Chapter 2—Background: Livestock and Poultry Industry Structure, Environmental Quality, and Regulatory Climate

The animal sector has undergone major changes in the last several decades. Economic factors pertaining to demand for meat products and organizational changes to enhance economic efficiency have resulted in larger confined production facilities that are often geographically concentrated. Increased facility size and regional concentration of livestock and poultry operations have given rise to concerns over the management of manure and potential impacts on environmental (particularly water) quality. This chapter reviews structural trends in the animal industry, potential impacts on water quality, and changes in the regulatory environment facing animal feeding operations.

Structural Change and Concentration of Animals

The number of farms with confined animals has declined dramatically and steadily from 435,000 in 1982 to 213,000 in 1997 (Gollehon et al., 2001). This decline occurred primarily in smaller operations (less than 300 animal units of 1,000 lb live weight). During the same period, the number of medium (300-1,000 animal units) and large operations (more than 1,000 animal units) grew. Medium-size operations grew by 4,400 farms to account for about 6 percent of all confined livestock and poultry farms in 1997, while large farms more than doubled to almost 4,000 farms (2 percent).

While total animal farms declined, the number of confined animals increased 10 percent between 1982 and 1997, indicating a significant increase in the average number of animals per farm. A decline in animals on small farms was more than offset by growth on medium-sized farms and large farms (Gollehon et al., 2001). In 1997, the largest 2 percent of all livestock farms produced 43 percent of all animals, by weight (Gollehon et al., 2001).

The driving forces behind structural change in livestock and poultry production are no different than those that affect many other industries: innovation and economies of size. Using new technologies and practices yields significant profits. To make use of these technologies and to capture economies of size often requires significant amounts of capital. Organizational innovations, such as production contract arrangements, enable growers to access the capital necessary to adopt innovative technologies and garner economies of size. The significant economic benefits from vertical coordination in the animal sector, particularly for poultry and swine, have led to both larger operations and a geographic concentration of animal production (Martinez, 2002; Martinez, 1999; McBride, 1997; McBride and Key, 2003).

The innovation and economies of size that characterize the livestock and poultry sector also served to separate animal production from crop production. Large, specialized facilities today focus on producing animals and purchase most of their feed from off the farm. This means there is less land on the farm on which to spread manure. The amount of land per animal unit across all animal types declined nearly 40 percent between 1982 and 1997 (Gollehon et al., 2001).

Increased animal concentrations and less land per animal have raised concerns that nutrients in manure are not being fully utilized by crops and are increasingly likely to enter ground and surface water. These concerns are heightened by events such as the lagoon rupture in Onslow County, NC, that released 25 million gallons of concentrated waste into the New River in 1995 (Mallin, 2000) and outbreaks of the toxic dinoflagellate *pfiesteria piscicida* in North Carolina and Maryland (Pease et al., 1998). Previous literature clearly points out that the value of manure is not sufficient for large confined feeding operations to manage according to agronomic needs, even before considering the environmental impacts (Roka and Hoag, 1996; Henry and Seagraves, 1960). Continued overapplication of nutrients on land increases the potential for environmental damage.

Confined Animals and Excess Nutrients

Land application has been and remains the predominant method for disposing of manure and recycling its nutrient and organic content (USDA-EPA, 1999). If manure is properly managed, plants assimilate most nutrients. When too much manure is spread on the land, nutrients build up in the soil and enter nearby water resources through runoff or leaching.

In 1997, a large percentage of recoverable nutrients from manure (nutrients that are available for application after collection and storage) were in excess of what the cropland controlled by animal feeding operations could assimilate, based on reported acreage and crop yields (Gollehon et al., 2001). Excess manure nutrients indicate a potential for environmental damages resulting from nutrient transport to water resources. Actual impacts depend on the magnitude of the nutrient surplus, whether manure nutrients leave the farm, the nutrient management practices used on the farm, the vulnerability of water resources to nutrient pollution, and agro-ecological conditions such as soil type and climate (Jones, 2001).

