

Problems Associated with CAFOs

The size, density, and geographic clustering of CAFOs pose several important problems. First, putting large numbers of animals together in a relatively small area produces a huge amount of manure. The storage and ultimate disposal of this manure can present environmental and health challenges.

The most feasible and cheapest means of manure disposal is to apply it to crop fields or pastures. Because manure from CAFOs is very heavy,

4 Birds, unlike mammals, do not produce urine that is primarily water; some poultry operations therefore produce "litter" that has much lower water content than manure from pigs and cattle. It is often disposed of by spreading on fields.
5 The EPA uses the term animal unit, or AU, to compare different types of livestock. For example, while one beef cow equals one AU, it takes 2.5 market-sized pigs to equal one AU. A CAFO typically contains 1,000 AU or more.
6 Hoop barns are structures with curved roofs that, compared with CAFOs, are typically much less expensive, maintain pigs at lower densities, and provide bedding material such as straw.

however, it can be prohibitively expensive to transport the manure beyond a short distance. Disposal may therefore be accomplished by pumping the liquefied manure onto nearby "sprayfields" (a practice that can only distribute manure over a relatively short distance), or by trucking it a greater distance (which adds additional expense).

The weight of CAFO manure is due to the mixing of urine and feces, which forms a slurry that is mostly liquid, and additional liquid is often added when manure is flushed with water into storage facilities such as lagoons. Placing a large number of animals in a small space often means that more manure is produced than can be properly disposed of on fields close to the CAFO.

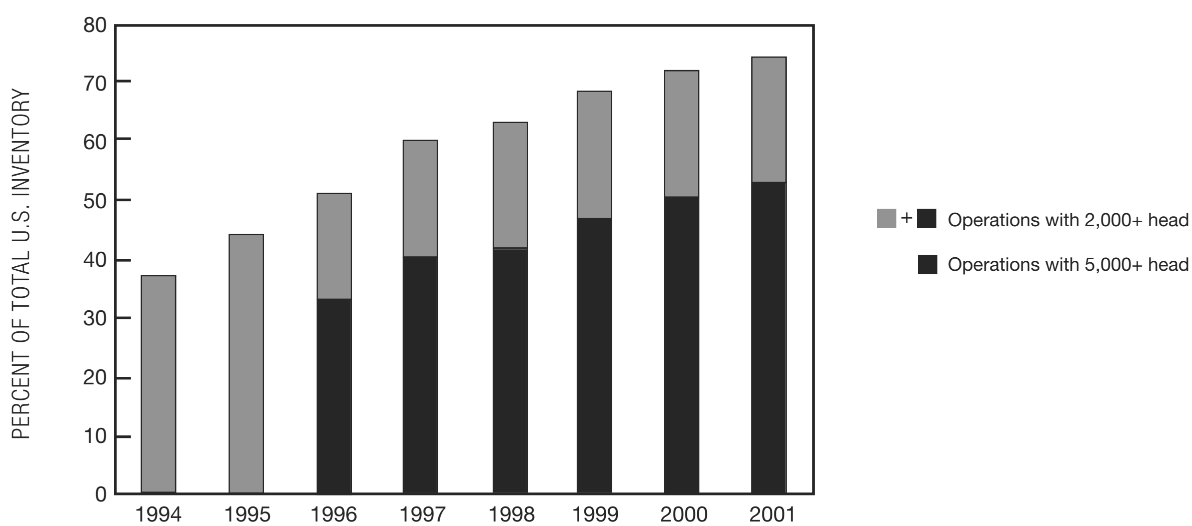
Other problems stem from the density of the animals in individual operations. High-density confinement means that animals may be exposed to their own manure, which is typically collected within the stocking facilities, often after dropping through slatted floors. The manure can harbor and spread disease-causing organisms, and gases such as ammonia and hydrogen sulfide emitted from the manure can be harmful to both animals and workers. CAFOs also release these harmful products into the surrounding air and water, causing problems far beyond the facility itself.

Large manure storage facilities are often required because the application of manure to fields is often restricted to certain times of the year (e.g., when the ground is not frozen). Such storage facilities raise additional environmental concerns. They can overflow or collapse, sending unprocessed manure into surface water, killing fish and contributing to degradation of the aquatic environment. Water pollution can also occur due to leakage through the ground under the storage facility, contaminating groundwater supplies such as wells and aquifers. Finally, these facilities also emit gases, especially ammonia, that cause air pollution and global warming.

CAFOs Are Getting Bigger

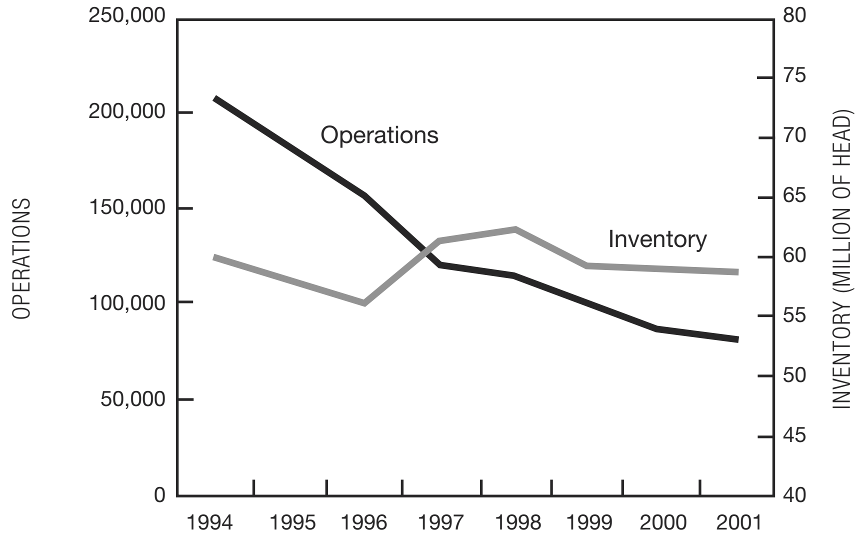
It should be acknowledged that many CAFOs are much larger than the lower limit recognized by the EPA. This is illustrated for hog production in Figure 1, which shows the percent of hogs produced at operations larger than 2,000 head and 5,000 head (double the minimum CAFO size) from 1994 to 2001 (McBride and Key 2003). Over 50 percent of total

Figure 1. **U.S. Hog Inventory on the Largest Farms**



Operations with 5,000+ head were not reported prior to 1996.
SOURCE: McBride and Key 2003.

Figure 2. **Number of U.S. Hog Operations and Hog Inventory**



An operation is any place having one or more hogs on hand at any time during the year.
SOURCE: McBride and Key 2003.

hog production occurred on CAFOs with more than 5,000 hogs by 2001. The average hog CAFO in the EPA's southern seaboard region held more than 12,000 head per year in 2004 (McBride and Key 2007).

On the other hand, as illustrated in Figure 2, the total number of swine in the United States remained about the same over this time period, demonstrating that increased size of operations was not required to supply the domestic demand for pork. Between 1994 and 2001, the number of hog operations fell by more than 50 percent. Between 1982 and 2006, the number of hog operations fell by a factor of almost 10, from just under 500,000 to about 60,000 (NASS 2007).

The total number of beef cattle produced in the United States has declined somewhat over the past several decades, while broilers have increased dramatically. Between 1966 and 2006, the amount of broiler meat produced in the United States increased by about 500 percent.

The proportion of animals produced on CAFOs has increased greatly over the past several decades, and the geographic distribution of CAFOs has also become more concentrated. Despite the fact that many smaller livestock operations remain, their numbers have been falling dramatically (Table 1, p. 16),[7] and CAFOs are now responsible for producing much of the animal products sold in the United States.

Table 2 (p. 16) shows the number of animals raised by operations of different sizes in the United States.[8] The much greater size of animal operations over 1,000 AU compared with smaller operations means that even though there are many fewer large operations, they produce more animals than any other size class as of 1997 (although medium-sized operations continue to produce a substantial number of animals). Large CAFOs clearly have been replacing other ways of raising livestock.

Nevertheless, the fact that there are still many operations of small and medium size suggests that

7 About 92 percent of all operations larger than 1,000 AU are confined operations (Kellogg et al. 2000).

8 About 16 million AU are raised in CAFOs; therefore about 35 percent of all AU at large operations are unconfined. However, about 7.3 million AU on these large unconfined operations are in categories other than feedlot beef cows or dairy cows (Kellogg et al. 2000). The overwhelming majority of these are likely to be cow-calf operations with animals on range or pasture, and virtually all beef calves over 500 lb. from these operations are eventually transferred to feedlot CAFOs. Excluding these cows, about 91 percent of all animals at operations larger than 1,000 AU are in confined operations, including virtually all large beef cattle- and swine-finishing operations, and virtually all chicken operations.

Table 1. **Number of Livestock Operations by Size,* 1982–1997**

Farm Size Category	1982	1987	1992	1997	Percent Change 1982 to 1997
Less Than 25 Total AU	660,425	577,488	496,206	474,335	-28
25 to <50 Total AU	263,355	233,366	217,423	203,402	-23
50 to <150 Total	336,505	297,081	275,128	246,220	-27
150 to <300 Total AU	84,041	79,952	80,178	77,219	-8
300 to <1,000 Total AU	35,437	35,697	38,666	41,534	+17
1,000 or More Total AU	5,442	5,757	6,526	8,021	+47
All Operations	1,385,205	1,229,341	1,114,127	1,048,731	-24

*Operation size is measured in animal units (AU); numbers include both confined and unconfined animal operations.
SOURCE: Kellogg et al. 2000.

Table 2. **Number of Animals by Operation Size,* 1982–1997**

Farm Size Category	1982	1987	1992	1997	Percent Change 1982 to 1997
Less Than 25 Total AU	7,311,927	6,406,057	5,727,476	5,407,009	-26
25 to <50 Total AU	9,465,723	8,379,402	7,797,699	7,277,610	-23
50 to <150 Total	29,009,019	25,722,744	23,961,311	21,460,328	-26
150 to <300 Total AU	17,142,530	16,352,605	16,483,027	15,967,020	-7
300 to <1,000 Total AU	16,912,228	17,061,674	18,603,343	20,271,518	+20
1,000 or More Total AU	15,779,144	17,285,205	19,364,252	24,925,729	+58
All Operations	95,620,570	91,207,687	91,937,108	95,309,215	0

*Operation size is measured in animal units (AU); numbers include both confined and unconfined animal operations.
SOURCE: Kellogg et al. 2000.

alternatives to large CAFOs need not only be tiny operations. As seen in Table 1, for example, there were almost 10 times as many medium-sized hog operations (in the range of 150 to 300 animals) than CAFOs in 1997, despite years of increasing concentration. There are, therefore, a variety of building blocks that could be used to construct an alternative to the CAFO system.

Bigger Does Not Mean More Efficient

The prevalence of CAFOs raises questions about why they have prospered, and conversely why other types of animal agriculture have been displaced. Does the spread of CAFOs reflect inherent economic advantages compared with other ways of raising livestock, or are there other explanations? If CAFOs do have some benefits in terms of production efficiency, it is important to weigh those advantages against disadvantages such as the pollution caused by animal waste.

To assess the efficiency of CAFOs we must first choose one of several possible definitions. One measure of efficiency is costs per unit of production. These costs typically include labor, materials, and energy, but CAFOs also cause harm to the environment and people that are "costs" to society.

When such costs to the environment, public health, or rural communities are borne by society rather than the producer they are termed "negative externalities" (or just "externalities" for the purposes of this report). If CAFOs were required to remediate or prevent the cost of these externalities, they would incur higher production costs and thus be considered less efficient than they currently appear. In addition, CAFOs receive subsidies that help defray their production costs. Because these subsidies are typically funded by taxes, society is paying to reduce CAFOs' production costs in more ways than one.

So, when examined in a broader societal context, suppositions about the higher economic efficiency of CAFOs can be seen as half-truths. The primary purpose of this report is to examine some of the costs our society pays for CAFOs from an environmental and public health perspective, and how subsidies create an illusion of CAFO efficiency.

The societal costs of pollution externalities and grain subsidies—that is, costs for which CAFO owners have never been held accountable—are examined primarily in Chapters 2 and 3. But first, we consider narrower aspects of efficiency that encompass those costs CAFO owners *have* historically paid.

Factors Contributing to CAFO Growth

Several key factors have driven CAFO expansion, one being the availability of cheap inputs (i.e., expenses such as grain, water, and energy that have variable costs). We consider the importance of low-cost grain below.

Another factor that will be briefly addressed in Chapter 3 is technological change. This has taken the form of developing breeds of livestock that better suit the CAFO environment and that facilitate high-speed processing, reliance on antibiotics to compensate for conditions that favor disease, and feed formulations that allow animals to be produced in a way that meets the demands of CAFOs. These changes and others have often been accomplished through taxpayer-supported research at public universities.

In addition, the ability of CAFOs to shift the costs of their pollution onto the public in the form of externalities such as air and water pollution reduces the apparent costs of production. The cost of these externalities is considered at greater length in Chapter 3.

In this chapter we will examine economic efficiencies and processor-related market control.

Economic efficiency

Economies of scale, which help larger operations run more efficiently by using production tools not readily available to smaller operations, are often overemphasized in discussions of CAFO efficiency. Economies of scale do exist for CAFOs when costs such as manure disposal are avoided, but are often small and reach optimum levels at an operation size below that of large CAFOs.

Much more important has been the availability of low-cost grain, which allows CAFOs to maintain large numbers of animals in a small space (because the grain can be brought to the animals rather than having the animals forage for their food, as in pastures). Corn and soybeans, the primary feed grains, are high in easily digestible carbohydrates and protein compared with forage. Their high nutritional value per unit of weight allows large volumes of these grains to be shipped at relatively low expense,[9] further facilitating the centralization of animal feeding operations. For example, the ability to ship grain at low cost to the Mid-Atlantic, which lies outside major corn- and soybean-growing regions, has facilitated the dramatic growth of CAFOs in North Carolina—now the second largest hog-producing state and fourth largest producer of broilers.

9 Soybeans are technically not grain, but for the sake of simplicity will be referred to as grain along with corn in this report (unless otherwise noted).

The high nutrient content of grain also gives it a high "conversion efficiency" compared with many other feed sources. Conversion efficiency refers to the amount of feed needed to produce a unit of animal product. Cattle, even though they evolved to eat forage, generally add weight somewhat faster and produce more milk when fed grain rather than pasture or forage.

Livestock also expend more energy to maintain body temperature and mobility on pasture and other CAFO alternatives, which contributes to lower conversion efficiency. Animals that are housed in temperature-controlled facilities and have restricted mobility can devote more of their food consumption to gaining weight or producing eggs or milk. In other words, animals in heated facilities are kept warm through the use of fossil fuel energy rather than the metabolic energy they would otherwise expend.

Beginning in the 1950s, the growth of broiler CAFOs applied pressure to other livestock sectors to adopt similar measures for increasing production and reducing costs. Chickens convert grain into meat more efficiently than cattle or hogs: it typically takes about 2.3 lb. of grain to produce a pound of chicken, but 5.9 lb. to produce a pound of pork and 13 lb. for a pound of beef (Pimentel and Pimentel 2003), so even after adopting CAFO production methods, a grain-based diet for poultry maintains some advantages compared with other types of livestock.

Despite its advantages for weight gain, heavy dependence on feed grain can only occur if it is less expensive than alternatives such as forage. This is because feed is a large part of CAFOs' production costs—about 60 percent for hogs and broilers (Starmer, Witteman, and Wise 2006). As discussed at length in the following chapter, the low cost of grain in recent decades has been largely supported by federal government policies that 1) provide taxpayer subsidies for cheap grain and 2) have eliminated grain supply controls, allowing prices to fall. Because feed comprises such a large expense for the CAFO industry, the cost to taxpayers for this subsidy is high.

Low-cost inputs such as grain favor CAFO expansion when prices for animal products are low. This has generally been the case during the past several decades. Low-cost inputs spread the high fixed costs of confinement infrastructure (such as the buildings that contain the animals) over many units of production. CAFOs can compensate for low profit margins per animal by producing large numbers of animals. By contrast, small and diversified producers often have relatively lower fixed costs and higher variable costs, and may attempt to lower their costs by reducing production when prices are low. In this way, CAFOs may expand at the expense of smaller operations.

Another factor in CAFO efficiency is economies of scale. Hypothetically, a large facility may be able to afford machinery that greatly improves production efficiency because its cost is distributed over a large amount of finished product (in this case, processed animals). A smaller facility could not take advantage of such efficiency because the cost of the machinery would be spread over too few products. Studies of this factor in the hog industry (e.g., McBride and Key 2003) suggest that economies of scale exist, but are often minimal for animal producers larger than medium-sized AFOs or small CAFOs. Therefore, economies of scale do not significantly favor CAFOs over medium-sized operations.

A summary of several studies comparing the production costs of hog operations by size showed that smaller and medium-sized hog farms had costs that, compared with the largest farms, ranged from the same to 15 to 28 percent higher (Weida 2004a). For example, in one of the cited studies, three years' worth of data suggested that the optimal operation size based on cost of production was 120 sows (producing about 2,400 hogs per year). Typical costs in other studies were about 5 to 11 percent higher for the smaller farms of 150 to 250 sows (producing about 3,000 to 5,000 hogs per year) compared with operations of 3,500 sows. Medium-sized AFOs were typically more efficient than the smallest operations. Profits per hog for the best third of producers in another of the cited studies, regardless of operation size, averaged about $10 per hog in 1999 dollars.

Smaller to medium-sized independent hog producers span a range of production efficiencies, and the more efficient of these operations are cost-competitive with larger CAFOs (Ikerd 2004; McBride and Key 2003). These more-efficient smaller, independent operations produce hogs at about the same cost as the larger CAFOs. In a more recent study, costs for very large hog feeder-to-finish CAFOs averaged about 9 percent less than medium-sized operations (500 to 1,999 head). However, 38 percent of medium-sized operations had costs below $40 per hundredweight (cwt), compared with 64 percent of very large CAFOs. A similar percentage of medium-sized operations, and about 16 percent of small ones, had the same or lower production costs than the average very large hog CAFO. Many medium-sized operations used production practices associated with higher efficiency, such as "all-in-all-out" production and "phase feeding" (McBride and Key 2007).[10] These data suggest that management skills may often be more important than size in determining efficiency, and that medium-sized and some small AFOs are capable of production as cost-effective as CAFOs—even without considering the externalities of manure that CAFOs impose in greater amounts than smaller operations.[11]

Comparisons based on scale are difficult when comparing fundamentally different types of animal production. For example, such comparisons may be useful when comparing CAFOs to smaller but otherwise similar AFOs. Various alternative livestock and poultry production methods, however, may differ substantially from CAFOs in the technology, capital, and labor processes they employ, and the consumer markets they target. In those cases, factors other than scale may also be important in determining efficiency or economic viability.

For example, hog hoop barns that use deep bedding are generally a substantially less expensive alternative to hog CAFO shelters. On the other hand, because hoop barns typically allow more space per animal (especially if the hogs are provided with outdoor access), fewer animals may be raised per unit of land. Bedding in hoop barns—typically small-grain straw or corn stalks—also adds expense, because hog CAFOs typically have no bedding. In addition, feed conversion rates in Iowa (where most studies of hoop barns have taken place) are somewhat lower in typically unheated hoop barns in winter (Kliebenstein et al. 2003). Thus, comparisons between hoop barns and CAFOs based primarily on scale may not be appropriate to determine the financial viability of these alternative methods for raising hogs.

Processor-driven market control

Another major factor in the growing predominance of CAFOs is the integrated structure of the industry. Animal production and processing has become increasingly integrated and concentrated over the past several decades. In particular, a few very large animal processors largely control the supply of animals through ownership or contracting arrangements.

And because of increasing functional integration, processors have gained considerable economic power over producers, who depend on processors to slaughter their animals and distribute their products. In most cases, contracts (especially production contracts) have become the primary marketing arrangement between animal producers and processors or packers (often referred to as "integrators").

Industry concentration has risen substantially over the past several decades, to a point where it may have a substantial impact on producers. An industry in which the market share of the four largest firms ("four-firm concentration" or CR4) totals more than 40 percent is often considered to threaten free-market mechanisms by giving those firms too

[10] All-in-all-out production keeps animals of the same age together in discrete batches, rather than mingling animals of different ages. Phase feeding matches animals' diets to their specific life stage.

[11] It has been observed that many operators of smaller and independent hog farms are older and preparing for retirement (McBride and Key 2003). These older owners may be less willing to invest in newer management approaches or make capital improvements that would improve efficiency. Younger or newer producers, on the other hand, may be more attracted to CAFO production methods such as contract arrangements with processors for several reasons; reduction of risk has been suggested as one. Better availability of credit has also been associated with contract production, and because of the high capital expenses associated with CAFOs, may be a significant motivating factor (MacDonald et al. 2004; Knoeber and Thurman 1995). Insufficient open-market options for independent producers may be another reason.

much control over pricing and supply (Heffernan 2000). The broiler chicken processing industry's CR4 is 56 percent, the beef industry's is 83.5 percent, and the hog industry's is 64 percent, and each has been rising steadily for the past several decades. In 1990 these numbers were 44 percent, 72 percent, and 40 percent, respectively (Hendrickson and Heffernan 2005). In 1987, the pork packers' CR4 was 37 percent, and the broiler processors' was 35 percent in 1986—both below the 40 percent benchmark. The dairy processing industry is more complex than other sectors, but is also undergoing increasing concentration (Hendrickson et al. 2001).