While small and medium-size livestock and poultry operations produce a large share of total nutrients, the largest operations generate the largest share of nutrients in excess of crop needs (Gollehon et al., 2001). This is consistent with a finding (Roka and Hoag, 1996; Henry and Seagraves, 1960) that large operations tend to view manure as a waste rather than a resource, and dispose of it on land closest to the facility. For example, the 6 percent of farms larger than 1,000 animal units (AUs[1]) were estimated to generate 65 percent of excess nitrogen and 68 percent of excess phosphorus (fig. 2-1) in 1997. The poultry sector produces the most total nutrients of any sector, even though it made up only 15 percent of confined animal farms. In 1997, poultry were estimated to generate 60 percent of all excess nitrogen on confined animal farms, and 61 percent of excess phosphorus (fig. 2-2). Dairy made up nearly half of confined animal farms, yet generated only 7 percent of excess nitrogen and 5 percent of excess phosphorus.

The calculations of onfarm nutrient excess may overstate excess manure nutrients actually applied because some manure is moved off production farms in some cases. However, because of transportation costs, the use of animal manure as a fertilizer may not be economically feasible on many non-livestock farms. Historically, a large share of the manure produced does not leave the farm on which it is produced (Bosch and Napit, 1992; Bouldin et al., 1984). Among the major field crops, the share of acres treated with manure ranges from about 15 percent for corn and 10 percent for soybeans to less than 3 percent for wheat (USDA, ERS, 2000a).

However, total excess nutrients on confined livestock farms are more likely to be understated than overstated in this analysis because neither commercial fertilizer applications nor atmospheric deposition of nutrients are considered. Most crop farms without livestock, and many farms with livestock, use commercial fertilizers because they are less bulky, easier to apply, and have a more certain nutrient content than manure. For many producers, the convenience of commercial fertilizer often outweighs the value of manure as both a source of nutrients and a soil amendment that improves the physical and chemical properties of cropland.

When animals are concentrated geographically, operators may have difficulty finding enough land off the producing farm to fully assimilate the nutrients in the manure. Many factors can limit the amount of land available for spreading, including land cover, topography, depth to water table, location of streams and wells, local regulations, transportation costs, and crop producer preferences. Gollehon et al. (2001) found that most counties had adequate cropland to handle the manure generated by all animal types raised on confined facilities in those counties, assuming that all crop and pasture lands were available to livestock producers. However, the assimilative capacity of nearby land was potentially limiting in some areas of high animal concentrations.

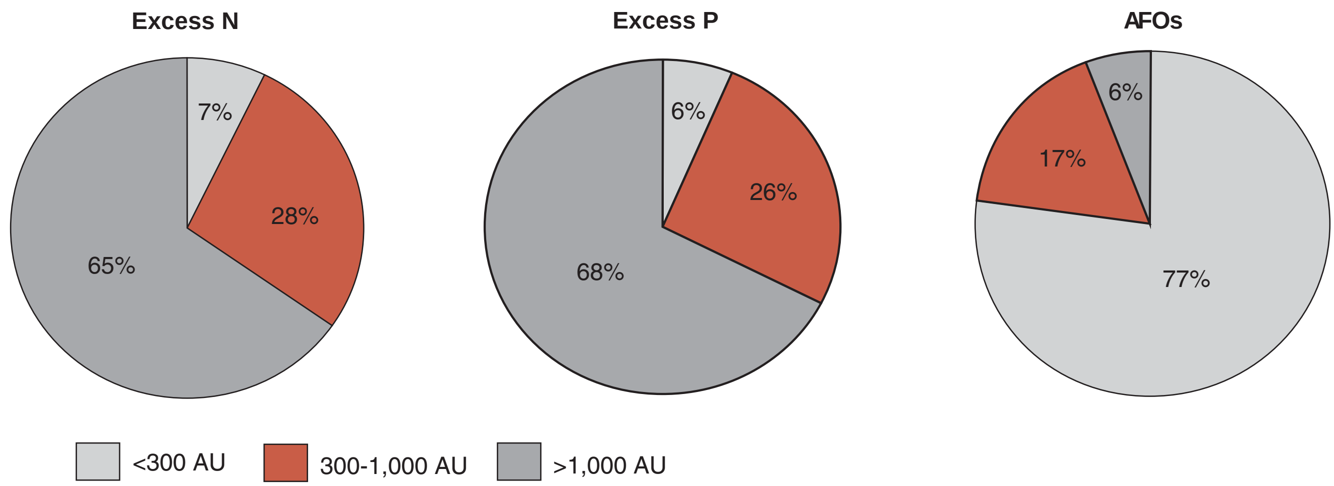
In 68 counties nationwide, the estimated manure nitrogen produced on confined livestock and poultry farms exceeded the assimilative capacity of all the county's crop and pasture land. These counties are primarily in North Carolina, northern Georgia, Alabama, central Mississippi, western Arkansas, and California. Many more counties (152) had county-level excesses of phosphorus. These counties are primarily in western Virginia, eastern Maryland, Delaware, eastern North Carolina, northern Georgia and Alabama, central Mississippi, western Arkansas, and southern California.

Manure Nutrients and Water Quality

Nitrogen and phosphorus are significant pollutants of U.S. waters. Nutrient pollution is a leading cause of water quality impairment in lakes, rivers, and estuaries (U.S. EPA, 2000a). Nitrogen is easily soluble and readily transported to surface waters through runoff and tile drainage, and to ground water through leachate. Phosphorus is only moderately soluble and relatively immobile in soils, but erosion can transport

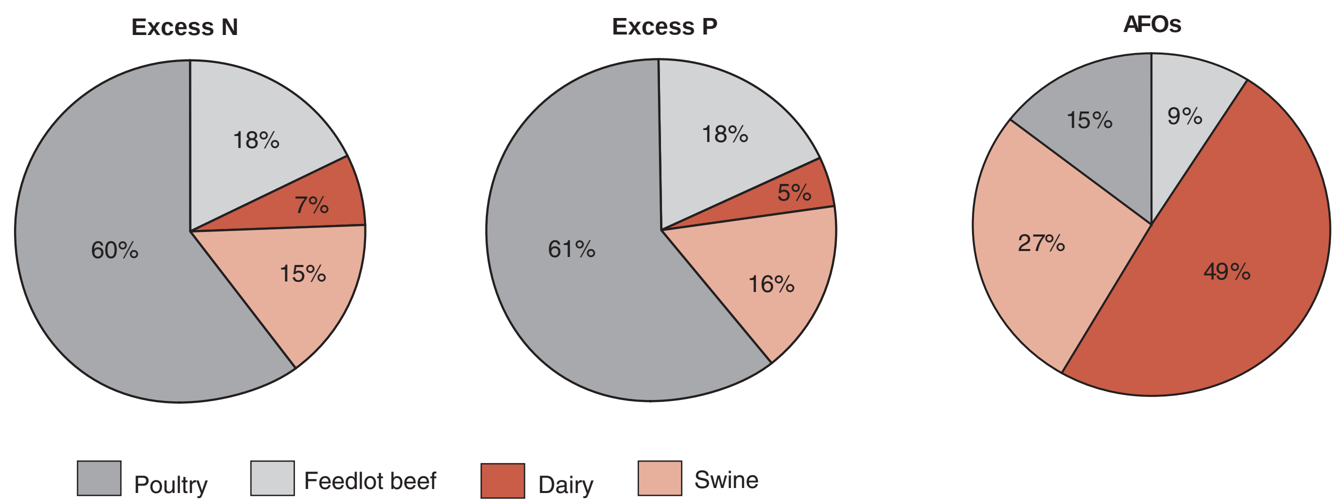
[1] An animal unit is defined by EPA as 1 slaughter and feeder cattle, 0.7 mature dairy cow, 2.5 swine weighing more than 25 kg, 30 laying hens or broilers if a facility uses a liquid manure system, and 100 laying hens if a facility uses continuous overflow watering.

Figure 2-1
Excess nitrogen, excess phosphorus, and AFOs by size class



Source: Kellogg, 2002.

Figure 2-2
Excess nitrogen, excess phosphorus, and AFOs by animal type



Source: Kellogg, 2002.

considerable amounts of sediment-adsorbed phosphate to surface waters. If soils have been overfertilized, rates of dissolved phosphorus losses in runoff will increase due to buildup of phosphates in the soil.

Nitrogen and phosphorus accelerate algae production in receiving surface waters, resulting in a variety of problems including clogged pipelines, fish kills, and reduced recreational opportunities (U.S. EPA, 2000a). Besides harming aquatic ecosystems, nitrogen in water is also a potential human health threat, particularly to infants.