Several of the largest companies, such as Cargill, ConAgra, Smithfield, and Tyson, have substantial holdings in several livestock sectors, and also own large numbers of animals. For example, Smithfield is by far the largest owner of hogs in the country. Cargill and ConAgra are also grain suppliers (Hendrickson and Heffernan 2005). Growing ownership by processors (called "captive supply"), a high percentage of production contracts, and shrinking open (or "spot") markets have the potential to distort markets in favor of lower prices for producers.

Despite this growing industry concentration, the federal authority charged with oversight of the processor industry, the USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA), has been strongly criticized for lax regulation of anti-competitive practices under the Packers and Stockyards Act (PSA). In reports beginning in 2000, the Government Accountability Office (GAO, formerly the General Accounting Office) and the USDA's Office of Inspector General (OIG) found that GIPSA lacked the organizational structure and processes needed to effectively monitor and enforce PSA provisions (GAO 2000). In particular, GIPSA did not adequately involve attorneys from its Office of General Counsel in its investigations of potential anti-competitive practice violations.

Although GIPSA agreed to many of the recommendations of the GAO's 2000 report, later investigations by the GAO and OIG found that important agreed-upon improvements had not been implemented (USDA 2006; GAO 2005), and lawyers had not been adequately integrated into GIPSA actions. The GAO noted that GIPSA senior management thwarted investigations through delays and inaction, and that GIPSA officials had not adequately responded to the GAO and OIG reports (GAO 2006). The investigations of GIPSA oversight of the processor industry suggest that anti-competitive practices against smaller and independent animal producers are unlikely to be prevented under the current system.

The limited access of small and medium-sized producers to slaughterhouses is exacerbated by USDA inspection requirements. With the exception of small chicken producers in many states that sell directly to consumers, health inspections are necessary for marketing, and federal inspections are required for sales across state lines. Access to regulator-approved facilities is therefore needed to ensure broad market access. In other words, difficulty in gaining access to processors not only impedes producers' ability to slaughter their animals, but also may restrict their ability to market their products. The resulting bottleneck between producer and consumer can reduce the viability of smaller and alternative producers even when their products may be competitive based on production costs.

Poultry processors, for example, have become larger and have built larger slaughterhouses. At the same time, smaller processors and processing plants have left the industry (Ollinger, MacDonald, and Madison 2005). The remaining large processors preferentially contract with large producers (i.e., CAFOs) and do not accept chickens or hogs from independent producers. This problem is exacerbated by the need for slaughterhouses to be close to producers due to the potential harm done to animals during transportation.

Contracts are key features of the CAFO system. Broiler and egg production, the first types of animal production to develop CAFOs, were almost entirely dominated by contracting in 2001 (as shown in Table 3), with 88 percent of production under contract. Almost 61 percent of hogs were also produced under contract in 2001, while only 31 percent were produced under contract from 1994 to 1995. Dairy contracts jumped from about 37 percent between 1991 and 1993 to about 57 percent between 1994 and 1995. Beef cattle were the only animals considered in this report of which less than half (21 percent) were produced under contract (MacDonald et al. 2004).

Furthermore, only the largest producers typically use contracts. For example, 65 percent of the largest hog producers ($1 million production value or greater) were under contract in 2001, while only about 8 percent of small hog farms (less than $250,000 production value) used contracts. Even more dramatically, 92 percent of the total value of hog production was produced under contract that year (MacDonald et al. 2004).

The role of integrators in contract processing

Processors are often referred to as integrators because they combine the production and processing aspects of the industry through animal ownership or contracts. Integrators have preferences about the size of livestock producers with which they contract, so their decisions may have an important bearing on producer size.

As noted above, most livestock are produced under contractual arrangements with large integrators. Therefore, access to processors for slaughter and distribution of animal products may often depend on the producers' ability to enter into contracts with processors. Because processors favor contracts with large feeding operations, smaller or alternative animal producers can have difficulty processing and marketing their products, even if they produce these products at competitive prices. And because the large majority of animals and products are processed under contract, independent producers may have difficulty in finding processors that will buy their products (or buy them at a fair price).

Probably most important, however, is the need of large processing plants to operate near full capacity to realize economies of scale (MacDonald et al. 2000). This encourages the use of contracts with large suppliers and captured supply, which can ensure processing at full capacity.

In the case of hog and beef processors, economies of scale at the largest processing plants provide only about a 3 to 5 percent cost savings for beef and hog slaughter compared with plants one-quarter their size, and these savings are only realized if the slaughterhouses run near full capacity. This favors processors that reduce their risk of operating below capacity by contracting with CAFOs (MacDonald et al. 2000).

Economies of scale are greater for poultry processing, and may be more directly associated with the growth in large processing plants. The largest plants realized cost savings of about 8 percent compared with smaller plants in 1992. Therefore,

Table 3. **Percent of Livestock Production under Contract by Sector**

Commodity	1991–1993	1994–1995	1996–1997	1998–2000	2001
Livestock	32.8	42.9	44.8	48.0	46.8
Cattle	na	19.0	17.0	24.3	20.9
Hogs	na	31.1	34.2	55.1	60.6
Poultry and Eggs	88.7	84.6	84.0	88.8	88.1
Dairy	36.8	56.7	58.2	53.6	53.1
Other Livestock	0.2	9.3	4.9	10.9	9.3

na=not available
Data drawn from USDA Farm Costs and Returns Survey (1991–1995); USDA Agricultural Resource Management Survey (1996–2001)
SOURCE: MacDonald et al. 2004.

economies of scale may explain a substantial amount of the consolidation in the poultry processing industry (Ollinger, MacDonald, and Madison 2000). Although economies of scale are less pronounced for swine processors, that sector seems to be following a similar pattern.

The increasing size of meat slaughtering operations has occurred alongside the growth of CAFOs. This has led to the disappearance of smaller processors that might be more accessible to smaller producers (Ollinger, MacDonald, and Madison 2005). By 1992 large plants processed 88 percent of chickens (Ollinger, MacDonald, and Madison 2005), and as of 1997, four firms handled almost 80 percent of steer and heifer slaughter—twice as much as two decades earlier. Large plants handled 38 percent of hog slaughter in 1977, but 88 percent by 1997 (Table 4).

With the increase in large processors and large plants operating through contracts with producers, and a simultaneous decrease in smaller processors, it is becoming increasingly difficult for smaller independent and alternative producers to find slaughterhouses willing to process their animals (Fanatico 2003). This problem is exacerbated for specialty producers in niche markets such as pastured-raised beef, which require segregation of their products from mainstream products.

An alternative to contracts is open bidding (also called a competitive or "spot" market), which was the common means for producers to sell to processors prior to the predominance of contracting. As contracting has expanded, spot markets have become more restricted in many regions, which may limit them as a marketing option for smaller producers (MacDonald et al. 2004). An added problem is that when spot markets become too small they may no longer function efficiently, which can lower prices for producers.

Although cattle producers may be unhappy with spot market prices, the data show only modestly lower spot prices compared with contracts (MacDonald et al. 2004). Nevertheless, because low prices for animals may occur for both contract and spot markets due to the economic concentration of processors and their ability to cross-subsidize different sectors of their business (Heffernan 2000), spot market prices that are only modestly lower than contracts do not necessarily reflect fair pricing for producers.

In summary, the evidence suggests that several factors have influenced the expansion of CAFOs over the past several decades, including the availability of low-cost grain and coordination between CAFOs and large processors through contracts and ownership. The ability of CAFOs to shift the costs of their pollution onto society has also been important, but is considered separately in Chapter 3. Economies of scale exist for some CAFOs but are often modest, while many medium-sized AFOs are as efficient as the largest CAFOs.

Table 4. **Percent of Animals Slaughtered in Large Plants**

Report Year	Slaughter Classes and Size Cutoff*				
	All Cattle (<500,000)	Steers/Heifers (<500,000)	Steers/Heifers (>1 million)	Cows/Bulls (<150,000)	Hogs (>1 million)
1977	12	16	nr	10	38
1982	28	36	nr	15	59
1987	51	63	31	20	72
1992	61	76	34	38	86
1997	65	80	63	57	88

*Size cutoff (in parentheses) refers to the number of animals slaughtered annually.
nr=not reported
Data drawn from U.S. Department of Agriculture (1999).
SOURCE: MacDonald et al. 2000.

Are CAFO Alternatives Cost-effective?

Smaller to medium-sized AFOs that are adequately distributed geographically may address some of the concerns posed by CAFOs. But what about other alternatives that may avoid more of the problems that CAFOs cause? Are these alternatives cost-effective?

Although the following review is not intended to be comprehensive, it shows that several of the better-researched alternatives can indeed compete with confinement operations. This is something of a surprise considering that the great majority of research dollars have been devoted to improving CAFO performance while largely neglecting alternative methods. In fact, one of the often-touted advantages of CAFOs is their ability to adopt technological advances such as breeds that gain weight quickly—advances that are sometimes available only to large producers.

The disparity in research effort also suggests that there may be substantial opportunities to improve the efficiency of alternatives. This review is therefore only a snapshot of an evolving picture, and as such provides only a rough indication of the possibilities.

Hog production alternatives

Some of the best-studied alternatives to CAFOs involve hog production. One of these alternatives is hoop barns—open-ended structures with curved roofs, in which hogs are allowed to "nest" in straw bedding. Hogs may also be raised on pasture.

In one test, hogs raised in hoop barns in North Dakota provided 6.63 percent higher net income per pig than conventional confinement. This test also evaluated pasture-raised hogs and found that the net return was 4.07 percent higher than confinement (Landblom et al. 2001). These results are also supported by Iowa Livestock Enterprise budgets calculated for confined and pasture-raised hogs for 2003. That report determined the break-even selling price for pasture-raised hogs was $43.56/cwt, compared with $43.60/cwt for confined hogs (May, Edwards, and Lawrence 2003). Mid-gestation swine raised on alfalfa pasture, with only 40 percent of their diet from corn, gained weight and performed as well as swine fed an exclusively corn/soy diet (Honeyman and Roush 1999).

Financial viability based on net returns (including amortization of infrastructure and debt) has been used to determine how well hoop barns compare with confinement operations. Because hoop barn production is more sensitive to different input parameters than confinement, it will perform better or worse than CAFOs under different circumstances. For example, in one test conducted in Iowa during winter, when feed conversion efficiency is poorer than for confinement systems, hoop barns do less well by comparison. In warmer months, when conversion efficiencies are comparable, hoop barns often do as well or better than confinement production (Honeyman and Harmon 2003; Kliebenstein et al. 2003).

Poorer winter conversion efficiency, which results in a slightly poorer overall efficiency, means that the financial viability of hoop barns is likely to be more sensitive to grain prices than CAFOs. For instance, hoop barns will do less well by comparison particularly when grain prices are high and the grain must be purchased rather than raised on the farm. This alternative is also more sensitive to returns on investment: hoop barns delivered a higher return at prices over $54/cwt, while confinement operations delivered better returns at lower prices. In addition, slightly more labor (three to six minutes per pig) was needed for hoop barns, so net returns for confinement hogs were about 20 percent higher in this test.

An additional consideration not evaluated in these studies is the effect of geographic location on economic efficiency. For example, hoop barns may perform better in locations where the climate is milder than Iowa and the feed conversion ratios will thus be higher. On the other hand, because Iowa—the country's top hog-producing state—is also located in the country's corn belt, its grain prices are lower than some other regions of the country. This may favor production in hoop barns in Iowa even if feed conversion efficiencies are lower than in states that have milder climates but little grain production.

When well-managed, pasture can meet some of the nutritional requirements for gestating sows (Honeyman and Roush 1999), at least seasonally. This can reduce some of the cost of grain. For example, one three-year study demonstrated that as much as 66 percent of a sow's feed requirements can be obtained from a well-managed pasture program if vitamin and mineral supplements are included (Gegner 2004).

Beef and dairy production alternatives

Cattle are capable of receiving all or most of their dietary requirements from pasture or forage (such as alfalfa hay) rather than grain. This is because cattle, as well as other ruminants such as sheep and goats, have digestive systems that can efficiently process forage including alfalfa and grasses, which have high cellulose content and relatively low levels of simple carbohydrates such as starch or sugars.

Comparisons have been made between confinement and modern pasturing methods for cattle, such as managed intensive rotational grazing (MIRG). This method carefully moves cattle to separated paddocks before pasture is overgrazed, preventing degradation and allowing re-growth. This also reduces the risk of disease due to pathogens and parasites that can be found in manure, because most of these do not survive for long periods in the environment. Furthermore, pasture production avoids at least some of the cost and energy involved in harvesting feed grains or forages.

Preliminary work with beef cattle suggests that hoop barns may also be favorable compared with open feedlots. The costs may be slightly higher, but manure runoff issues could be much improved (Honeyman et al. 2008).

In a Minnesota study, two pasture-based dairy farms were as or more profitable than a conventional confinement counterpart, although the confinement operation was considerably smaller than a CAFO. The pasture farms sold organic milk and therefore benefited from a 14 percent price premium (DiGiacomo et al. 2001); this helped the more profitable of the two produce twice the net profit of comparably sized dairy farms in south-central Minnesota ($200,000 to $500,000 in gross income)—most of which are likely to be confinement operations. Even without that premium, one pasture farm was financially comparable with the conventional farm, while the other outperformed its conventional counterpart.

The more profitable pasture farm produced about 33 percent less milk per cow than the confinement operation but had lower cow replacement costs. In general, pastured dairy cows in the area produced about 24 percent less milk per cow than non-pastured cows. The more profitable pasture dairy used 59 percent less grain or concentrate to produce a pound of milk than traditional dairies, while pasture dairies as a group used about 14 percent less.

The pasture-based dairies raised their own grain and hay for use during the period from November through March when pasture was unavailable in Minnesota. Because of their reliance on pasture rather than grain for much of the year, these operations should be somewhat less sensitive to changes in grain prices. They may therefore have been relatively more profitable in 2007. By raising their own grain, these farms would not have to pay prices above the cost of production. Finally, these dairies also produced considerably less water pollution compared with grain grown for the conventional dairy under conservation tillage.

A recent meta-analysis compared the relative productivity (yield) of organic and conventional animal production (Badgley et al. 2007).[12] Animal products included beef, pork, chicken, milk, and eggs. The authors considered 22 studies from developed countries, primarily in Europe, that typically produce most of their animal products in CAFOs. Overall, organic productivity was about 3 percent below that of conventional animal operations.

12 Because this study is a summary of other studies, the precise methods practiced by each organic farm are not revealed.

Looking Beyond Narrowly Defined Costs

As seen in the sections above, many alternative production methods can be as profitable as CAFOs (or more so), but tend to be somewhat less efficient in terms of feed conversion. In other words, more feed is often needed to produce a unit of product (meat, milk, or eggs) compared with CAFOs. But these analyses do not take the costs of externalities into account. Doing so is a complicated task; what follows merely scratches the surface.

First, alternatives are often less reliant on grain production—itself a system of questionable sustainability under prevalent farming practices. Although this topic is beyond the scope of this report, grain production is a major contributor not only to soil degradation, but also to the pollution of aquatic ecosystems that are important sources of food (Tilman et al. 2002). Less than half of the synthetic fertilizer applied to feed crops is utilized, with much of the rest contributing to water pollution. Some is converted into nitrous oxide (Tilman et al. 2002), an extremely potent heat-trapping gas that contributes to global warming.

The costs of the damage caused by crop externalities may decrease when alternative livestock production methods substitute pasture and perennial forages for grains. Properly maintained perennial pasture builds soil, protects water quality by reducing nutrient runoff and leaching, and captures carbon dioxide—the heat-trapping gas most responsible for global warming—at higher rates than grain crops, apparently even when compared with conservation-tillage systems used with soybeans or corn (Russelle, Entz, and Franzluebbers 2007; Boody et al. 2005). It is important to keep in mind, however, that overgrazed or otherwise poorly maintained pasture can also create substantial externalities in the form of land degradation and water pollution (Russelle, Entz, and Franzluebbers 2007; Hubbard, Newton, and Hill 2005).

In addition, animals produced on pasture have been estimated to produce almost 10 times less ammonia than confined livestock (Anderson, Strader, and Davidson 2003). Ammonia emissions from manure are a major source of water and air pollution, and form fine particulates that can cause respiratory ailments. A summary of several research projects reports that grazing dairy cattle release an average of 6.4 kg of ammonia per cow per year, with 10.5 percent lost to volatilization (the movement of ammonia from manure into the atmosphere as a gas), while dairy cattle in confinement produced 15.5 kg per cow per year, with 22 to 45 percent lost to volatilization and another 13 percent lost during spreading (Anderson et al. 2003). Pastured dairy cattle thus produce about 0.67 kg of volatilized ammonia per year, while confined dairy cows release about 5.4 to 9.0 kg per cow. According to these values, confined dairy cows produce about 8 to 13 times as much volatilized ammonia per cow as pastured dairy cattle.

Confined dairy cows fed a diet primarily of grain typically produce more milk per cow than grazing dairy cows. However, even when calculated on a per-milk-unit basis (assuming 30 percent higher milk production for confined cows), confined cows produce about six to nine times more volatilized ammonia than pastured cows.

Integration of animal and crop agriculture provided by CAFO alternatives generally benefits both types of farming and the environment. An integrated system in Minnesota that tested two different watersheds found that phosphorus in streams was reduced by about 70 percent, nitrogen by 51 to 74 percent, and sediment by 35 to 84 percent (Boody et al. 2005). A model integrated regional livestock and crop system in Iowa, with animals in close-enough proximity to crops or pasture to replace synthetic nitrogen fertilizer with manure, and where pasture replaced some of the corn and soybeans, could produce livestock with environmental benefits such as reduced water pollution (Burkart et al. 2005). In addition, the number of finished hogs in this system could actually increase from the current 940,479 head to 7,566,400 within the study area (a watershed). There is clearly a major advantage in linking livestock to crops, which can be readily achieved by relocating livestock near crops.

Impact on global warming

One important externality of livestock production is the emission of heat-trapping gases such as methane. Cattle are a major source of methane, which is produced during both the fermentation of feed in the animal's gut and the anaerobic fermentation of manure in CAFO lagoons and other manure holding structures.

Cows that feed on pasture or forage produce more methane during digestion than grain-fed cows (Clemens and Ahlgrimm 2001). Though this may be reduced substantially by optimizing productivity through MIRG (DeRamus et al. 2003), it is not clear that methane levels can be reduced to those of grain-fed cattle.

Production of the heat-trapping gas nitrous oxide from the breakdown of fertilizer used to produce grain must also be weighed against the production of nitrous oxide from manure produced by CAFOs and their alternatives. Therefore the net effect on global warming pollution from pasture- versus grain-fed livestock is unclear (Liebig et al. 2005).

It should be noted, however, that although methane production may be about 125 percent higher on pasture operations compared with CAFOs (Boody et al. 2005), the atmospheric impact would likely be offset by higher capture of carbon dioxide (Russelle, Entz, and Franzluebbers 2007). The results of several studies suggest that perennial pasture may capture about 0.9 metric ton of carbon dioxide per hectare per year, while commodity crops in Minnesota—even when grown under conservation tillage—capture only one-third that amount (Boody et al. 2005).

On balance, it appears likely that alternative production systems that reduce the size and geographic density of animal feeding operations have substantial benefits compared with CAFOs. It is not possible at this time to determine whether lower global warming pollution is one of those benefits, but alternative integrated animal and crop production systems will likely substantially reduce other externalities associated with CAFOs.

Conclusions

The small sample of studies discussed above cannot be used to draw sharp conclusions about the productivity of alternative animal production methods compared with CAFOs. Many variables can affect both productivity and profitability, including management capability, geography (e.g., regional climate), and availability of processors and markets. Some important parameters also change over time as research develops new innovations and breeds or as the prices of grain, energy, and other inputs change.

Despite these data limitations, however, this overview of alternative animal production and historic trends related to animal feeding operations allows us to draw some broad conclusions about CAFOs and alternative animal production methods. First, although CAFOs often exhibit some minor economies of scale, superior management may often be more important in determining production efficiency in at least some sectors. Well-managed smaller to medium-sized swine operations, for example, are as economically efficient as large CAFOs. Alternative systems can often produce animal products cost-effectively, and at a net profit to producers.

Second, the largest obstacle facing alternatives is not the inability to produce animals efficiently, but the effects of processor-related market power. Challenges in this regard (vertically coordinated production contracts between CAFOs and processors, elimination of smaller processors, and shrinking of efficient spot markets in some areas) could hamper smaller and alternative producers even when they may otherwise produce animals in a cost-effective and profitable manner.

Finally, alternatives that integrate animal and crop production can provide benefits to farms and society alike, in the form of higher profitability and reduced externalities. Linking manure to cropping systems, for example, creates major economic, social, and environmental benefits for an entire region. Considering the relatively limited research currently available on ways to improve alternative animal farming systems, further research is needed to expand these benefits.

Chapter 2

DIRECT AND INDIRECT SUBSIDIES TO CAFOs

The price consumers pay for animal products at the grocery store does not reflect all of the costs society as a whole pays for these products. One of the important ways these costs are masked is through the provision of subsidies to CAFOs. Some subsidies may go directly to CAFOs; others (so-called indirect or implicit subsidies) go to other parts of the economy and are then passed on to CAFOs. These indirect subsidies may easily go unnoticed by the general public, but are just as important to CAFOs in facilitating their operation and growth. Where subsidies go to CAFOs preferentially over other production systems, they provide an especially important advantage.