Nutrients in water resources originate from a number of sources, including industry, municipal waste treatment, agriculture, and atmospheric deposition. While well-publicized events such as those in North Carolina and Maryland fueled the public's perceptions of the problems from animal operations, a large number of watershed and plot studies have authenticated animal agriculture's impacts on water quality. States reported to EPA in 1996 that animal operations (feedlots, animal feeding operations, and animal holding areas) were a major factor in 5 percent of rivers and streams impaired by agriculture, and a contributing source in 15 percent more (U.S. EPA, 1998).[2] A USGS study of

[2] U.S. EPA's assessment relies on State self-reporting, which is incomplete and inconsistent between States (U.S. GAO, 2000). The Clean Water Act required that such a report be submitted to Congress every 2 years.

nitrogen loadings in 16 watersheds found that manure was the largest source in 6, primarily in the Southeast and Mid-Atlantic States (Puckett, 1994). In the Mississippi River's drainage basin, animal manure was estimated to contribute 15 percent of the nitrogen load entering the Gulf of Mexico (Goolsby et al., 1999). Nitrogen from the Mississippi River was found to be the leading contributor to a large zone of hypoxic (oxygen deficient) waters in the northern Gulf (Rabalais et al., 1999). A study of the relation between nitrogen concentrations in surface water and land use in the upper Midwest found that the level of nitrogen contamination is most strongly related to streamflow, acreage in corn and soybean production, density of cattle production, and population density (Mueller et al., 1993). Monitoring by USGS in the National Water Quality Assessment Program found that the highest concentrations of nitrogen in streams occurred in agricultural basins, and were correlated with nitrogen inputs from fertilizers and manure (USGS, 1999).

The State of Minnesota recently conducted an extensive environmental impact assessment of animal agriculture's impacts on water resources, and reviewed hundreds of studies conducted by scientists across the country (Mulla et al., 1999). Some of the main points they developed from the literature include:

- Livestock waste can contribute significantly to phosphorus loads in surface waters.
- Feedlot runoff contains extremely large loads of nutrients; if not properly collected before entering surface waters, this runoff can severely degrade surface-water quality.
- Nutrient losses in runoff from manured or fertilized fields were much greater than losses from unmanured or unfertilized control plots.
- Nutrient losses in runoff increased with the rate of manure or fertilizer applied.
- States with high concentrations of feedlots generally experience 20-50 lagoon spills and feedlot runoff events per year that degrade water quality.
- As the size of animal operations increases, nutrient imbalances also typically increase. This is mainly due to a lack of proper land area for spreading manure.
- As the density of animals in a watershed increases, the impact on surface-water quality grows. This is primarily due to increased production of manure nutrients, and inadequate crediting of nutrients in manure when farmers calculate their nutrient applications to cropland.

Environmental Regulations

In response to these concerns, a variety of Federal and State regulations have been enacted or proposed. The major Federal environmental law affecting animal operations is the Clean Water Act (CWA). Specifically, animal feeding operations (AFOs) may be covered by the National Pollutant Discharge Elimination System (NPDES) program established under the Act. NPDES permits are required by point sources (facilities that discharge directly to water resources through a discrete ditch or pipe) before they can discharge into navigable waters. The permits specify a level of treatment for each effluent source. Federal NPDES permits may be issued by any of the 44 States authorized to implement the NPDES program, or by EPA.

Agriculture is typically exempted from NPDES requirements. However, under regulations developed by EPA in 1974, certain AFOs can be designated "concentrated animal feeding operations" (CAFOs) and considered a point source under the NPDES program. EPA's regulations (contained in 40 C.F.R. §122.23 and Part 122, Appendix B) define an AFO as a facility where:

- Animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and
- Crops, vegetation, forage growth, or postharvest residues are not sustained in the normal growing season over any portion of the lot or facility where the animals are housed. (This does not include fields where manure might be spread.)

A CAFO is defined as an AFO that:

- Confines more than 1,000 animal units, or
- Confines between 301 and 1,000 AUs and discharges pollutants into waters through a manmade ditch, flushing system, or similar manmade device, or directly into waters that pass through the facility, or
- Is determined to be a significant contributor of pollutants to U.S. waters.