In this chapter, several types of subsidies that have been given to the CAFO industry are examined. One particularly substantial indirect subsidy has been payments made to commodity crop growers, largely for corn and soybeans, which is passed on to the CAFO industry in the form of artificially low feed grain prices. These low prices have largely been the result of the elimination of grain supply controls that were intended to keep prices at a reasonable level. This and other changes in federal farm legislation have allowed the price of feed grains to drop below the cost of production in many years. In response, lawmakers have compensated grain growers for most of the difference between their cost of production and low market prices. Such indirect crop subsidies have amounted to a windfall of several billion dollars per year for the CAFO industry.

The second type of subsidy examined in this report is direct payments made to the CAFO industry through the federal Environmental Quality Incentives Program (EQIP), which provides about $100 million per year to CAFOs to reduce some of the environmental damage they cause. EQIP subsidies, like commodity crop subsidies, are ultimately paid for by taxpayers, and could become increasingly important as pressure is applied to the industry to clean up its practices.

Although the reduction of harm caused by CAFOs is desirable, EQIP payments raise legitimate questions about whether the public should underwrite CAFOs in this way. This is especially important when considered in the context of alternative production systems that are efficient, cause fewer problems, and have greater societal benefits.

Subsidies are appropriate buffers for the agricultural sector against the uncertainties of nature and price dips due to overproduction, and they encourage conservation and technological innovation. However, it is essential that subsidies also encourage and support desirable agricultural practices.

How Crop Subsidies Have Propped Up CAFOs

Livestock raised in confinement eat an enormous amount of corn and soybeans. Grain and animal production (and their respective costs) are therefore inseparable when evaluating CAFO production. Over the last 80 years or so, U.S. farm policy has subsidized the production of commodity crops such as corn and soybeans in a variety of ways; currently, some payments are made to commodity farmers regardless of market prices or production costs. Here we examine whether these subsidies have contributed to the growth of CAFOs, which are the primary users of these crops.

A majority of the two most widely cultivated crops in the United States, corn and soybeans, is fed to livestock. In 2007, corn was grown on about

93 million acres and soybeans on about 64 million acres. Alfalfa is grown for livestock forage on about 22 million acres (out of the 60 million total acres devoted to various types of hay); sorghum (mostly for feed) is grown on about 8 million acres and substantial amounts of corn stover (stalks and leaves) are also used for cattle forage or silage.

By contrast, wheat (the crop most widely grown primarily for food in the United States) is planted on about 60 million acres, and rice on less than 3 million acres. Most familiar vegetable and fruit crops are grown on even smaller acreages. For example, potatoes are grown on about 1.1 million acres, tomatoes on about 425,000 acres, apples on about 360,000 acres, lettuce on about 310,000 acres, and carrots on about 100,000 acres (NASS 2008).

The tremendous amount of corn and soybeans grown for animal feed reflects the huge amount of animal production in the United States.[13] Feed grain costs make up a large proportion of the cost of raising animals in CAFOs: corn and soybeans generally make up about 50 to 60 percent of the cost of producing chickens, eggs, and pork, and somewhat less for dairy and beef. Because cows can efficiently digest the cellulose that comprises most of a plant's stalks and leaves, cattle could survive on those parts of crops rather than on kernels or beans. However, in CAFOs a cow's diet is largely composed of grain, which has high caloric or protein content, can be easily transported to the animals compared with bulkier forages, and is relatively cheap.

Because of the close connection between crop prices and CAFO costs, it is important to understand the forces that determine grain prices in the United States. Federal government policy, for one, has a significant effect on the price of corn, soybeans, and a few other crops. The government has implemented various programs under Title I of the farm bill to buffer farmers against loss (such as losses resulting from farmers' tendency to overproduce commodity crops, leading to crop prices that are often below the cost of production). Farmers also tend to accept lower market prices because they are not as economically concentrated as farm input industries or food processors and retailers, and their commodities are perishable.

The farm bill has been reenacted and modified approximately every five years since the 1930s. Prior to the 1980s, its commodity programs focused primarily on controlling the supply and price of the covered crops. Such policies have included government purchase of grain surpluses and the transfer of grain acreage into government-supported conservation set-aside and reserve programs. Policies directed at controlling the supply of grain have the general effect of keeping the market price high (above the cost of production), thereby allowing farmers to make a profit (Ray, De La Torre Ugarte, and Tiller 2003). Though price supports and supply controls from farm bills prior to 1996 could only moderate rather than completely prevent below-cost production, they nonetheless had a substantial impact on prices.[14]

Since the 1980s, and especially since 1996, Title I programs have moved away from controlling the supply or price of commodity crops (Ray, De La Torre Ugarte, and Tiller 2003). The newer programs support commodity crop farmers with disaster emergency payments, marketing loan gains, and loan deficiency payments when the cost of production exceeds the crop price. Until the past two years of rising market prices, these programs compensated for much of the difference between production costs and low prices. As a consequence, the price of grains was allowed to fall as the crops were overproduced. Between the passage of the 1996 farm bill and 2005, for example, corn prices dropped 32 percent and soybean prices fell 21 percent, while corn production increased by 28 percent and soybean production rose 42 percent (ERS 2005). One study

13 It is also a reflection of the fact that it takes several pounds of grain to produce one pound of animal product. This is an extremely important issue in terms of agricultural sustainability, but is beyond the scope of this report.
14 The tendency toward low commodity prices is primarily a function of farm economics, and only partially altered by subsidies (Ray, De La Torre Ugarte, and Tiller 2003).

found that the price of corn following passage of the 1996 farm bill averaged 23 percent below the cost of production, and soybean prices averaged 15 percent below cost. By contrast, corn prices averaged 17 percent below the cost of production during the 11 years prior to the 1996 farm bill, and soybean prices averaged 5 percent below cost (Starmer, Witteman, and Wise 2006).

In essence, Title I payments to commodity crop farmers compensate farmers when the price of corn and soybeans falls below their production costs. Without these subsidies, commodity crop farmers would not be able to stay in business indefinitely under such conditions. However, as will be discussed below, these subsidies do not always entirely compensate grain farmers for the cost of production.[15]

If crop subsidies were not in place, CAFO operators would have paid more for the grain vital to their operations. The recent surge in demand for ethanol has dramatically increased the price of corn, which is now above the cost of production. Some of the possible implications for future CAFO production are discussed below, but from a historical perspective, low grain prices have encouraged the growth and development of CAFOs over the past several decades. The amount of Title I subsidies given to CAFOs is reflected in the difference between the production costs of corn and soybeans and the prices paid by CAFOs, as well as the percentage of each CAFO's production costs these grains comprise.

Indirect Subsidies to Poultry CAFOs

Studies have determined the indirect subsidies given to broiler chicken CAFOs (Starmer and Wise 2007a; Starmer, Witteman, and Wise 2006). This work shows that between 1986 and 1996, the broiler industry's operating costs were reduced by an average of 6 percent below what they would have been if prices reflected the actual cost of producing corn and soybeans in the United States. After passage of the 1996 farm bill, the indirect subsidy to CAFOs rose to 13 percent of the cost of production, or about $1.25 billion per year. According to the EPA, there were about 1,632 broiler CAFOs as of 2003 (EPA 2003), and these operations produce the large majority of broilers. Therefore, although a small overestimation, each of these CAFOs received an average of about $766,000 per year in subsidies.

The indirect subsidy for laying hens has been calculated following the methods developed for broilers (Starmer 2007; Starmer, Witteman, and Wise 2006). As with broilers, processors rely almost exclusively on production contracts that specify inputs such as feed (MacDonald et al. 2004). As with broilers and hogs, the cost of these grains makes up about 60 percent of the total production cost of eggs. Standardized feeding practices allow generalizations to be made about feed data across the industry: for example, Title I subsidies compensated for layer CAFOs' feed costs by an average of 13 percent per year between 1997 and 2005. This resulted in an average of about $432 million per year for the industry nationally. The EPA estimates that there were 1,112 layer CAFOs in 2003, and calculations based on the average yearly subsidy for the layer CAFO industry arrive at an average subsidy for each CAFO of about $388,000 per year.

Indirect Subsidies to Hog CAFOs

Hog CAFOs, like chicken CAFOs, are highly dependent on grain. One study (Starmer and Wise 2007a) found that the indirect subsidy given to the largest hog CAFOs (those with more than 5,000 animals) averaged 15 percent of operating costs per year between 1996 and 2005. This amounts to an average subsidy of about $652 million collectively per year.

15 The data on commodity price and production costs are average values, so some farmers have made more than the cost of production, and others less. Another factor in this equation is that many farmers now derive a substantial part of their incomes from off-farm work. Therefore, non-farming income could help prop up some money-losing farms. Other unprofitable farms have gone out of business. A detailed analysis of these issues is beyond the scope of this report.

The EPA definition of hog CAFOs used for this report includes operations of more than 2,500 animals, but USDA data used to calculate the grain subsidy for hog CAFOs do not include a size category that corresponds exactly to the EPA's lower limit of 2,500 hogs. The calculations that come closest to the EPA category used in this report come from a study of hog operations larger than 2,000 animals (Starmer and Wise 2007a), which generally use production methods similar to larger CAFOs.[16] This study found that the average indirect subsidy for hog operations of 2,000 animals or more amounted to more than $945 million per year since 1997. In 2006, 2,910 operations containing more than 2,000 pigs held 88 percent of U.S. hog inventory (NASS 2007). A rough estimate of the subsidy for each large hog CAFO is therefore about $325,000 per operation per year.

Hog operation ownership data allow further breakdown of savings by size of operation;[17] for example, owners of operations totaling 50,000 or more hogs produced 54 percent of total U.S. hog inventory in 2006, or about 61 percent of the CAFO inventory. The largest CAFO owners therefore benefited from about $576 million in subsidies for the year. **The 115 owners of operations with more than 50,000 hogs each received an average subsidy of about $5.01 million for the year.** By contrast, the 1,690 owners of operations totaling between 2,000 and 4,999 hogs held 10.8 percent of the CAFO inventory, and therefore averaged about $60,000 in subsidies per owner.

Indirect Subsidies to Beef and Dairy CAFOs

Grain makes up a smaller but still significant portion of the production costs of raising cattle—13 to 17 percent of the costs of producing feedlot beef cattle. This industry's overall production costs were reduced an average of about 5 percent per year over the past 10 years due to indirect subsidies given to grain growers.

The composition of feed for dairy cows is less uniform than other sectors, but remains a substantial cost of dairy production. Data from Iowa, Kansas, Ohio, and Wisconsin between 2002 and 2003 show that feed represents between 38 and 43 percent of production costs, of which corn represents between 11 and 22 percent. Therefore, if the true cost of production was paid for feed corn, total production costs would be raised by about 4 to 7 percent for these states, with the weighted average over 6 percent (Starmer 2007).

Calculations for this report (Starmer 2007) using the same methods as for poultry and hogs (Starmer, Witteman, and Wise 2006) show that Title I crop payments also provide large indirect subsidies to beef and dairy CAFOs. Although the cost data for dairy CAFOs are limited and expected to vary by year and region, we can arrive at a rough estimate of the indirect subsidies given to these operations.

USDA statistics do not include a category that corresponds exactly to the EPA definition of a dairy CAFO (700 or more animals). We therefore used the closest USDA category—more than 500 cows—for our calculations. The annual national feed savings for such dairies, as extrapolated from Iowa, Kansas, Ohio, and Wisconsin, amounts to about $733 million per year. In 2006 there were 3,143 dairy operations with 500 or more cows, accounting for 46.7 percent of the U.S. inventory (NASS 2007). Therefore, the average subsidy for each CAFO is roughly estimated to have been about $233,000 per year.

As with hogs, the largest dairy CAFOs benefit more than their smaller counterparts from the low cost of grain. Confined operations of more than 2,000 animals contained 21.6 percent of the U.S. inventory in 2006, or about 46 percent of dairy CAFO inventory. There were 573 of these very large opera-

16 The entire class of hog operations containing 2,000 to 4,999 hogs comprises only 9.5 percent of hog production, according to NASS data for 2006. Therefore, hog operations between 2,000 and 2,499 hogs likely produced less than 1.6 percent of hogs.

17 A single owner may own multiple operations, and owners with the largest number of operations also maintain the largest operations in size.

tions nationally (NASS 2007), receiving an average subsidy of about $588,000 each per year. By contrast, smaller CAFOs (700 to 999 cows) and medium-sized AFOs (500 to 699 cows) collectively contained 12.6 percent of U.S. dairy cow inventory, or about 27 percent of dairy CAFO inventory. These 1,700 operations therefore benefited from an average subsidy of about $116,000 each.

Data collected by the USDA on feedlot beef cattle are not as extensive as for other sectors, so data from several states have been used to approximate the indirect subsidies paid to feedlot beef cattle CAFOs. As with the dairy industry, these calculations must be understood to be a small sample of the costs and feed compositions that may occur in various parts of the country. And unlike the data for dairy cattle, data from Iowa and Minnesota for feedlot cattle span the longer period of 1997 to 2003.

Corn makes up a larger share of the feed cost compared with dairy cows (an average of 72 percent), but feed in general makes up a similar share of the total production costs compared with dairy cows (about 16 percent) and a smaller share compared with hogs or poultry. This is largely because calves (purchased by beef cattle feedlots), make up a larger share of beef cattle production costs than animals in other sectors, and therefore grain makes up correspondingly less of the total cost of producing beef cattle than dairy cows or other livestock. Extrapolated to national production levels, our calculations find that the implicit subsidies for feedlot cattle CAFOs average about $500 million per year, or about 5 percent of total production costs per year between 1997 and 2003.

According to the USDA, extremely large feedlots now dominate beef cattle marketing. Feedlots smaller than 1,000 animals sold only about 14 percent of beef cattle but made up almost 98 percent of all feedlots (GIPSA 2002). Feedlots of 1,000 to 32,000 animals sold about 22 percent of beef cattle and represented about 26 percent of beef CAFOs, thereby receiving an average subsidy of about $72,000 each. The 168 largest beef feedlots (over 32,000 animals) sold more than 64 percent of feedlot cattle and represented about 74 percent of beef CAFOs (GIPSA 2002). **These huge operations received an average of about $2.2 million per feedlot in grain subsidies per year.**

Indirect Subsidies across Sectors

In summary, commodity crop subsidies that compensate for low grain prices contributed about $34.74 billion between 1997 and 2005 to poultry, swine, beef, and dairy CAFOs (see also Starmer and Wise 2007b). This amounts to about $3.86 billion per year, with the proviso that data for dairy cows and beef cattle are limited by region and year, and therefore nationwide averages over time are provided for illustration purposes rather than as highly accurate values for these sectors. The data from the preceding analyses are summarized in Table 5 (p. 34).

Because of integration in the animal products industry, these savings are a boon to processors as well as CAFOs. For example, the four largest broiler companies saved approximately $5.6 billion from 1997 to 2005, and the four largest swine processors saved about $4.3 billion (Starmer and Wise 2007b).

Subsidies for Alternative Production Methods

It is useful to ask whether alternative methods of producing livestock have also benefited from Title I crop subsidies. Have these subsidies favored CAFOs over other means of producing livestock that have fewer externalities? Diversified farms—those that produce both grain and livestock—are one alternative to specialized CAFOs, which grow little or no grain.[18] For example, national survey data (Boessen, Lawrence, and Grimes 2004) found that 94 percent of small hog producers grew corn and 90 percent grew soybeans, while 84 percent of medium-sized producers grew corn and 80 percent grew soybeans. Fewer hog CAFOs grew corn (73 percent) and soybeans (68 percent). These data did not include a subcategory for the largest hog CAFOs, which could have indicated whether these very large operations

Table 5. **Indirect Subsidies to the CAFO Industry, 1997–2005**

Sector	Average Annual Subsidy	Average Annual Subsidy per CAFO	Average Annual Subsidy per Large CAFO	Average Reduction in Cost of Production
Broilers	$1.25 billion	$766,000	na	13%
Dairy	$733 million	$233,000	$588,000	6%
Eggs	$432 million	$388,000	na	13%
Feedlot Beef	$500 million	$72,000	$2.20 million	5%
Swine	$945 million	$325,000	$5.01 million	15%
Total	$3.86 billion			

na=not available
SOURCES: Starmer 2007; Starmer and Wise 2007a; Starmer, Witteman, and Wise 2006.

also grow some of their own grain, and did not reveal the percentage of feed grain produced on-farm in each size category.

Other data indicate that CAFOs have much less cropland available, relative to the amount of animals, compared with smaller operations (Kellogg et al. 2000). Medium-sized operations of 150 to 300 AU (animal units) had 0.17 AU per acre of cropland available to receive manure in 1997, while CAFOs had 1.7 AU per acre—or 10 times less land per animal. Smaller and medium-sized diversified farms would generally be expected to use all of the manure produced by their animals, in an economically and environmentally favorable manner (provided their cropland is near the livestock operation).

Changes in the 1990 farm bill allowed farmers to retain the grain they produce but still receive loan deficiency payments. Therefore, diversified farms could benefit from Title I subsidies even if they retained their grain as feed for their own animals rather than opting to sell it. However, grain subsidies do not necessarily entirely compensate for low grain prices. One study (Ray, De La Torre Ugarte, and Tiller 2003) found that, over a two-year period, Title I subsides usually did not fully compensate farmers for the difference between production costs and grain prices, creating a "subsidy gap." Even with subsidies, returns for corn were 6 percent below production costs for 2000 and 1 percent above production costs for 2001; soybean returns were 9 percent and 11 percent below production costs, respectively.

CAFOs that buy grain would not experience this subsidy gap because they would purchase grain at the low market price, while diversified farmers would have to contend with production costs not entirely compensated by subsidies. Even though diversified farms could benefit from crop subsidies, they would not receive as great a benefit as CAFOs that purchase grain.

To illustrate the subsidy gap, our calculations show the lower feed cost for CAFOs compared with hog farmers who grew their own grain in 2000 and 2001 (Table 6). Title I subsidies would therefore have favored the development of CAFOs over diversified farms. It should also be noted that even with subsidies for diversified farms that grow their own grain, such farms may generally have produced this grain at a loss.

Indirect subsidies for pasture systems

To the extent that alternative means of livestock production do not use subsidized grain, they would not benefit from Title I crop subsidies. In particular,

18 The term "diversified farm" is used here in the very narrow sense of a farm that produces both grain and livestock. However, in other contexts, this term has been used to define farms that produce many different crops as well as livestock. Such highly diverse farms often have additional sustainability advantages.

Table 6. **Comparison of Subsidies for CAFOs and Diversified Farms**

Hog CAFOs	2000	2001	Diversified Hog Farms	2000	2001
Market Price for Feed ($/ton)	$92.72	$92.48	Cost of Feed Production Minus Subsidies ($/ton)	$103.06	$97.94
True Cost of Feed Production ($/ton)	$137.35	$126.86	True Cost of Feed Production ($/ton)	$138.38	$127.41
Indirect Feed Subsidy	48%	37%	Feed Subsidy	34%	30%

SOURCE: Starmer 2007; calculations based on differences between subsidies and production costs from Ray, De La Torre Ugarte, and Tiller 2003.

pasture production and non-grain forages are not subsidized and are therefore put at a disadvantage by these non-market practices.

The Effect of Changing Grain Prices

Rising demand for fuel ethanol in the United States has dramatically changed the economics of grain production by pushing corn prices to historic highs, from around two dollars per bushel in 2005 to three dollars per bushel in 2006 and $3.88 in December 2007 (NASS 2008a and 2008b). Many experts such as the Food and Agricultural Policy Research Institute (FAPRI), upon which the federal government often relies for agricultural analyses, predict that corn prices will remain high at least through 2011.

The price of corn is no longer below the cost of production, and soybean prices are expected to come closer to the cost of production over the coming years. Under these circumstances, the feed price subsidies that have benefited CAFOs historically seem to be rapidly coming to an end—at least for the next several years. It is therefore relevant to ask how these higher feed prices may affect CAFOs in coming years.

Increased demand has, in turn, led to increased planting of corn: about 93 million acres in 2007 compared with 82 million acres in 2005 (NASS 2008a). Although such large increases in acreage would have driven prices down in the past, this seems unlikely in the near future because of increasing demand for ethanol and growing international demand. Continued growth in ethanol demand will depend in part on resolving limitations in production and distribution infrastructure, the price of imported ethanol, and continuing domestic ethanol subsidies, but is not likely to disappear entirely. According to estimates based on current technology, the entire domestic corn crop would meet only about 12 percent of U.S. gasoline and 6 percent of U.S. diesel needs (Hill et al. 2006). Therefore, even modest percentage increases in ethanol fuel use could continue to put heavy demand on corn.

Calculations using FAPRI data determine the cost-price margins for corn and soybeans from 2006 to 2011 (Starmer 2007). Corn is expected to continue selling at a price that exceeds the cost of production, while soybean prices move closer to profitability over the next several years. If current trends continue, corn would exceed the cost of production by 25 percent in 2011. Overall feed prices for hogs would average about 3 percent over the cost of production for the period. Because hog production benefited from an indirect subsidy averaging about 13 percent from 1997 to 2005, the net increase in production costs between 2007 and 2011 would be about 15 percent. Similar calculations would apply to the other livestock sectors discussed in this report. Given the rapidly changing prices for grain crops, these data are likely to become outdated

19 It should be noted that cost of crop production is determined in part by the prices of farm supplies. Some sectors of the farm supply industry, notably the seed industry, have become more economically concentrated over the past several decades. Resulting price increases in seeds or other farm supplies may erode the profits of grain farmers.

quickly, but nonetheless illustrate that the indirect subsidies of the past have largely disappeared.[19]

As the market price of corn or other feed grains exceeds the cost of production, diversified farms that produce their own grain gain some economic advantages. As noted in Table 6, specialized CAFOs benefit more from crop subsidies than diversified farms. Conversely, as grain prices rise, CAFOs lose relatively more of this benefit compared with diversified farms that grow their own grain. Rising grain prices allow diversified farms to avoid paying the difference between the costs of production and the higher price they would otherwise have to pay for feed if they did not produce their own grain. Additionally, production systems that use pasture and forage rely less on grain than CAFOs and may also acquire an economic advantage.