The CAFO definition contained an exemption for facilities that discharge only in the event of a 25-year, 24-hour storm event. The definition also exempted poultry operations that used dry manure handling systems. The Effluent Limit Guideline (which establishes the discharge goal for facilities requiring a permit) applicable to the NPDES permit for CAFOs is no discharge of pollutants to waters except in the event of a 25-year, 24-hour storm (40 C.F.R. § 412).

These provisions, notably, were applied only to the animal production facility. The rules presumed that manure removed from the production area was handled appropriately through land application. Land application of nutrients was traditionally treated as a nonpoint-source pollution issue, and as such, not regulated under the Clean Water Act. The high animal densities and potentially high levels of excess nutrients brought about by structural change in livestock production indicated that manure nutrients were being overapplied, but Clean Water Act regulations provided no direct response until recently.

Most States have implemented regulations for controlling the environmental impacts of AFOs that start to address the problems associated with modern production methods (table 2-1). Thirty-five states have some type of non-NPDES permit, license, or authorization program that covers CAFOs or AFOs. Of note, 34 States have a requirement covering manure application rates (prior to Federal requirements), and 27 States require the development and use of manure management plans.

Voluntary agricultural programs improve water quality by promoting various nutrient management practices. The Environmental Quality Incentive Program (EQIP) was initiated in the 1996 Federal Agriculture Improvement and Reform Act (1996 Farm Act) and amended by the 2002 Farm Security and Rural Investment Act (2002 Farm Act). EQIP provides technical assistance, cost-share payments, and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm. Animal feeding operations can receive financial assistance for waste management structures and for nutrient management. Contracts for financial assistance are for 1 to 10 years, with a maximum of $450,000 per farm over FY2002-2007. By statute, 60 percent of the available funding for the program is earmarked for practices related to livestock production. EQIP was funded at about $200 million per year from 1996 trough 2000. Funding is authorized to increase incrementally from $400 million in 2002 to $1.3 billion in 2007.

Changing Regulatory Landscape

In response to the changing structure of animal production, USDA and EPA announced in 1999 the Unified National Strategy for Animal Feeding Operations (USDA-EPA, 1999). The Strategy sets forth a framework of actions that USDA and EPA plan to take, under existing legal and regulatory authority, to minimize water quality and public health impacts from improperly managed animal manure. The Unified Strategy, when fully implemented, will set minimum standards for all State water quality protection programs.

The Unified Strategy establishes the goal that all AFO owners and operators develop and implement technically sound, economically feasible, and site-specific comprehensive nutrient management plans for properly managing the animal manures produced at their facilities, including onfarm application and off-farm disposal, if any. The Strategy cites land application as the most desirable method of using manure because of the value of its nutrients and organic matter (USDA-EPA, 1999). Nutrient management plans, adopted voluntarily or through regulation, would be tailored to address the individual needs and practices of each AFO.

To approach the goals of the Unified Strategy and to mitigate actual and potential water quality impacts from CAFOs, EPA revised the regulations for CAFOs at the end of 2002 (U.S. EPA, 2003). Some of the major changes for the NPDES permit and Effluent Limit Guidelines are:

- Eliminating the 25-year/24-hour storm exemption.
- Eliminating the exemption for poultry operations with dry manure handling systems.
- Making a nutrient management plan part of the NPDES permit, including land application of animal manure.
- Adopting a zero-discharge requirement with no overflow allowance for new swine, veal, and poultry CAFOs.
- Requiring installation of depth markers for open liquid impoundments (lagoons).

EPA estimates that up to 15,500 operations might qualify as CAFOs under the proposed regulations. Currently, about 12,000 operations are large enough