To the extent that the FAPRI projections are fulfilled or exceeded, CAFOs' costs could rise substantially in coming years. The elimination of the subsidy gap and a lower cost for growing rather than buying feed grain could eliminate some of the economic advantage that large hog and other CAFOs currently maintain over diversified medium-sized animal operations.

It is not clear, however, whether such a change in profitability would result in substantial increases in alternative animal farming. As noted in Chapter 1, several alternative production methods including well-managed medium-sized AFOs are already roughly cost-competitive with CAFOs, but often have difficulty gaining market access. Structural barriers to alternative animal production, such as the preference of processors to contract with large producers, are not eliminated by increasing grain prices. The possible cost advantages that alternative production methods could acquire may not be dramatic enough to overcome these structural barriers, and point to the need for policies that will facilitate the growth of beneficial animal production methods.

The role of feed alternatives

Another consideration that may affect the feed costs for CAFOs and other grain-feeding operations is the use of feed alternatives that may be less expensive than grain, such as the major by-product of the ethanol fermentation process: so-called dried distillers grains with solubles (DDGS). DDGS has considerable nutritional value, is enriched in protein content compared with corn, and may be considerably less expensive under some circumstances. Most of the starch, the readily available carbohydrate source in corn (and the main source of easily digestible calories for livestock), is converted into ethanol and thereby removed from the grain. The overall nutrient content, however, is concentrated in DDGS compared with corn, and fiber digestibility is increased, compensating in part for lost starch.

Several factors currently limit the use of DDGS as a substitute for corn and other grains. A recent hog-finishing study showed that although a diet with 10 percent DDGS provided good performance, diets that included 20 to 30 percent DDGS reduced daily weight gain (Whitney et al. 2006). Although feed costs were lowered compared with corn priced at two to four dollars per bushel, this did not compensate for the lower weight gain, making DDGS economical only at the 10 percent feed level. Therefore, the study authors recommended that DDGS should make up less than 20 percent of a hog-finishing diet.

Similarly, recent research on broilers demonstrated that substituting DDGS for 15 percent of grain did not reduce the weight or quality of the chickens, but 30 percent DDGS adversely affected growth rates even when alternating with 0 percent DDGS on a weekly basis (Wang et al. 2007). Cattle can utilize greater concentrations of DDGS in their feed, with dairy cows using about 20 percent and beef cows about 30 percent or more (Hicks 2007; Schingoethe 2006).

A second limitation of DDGS is that it contains considerable moisture. This greatly limits storage time due to spoilage, and increases transportation costs compared with dry grains. DDGS can be dried and formed into pellets, but drying adds expense and uses energy. For these reasons, DDGS is currently most feasible—to the extent they can be used—for cattle located close to CAFOs.

Finally, major changes in livestock diet may have unanticipated consequences. Recent work indicates that beef cattle fed 25 percent DDGS may produce significantly higher levels of *Escherichia coli* O157 than beef cattle fed a conventional diet (Jacob et al. 2007). Increased levels of this serious food-borne pathogen would be an undesirable side effect of using DDGS, counteracting the benefit of lower production costs with another potential public health threat.

Summary of Indirect Subsidies to CAFOs

Title I farm bill crop subsidies have provided huge indirect subsidies to CAFOs: estimated at $3.8 billion a year over the eight-year period from 1997 to 2005 (Starmer 2007; Starmer and Wise 2007b). This not only makes CAFOs appear more economically efficient than they actually are, but also gives CAFOs an advantage over alternative means of producing animal products that do not benefit (or benefit less) from these subsidies.

Rising grain costs driven by corn ethanol demand have made such alternatives more favorable economically, but structural barriers may prevent or slow the ability of alternatives to penetrate the market. Alternative feeds for CAFOs, especially DDGS produced in large quantities as an ethanol by-product, currently have several limitations that prevent them from displacing more than a small to moderate amount of corn feed.

Direct Subsidies to CAFOs

In addition to the indirect subsidies CAFOs receive in the form of crop support and lack of accountability for externalities, direct government subsidies also encourage the proliferation of CAFOs. Where direct subsidies favor CAFOs over other ways of raising livestock, they may also discourage otherwise viable alternatives. At the national level, perhaps the largest single direct subsidy to CAFOs is the Environmental Quality Incentives Program (EQIP), originally intended to help small and medium-sized livestock farms address pollution issues. We examine EQIP in some detail, but it should be kept in mind that many similar initiatives at the state level may collectively contribute substantial additional subsidies to CAFOs.

EQIP originated as part of the 1985 farm bill and was renewed in all subsequent farm bills including the 2002 version. The intent of the program was to provide subsidies and incentives that would help both crop and livestock farmers prevent environmental harm. In the case of livestock operations, CAFOs (defined as operations with 1,000 AU or more) were specifically excluded from the earlier versions of the program, which focused on pasture-based animal farms and other smaller operations that may have difficulty acquiring the funds needed to implement pollution control. The program was relatively modest at the time; for example, the version passed in 1996 allocated a total of $200 million per year in federal funding.

In 2002, however, the program's emphasis was changed dramatically, making CAFOs a major funding recipient. The upper cap for contracts with individual farms was raised dramatically from $50,000 to $450,000 per project, and total program funding rose from $400 million in 2002 to a projected $1.36 billion in 2007 (NRCS 2003).

At the same time, the program's regulatory language mandates that 60 percent of EQIP funding should be devoted to animal farming, ensuring a large amount of funds are available for these operations (NRCS 2003). Though the language does not specifically base funding on operation size (NRCS 2003), priorities are described that favor projects capable of achieving the greatest reduction in environmental degradation (which favors CAFOs). In a white paper prepared prior to finalizing the 2002 program, the USDA's Natural Resources Conservation Service (NRCS) explicitly suggested that because similar amounts of effort and cost are needed to implement each EQIP contract, more benefit might be garnered by allocating funds to large

CAFOs rather than a greater number of smaller operations (NRCS 2002).

The new EQIP regulation prioritizes activities that only CAFOs typically have the need to pursue, such as improvement of waste storage facilities, comprehensive nutrient management plans, and transportation of manure tied to environmentally and agronomically sound crop application rates. The explicit rationale provided for this ranking is that greater environmental improvement can be achieved by alleviating CAFO-related problems than pasture-related problems.

EQIP funding also favors CAFOs by holding the farming operation responsible for a portion of the project costs; the share of costs supplied by EQIP typically stops at 65 percent. While remediation associated with several CAFO waste management methods is often funded at the program maximum of 75 percent of the total project cost, EQIP recommends a maximum funding level for pasture-based practices of only 55 percent (NRCS 2003). This means that pasture-based farmers can expect to pay for relatively more of an EQIP project themselves than CAFO owners. This may discourage some pasture-based farmers from applying for EQIP funds, thereby reducing CAFOs' competition for EQIP funds.

The prioritizing of applications seeking EQIP funds is important because the total funds available are greatly exceeded by the demand. Most EQIP applications therefore remain unfunded.

Estimating EQIP subsidies to CAFOs

The most straightforward way to determine whether CAFOs are now favored in EQIP funding over smaller and alternative operations would be a direct comparison of disbursements based on farm size and type and the practice addressed by the EQIP allocation. However, such data do not appear to be readily available at the state or national level. Because of this lack of data, we cannot determine either how great the subsidizing of CAFOs has been or the relative amount of subsidizing compared with other types of animal farming operations. Despite this limitation, it is clear that the relative subsidy to CAFOs compared with other animal operations must be considerably higher than in previous farm bills, because CAFOs were formerly excluded altogether.

A rough approximation of the national CAFO subsidy can be made using the recommendations made by the NRCS in finalizing the EQIP rule for the 2002 farm bill. The NRCS estimated at the time that approximately $563 million, or 12.5 percent of the total funding, would go to CAFOs over a five-year period (NRCS 2003), an average of about $94 million per year. Another approach is to consider that 60 percent of EQIP funding is slated for animal farming, and 25 percent of that allocation is intended for CAFOs (NRCS 2003). That means 15 percent of EQIP funding would go to CAFOs—about $676 million, or an average of $113 million per year.

It is not possible to clearly determine which approach is more accurate, due to a lack of appropriate data collection that would distinguish allocations by size and type of operation. Based on rankings favoring incentives to CAFOs, these values might be expected to be a minimum allocation. This amount could also include livestock such as turkeys and sheep that are not evaluated in this report, but present similar concerns as other CAFOs.

In 2006, about $152 million was allocated explicitly for confined livestock operations, while about $85 million was allocated to unconfined operations (Figure 3, p. 43). In addition, about $247 million was allocated for "undistinguishable" practices (i.e., those that could apply to either confined or unconfined animal operations); the amount allocated to each type of operation is unknown. However, if we assume that the distribution between confined and unconfined operations in this category is the same as with the known disbursements, some estimate of the additional amount going to CAFOs can be calculated.

In the known categories, about 64 percent of funding went to confinement operations and 36 percent to unconfined operations. Using this same proportion for the undistinguishable category, another

$158 million would have been disbursed to confinement operations, for a total of about $310 million. If 25 percent of this total went to CAFOs, these operations would have received about $77.5 million in 2006. However, as noted above, there are reasons to believe that CAFOs may have actually received a considerably higher percentage of the funds.

For 2007, the total EQIP disbursement was projected to be $1.3 billion (NRCS 2003). If 60 percent of this amount went to animal agriculture, and 64 percent of that went to confined operations, and 25 percent of confinement funds went to CAFOs, then the expected CAFO subsidy would have been $125 million in 2007. (The uncertainties in these calculations due to a lack of public data show that better national accounting of CAFO fund distribution based on operation type, size, and use is needed.)

CAFOs first became eligible for EQIP funds at the same time as the Clean Water Act was expanded to cover CAFO pollution. EQIP subsidies therefore came at a fortuitous time for CAFOs, which were facing new manure management requirements.

Each state determines how it will distribute federal EQIP funds, and maintains online information about its implementation of EQIP programs. States often provide details on the practices for which EQIP funds are allocated and the amount of the disbursements. Although the size and types of operations are not revealed, some practices that are largely or exclusively limited to CAFOs, CAFOs and AFOs combined, or pasture-based operations allow us to draw inferences about EQIP disbursements. For example, manure transportation subsidies are unlikely to apply to pasture-based operations and are most often important for CAFOs. Several of the EQIP programs of major CAFO states are briefly discussed below.

EQIP subsidies in California

As shown in Figure 3 (p. 43), dairy operations receive the largest share of federal EQIP subsidies for confined animal operations (42 percent). California has more dairy cows and CAFOs than any other state, and therefore likely receives a substantial proportion of these funds. In 2007, a California EQIP program for waste storage and alternative waste treatment practices split the share of costs between AFOs larger and smaller than 300 AU. The program specifies that most of the funds would be distributed to those AFOs below 300 AU (smaller to medium-sized operations).

On the other hand, a California EQIP water quality initiative is directed at animal operations facing new state and federal waste permit requirements. Changes in the federal Clean Water Act requiring permits and comprehensive nutrient management plans are largely specific to CAFOs (more than 700 dairy cows) rather than smaller AFOs or pasture-based animal farms. This water quality initiative may therefore predominantly target CAFOs, but state programs may affect the distribution of these subsidies because the states have considerable authority in implementing EQIP. This water quality initiative represents California's largest EQIP budget item, at $10 million, or 21 percent of the budget (NRCS 2007b).

EQIP subsidies in Arkansas and Georgia

Arkansas and Georgia are the two states that produce the most broiler chickens. Arkansas targeted 25 percent of its 2008 EQIP funds for animal waste management, and an additional 2 percent to "waste systems closure" (NRCS 2008a). In 2007, Arkansas allocated $2.9 million to livestock waste management for water quality (NRCS 2007d). Arkansas also offered an incentive program subsidizing litter transfer to crop fields; this program may target CAFOs because it requires applicants to document "excess manure produced on the farm." Because many smaller or medium-sized farms usually have enough of their own land to apply manure at appropriate rates (Kellogg et al. 2000), most farms that need to transfer manure are likely to be CAFOs.

Georgia also implemented a pilot litter transfer program for 2007–2008, funded by EQIP at up to $10 per ton and up to $10,000 per year per farm. Figure 4 (p. 44) shows the counties targeted in the program, with red designating those counties producing and contributing litter, and green designating those counties receiving litter during the first year of the program. The program specifies that only these counties may receive subsidies. The distance between the nearest contributing and receiving counties is close to 50 miles, while typical distances could exceed 100 miles; since large distances are not usually required for manure transfer from smaller or medium-sized operations, we can infer that this program may subsidize CAFOs more than small to medium-sized operations. These distances would also have a substantial impact on an operation's transportation costs and energy use.

After the first year of the program, additional manure-receiving counties were added and counties were prioritized by a point system. A few moderate-priority counties closer to manure sources were added, but most high-priority manure-receiving counties remain in central Georgia.

EQIP subsidies in Iowa and North Carolina

Iowa and North Carolina are the two states with the most swine CAFOs. Requirements for EQIP funding in Iowa give considerable weight to CAFOs; in 2008, for example, several of the state's highest-ranked eligibility criteria pertained to concerns about the animal waste produced by CAFOs, including "Surface and subsurface water quality related to the presence of excessive nutrients and organics related to livestock production by concentrated animal feeding operation's (CAFO's) [sic] on open feedlots" (NRCS 2008b). One of the four major criteria used for disbursement of funds favors those counties with the most livestock.

In North Carolina, animal farming practices clearly pertaining to AFOs and CAFOs comprise a large proportion of EQIP funding. Allocations for waste storage facilities, for example, amounted to $4.5 million in 2007 (30 percent of total allocations), compared with $2.9 million in 2002. The 2007 amount is at least three times larger than the next largest categories of fencing, composting, and closure of waste impoundments, which each represented about 6 to 10 percent of allocations (NRCS 2008c).

The state paid almost $1 million in 2007 to close waste storage facilities, which were often abandoned (NRCS 2008c). Disbursement data do not typically mention operation size, but the data on waste storage facilities show dramatically increasing amounts per operation since 2001. In that year, the average subsidy was about $10,000 per unit; by 2007 it had grown to about $36,000 per unit, favoring larger operations.

A new EQIP program to be launched in North Carolina in 2008, the ground and surface water conservation supplement, will be exclusively allocated to operations that raise confined swine. Contracts will be capped at $10,000 each.

Summary of Direct CAFO Subsidies Under EQIP

EQIP changed in 2002 from a program specifically aimed at smaller farming operations to one that included—and favored—CAFOs. This represents a significant change of emphasis from the first 17 years of the program, and provides CAFOs with a new competitive advantage. In addition, because the program has grown substantially in total available funding, the actual subsidies are more than six times larger than they were seven years ago. In other words, more money is going to support CAFOs now than smaller farms received a decade ago (although a substantial amount of small-farm support likely remains).

Overall, EQIP CAFO subsidies for the past several years were likely to have totaled about $100 million or more per year, although it must be noted that this can only serve as a very rough estimate because disbursement data by operation size are not readily available. Because of growing concern about the environmental impact of CAFOs (as reflected in new Clean Water Act provisions recently directed at CAFO pollution), data should be collected and made public based on operation size and type.

Chapter 3

EXTERNALIZED COSTS OF CAFOs

Raising livestock and poultry can cause substantial harm to people and the environment. As discussed in Chapter 1, the costs associated with this harm (which are not included in the costs of production) are called externalities.

Nutrients from manure can become externalities by entering the air via volatilization (Walker et al. 2000) or by entering ground or surface water (Burkholder et al. 2007; Mallin and Cahoon 2003). Large waste spills from CAFOs have been documented (Mallin 2000), and when hundreds of thousands or millions of gallons of animal waste spill into a stream, river, or estuary, a series of cascading effects results in externalities such as the death of thousands of fish, expenditure of many hours by state personnel to assess the damages, closure of local marinas and recreational facilities due to contamination by pathogenic microbes, lost work days caused by illness, closure of downstream shellfish beds, and negative effects on the local food web (such as the death of aquatic organisms that other animals depend on for food).

Typically the CAFO operator will be assessed a relatively small fine for such a spill. Thus, taxpayers and local residents or businesspeople will be forced to shoulder the cost of externalities by paying for fish restocking and overtime for regulatory personnel, and by absorbing losses from fishing, shellfishing, and other water-related industries. Similar harmful effects can result from water pollution caused by the over-application of CAFO manure to farmland, leakage from manure holding facilities, and the redeposition of airborne CAFO ammonia.

It is often difficult to assign a monetary value to externalities, but in some instances it is possible. For example, odors and noxious gas emissions are a common adverse effect of high animal concentrations (Wing and Wolf 2000), but the resulting reduction in quality of life for people living near CAFOs is difficult to quantify directly. However, these costs may be reflected in depressed residential property values that have been quantified (Weida 2004). In this chapter, both quantified and unquantified externalities will be considered.

Whether quantified or not, externalized costs are borne by society rather than the industry that caused the damage. If the costs to prevent (or remediate) the damage were instead borne by the industry, its cost of production would increase and could be reflected in the marketplace by higher prices. This could facilitate competition by alternatives that do not cause these externalities. To the extent that the costs of externalities are avoided, they constitute a form of subsidy to the industry that caused them.

Below we discuss in detail several of the major externalized costs of CAFOs. In particular, costs to the environment in the form of water and air pollution are considered at length. One important consideration of nutrient pollution is the tradeoff between water and air pollution. Reducing water pollution, if not done properly, can exacerbate air pollution and, ironically, fail to resolve water pollution on a regional scale. This tradeoff has serious implications for nutrient management policies. We also discuss the harm from pathogens, especially antibiotic-resistant pathogens, and the harm to rural communities.

For each topic, we describe the damage done by CAFOs and how we might estimate the monetary costs associated with that damage. Although comprehensive economic assessments of the monetary costs are not available, efforts have been made to provide cost estimates for certain aspects of these externalities, which are useful in providing a general sense of the extent of the subsidy represented by externalized costs. Other important topics such as water and energy use we leave for future evaluations.

Pollution Caused by CAFO Manure

Manure from CAFOs is a major source of water pollution because these operations produce too much manure in too small an area, and this manure is rarely treated to eliminate potentially harmful components before being applied to crop fields or stored in facilities such as lagoons or pits (EPA 2003). By comparison, the majority of human waste is processed by municipal wastewater facilities or septic systems before it can re-enter our water. The manure produced by individual CAFOs exceeds that produced by smaller AFOs or alternative animal farming operations, and as we will discuss, is also more likely to harm the environment and public health than that produced on other types of farms.

Most CAFOs collect and store manure prior to its application on farmland or fields. The most common storage structures for manure from dairy cattle and hogs are either lagoons or pits; poultry manure, because it has lower water content than cattle or hog manure, can be gathered into piles. Poultry manure is also often mixed with material such as wood chips that are spread on the floor of broiler facilities several times a year. The resulting combination of poultry manure, wood chips, wasted feed, and bedding material is referred to as litter. Poultry manure that has higher water content is stored in lagoons. Manure pits and lagoons may leak below the soil surface and contaminate groundwater, which may infiltrate wells that supply potable water (Volland, Zupancic, and Chappelle 2003; Huffman and Westerman 1995).

Most of the nitrogen in manure begins in either a complex organic form or as ammonia. Much of the ammonia is converted in aerobic environments, as on crop fields, into nitrate. Nitrogen in the form of nitrate is highly mobile in soils and is the constituent of manure most likely to have an adverse effect in drinking water. Concentrations of 10 mg/l of nitrate in drinking water may cause methemoglobinemia, or "blue baby syndrome," which may cause mortality (Fan and Steinberg 1996; Johnson and Koss 1990). Nitrate consumption has also been linked to certain cancers.

Groundwater pollution

Studies by the Kansas Geological Survey found that contamination in 42 percent of tested wells derived from animal waste (cited in Volland, Zupancic, and Chappelle 2003). U.S. Geological Survey (USGS) testing determined that animal waste was responsible for contamination of wells at 9 of 35 swine feeding operations in Oklahoma where nitrate levels exceeded the EPA safe drinking water limit of 10 mg/l (Becker, Peter, and Masoner 2002). In North Carolina, groundwater near 11 swine lagoons had an average nitrogen concentration of 143 mg/l (Huffman and Westerman 1995). Groundwater may move laterally and eventually enter surface water sources such as rivers, and may thereby contribute to eutrophication (the potentially harmful proliferation of plant life in nutrient-rich water) or other problems. Symptoms of eutrophication include nuisance or toxic algal blooms, low levels of dissolved oxygen (which can cause fish die-offs), aquatic food web disruptions, and taste, odor, or aesthetic problems in water resources.

Movement of leaked nitrogen from CAFO manure lagoons may continue to be a threat to groundwater even after a CAFO closes and the lagoon is emptied. Increased exposure to air may allow ammonia previously leaked into the soil under the lagoon to be converted into nitrate. Because nitrate is highly mobile in soil, it may reach groundwater more readily than ammonia. Ignoring the contaminated soil beneath a closed lagoon could therefore allow substantial quantities of nitrate to reach groundwater.

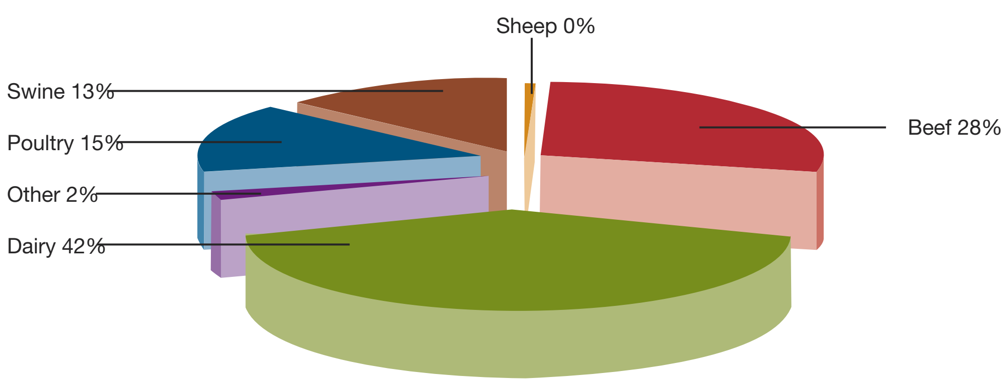
One study (Volland, Zupancic, and Chappelle 2003) estimated that the cost to remediate the contaminated soil under dairy and hog CAFOs in

continued on page 51

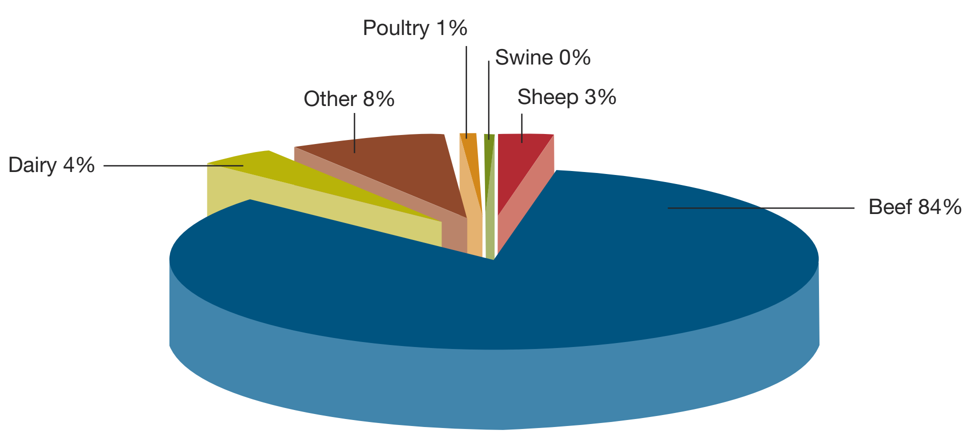
Figure 3. **Federal EQIP Funding for 2006**

Livestock Type	Total Cost-Share Approved	Confined Cost-Share Approved	Unconfined Cost-Share Approved	Practices Undistinguishable Cost-Share Approved	Number of Contracts
Sheep	$6,552,097	$701,466	$2,246,764	$3,603,867	296
Beef	$312,634,324	$43,062,776	$71,465,241	$198,106,306	17,605
Dairy	$90,101,196	$62,284,196	$3,372,295	$24,444,705	1,951
Other	$20,410,903	$3,198,336	$6,526,001	$10,686,566	1,118
Poultry	$28,478,004	$23,036,577	$629,270	$4,812,157	1,252
Swine	$25,570,331	$20,116,235	$327,272	$5,126,824	658
Subtotal	**$483,746,854**	**$152,399,586**	**$84,566,843**	**$246,780,425**	**22,880**
Non-Livestock	$304,220,696	$0	$0	$0	18,310
Total	**$787,967,550**	**$152,399,586**	**$84,566,843**	**$246,780,425**	**41,190**

National FY2006 Confined Livestock Cost-Share Approved

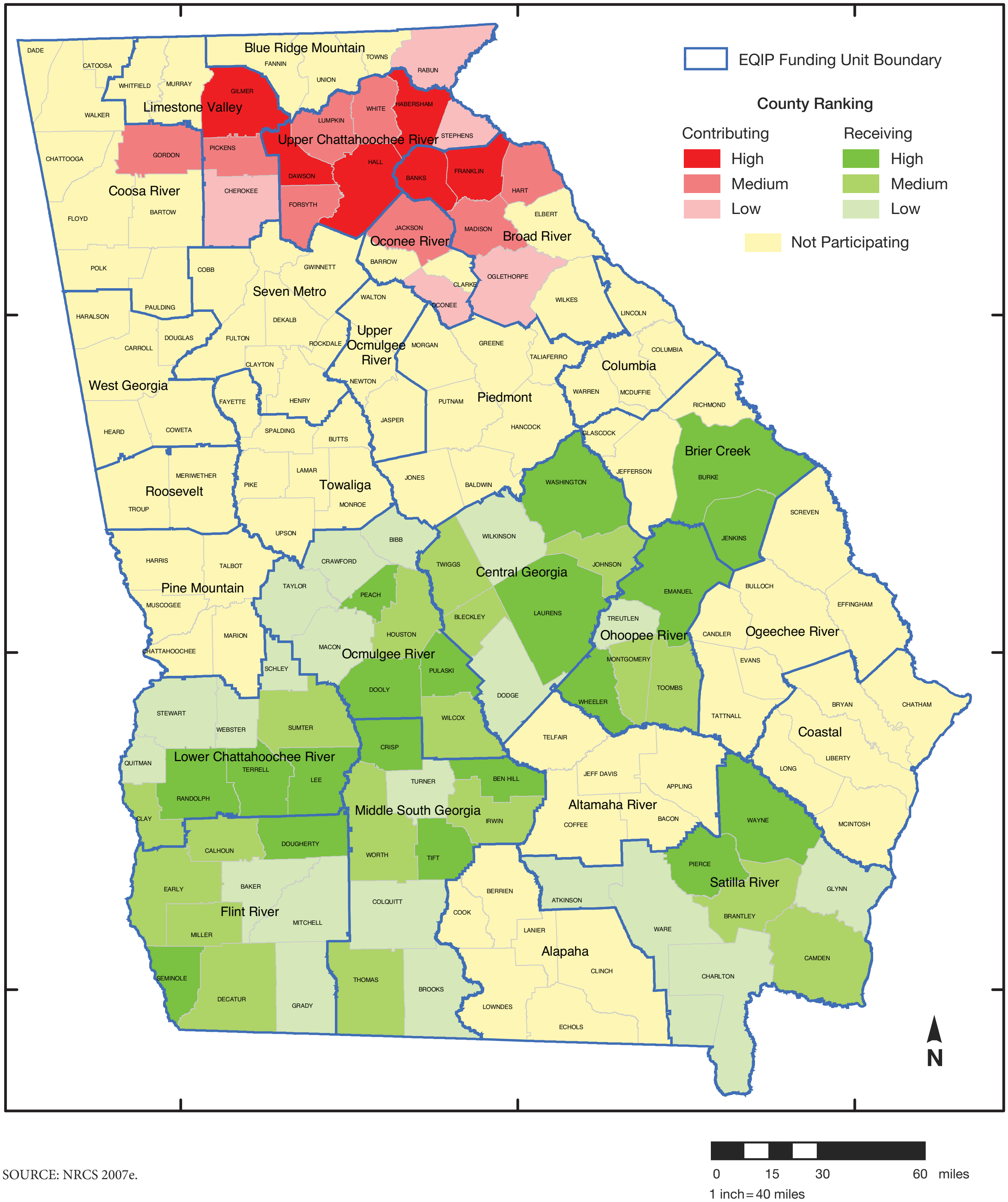


National FY2006 Unconfined Livestock Cost-Share Approved



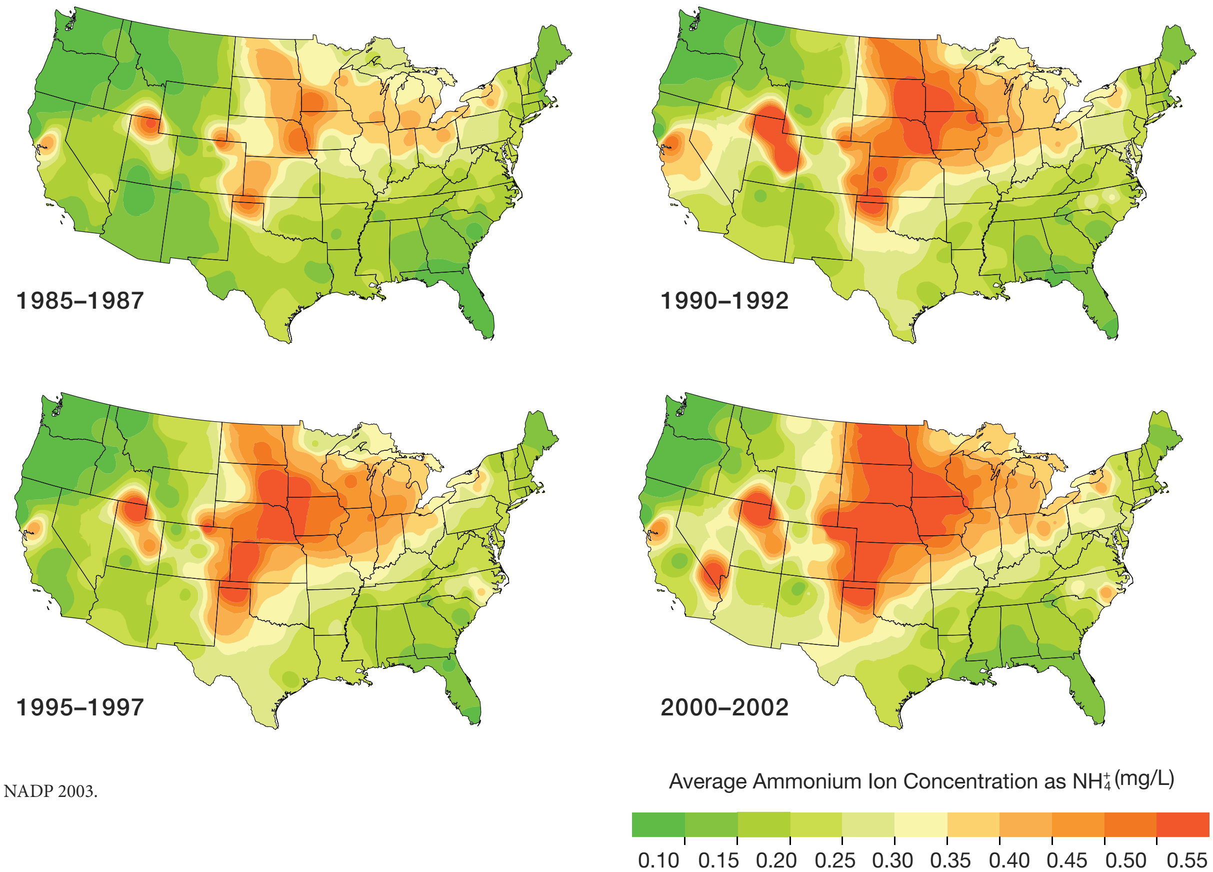
SOURCE: NRCS 2007.

Figure 4. **Counties Eligible for EQIP Subsidies in Georgia's Poultry Litter Transfer Program, 2006**



SOURCE: NRCS 2007e.

Figure 5. **Average Atmospheric Ammonium Ion Concentration, 1985–2002**



SOURCE: NADP 2003.

Figure 6. **Wet Deposition of Ammonium Nitrogen, 2002**

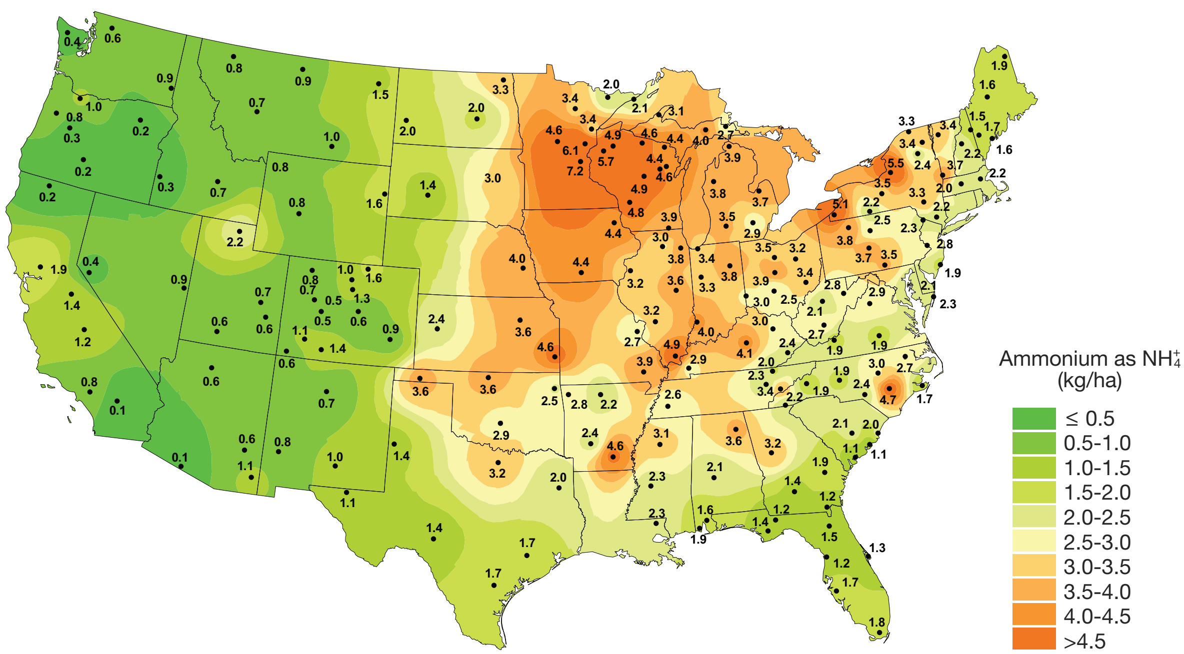
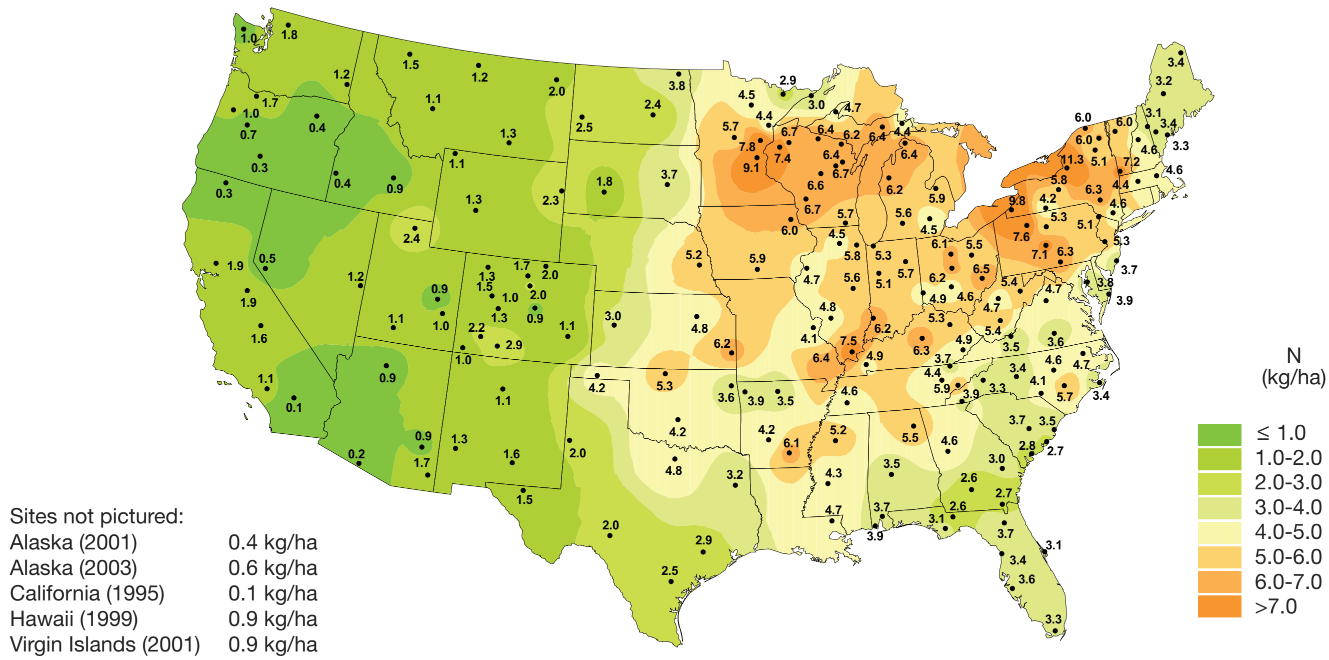
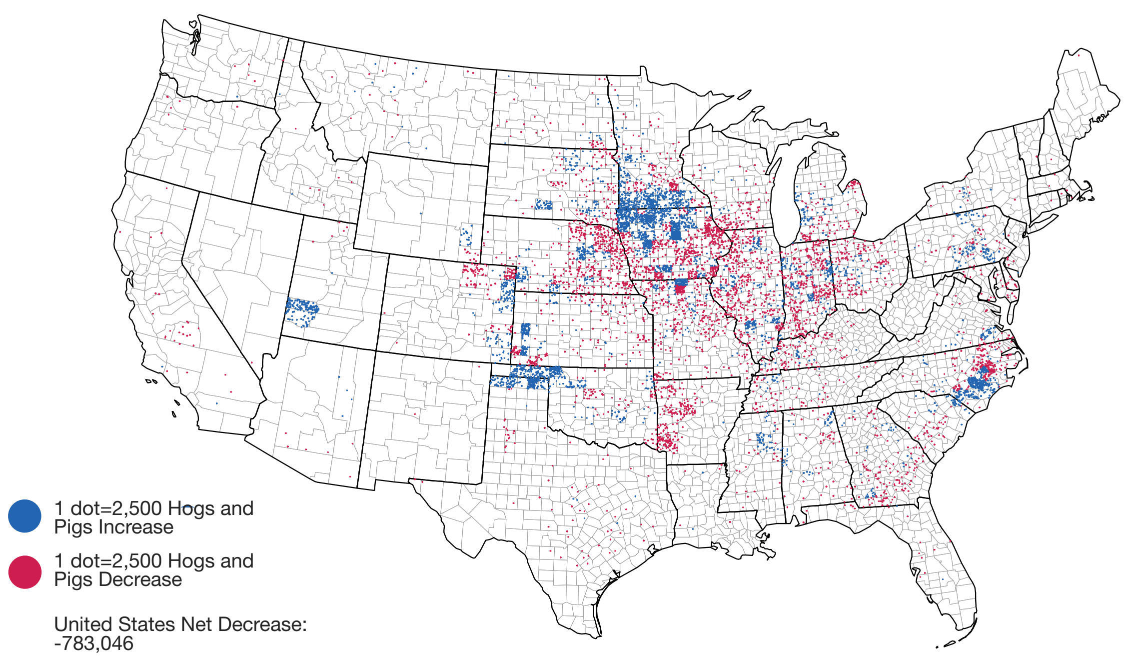


Figure 7. **Wet Deposition of Ammonia and Nitrate Nitrogen, 2002**



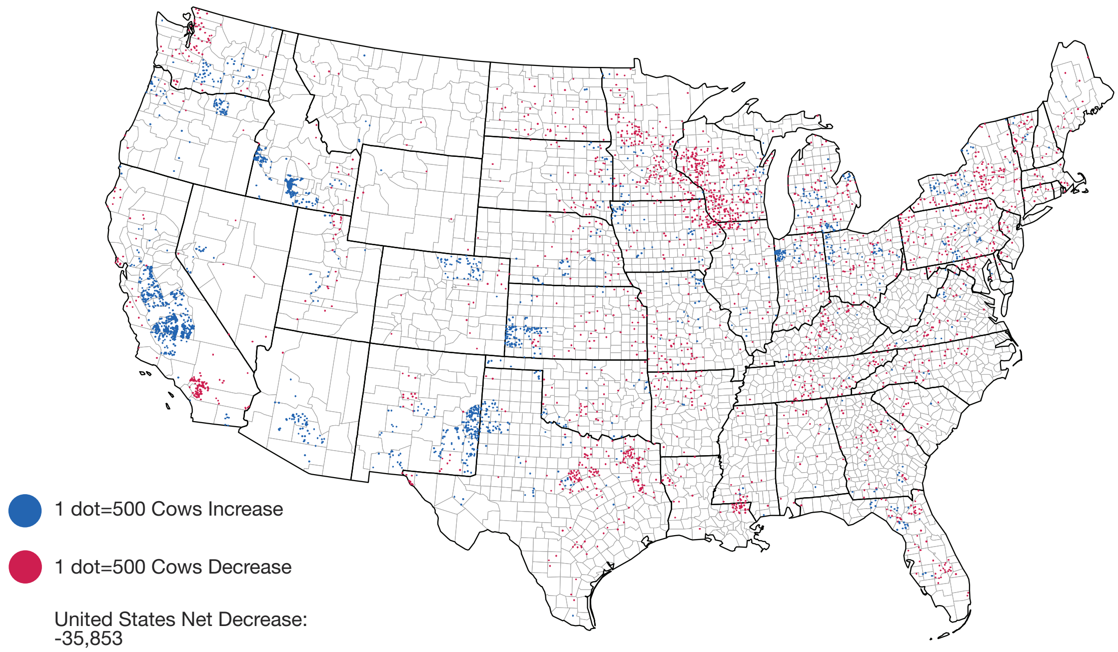
National Atmospheric Deposition Program/National Trends Network
SOURCE: NADP 2003.