Table 2-1—State regulations for controlling animal manure

	Permit type			Permit conditions		
State	Federal NPDES	State NPDES	State non-NPDES	Effluent limits	Management plan	Land application plan
AL		X		X	X	X
AK	X					
AR		X	X	X	X	X
AZ	X		X			X
CA		X	X	X		X
CO			X	X	X	X
CT		X	X		X	X
DE		X	X			
FL		X	X	X		X
GA		X	X	X		X
HI		X				
IA	X	X	X	X		
ID	X		X	X	X	X
IL		X	X	X	X	X
IN		X	X		X	X
KY		X	X	X	X	X
KS		X	X		X	X
LA		X	X	X	X	X
MA	X					
MD		X	X			X
ME	X					
MI			X	X		
MN		X	X	X	X	X
MO		X	X	X	X	X
MS		X	X	X		
MT		X	X	X		X
NE		X	X	X	X	X
NC			X	X	X	X
ND		X	X			X
NH	X					
NJ		X				X
NM	X		X		X	X
NV		X				
NY	X				X	
OH		X	X		X	X
OK		X	X	X	X	X
OR		X	X			X
PA		X	X		X	X
RI		X				
SC		X	X	X	X	
SD		X	X	X		
TN		X		X		
TX		X	X	X	X	X
UT		X				X
VA		X	X	X	X	X
VT		X		X		X
WA		X	X	X	X	X
WI		X	X	X		X
WV		X		X	X	
WY		X		X	X	X
Totals	7	40	35	29	27	34

Source: U.S. EPA, 2002b, "State Compendium: Programs and Regulatory Activities Related to Animal Feeding Operations," www.epa.gov/owm/stcpfin.pdf

Permit conditions are requirements imposed through either NPDES or State non-NPDES programs.

to be considered CAFOs, but only about 2,500 actually have permits. This difference is due to the storm exemption, the poultry/dry manure exemption, and lax enforcement.

Of note, the new regulations require that CAFO nutrient management plans be based on the most limiting nutrient for applying animal manure and commercial fertilizer to cropland. This requirement essentially expands the coverage of the Clean Water Act from the production facility to the land where manure is applied. Plans would be nitrogen-based in areas where soil phosphorus is low. Where soils have high phosphorus content, plans would be phosphorus-based. A nutrient standard will limit manure application rates on most land, increasing competition for land where "spreadable" land (land capable of using manure as a plant fertilizer) is relatively scarce, and inflating overall manure management costs. This is especially true if nutrient management plans are phosphorus based. Animal manure contains more phosphorus than nitrogen relative to plant needs, meaning that less manure can be spread on a given acre under a phosphorus limit than a nitrogen limit (Mullins, 2000). Therefore, with a given amount of manure, more land would be required for spreading under a phosphorus limit than a nitrogen limit.

Changes in industry structure and environmental regulations raise important questions about the economic impacts of abiding by the new nutrient standards. These impacts are the subject of this report.

Overview of Previous Literature

The economic literature on the environmental aspects of manure from confined animal feeding operations has taken two tracks. One deals with the joint production of meat and manure and the incentives to take advantage of the nutrient content of manure. The other deals with the costs to the industry of meeting restrictions on manure management in order to achieve an environmental goal.

Henry and Seagraves (1960) presented the basic economics of transporting animal waste. They recognized the potential environmental problems from poultry litter as that sector was moving toward larger production facilities. The two most important factors that determine the net value of manure are its nutrient content and the distance it needs to travel before it is used. Nutrient content enhances manure's value, while transportation distance reduces it. The authors conclude that the unprofitability of moving litter long distances (because of an unfavorable weight-to-nutrient ratio) leads to nearby application. With higher application rates that surpass crop needs, the value of manure drops because crops cannot utilize the extra nutrients.

Roka and Hoag (1996) looked for evidence that swine producers factor the value of manure into their livestock management decisions. In their estimation, a farmer makes three decisions that affect the value of manure: choice of a treatment system, choice of area receiving effluent, and choice of crops grown. The authors found that the value of pork dominates a producer's hog marketing decisions, and that producers are relatively insensitive to the value of manure. Under the most favorable conditions, manure value is negative (-$2.94/head), yet production cycles or other management options were not changed in order to increase manure's value. Manure's negative value may prompt farmers to view it as a waste rather than a resource, and to overapply it on land nearest the production facility.

Gollehon et al. (2001) and Kellogg et al. (2000) demonstrate that large confined animal operations produce excess nutrients. Census of Agriculture data show the relationship between increased concentration in the livestock/poultry industry and the increase in onfarm "excess" manure nutrients, or nutrients above a crop's needs. They showed that excess nutrients have increased between 1982 and 1997, and that excess nutrients occurred primarily on large facilities.