Figure 8. **Geographic Concentration of Hog Production, 1997–2002**



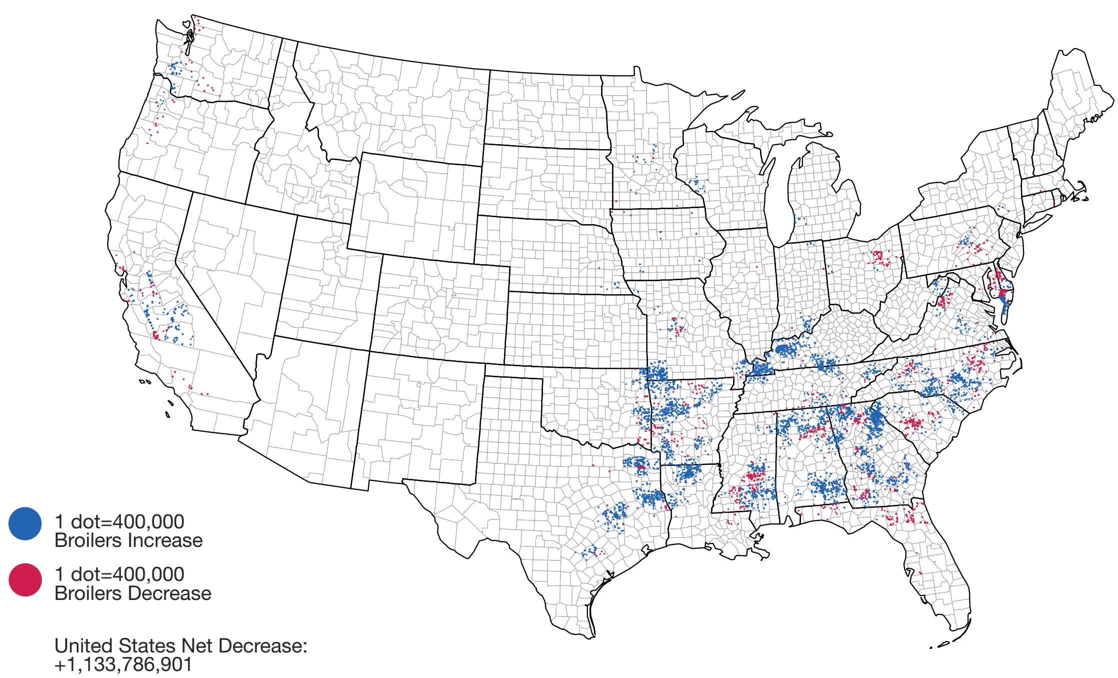
SOURCE: NASS 2002b.

Figure 9. **Geographic Concentration of Dairy Cows, 1997–2002**



SOURCE: NASS 2002b.

Figure 10. **Geographic Concentration of Broiler Production, 1997–2002**



SOURCE: NASS 2002b.

Figure 11. **CAFO Manure Lagoon**
Liquid manure from CAFOs is often stored in open-air reservoirs.
Photo credit: Courtesy of USDA.

Figure 12. **Environmental Danger of CAFOs**
In this 1999 image, raw manure from hog CAFOs overflows during flooding caused by Hurricane Floyd.

Photo credit: Courtesy of Rick Dove, www.doveimaging.com and www.neuseriver.com.

Figure 13.
CAFO Manure Pile
This enormous pile of manure was CAFO-generated.
Photo credit: Courtesy of Factoryfarm.org.

Figure 14.
CAFO Manure Lagoon
Manure is flushed with water into a lagoon at this North Carolina hog CAFO.
Photo credit: Courtesy of USDA.

Figure 15. **Unsanitary Conditions in Cattle CAFO**
These feedlot cows are caked in manure.
Photo credit: Courtesy of CARE/Factoryfarm.org.

Figure 16. **Alternative Cattle Production**
Well-maintained pasture systems are efficient and safer for the environment than CAFOs.
Photo credit: Courtesy of SARE.

above
Figure 17. **Crowding in Chicken CAFO**
At least 30,000 birds are packed into chicken CAFOs.
Photo credit: Courtesy of USDA.

right
Figure 18. **Alternative Poultry Production**
Pasture-raised chickens consume forage and insects as well as grain.
Photo credit: Courtesy of Stan Skillington.

Figure 19.
Crowding in Hog CAFO
Amimals in CAFOs are packed tightly together.
Photo credit: Courtesy of Farmsanctuary.com.

Figure 20. **Hog Hoop Barn**
Hoop barns give pigs straw bedding material and more room to move.
Photo credit: Courtesy of North Carolina State University.

Figure 21. **Alternative Pork Production**
Pasture-raised pigs are free to forage on this Colorado ranch.
Photo credit: Courtesy of Doug and Kim Wiley.

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Kansas alone could amount to $56 million—and Kansas is not a national leader in either dairy or hog production. States that have a larger number of such CAFOs (e.g., California, Iowa, Minnesota, North Carolina, Wisconsin) may face much more extensive lagoon or pit leakage problems than Kansas, depending on geology and other factors. It has been noted that the North Carolina coastal plain features many risk factors for waste runoff and leakage, such as soil percolation potential (Mallin and Cahoon 2003).

The extent of leakage and penetration into groundwater depends on a number of factors that vary considerably between CAFOs, including whether the pit or lagoon is lined, the type of lining, the type of subsoil, the depth of groundwater and aquifers, and the age of the facility. It is clear, however, that leakage is a common problem. It is also important to consider that once pollution has reached an aquifer, it may remain for years, decades, or longer.

We have used the Kansas data to calculate a rough estimate of the total cost of soil remediation under U.S. dairy and swine CAFOs. By dividing the total number of swine and dairy CAFOs by the number of such CAFOs in Kansas (NASS 2002a), then multiplying that figure by $56 million, we arrived at a national cost of $4.1 billion.[20] We did not extend these calculations to poultry and beef CAFOs because their manure storage methods are often considerably different than hog and dairy CAFOs. However, poultry and beef CAFOs also may contribute to manure leaching into groundwater under their manure collection structures.

Compared with nitrate, phosphorus is usually much less soluble in agricultural soils. It has therefore been thought that the primary means by which manure phosphorus enters water is through the runoff of phosphorus bound to soil particles, which in turn has led to a focus on conservation practices intended to limit runoff and soil erosion. Accumulation of phosphorus in soil over a number of years can also lead to increased dissolved phosphorus (Toth et al. 2006; Boesch 2001). Recent data suggest that over several years, phosphorus application at rates above that which can be utilized by crops results in leaching of *dissolved* phosphorus into groundwater in saturated and organic soils (Koopmans et al. 2007; van Es et al. 2004). Measurements of crop field drainage tiles showed substantial dissolved phosphorus from some soils after manure application (van Es et al. 2004).

Groundwater pollution can also result in surface water pollution, because groundwater may enter surface water such as streams or rivers.

Surface water pollution

Manure may spill from holding structures into nearby waterways due to severe weather or poor design or construction. Particularly dramatic instances of surface water contamination have occurred, drawing attention to the vulnerability of these structures and the impact they can have on watersheds. In 1995, for example, 25 million gallons of raw swine waste was released from a single failed lagoon into North Carolina's New River and its estuary, polluting approximately 22 miles of river. This spill caused fish kills, algal blooms, and fecal bacteria contamination, as did a poultry lagoon failure the same year (Burkholder et al. 1997; Mallin et al. 1997). Massive contamination also occurred when Hurricanes Fran, Bonnie, and Floyd hit the North Carolina coast in the 1990s (Mallin and Corbett 2006). Several large spills have also been recorded in other states (Mallin 2000), along with numerous smaller spills.

Although catastrophic failures of manure lagoons have garnered the most public attention, the most common source of water pollution from CAFOs may be the intentional application of manure onto farmland. Nutrients and other pollutants

20 As noted in Chapter 2, NASS data do not have categories corresponding exactly to the EPA definitions of hog and dairy CAFOs, so we used the closest categories available: 500 or more diary cows and 2,000 or more hogs. The number of Kansas hog CAFOs was obtained by multiplying the number of hog farms larger than 1,000 animals in the state by a factor equal to the number of U.S. hog farms larger than 2,000 animals divided by the number of U.S. hog farms larger than 1,000 animals. This estimate may differ from that used in Volland, Zupancic, and Chappelle 2003.

such as antibiotics, other pharmaceuticals, and heavy metals can move from fields where manure has been applied (Barker and Zublena 1995) due to storm runoff into streams or leaching into the soil below plant root levels (Karr et al. 2001), eventually reaching groundwater or surface water (by transport through field drainage tiles). Vegetation buffers intended to deter the movement of runoff and nutrients into streams and rivers are often inadequate because nutrients—especially nitrogen—may pass under them (Karr et al. 2001).

Damage to aquatic ecosystems

As indicated above, the two main contributors to water pollution from CAFOs are soluble nitrogen compounds (such as nitrate and ammonia) and phosphorus. Both nitrogen compounds and phosphorus contribute to the eutrophication of bodies of water characterized by algal blooms and fish die-offs. Phosphorus tends to be the key factor in causing freshwater eutrophication, while nitrogen is more often important in open marine environments, but both can be important in either environment. In addition, nitrogen in the form of ammonia can be directly toxic to aquatic organisms, and nitrous oxides (another product of manure) are potent heat-trapping gases. Ammonia pollution can also lower the level of dissolved oxygen in streams, lakes, and estuaries through the process of nitrification, by which bacteria oxidize ammonia into nitrite and nitrate (Clark et al. 1977).

Eutrophication has led to hypoxia (oxygen deficiency) in extensive areas of the Gulf of Mexico and Chesapeake Bay (Boesch, Brinsfield, and Magnien 2001; Rabalais, Turner and Wiseman 2001). These areas are often called "dead zones" because the levels of oxygen found there are too low to support many types of animals, such as many species of commercially important fish and shrimp. Hypoxia therefore has a substantial economic impact. The hypoxic zone in the Gulf of Mexico is associated with nitrogen entering from the Mississippi River, and has been expanding in recent years. From 1985 to 1992, the hypoxic zone averaged 8,000 to 9,000 km^2; from 1993 to 2000 it reached as much as 16,000 to 20,000 km^2 (Rabalais, Turner, and Wiseman 2001).

Manure and synthetic fertilizers applied to crops are largely responsible for the nitrogen that pollutes bodies of water. Animal agriculture that depends on grain production is also indirectly responsible for much of the nitrogen from crops, because most grain—and therefore most grain crop acreage—is used to feed animals. Livestock have been estimated to contribute about 15 percent of the inorganic nitrogen entering the Gulf of Mexico (Goolsby et al. 1999), but more recent research has raised the possibility that this figure may actually underestimate that contribution (Weldon and Hornbuckle 2006).

Pollution and hypoxia in coastal water and estuaries may be especially important because many open-ocean fish spawn at these sites (Boesch et al. 2001). For example, up to 90 percent of Atlantic Coast striped bass (*Morone saxatilis*), an important commercial and sport fish, spawn in the Chesapeake Bay (Chesapeake Bay Project 2007). Catches of striped bass in the bay have been declining, as have those of blue crab (*Callinectes sapidus*), the most important commercial species in the bay (Chesapeake Bay Project 2007). Although these declines are likely attributable to several factors, both species inhabit parts of the bay (for parts of their life cycles) that may be subject to hypoxia. In addition, increased turbidity (poor transmission of light through the water) due in part to eutrophic plankton blooms contributes to a decline in submerged grasses that provide vital habitat for blue crab and other marine life (Boesch et al. 2001). The dockside value to Maryland and Virginia of this single fishery (without considering economic multiplier effects) was estimated to be about $52 million in 2002 (Chesapeake Bay Commission 2003).

Pollution from airborne nitrogen

Manure components, especially nitrogen compounds, can be important sources of air pollution. Volatilized nitrogen (in the form of ammonia) is also an important source of terrestrial and water pollution because, as discussed below, most of it

Regulation of CAFO Manure

The regulation of pollution from CAFO manure has a significant impact on whether this pollution continues to be an externalized cost of production, and therefore whether CAFOs continue to receive a competitive advantage over alternative types of animal production by avoiding these costs.

As noted earlier, recent changes in the Clean Water Act target CAFO water pollution caused by over-application of manure to fields (EPA 2003). One way the Clean Water Act regulates CAFO pollution is through the issuance and enforcement of permits under the National Pollution Discharge Elimination System (NPDES). Regulatory changes proposed by the EPA would affect the issuance of NPDES permits as well as related effluent standards and comprehensive nutrient management plans.

After the EPA made some initial changes to the system in 2003, several environmental groups sued the agency, claiming the additional changes it had proposed would be inadequate to prevent CAFO pollution. The court upheld some aspects of the plaintiffs' arguments while disagreeing with others. This led to the development of new proposed regulations that would require some CAFOs to hold permits for manure management and would set standards for manure application rates to prevent water pollution (Centner 2006; EPA 2006). Compliance with these new standards could be expensive, but will depend in part on the specifics of the final rule, which the EPA plans to complete by early 2009 (EPA 2007). In addition, programs such as EQIP could subsidize compliance.

Potential roadblocks

The wording of the EPA's proposed NPDES regulation has raised a question about whether CAFOs could legally avoid the permitting process in the absence of a determination that they actually "discharge" manure pollution (Centner 2006). Under the current language, the EPA would require "only the owners and operators of those CAFOs that discharge or propose to discharge to seek coverage under a permit" (EPA 2006). If this qualification is part of the final rule, it may give CAFO owners a great degree of discretion in deciding whether to obtain a permit (and develop an accompanying nutrient management plan) in the absence of actual contamination data.

Furthermore, inconsistent enforcement of permit regulations has been a concern in the past and may be under the new rule as well. For example, although Michigan and Wisconsin each had more than 100 CAFOs, Wisconsin had issued 110 permits but Michigan had issued none (GAO 2003).

How these issues are resolved will have serious implications for whether CAFOs continue to avoid accountability for the water pollution caused by their manure.

returns to the earth within 80 km of its origin (Walker et al. 2000), where it harms vegetation and reaches water sources. Nitrous oxide, another gas produced from manure and synthetic fertilizers, is an important heat-trapping gas, but the impact of CAFOs on global warming is not considered here.

Livestock are the biggest source of anthropogenic (i.e., influenced by human activity) ammonia emissions in the United States. Animal waste is responsible for about 3 x 10^9 kg of airborne ammonia per year, while the next largest source, synthetic fertilizer, produces about 8 x 10^8 kg of ammonia. According to some estimates, animal sources contribute as much as 75 percent of anthropogenic ammonia, and fertilizer contributes about 20 percent, with all other human sources such as transportation and industry accounting for only about 5 percent (Anderson, Strader, and Davidson 2003). By contrast, dairy cows raised on pasture have been estimated to produce about 5 to 10 times less ammonia emissions than confined livestock (Anderson, Strader, and Davidson 2003). Recent changes in the methods used by the EPA to determine ammonia emissions from livestock reduce estimates by about 33 percent compared with previous methods, due to more refined partitioning of animal manure handling (EPA 2004). Nevertheless, this newer method continues to rank livestock as the largest producer of ammonia, by several times more than any other source.

Nitrogen is found in several different forms in manure, and these different forms have different fates and effects on the environment. A large amount of the nitrogen in manure lagoons and pits, for example, takes the form of ammonia—typically about 60 percent for dairy manure, 90 percent for beef cattle runoff ponds, 73 percent for poultry, and 63 percent for hogs (Soil Conservation Service 1992). Feed characteristics can alter these values. Ammonia is a simple compound that does not contain carbon, and is the primary form of inorganic nitrogen in manure.

Much of the rest of the nitrogen in manure is found in carbon-containing molecules referred to as organic nitrogen. This organic nitrogen is converted into ammonia and other forms of nitrogen.

How manure is stored and applied to fields largely determines how much of the ammonia volatilizes. Open manure lagoons or pits, for example, allow substantial amounts of ammonia to escape into the air. The amount of inorganic nitrogen in manure and how it is applied to the soil is important as well. When over-applied, the type of application method largely determines whether the ammonia is volatilized and creates air pollution (and, indirectly, water pollution), or remains in the soil where some of it can pollute water resources.

Phosphorus from manure, unlike ammonia, does not form a gas, and therefore does not typically leave manure via the atmosphere. This difference between ammonia and phosphorus has important implications for the distribution of manure onto farmland and for tradeoffs between air and water pollution discussed below.

A large percentage of volatilized ammonia finds its way back to the ground or water locally or regionally. This can occur through dry deposition or wet deposition (facilitated by rain or snow). Research in Europe showed that about 50 percent of volatilized ammonia is deposited within approximately 50 km of the source (Ferm 1998). Calculations have also predicted that 38,000 of 43,000 short tons of volatilized ammonia produced by North Carolina's 2,295 CAFOs, or 88 percent, is deposited within a radius of 50 km (Murray 2003). This suggests that most of the ammonia that is either volatilized from CAFOs directly or after application onto farmland will be redeposited across the region.

The growing number of CAFOs has occurred alongside, and may be correlated with, dramatically increased airborne ammonium ion concentrations in several parts of the United States over the past 18 years (Figure 5, p. 45). Ammonia ions are rapidly formed in the atmosphere from volatilized ammonia. In many areas ammonium ion concentrations have increased by a factor of two to four, and areas of high ammonium concentration (over 0.5 mg/l) have expanded substantially. The areas of greatest ammonium concentration correspond roughly with those areas that have the largest number of dairy, beef, and hog CAFOs, although areas with the highest numbers of broiler CAFOs (in the southern part of the country) do not show increased ammonium.

Figure 6 (p. 45) illustrates wet deposition of ammonia for 2002, showing that in many areas, substantial amounts of ammonia reach the ground or water. Areas of high deposition generally correspond with regions of high CAFO concentrations, with California an exception. Dry deposition, which is not measured in this figure, can contribute substantial additional amounts of ammonia, perhaps as much as or more than wet deposition under some conditions (Ferm 1998). In North Carolina, ammonium concentrations have increased significantly in recent years in the Neuse River (Burkholder et al. 2006) and the northeastern portion of the Cape Fear River (Burkholder et al. 2006; Mallin and Cahoon 2003). These rivers drain the largest swine-producing areas on the East Coast, which are also areas with high levels of ammonia wet deposition (Figure 6, p. 45).

When ammonia returns to the earth, either by wet or dry deposition, it can directly damage terrestrial ecosystems or move through the soil profile into ground and surface water, causing water pollution of the types discussed earlier. Unlike nitrogen that enters ground or surface water from crop fields or manure storage facilities, airborne nitrogen can be deposited in unmanaged terrestrial ecosystems such as grasslands, forests, and deserts. Many natural ecosystems have evolved under relatively low nitrogen availability, and increased nitrogen deposition may reduce biodiversity in such ecosystems by favoring those species that benefit from high nitrogen levels (Vitousek et al. 1997).

Furthermore, ammonia (NH_3) typically forms ammonium ions (NH_4^+) after entering the atmosphere, which can contribute to acidification of soils after deposition (Krupa 2003; Vitousek et al. 1997). Soils and lakes that are not well buffered against changes in pH are particularly susceptible to acidification, which harms plants and the ecosystems that depend on them.

The concentration of ammonia deposition in many areas of the United States now exceeds the amount that may harm forests (termed the "critical load"). For example, the critical load for deciduous forests has been calculated to range from about 5 to 20 kg of nitrogen (N) per hectare per year, and for coniferous forests, from 3 to 15 kg N/ha per year (Ferm 1998). When ammonia wet deposition is combined with nitrate wet deposition (Figure 7, p. 46), areas at risk for exceeding these critical loads are revealed, along with higher levels of nitrogen deposition (note the difference in scales used for Figures 6 and 7).

The contribution to water pollution from nitrogen deposited from the atmosphere can be considerable. A recent study of 10 estuaries along the East Coast estimated that atmospheric nitrogen deposition accounted for 15 to 42 percent of total nitrogen input (Castro and Driscoll 2002). Studies of the Chesapeake Bay have attributed 25 to 80 percent of the total nitrogen to airborne deposition, but more recent modeling has suggested a figure closer to 20 percent or less (Sheeder, Lynch, and Grimm 2002). However, this remains an important contribution, since other work has estimated that nitrogen input may have to be reduced by almost 90 percent to eliminate hypoxia (Boesch et al 2001).

In addition to ammonia, manure from CAFOs contributes to air pollution through the emission of hydrogen sulfide, particulates, odors, and pathogens. Fine particulates formed from ammonia can be a cause of respiratory disease. (Ammonia is also an irritant when inhaled, and can cause respiratory problems in both livestock and CAFO workers.)

Ammonia ions that form from volatilized ammonia can be an important component of fine particulate matter (categorized as $PM_{2.5}$). These small particles—less than 2.5 microns in diameter—are particularly hazardous to respiratory health because they lodge more deeply in the lungs than the larger particles that were previously the main focus of concern (McCubbin et al. 2002). $PM_{2.5}$ may form when ammonia from CAFOs combines in the air with nitrogen oxides or sulfur dioxide from automobiles, industry, or power plants. As of 1995, ammonia comprised 47 percent of $PM_{2.5}$ by mass in the eastern United States (Anderson, Strader, and Davidson 2003).

Manure and livestock also produce global warming pollution in the form of methane and nitrous oxides. These gases are not as abundant as carbon dioxide (the primary contributor to climate change) but are much more potent in trapping heat: methane by a factor of about 24 and nitrous oxides by a factor of about 295.

The Costs of Manure Disposal

Because manure is an effective and valuable fertilizer, it might be assumed that CAFOs could readily find nearby farmers willing to accept or even buy it. This is often not the case. In some situations, adequate farmland is simply too far away from CAFOs for manure transport to be a viable option, but even when farmland is nearby, manure is not always accepted. For example, corn and soybeans are the most widely grown crops in the United States, but data show that on average, only about 17 percent of corn and 2 to 9 percent of soybean acreage accept manure (Ribaudo et al. 2003). For wheat, grown in areas where beef CAFOs are prevalent, the manure acceptance rate has been about 3 percent.

One important consideration for farmers is that the nutrient content of manure can vary considerably from batch to batch depending on the type of manure (i.e., the animal source), what the animals were fed, how the manure was stored, and how it is applied to the field. This lack of uniformity requires testing to determine nutrient content and how much manure a field will therefore need.

Noxious odors are a second reason often given to explain low manure acceptance rates. Odor is primarily a problem associated with manure from CAFOs rather than smaller animal operations due in part to the way it is stored and applied to fields. CAFO manure stored in pits or lagoons is often low in oxygen, which can lead to the production of volatile compounds with offensive odors. These compounds include hydrogen sulfide (a gas that smells of rotten eggs), ammonia, phenol, indoles, skatole, volatile fatty acids, acetic acid, cresol, and dimethyl sulfide. Besides being disagreeable, prevalent CAFO odors have been linked to psychological disturbances and health problems in both livestock and people (Mackie, Stroot, and Varel 1998). Smaller operations do not often store large amounts of manure in pits and lagoons, so the low-oxygen conditions that exacerbate odors are not as likely to develop.

As a consequence of the small number of farmers willing to use CAFO manure and the huge amount of manure concentrated in a small locality, CAFOs must often transport their manure substantial distances to distribute it over enough farmland to avoid pollution problems and comply with Clean Water Act standards. Small and medium-sized operations, on the other hand, often have enough available cropland to apply manure at rates that do not cause substantial water pollution (Ribaudo et al. 2003).

Manure is heavy due to its high water content, and therefore expensive to transport. Manure stored in holding facilities such as lagoons or pits has particularly high water content because it is a mixture of feces and urine that is often flushed out of livestock housing facilities with water. For example, dairy cow, poultry, and pig manure held in lagoons typically consists of more than 99 percent water. Poultry litter has lower water content: about 24 percent for broilers and 50 percent for layers. Dairy cow waste is about 80 to 85 percent water as excreted, while hog and beef cattle waste is about 90 percent water (Soil Conservation Service 1992). This high water content has encouraged the spraying of this waste onto “sprayfields” close to lagoons.

There can be substantial regional differences in the amount of farmland in an area and the percentage willing to accept manure. These regional limitations can increase costs by requiring greater transportation distances. Because CAFOs have been able to “decouple” the growing of feed, especially corn and soybeans, from animal production,[21] they do not necessarily need to be located in the same

21 Because grain is relatively light when dried, it can be shipped long distances at relatively low cost (as long as fuel costs are low). CAFOs, by relying on grain as their primary feed component, have therefore been able to locate their operations geographically separated, or decoupled, from the areas that produce this feed.

regions where feed is grown. For example, the Midwest's corn belt has a lot of cropland but relatively fewer hog CAFOs per acre of cropland than the Mid-Atlantic and West (Ribaudo et al. 2003); if the trend observed over the past several decades of substantial CAFO growth in these latter regions continues, crop availability for CAFO manure may become even more of a problem.

Other factors contributing to this problem are the geographic concentration of CAFOs and the increasing size of individual feeding operations. The environmental risks associated with these factors are often outweighed by financial considerations. For example, some poultry processors demand increasingly larger numbers of animals to run through their operations (Ollinger, MacDonald, and Madison 2005), and need the animals to be raised near processing plants because transportation can lead to significant mortality and weight loss.

A substantial percentage of hog production has become concentrated in the Mid-Atlantic, especially North Carolina, over the past two decades. North Carolina now trails only Iowa in hog production, but was ranked sixth as recently as 1990 (NASS 2008a). Hog CAFOs may even be in the process of becoming more geographically concentrated within states. Figure 8 (p. 46) shows the increasing concentration of hog production in specific regions and the simultaneous decrease in production in surrounding areas. This trend was already occurring in the 1980s and especially the 1990s.

Most beef cattle feedlots have moved to five western Great Plains states. California has emerged as the largest dairy-producing state even though it does not grow large amounts of corn or soybeans, joining the ranks of such traditional dairy producers as New York, Pennsylvania, and Wisconsin (NASS 2008a).

As already mentioned, broiler chicken production is concentrated in the Southeast (Figure 10, p. 47), another region without enough cropland to adequately utilize all of the manure its CAFOs produce. This concentration has dramatically increased in recent decades due to rising demand for broiler chickens.

Regional CAFO expansion may make it increasingly difficult for greater amounts of manure to be adequately spread onto cropland. As CAFO production in a given region becomes more dense, access to local crop fields may decrease while the distance needed to reach available fields increases.

Methods for calculating manure disposal costs

One way of estimating the costs of CAFO pollution is to determine the amount of money CAFO owners would have to pay to transport manure away from their operations in order to reduce pollution. These calculations do not include costs from other sources of harm caused by CAFOs, such as leakage from manure lagoons, and therefore are incomplete cost estimates. Nonetheless, it can be said with certainty that the various costs involved in addressing the unhealthy concentrations of manure on CAFOs amount to a large subsidy for the industry.

Another way to consider the harm done by externalities is to calculate the value of the societal benefits lost as a result. Accurate calculations are difficult because benefits are numerous and dispersed throughout society. The EPA, for example, calculated the benefits from implementation of the 2003 Clean Water Act amendments at about $290 million per year nationally (EPA 2003), but substantially underestimated the total by not addressing some specific benefits of reduced CAFO pollution (e.g., reduced estuary eutrophication, reduced antibiotic use, and benefits to rural communities such as increased property values and better health). And because this regulation does not address air pollution, no values were assigned for benefits such as reduced harm to forests and reduced health problems related to fine particulate matter.

Calculations that estimate the cost of reducing manure pollution through better land distribution may be more accurate. This approach would address more of the environmental damage and some of the health damage caused by manure than the limited analyses of lost benefits currently available.

Substantial expense would be required to comply with Clean Water Act standards for manure application in all parts of the country. One study estimated the cost of compliance for various CAFOs under different assumptions about farmers' willingness to accept manure (WTAM) as a substitute for synthetic fertilizer, including WTAM levels considerably higher than the current actual percentage (Ribaudo et al. 2003). The study authors acknowledged that a 20 percent WTAM may represent a more realistic national average than some of the higher WTAM values also used in the study. Calculations for applying manure to fields in the Chesapeake Bay watershed using a WTAM of 20 percent for a nitrogen-limited standard arrived at a total annual cost of $133.8 million.

Environmentally acceptable manure application rates can be set based on either nitrogen or phosphorus limits; the choice should be determined by whichever nutrient has the greater potential for causing pollution. This in turn depends on specific characteristics of the accepting farm, including the content of each nutrient in the soil, the types of crops grown, and soil type. Phosphorus often represents more of a problem than nitrogen, so application rates based on phosphorus limits may often be more appropriate.

Total costs for the Chesapeake Bay region based on a phosphorus-limited application rate have been estimated at $152.8 million, using a 60 percent WTAM (Ribaudo et al. 2003). Because fuel costs have risen dramatically in recent years, the current costs would undoubtedly be higher. The same study notes that without such a high WTAM value, there is not enough farmland in the region to adequately distribute manure under a phosphorus standard. Determining the cost of achieving a phosphorus standard with a WTAM less than 60 percent would therefore be complicated by the fact that excess manure would have to be disposed of by other means, with uncertain costs. For example, at a 20 percent WTAM in the Chesapeake Bay region, more than 1.5 million tons of manure would remain after proper field application. Disposing of this manure by other means would add substantially to the total cost. This dilemma illustrates the difficulty of achieving adequate distribution of CAFO manure.

The authors note that the net return for animal production in the Chesapeake Bay region at the time was $313 million. Therefore, the cost of proper manure application calculated above comprises about 43 to 49 percent of the net return for animal production in the region. Even at a WTAM of 100 percent, the cost of proper field application under a phosphorus standard is calculated to be $143 million, or about 46 percent of net return.

Even at low levels of manure acceptance, the study found that smaller animal farms could find enough nearby cropland to accept all of their manure, thereby avoiding the costs associated with longer transportation distances. Because the animals on smaller farms are more dispersed than in CAFOs, more of the farmland will meet EPA application standards, making manure an asset rather than a liability for these farms. For small to medium-sized animal operations that also grow crops or pasture (diversified farms), some or all of the manure produced by the livestock could be used on the farm.

Costs of reducing air and water pollution

Though the proper application of manure on fields will reduce air pollution from CAFOs, it may increase water pollution. Conversely, some of the methods that reduce water pollution from fields where manure is applied increase air pollution. This is because practices such as spraying manure onto fields, applying manure on top of fields without spraying, and leaving manure in uncovered storage facilities for prolonged periods of time all allow substantial amounts of ammonia to volatilize. Currently, the primary way of avoiding this tradeoff between air and water pollution requires both the storage of manure in ways that reduce ammonia volatilization and access to more land for manure distribution, and manure spreading methods that reduce ammonia volatilization.

Water and air pollution caused by CAFOs are therefore inextricably linked, and addressing one without the other can have unanticipated harmful consequences. There is currently little incentive to limit air pollution from manure, however, because our primary air pollution law, the Clean Air Act, does not typically address ammonia volatilization from manure. The National Research Council recognized the need to reduce these emissions and recommended that controls be designed and implemented (NRC 2004).

A resulting increase in costs may be a disincentive for CAFO owners to adopt practices such as covering manure lagoons or injecting manure into field soil; the latter reduces ammonia emissions by about 50 percent for shallow injection and almost entirely for deep injection (Rotz 2004), but costs more than spraying or broadcasting manure (Aillery et al. 2005). The loss of ammonia nitrogen to volatilization also reduces the quality of the manure as fertilizer, due to the resulting decrease in nitrogen-to-phosphorus ratio.

What, then, would it cost to apply CAFO manure to enough land to prevent or greatly reduce both water and air pollution? A detailed USDA study built upon previous studies of the amount of farmland needed to avoid water pollution from CAFO manure, under the assumption that ammonia gas reduction measures would apply to all AFOs and water pollution reduction would be based on either nitrogen or phosphorus limits for CAFOs (Alliery et al. 2005). The report also considered the industry's possible responses to increased costs, such as passing some costs on to consumers and reducing production in the case of hogs.

Simply complying with the new Clean Water Act provisions discussed earlier (i.e., without reducing air pollution from ammonia) would cost CAFOs a total of $534.46 million annually. When both water and air pollution reduction practices were considered, the total annual costs rose to as much as $1.16 billion.

Several of the assumptions and values used in the USDA's calculations may have substantially underestimated the actual costs. For example, the report used a WTAM of 30 percent—well above the current levels for corn, soybeans, and wheat noted above. In addition, the cost of airborne ammonia abatement was only calculated for values up to a maximum reduction of 40 percent, because the cost of greater reductions could not be accurately determined. Current ammonia wet deposition data suggest that a 40 percent reduction in airborne ammonia would continue to leave many areas with deposition rates that may exceed soil critical load levels and cause environmental harm. This may be even more of a problem if dry deposition of ammonia and nitrate are considered along with wet deposition.

On the other hand, some aspects of this analysis may have overestimated the costs of reducing air and water pollution. In particular, the report considered air pollution reduction for all AFOs, despite the fact that CAFOs produce about 65 percent of all livestock manure. Therefore, if the costs of reducing airborne ammonia were proportional to the amount of manure produced, about two-thirds of the cost would be borne by CAFOs.

The USDA's analysis nevertheless represents the most complete national estimates currently available for the costs associated with reducing both air and water pollution from CAFOs. The measures considered would only partially prevent such pollution, and do not address other dangers such as antibiotic-resistant pathogens and harm to rural communities (discussed below). It is therefore important to remember that these values only partially cover the costs of preventing harm from CAFOs.

Other Externalized Costs

CAFOs have numerous environmental, health, and social impacts in addition to the ecological harm caused by manure. Many of these generate costs that are currently borne by society as a whole; here we will specifically consider some of the costs to rural communities located near CAFOs and some of the costs from antibiotic-resistant pathogens that develop in part due to the overuse of antibiotics in CAFOs. We will also briefly discuss how the genetic uniformity encouraged by CAFOs and meat processors to facilitate their production methods may also contribute to increased disease among livestock.

Public health risks in rural communities

CAFOs often reduce the quality of life and the health of people living near these operations. The odors emanating from CAFOs may be substantial for up to several miles and have been found to have negative effects on well-being. Even worse, exposure to pathogens, harmful airborne particles, and contaminated water supplies is often higher for people who live close to CAFOs—especially for employees of CAFOs and their families. Any of these factors can lower property values in the surrounding areas. And because CAFOs are often situated near low-income communities (Donham et al. 2007), residents may be more vulnerable to the dangers because these communities typically have less political clout than others.

Studies show that at least 25 percent of CAFO workers suffer from respiratory diseases such as chronic bronchitis and occupational asthma (Donham et al. 2007; Thu 2001). People living near swine CAFOs have a higher incidence of specific diseases compared with control groups in several studies (Donham et al. 2007; Wing and Wolf 2000; Thu et al. 1997). This is likely due to the fact that CAFOs produce substantial levels of substances that may be responsible for respiratory illness, including ammonia, hydrogen sulfide, particulate matter, and endotoxin (a by-product of bacterial membranes).

Adverse effects are often significant at distances of up to two or three miles from CAFOs, and become more severe as operation size increases. One study in particular noted a strong correlation between the types of symptoms reported by residents and those studied in CAFO workers, especially respiratory and gastrointestinal distress, strongly suggesting that CAFOs were the cause (Wing and Wolf 2000).

Populations living near CAFOs may be at higher risk of exposure to pathogens in the air or water, or through direct contact with animals. Furthermore, these pathogens may have developed resistance to antibiotics used at the CAFO (see below). Substantial levels of antibiotic-resistant pathogens or indicator species (bacteria that are not themselves pathogenic, but are often found together with pathogens) have been isolated from the air in swine CAFOs (Chapin et al. 2005), and potentially pathogenic bacteria—especially *Staphylococcus aureus*—were found up to 150 m downwind from swine CAFOs (Green et al. 2006), suggesting that significant risk from airborne pathogens is greatest relatively close to CAFOs. However, because pathogens such as *S. aureus* may also spread between people after acquisition, infection originating in or near CAFOs may be further spread by contact between people.

Water sources near CAFOs may also act as vectors of infection for the nearby population. Antibiotic-resistant bacteria or resistance genes that originated at swine and other CAFOs have been detected in ground and surface water by several studies (Sapkota et al. 2007; Sayah et al. 2005; Chee-Sanford et al. 2001). Because groundwater supplies 97 percent of rural drinking water (USGS 1995) and water from individual wells is often untreated, exposure from these sources could be significant. For example, one study found fecal indicator bacteria (*Enterococci* and coliforms) in test wells 250 and 400 m downgradient from swine CAFOs (i.e., where groundwater is at a deeper level than directly below the CAFO), at levels that exceeded EPA safe drinking water guidelines (Sapkota et al. 2007). These bacteria also had substantially higher levels of resistance to several antibiotics compared with samples recovered upgradient from CAFOs.

Another study found tetracycline-resistant bacteria 250 m downgradient from a swine CAFO (Chee-Sanford et al. 2001); these bacteria were continuously present over a three-year period (Koike et al. 2007). Soil-dwelling bacteria found in groundwater downgradient from CAFOs carried identical tetracycline-resistance genes as those found in swine manure lagoons, while bacteria from upgradient sites did not (Koike et al. 2007). This strongly suggests not only that lateral gene transfer had occurred between CAFO bacterial species and those better adapted to surviving and spreading in soil, but also that the spread of resistance may be facilitated by transfer to environmentally adapted species.

Some data suggest that hog CAFOs may represent a particularly serious threat to community health. For example, one study showed that although a swine CAFO appeared to have significant effects on the health of nearby residents, a dairy confinement operation did not (Wing and Wolf 2000). It should be noted that the hog CAFO in this study was much larger (6,000 head) than the dairy operation (300 head). As noted earlier, larger operations affect people at greater distances than smaller operations. Most studies to date appear to have focused on the deleterious health effects of hog CAFOs, but elevated levels of substances associated with harm to hog CAFO workers have also been found in other sectors.

Economic costs to rural communities

CAFOs also have a more adverse economic impact on rural communities compared with smaller and less industrialized animal farms. One study identified several ways that hog CAFOs threaten the viability of rural life: reduced property values, fewer jobs, smaller tax base, increased expenses such as road repair, and lower or absent economic multiplier effects (Weida 2004b).

Multiplier effects indicate the number of times money is exchanged within a region and reflect the higher economic value to the region of an enterprise that uses its revenues locally compared with an enterprise that moves money out of the region. Several studies suggest that the multiplier effects of smaller and independent hog operations are higher than those of CAFOs. For example, smaller farms tend to purchase more of their inputs locally or regionally than larger operations; farms with gross incomes of $100,000 or less made 95 percent of their expenditures locally compared with less than 20 percent for farms making more than $900,000 (Chism and Levins 1994). A study examining hog farms in Iowa found that smaller farms purchased about 75 percent of their feed from local suppliers, compared with 43 percent for larger operations (Lawrence, Otto, and Meyer 1997). Independent and smaller hog operations also generate more jobs for a given amount of revenue compared with vertically integrated CAFOs—almost three times as many in one study (Weida 2004b).

CAFOs also reduce the local tax base while potentially increasing community expenses. For instance, CAFOs can take advantage of tax breaks for industry or farming operations, but several communities have noted higher road maintenance costs due to CAFO truck traffic (Weida 2004b). Water treatment costs may also be substantial for communities downstream from CAFOs or drawing water from contaminated aquifers, such as cities in Oklahoma and Texas that sued nearby CAFOs due to pollution of the watersheds that supply these cites with drinking water (Martin 2006). And because property values are reduced near CAFOs, the residential tax base may suffer as well. Overall, economic growth was 55 percent slower in communities near hog CAFOs compared with communities with smaller hog operations (Weida 2004b).

One of the most tangible indicators of the harm caused by CAFOs in rural communities is the substantial reduction in property values. Several studies have found considerably lower values—5 to 40 percent lower or more—within distances of about three miles from hog CAFOs (e.g., Weida 2004b). One study estimated an average loss of about $2.68 million for the land within three miles of each CAFO in Missouri (Mubarak, Johnson, and Miller 1999).

These values cannot be accurately extrapolated to all CAFOs nationwide because of the large number of differences between CAFO sites, including the size and type of operation, management practices, local property values, and distribution of CAFOs. At any site, the impact on property values may be greater or less than that determined in the studies described here. It is likely however, that on a national basis the reduction in property values is widespread and considerable. It is therefore instructive to calculate these costs based on the Missouri data to convey the general magnitude rather than a precise value: using a conservative estimate of 9,884 CAFOs nationwide, the total loss in property value would be $26.5 billion.

Contribution to antibiotic resistance

An important disease risk associated with CAFOs is the evolution of antibiotic-resistant pathogens resulting from the misuse and overuse of antibiotics in livestock operations. Non-therapeutic use of antibiotics in such operations has been estimated to surpass all human use by a factor of about eight (Mellon, Benbrook, and Benbrook 2001).

Crowding, stress, and unsanitary conditions found in CAFOs result in a reliance on large amounts of antibiotics not only to treat illness, but also to promote growth and prevent disease. Because many animals are therefore exposed to antibiotics throughout their lives (often in the form of a feed additive), increasing resistance to these antibiotics may result in diseases that are more difficult to treat in humans and therefore cause greater harm than their antibiotic-susceptible counterparts. The administration of antibiotics is not allowed under organic standards and may also be less prevalent among CAFO alternatives such as pasture-based systems.

The use of antibiotics—particularly at the low levels and over the long periods typical for growth promotion—is widely acknowledged to increase the prevalence of antibiotic-resistant bacteria (Inglis et al. 2005; Shea et al. 2004; Lipsitch 2002; Smith et al. 2002). The non-therapeutic use of antibiotics in CAFOs may even lead to high levels of resistance more quickly than therapeutic applications, which use higher concentrations of antibiotics (Bacquero 2001). Therapeutic uses may also contribute to resistance (WHO 2003), especially if animals are raised under conditions that facilitate disease. On a positive note, when the European Union prohibited the use of antibiotics for growth promotion, the prevalence of antibiotic-resistant bacteria generally decreased (Emborg et al. 2003; Aarestrup et al. 2001).

Diseases caused by antibiotic-resistant pathogens are often more difficult to treat. In some cases, antibiotic resistance may also be associated with increased virulence, and initial use of ineffective antibiotics delays effective treatment. Such antibiotics may often be initially prescribed because the susceptibility of the infectious agent will not be known, and the resulting delay in effective treatment can sometimes lead to worse outcomes including longer hospital stays or death. For some pathogens, such as multiple-drug-resistant strains of *Enterococcus faecium*, few effective antibiotics may remain.

Higher health costs resulting from antibiotic resistance to food-borne pathogens have been repeatedly documented, especially for *Campylobacter jejuni* and *Salmonella* (Varma et al. 2005a; Varma et al. 2005b; Molbak 2005; Engberg et al. 2004; Swartz 2002; Travers and Barza 2002). Some studies, however, have argued that farm use is not generally responsible, or that higher therapeutic use following the discontinuation of use for growth promotion may be responsible (Phillips et al. 2004). Antibiotic-resistant strains of *Salmonella* have been associated with hospitalization rates more than 2.5 times higher than antibiotic-susceptible strains (Varma et al. 2005a), and with serious bloodstream infections resulting in higher rates of morbidity and mortality (Varma et al. 2005b). In addition, the duration of illness associated with quinilone-resistant strains of *Campylobacter* (13.2 d) was 28 percent longer than that associated with quinilone-sensitive strains (10.3 d) (Engberg et al. 2004).