Innes (2000) developed a conceptual model of livestock/poultry production and regulation to illuminate the issues of manure generation and management. The model represents the waste management decisions of private livestock producers, manure impacts on the environment, the effect of market forces, and implications for the design of efficient government regulatory policies. The model includes spills from animal waste storage (lagoons), nutrient leaching and runoff from fields, and direct ambient pollution from livestock operations, including odors, pests, and ammonia gases.

Innes used the model to evaluate how various regulations on livestock production affect economic efficiency, and found that the externalities associated with livestock production (e.g., water pollution and air pollution) result in too many large facilities that are also inefficiently large. Another finding is that regulations that focus only on waste handling result in inefficiencies in spatial arrangements of production. A solution to improve economic efficiency is to regulate livestock facility sizes and entry as well. Innes contends that when the government cannot directly regulate manure application, producers will always choose to spread more manure nutrients to nearby cropland than crops can use. In this instance, regulating observable producer choices that affect manure-spreading practices might enhance economic efficiency.

Farm-level assessments have dominated empirical research on how manure restrictions would affect livestock operations. These assessments generally rely on representative farm modeling to estimate costs of management changes needed to comply with an environmental goal. The models are generally optimized across various management options, including number of animals, storage system type, manure application rates, and crops grown.

Fleming et al. (1998) estimated the costs of spreading manure according to a nutrient application standard for various types of swine farms in the Midwest. This study emphasized the transportation costs of hauling manure to land for spreading. While not an optimization model for manure management, the model provides a means for estimating short-term costs of spreading manure. Fleming et al. also used the model to find an "optimal" herd size, balancing the costs of manure spreading with the benefits of manure nutrients for crop production. They concluded that manure nutrient returns are maximized where nutrient-hungry crops are grown close to a medium-size swine finishing facility and manure is stored in a nutrient-conserving manner (slurry tank). With a lagoon, the cost of delivering nutrients is always greater than the value of nutrients due to nutrient loss in storage. Basing manure applications on phosphorus levels was found to increase the value of manure nutrients, but also increased delivery cost because phosphorus-based application rates require more land for spreading. The authors also noted that the market value of hogs, not the value of manure nutrients, will generally drive swine production decisions.

Fleming and Long (2002) used the same model to evaluate the cost of restricting access to cropland with excess slope for the purpose of reducing surface runoff of nutrients and other contaminants. Reducing the amount of land available for application increases the costs of moving manure to suitable land. Swine producers in Kentucky would see increased manure management costs of 35 cents per head if manure nutrient applications were restricted to land with less than 12-percent slopes (7-percent reduction in suitable land area). Larger swine farms faced a much higher cost ($2.11 per head) because of the higher acreage requirements.

Schnitkey and Miranda (1993) estimated the longrun impact of phosphorus runoff controls on a representative hog-corn farm in the Midwest. Their model allowed adjustments in manure hauling distance, application rate, and number of animals on the operation. They found that placing runoff controls on livestock-crop producers would reduce both livestock supply and producer net income.

Yap et al. (2001) also used a representative farm model to estimate the economic impacts of phosphorus-based manure management for a north-central Indiana hog-grain farm. Adjustments to meet a phosphorus-based manure disposal policy included changes in cropping patterns, feed rations, manure disposal methods, and disposal locations. Like Schnitkey and Miranda, they found that moving from a nitrogen-based policy to a phosphorus-based policy reduced farmer net returns, even allowing for changes in feed rations, the use of a custom applicator, and hauling manure off the farm.

Huang and Magleby (2001) and Huang and Somwaru (2001) used individual farm models applied to survey data to estimate the costs of restricting the land application of manure for different size hog farms in two ERS-defined regions, the Heartland and Southern Seaboard.[3] Management options evaluated included adjustments in the amount of cropland receiving manure and in the manure application rate. The analysis looked at short-term impacts, assuming no change in operation size or management systems. (The models thus optimized on net returns from crop production alone rather than on net returns from both hog and crop production.) Both studies found that, for larger operations that are targeted by current policy, livestock production is the primary economic activity and, consistent with the findings of Roka and Hoag, these operations do not have the incentive to alter their operations to enhance the value of manure.