Although illness from food-borne bacteria is not always treated with antibiotics, a subset of patients requires hospitalization and antibiotic use. Therefore, antibiotic-resistant strains that develop due to CAFO practices may increase hospital costs and suffering compared with non-resistant strains. *Campylobacter* and *Salmonella* cause large numbers of illnesses: between 2 and 2.4 million *Campylobacter* infections per year in the United States and about 1.4 million *Salmonella* infections (Mead et al. 1999). Treatment of *Salmonella* with antibiotics in the United States may be as high as 40 percent of cases (Molbak 2005), and about 10 percent of *Campylobacter* infections require hospitalization

(Swartz 2002). Several factors may account for increased morbidity and mortality from antibiotic-resistant pathogens, including reduced efficacy of initial antibiotic choices, more limited choice of treatment options after diagnosis, and possible increased virulence of strains carrying antibiotic-resistance genes (Molbek 2005).

Resistance generated in animals also extends beyond familiar pathogens to commensal bacteria (those that commonly reside in animals and people without causing illness). This is a concern because resistance traits may be passed between bacterial species—from food-borne bacteria to commensal bacteria residing in our gastrointestinal tract, for example (Nikolich et al. 1994). Some typically commensal bacteria—*Enterococci, S. aureus,* and uropathogenic strains of *Escherichia coli*—may also cause serious disease under certain circumstances (e.g., during surgery, in patients with a compromised immune system, in patients using catheters).

In addition to causing disease through food consumption, other farm animal-associated bacteria, including *S. aureus*, may be passed to farmers, veterinarians, and their families and communities through direct contact with animals. Serious "community-acquired" strains of such bacteria (those not acquired in hospitals) have emerged in the past several years, with nearly 14 percent of MRSA infections acquired outside hospitals (Klevins et al. 2007).[22]

Recent work in the Netherlands has shown that a newly identified strain of MRSA has apparently emerged from farm animals and now comprises more than 20 percent of MRSA infections in that country (van Loo et al. 2007). The new strain has been found on pigs and cattle, and human infection has a strong geographic association with regions where these animals are raised. More recently, this strain has been isolated from pigs and pig farmers in Canada, and another strain found on Canadian pigs is known to cause infections in humans in the United States (Khanna et al. 2007).

Some urinary tract infections (UTIs) have recently been associated with antibiotic-resistant bacteria possibly acquired from animal products. About half of all women experience at least one UTI during their lifetime, often requiring antibiotic treatment, and the resulting cost of community-acquired UTIs in the United States has been estimated to be $1.6 billion per year (Foxman 2002). Although many are resolved relatively easily, some can lead to more serious outcomes such as pyelonephritis or septicemia.

Strains of antibiotic-resistant uropathogenic *E. coli* have been identified that bear substantial similarity to strains found on livestock (Ramchandani et al. 2005). In addition, UTIs caused by strains of *E. coli* resistant to multiple antibiotics, or by strains resistant to ampicillin or cephalosporin antibiotics, have been associated with higher consumption of poultry or pork, respectively (Manges et al. 2007). These studies suggest that antibiotic-resistant UTIs may be acquired from food sources, and that such infections may lead to higher physician or hospital costs and other consequences of increased disease severity.

Antibiotic-resistant strains that develop at CAFOs may continue to exist at high frequencies even after antibiotic use in animals has been discontinued or reduced, as demonstrated with vancomycin-resistant *Enterococci* in Denmark (Heuer et al. 2002a and 2002b). Resistance can sometimes persist due to changes in the bacteria; for example, antibiotic-resistant pathogens that are less fit in the absence of the antibiotic may acquire compensatory mutations over time that increase their ability to persist (Bjorkman et al. 2000; Levin and Bergstrom 2000). Such mutations have been observed, as have inherently high fitness levels, in antibiotic-resistant strains of food-borne *Campylobacter* and *Salmonella* (Zhang 2006).

22 *S. aureus* may be responsible for about 478 million hospitalizations per year in the United States, with MRSA strains causing about 19,000 deaths per year (Klevins et al. 2007).

The economic impact of antibiotic resistance

One way to quantify the externalities associated with the overuse of antibiotics in CAFOs is to calculate the costs of the harm caused by antibiotic-resistant bacteria. These costs include lost work days and the increased medical costs involved in treating more severe disease.

One widely cited study estimated the total annual cost of antibiotic resistance approaches $30 billion (Phelps 1989); *Salmonella* infections alone account for about $2.5 billion per year (ERS 2008). The majority of these costs—about 88 percent—are due to premature deaths. Because multi-drug resistance contributes substantially to disease severity and poor outcomes, this factor is likely to contribute substantially to the cost of premature deaths, although no specific calculations are available.

Assuming most U.S. consumers eat animal products, eliminating the non-therapeutic use of animal antibiotics would cost about $5 to $10 per person per year, or an annual total of about $1.5 billion to $3 billion, due to increased production costs that the industry would pass on to consumers (NRC 1999). These estimates do not consider costs associated with reducing therapeutic antibiotic use, which may be more common in CAFOs than some alternative types of animal production. Though these estimates are crude values, they serve to illustrate the substantial societal cost of antibiotic resistance associated with livestock production.

Health risks related to genetic uniformity

Although disease in animals is an important concern with any kind of livestock production, some diseases may be exacerbated in CAFOs and other AFOs. Concentrating animals in close proximity to one another generally enhances the potential transmission of microorganisms (Gilchrist et al 2007).

Under conditions of confinement, the natural resistance of livestock to pathogens is therefore an especially important factor in limiting the spread of disease—a factor generally strengthened by genetic diversity among animals (Hedrick 2002; Wills and Green 1995). Genetic diversity includes specific variations known to play a role in disease resistance, such as polymorphic alleles in the major histocompatibility complex (MHC) genes of the immune system (Vila, Seddon, and Ellegren 2005). Conversely, greater genetic uniformity increases the probability that pathogens to which animals are susceptible will spread and cause harm.

Unlike natural animal populations, which typically have considerable genetic diversity, animals in CAFOs have been bred for uniformity to facilitate industrial-scale production, processing, and product consistency. Research has determined that the continuing intensification of livestock production, with its emphasis on a few breeds and genetic sources, is contributing to reduced genetic diversity, and that the animals bred for such industrial-scale production may have less ability to resist diverse pathogens (FAO 2007).

That study also found that at least 20 percent, and likely more, of the world's livestock breeds are at risk for extinction. Although the genetic diversity of livestock remains relatively high globally, much of this diversity exists on small and subsistence farms, and diversity is declining both within breeds and through a reduction in the number of breeds. The study concludes that, without intervention to stop these trends, reduced genetic diversity could have negative consequences for disease resistance and our ability to adapt varied methods of raising livestock, such as pasture-based production, to a warmer climate.

Livestock breeding for CAFOs specifically emphasizes characteristics such as meat quality and ease of processing, rate of weight gain or milk production, and related properties (Blackburn et al. 2003). This results in increasing genetic uniformity for many species and breeds, reduced diversity within breeds, and a reduction in the number of primary breeds. For example, the U.S. dairy herd is now largely dominated by Holsteins, with much smaller numbers of Jerseys and a few other breeds. Swine operations rely on a few paternal lines including Duroc, Hampshire, and Berkshire, and maternal Yorkshire and Landrace breeds. Because the poultry sector uses proprietary lines, it is more difficult to determine genetic diversity, but it is believed to be narrow.

In contrast to industrialized livestock production, alternative production systems often require broader genetic diversity to match the needs of regional markets, climates, and other considerations. The growth of such systems has been recognized as an important means of preserving genetic diversity (Blackburn et al. 2003).

Summary of CAFO Externalities

CAFOs produce water and air pollution that harms fisheries and forests, drinking water, and recreational facilities. Other externalities include health problems caused by fine particles that lodge in the lungs, foul odors, and antibiotic-resistant pathogens. All of these problems are caused largely by the excessive numbers and crowding of animals in CAFOs, which result in too much manure in too small an area and the overuse of antibiotics to compensate for the stressful and unsanitary conditions.

Although it is difficult to attach monetary values to the harm caused by CAFOs, studies have estimated the cost of preventing at least some of this harm through the proper distribution of CAFO manure on farm fields. Even modest reductions of water and air pollution would cost more than $1 billion per year, and calculations based on more realistic rates of manure distribution would likely push this number considerably higher.

Other types of damage caused by CAFOs that cannot be completely addressed by proper manure distribution include reduced quality of life for rural communities (as indicated by lower property values), antibiotic-resistant pathogens, and increased genetic uniformity among livestock. Although these externalities cannot be adequately monetized at this time, they likely add billions of dollars to the cost of CAFOs.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

Contrary to what many people believe, the polluting and unhealthy system of raising livestock in crowded confinement facilities is not the most efficient way to produce eggs, meat, and milk in an industrial society, nor is it the inevitable outcome of market forces that provide the United States with sufficient food. This report shows that the CAFO system is driven not by efficiency but primarily by the market power held by large processors and public policy. Deliberate government policies that cost taxpayers billions of dollars every year helped to establish this system and now keep it afloat.

Food animal production in the United States is dominated by a small number of very large processors that either own animals or purchase them through production contracts—a system that favors CAFOs and limits market access for smaller independent producers. CAFOs also have relied on artificially cheap grain to offset the high fixed costs of the facilities and practices needed to produce large numbers of animals. The consequences of this system can be measured in environmental, economic, societal, and health costs.

In contrast, alternatives to CAFOs—especially mid-sized operations and those centered on pasture—have been shown to produce plentiful animal products at a comparable cost, and often at a higher profit than CAFOs.

Can Technology Fix CAFOs?

Increasing attention has been paid in recent years to technological means of reducing the harm caused by CAFOs. These technological "fixes" include feed formulations intended to reduce the nitrogen and phosphorus in manure, use of alum in manure holding facilities to remove much of the phosphorus, and lagoon covers and injection of manure into crop soils to reduce ammonia volatilization. Although these techniques and others may be useful—but in most cases, imperfect—ways of reducing individual problems caused by CAFOs, they all add to the cost of production while failing to address the bigger picture. Supporting alternative production methods that fundamentally avoid many of the problems associated with CAFOs would be a better and more cost-effective approach.

One technological fix that has been attracting considerable attention involves the capture of methane from manure to produce natural gas (or "biogas") that can be used as fuel. As discussed in this report, methane is produced under the anaerobic conditions found in many manure holding facilities such as lagoons.

While this technology would help reduce the odors and heat-trapping pollution created by CAFOs, it currently suffers from several limitations. First and most important, methane capture does not reduce the amount of nitrogen, phosphorus (in most schemes), or water in manure. All of these components contribute to serious problems discussed throughout this report. Biogas production also does not enhance manure's value as a fertilizer, because CAFOs will face the same costs and hurdles to distribute this technology's liquid residues on fields as with liquid manure.

Finally, biogas production does not address animal health or ethics issues related to overcrowding and stress, the overuse of antibiotics that can compromise human health and increase health costs, or some of the economic impacts of CAFOs on rural communities (such as reduced multiplier effects).

Wanted: Sound Agricultural Policy

Systems that are propped up by billions of dollars in public subsidies are not inevitable. The CAFO system has been nurtured by government policies that favor intensive, industrial-style production—often at the public's expense. These policies include heavily subsidized feed grain, lack of accountability for water and air pollution, counterproductive technological fixes such as the non-therapeutic use of antibiotics in livestock, and an ill-equipped regulatory system that looks the other way rather than confronting the growing economic power of large processors.

Because the success of CAFOs has depended on favorable policies rather than any inherent advantages in production methods, better policies could reverse the damaging ways agriculture is currently practiced in this country. Such policies would eliminate the artificial advantages currently granted to CAFOs, force CAFOs to take financial responsibility for the environmental harm they cause, and support research that would further improve alternative animal farming methods that have already proven safer and better for rural communities than CAFOs. Needed actions include:

- Strict and vigorous enforcement of antitrust and anti-competitive practice laws under the Packers and Stockyards Act (which cover captive supply, transparency of contracts, and access to open markets)
- Strong enforcement of the Clean Water Act as it pertains to CAFOs, including improved oversight at the state level or the takeover of responsibilities currently delegated to the states for approving and monitoring NPDES permits; improvements could include more inspectors and inspections, better monitoring and enforcement of manure-handling practices, and measurement of the effectiveness of pollution prevention practices
- Development of new regulations under the Clean Air Act that would reduce emissions of ammonia and other air pollutants from CAFOs, and ensure that CAFO operators cannot avoid such regulations by encouraging ammonia volatilization
- Continued monitoring and reporting of ammonia and hydrogen sulfide emissions as required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly referred to as the "Superfund") and the Emergency Planning and Community Right-to-Know Act (EPCRA)
- Replacement of farm bill commodity crop subsidies with subsidies that strengthen conservation programs and support prices when supplies are high (rather than allowing prices to fall below the cost of production)
- Reduction of the current $450,000 EQIP project cap to levels appropriate to smaller farms, with a focus on support for sound animal farming practices
- Revision of slaughterhouse regulations to facilitate larger numbers of smaller processors, including the elimination of requirements not appropriate for smaller facilities, combined with public health measures such as providing adequate numbers of federal inspectors or empowering and training state inspectors
- Substantial funding for research to improve alternative animal production methods (especially pasture-based) that are beneficial to the environment, public health, and rural communities

We believe that if CAFOs were required to take financial responsibility for the harm they cause, and entry into markets for alternatives was not held back by a heavily concentrated processing industry and public policies, efficient and safer alternatives would flourish.

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GLOSSARY

AFO (animal feeding operation)
A facility or **feedlot** where animals are confined at high densities and fed grain for at least 45 days a year. Includes **CAFOs** as well as smaller operations.

Alternative animal production
Animal farming other than **CAFOs,** including sustainable practices such as access to pasture and maintaining animals in small enough numbers or at low enough densities that the nearby land can safely absorb the animals' manure.

Animal unit (AU)
A value for counting animals that allows comparison between livestock species. For example, the EPA defines one AU as equal to one beef cow of **feedlot** size (typically at least 500 lb. when entering the feedlot) or 2.5 hogs over 55 lb.

Biogas
Combustible fuel produced from the methane in **CAFO** manure.

CAFO (confined animal feeding operation)
A large facility with at least 1,000 **animal units (AU)**. The EPA defines a CAFO as a facility that houses at least 700 dairy cows, 1,000 beef cattle, 2,500 hogs over 55 lb., 30,000 broiler chickens producing wet manure, 125,000 broiler chickens producing dry manure **(litter)**, or 82,000 laying hens. The EPA also defines smaller operations as CAFOs if they discharge manure directly into waterways.

Captive supply
Livestock owned or controlled (through contract arrangements) by a meat processor. High percentages of captive supply can reduce **spot markets,** potentially resulting in lower prices for producers than in a healthy open market.

Clean Water Act
The federal law that regulates water pollution.

Commensal
Organisms, such as bacteria, living in close association with other organisms in an arrangement that is beneficial to one party and does not harm either party. Some bacteria have a commensal relationship with their livestock hosts but are pathogenic to humans.

Commodity crops
Crops that are eligible to receive subsidies under Title I of the federal **farm bill,** including corn, wheat, rice, soybeans, and cotton.

Contract production
Livestock production based on an agreement to house, feed, and maintain animals supplied by a meat processor, then return the animals for **processing** when ready.

Conversion efficiency
The amount of feed needed to produce a unit of animal product.

CR4 (or four-firm concentration)
The amount of market share held by the four largest companies within an industry. A value higher than 40 percent often indicates a level of concentration that can interfere with free-market mechanisms.

Critical load
The maximum amount of nitrogen that can be deposited on a specific type of soil before damage (such as decreased biodiversity) will occur.

Direct subsidy
Payment to a business that reduces or compensates for production costs. Direct subsidies provided in federal **farm bills** have compensated grain farmers when market prices fell below the cost of production.

Diversified farm
For the purposes of this report, a farm that raises both livestock and crops. More generally, a farm that raises multiple crops or crops and livestock.

Downgradient
A point within the earth toward which water from a higher reference point will flow. In the case of groundwater, the gradient may not be reflected in a slope at the surface.

Dried distillers grains with solubles (DDGS)
The residue that remains after corn has been fermented to produce ethanol. Can be used to supplement livestock feed.

Economies of scale
Reductions in the cost of production that accrue specifically to large facilities or companies because 1) their costs are distributed over many units of production and 2) they may have access to efficiency-improving technologies that are not accessible to smaller companies.

EQIP (Environmental Quality Incentives Program)
A federal program that pays farmers to prevent some of the environmental damage they cause.

Eutrophication
The degradation of a body of water due to the growth and subsequent death of vegetation that lowers oxygen content as it decays, killing fish and other aquatic organisms. Excess nitrogen or phosphorus from **CAFOs** often produces eutrophic conditions.

Externalized costs
Environmental and health costs (related to pollution or increased illness, for example) that are borne by society instead of the enterprise responsible.

Farm bill
A package of federal laws that establishes U.S. agricultural policy and is typically renewed every five years.

Feedlots
Confined areas that are open to the air or partially roofed and house thousands of beef cattle while the animals are fattened on grain prior to slaughter.

Finishing operations
Facilities where animals (beef cattle, hogs, broiler chickens) are fattened on grain prior to slaughter. Large finishing operations are usually **CAFOs.**

Forage
Plant material eaten by livestock, such as alfalfa and grasses, stems, and leaves.

Hoop barns
Facilities that house small to medium-sized inventories of hogs in structures with curved roofs and hay bedding, often with access to the outdoors. A more sustainable method of hog production than **CAFOs.**

Hypoxia
In the context of this report, a condition of low oxygen content in bodies of water, often caused by **eutrophication.** Hypoxia related to **CAFO** pollution has contributed to the production of “dead zones” in the Gulf of Mexico and estuaries along the East Coast that cannot support fish or shellfish.

Indicator species
Organisms such as bacteria whose presence suggests the simultaneous presence of other organisms that may be more difficult to detect.

Indirect subsidy
Support a business receives as a result of **direct subsidies** paid to another party (e.g., low prices for supplies resulting from subsidies paid to the supplier).

Inputs
Supplies such as the feed, water, and antibiotics used to produce livestock.

Integration (or vertical integration/coordination)
Ownership or control of multiple stages of production by a single entity. In the context of animal production, meat processors often control multiple production stages (e.g., breeding, rearing, **finishing,** slaughter, **processing,** distribution) through livestock ownership or contract arrangements with an animal producer (such as a **CAFO**).

Lagoons
Open-air reservoirs that store liquid manure from **CAFOs.**

Litter
The mixture of poultry manure, excess feed, and bedding material (such as wood chips) that builds up in broiler facilities.

Livestock
Animals raised for their meat, milk, and eggs. For the purposes of this report, the term includes chickens along with cattle and pigs.

Loan deficiency payments
Direct subsidies paid by the federal government to compensate **commodity crop** growers for low market prices.

Management intensive rotational grazing (MIRG)
A method of raising livestock on pasture in which the animals are moved periodically so no single area is overgrazed. The rate of livestock movement is based on the optimum grazing levels for different forage species under different environmental conditions.

Morbidity
Disease, or the incidence of disease, in a population.

Multiplier effect
Amplification of the value of money by its circulation (exchange) in the local community (through the purchase of goods and services). The effect increases as circulation in the community increases.

National Pollution Discharge Elimination System (NPDES)
A pollution control program under the **Clean Water Act** that 1) sets limits on the amount of specific pollutants that may be discharged from an individual site such as a **CAFO**, 2) issues permits for pollution discharge, and 3) enforces monitoring and reporting requirements. The program is administered by the EPA.

$PM_{2.5}$
Fine particulate matter (2.5 microns in diameter or less) that can cause respiratory disease when inhaled.

Processing
The slaughter of livestock, carcass dressing, and packaging and distribution of the finished animal products.

Spot market
A real-time open market for sales of animal products; functions as an alternative to **contract production.**

Sprayfield
Land that is close to a manure storage facility and fertilized with liquid manure distributed by sprayers.

Subsidies
Payments that artificially support an industry by offsetting its costs of production or compensating producers for low market prices.

Turbidity
Condition in which the passage of light through water is impeded.

Upgradient
A point within the earth toward which water from a lower reference point will not flow. In the case of groundwater, the gradient may not be reflected in a slope at the surface.

Volatilization
The transformation of pollutants (such as the ammonia in manure) into their airborne form.

Willingness to accept manure (WTAM)
The percentage of farmers willing to accept manure from **CAFOs** or **AFOs** for application on their crop fields or pastures. Typical rates are between 5 and 20 percent for farmers of commodity crops such as corn, soybeans, and wheat.

The U.S. livestock industry—a large and vital part of agriculture in this country—has been undergoing a drastic change over the past several decades. Huge CAFOs (confined animal feeding operations) have become the predominant method of raising livestock, and the crowded conditions in these facilities have increased water and air pollution and other types of harm to public health and rural communities.

CAFOs are not the inevitable result of market forces. Instead, these unhealthy operations are largely the result of misguided public policy that can and should be changed.

In this report, the Union of Concerned Scientists analyzes both the policies that have facilitated the growth of CAFOs and the enormous costs imposed on society by CAFOs. We also discuss sophisticated and efficient alternatives for producing affordable animal products, and offer policy recommendations that can begin to lead us toward a healthy and sustainable food system.

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