Bosch et al. (1997) used three representative farm models to estimate the economic impacts from reducing phosphorus in poultry litter (through the use of phytase in feed) in the Chesapeake Bay watershed. Under a phosphorus-based application standard, using phytase to reduce the phosphorus content of poultry litter was found to increase its nutrient value by allowing it to be applied to cropland at a higher rate. This higher application rate enables more of the crop's nitrogen need to be met by poultry litter, so less commercial nitrogen is applied. However, the value of lit-

[3] The Heartland region mainly covers Iowa, Illinois and Indiana, and parts of Ohio and Missouri. The Southern Seaboard mainly covers Virginia, North Carolina, South Carolina, Georgia, and Alabama. A description of ERS regions can be found at http://www.ers.usda.gov/Emphases/Harmony/issues/resourceregions/resourceregions.htm#new

ter as a nutrient source is less under a phosphorus-based plan than under a nitrogen-based plan, whether phytase is used or not. Under a nitrogen-based plan, poultry litter meets both the nitrogen and phosphorus needs of the crops, and no commercial fertilizer is needed.

Pease et al. (1998) used representative dairy and dairy-poultry farms in Virginia to simulate farm income effects of nutrient management policies. Current nutrient applications exceeded recommendations on many farms. Nitrogen application restrictions were found to increase net returns for many dairies, indicating that dairies were treating manure as a waste. A phosphorus restriction provided a greater reduction in nutrient losses, but greatly reduced dairy and dairy-poultry farm incomes. The farm costs were deemed unsupportable for most dairies.

Bosch et al. (1998) estimated the savings to hog farms with anaerobic lagoons when using phytase-treated feed and faced with phosphorus-based manure application limits. Phytase can reduce the phosphorus content of manure. Using representative farm models, the authors showed that phytase was economically beneficial to farms with limited land. Farms with a higher land-to-hog ratio were better off without using phytase. They also found that phosphorus-based nutrient standards were more costly to hog farms than nitrogen-based standards, even with the use of phytase.

Babcock et al. (1997) used an accounting approach to estimate the cost to Iowa hog producers of incorporating manure in order to reduce runoff, odor, and volatilization of ammonia. They found that the cost per head for requiring soil incorporation of manure depended on the amount of manure hauled, how it was stored (which affects nutrient content), and the number of producers not currently incorporating. Compliance was estimated to increase costs 17 cents/hog if incorporating slurry and 68 cents/hog if incorporating lagoon liquid. These costs were deemed sufficient to hurt Iowa's competitiveness if the restrictions were Iowa-specific.

While the farm-level studies described above generally incorporate restrictions on land availability, they do not consider the effects of competition from nearby farms also seeking land on which to spread manure. A regional analysis that considers competition for manure disposal off the farm was conducted in the Eucha/Spavinaw watershed (ESW) in Oklahoma (Wimberly and Goodwin, 2000). The study examined the cost of exporting surplus poultry litter from the ESW watershed by using an accounting framework. Competition from other, closer sources of litter put ESW at a competitive disadvantage to those other areas. The total spread costs for ESW litter ($17 to $26 per ton) were greater than the market price for litter in destination watersheds ($15 per ton) because of transportation costs.

National-level modeling has been limited. FAPRI (2001) used a national economic model to assess the financial impact of EPA's proposed CAFO regulations on the livestock and poultry sector. Costs estimated by EPA for the implementation of the proposed regulations were used as inputs in the model, although specific waste management technologies were not modeled. Instead, industry costs for meeting effluent limit guidelines and for meeting a land application standard were aggregated and assessed for different-sized animal feeding operations in different regions. The authors showed that the added costs associated with regulatory compliance would eventually be reflected in higher prices within the respective livestock sectors. Farm numbers were also found to decrease, with smaller producers facing the greatest financial stress.

In summary, the literature on managing manure with a consideration of environmental impacts hits on several recurring themes. Animal manure is costly to move relative to its nutrient value, limiting the area to which it can be economically applied. Large operations generally do not consider the nutrient value of manure in making livestock management decisions, thus treating manure as a waste. This leads to overapplication of manure on land nearest to the facility. Restrictions on manure applications in order to meet environmental goals will increase the cost of raising animals by increasing the amount of land that is used for spreading manure and the distance that manure must be hauled.