Manure Stew – U.S. Ingredients: Carrots, Sticks, and Water

By

Robert C. Johansson*

Jonathan D. Kaplan

Contact Author:
Robert C. Johansson
Economic Research Service
United States Department of Agriculture
1800 M Street NW, 4015-S
Washington, DC 20036
Tele: (212) 694-5485
Fax: (212) 694-5776
Email: Rjohanss@ers.usda.gov

Selected Paper for the Annual Meetings of
The American Agricultural Economics Association
Montreal, Canada (July 2003)

* Robert Johansson and Jonathan Kaplan are economists with the Economic Research Service of the U.S. Department of Agriculture. The views expressed herein are those of the authors and not necessarily those of the Economic Research Service or the U.S. Department of Agriculture.

Manure Stew – U.S. Ingredients: Carrots, Sticks, and Water

The U.S. Environmental Protection Agency (EPA) estimates that agricultural pollution contributes to 60 percent of impaired river areas, 30 percent of impaired lake areas, 15 percent of the impaired estuarine areas, and 15 percent of the impaired coastal shoreline assessed (EPA, 2002a). All told, more than 11.6 million acres of U.S. rivers and lakes are impaired by excessive discharge of soil, pesticides, pathogens, nitrogen and phosphorus (EPA 2002b). Many of these pollutants contribute to water quality impairments such as eutrophication or hypoxia and stem from the agricultural production of crops, livestock, and poultry. U.S. policymakers have adopted a carrot-and-stick approach to address some of the water quality problems linked to agricultural production. Federal funding targeted towards the mitigation of agricultural impacts on water quality has increased ("carrots") and more stringent water quality regulations have been enacted pertaining to agricultural production ("sticks").

Specifically, funding for conservation practices on animal feeding operations (AFOs) and cropland through the Environmental Quality Incentives Program (EQIP) will increase from 2002 levels of $200 million to more than $1 billion by 2005 (USDA,NRCS 2002a). EQIP provides agri-environmental payments to producers in order to generate broadly defined environmental benefits and to assist producers to comply with local, state, and federal water quality regulations. In addition, EPA has mandated nutrient standards for the largest AFOs, known as concentrated animal feeding operations (CAFOs). These standards essentially require manure nutrients generated on CAFOs be spread on cropland at a rate no greater than the agronomic nutrient demand of the crops grown on that land, inclusive of commercial fertilizer applications.[1] We couch these policy responses in terms of agri-environmental "carrots" and regulatory "sticks," respectively.

The U.S. agricultural sector is likely to respond to these carrots and sticks in a variety of ways. A well-developed literature has examined the effects of agri-environmental payments for crop producers and their potential to reduce environmental impacts (see for example Cooper and Keim; Horan and Claassen). Similarly, recent national-level studies explore the implications of the new water quality regulations for animal production in the U.S. (USDA-NRCS 2002b; EPA 2001; FAPRI). In general, these studies predict adverse economic impacts for the affected AFOs, improved water quality, and increased commodity prices. However, notably missing from the literature are analyses of how these two approaches for improving water quality might interact across crop, livestock, and poultry sectors.

To the best of our knowledge, no previous study investigates the interaction of agri-environmental payments and water quality regulation in an animal and crop production setting. Also missing from the literature is a discussion of how crop producers might respond to increased agri-environmental payments for the adoption of best management practices and likely increases in the demand from livestock and poultry producers for acres on which to spread their manure. In addition, while there are many studies that evaluate potential impacts of required nutrient standards for a particular livestock or poultry sector in a particular region, there is little discussion of how these impacts may be tempered by agri-environmental payments. For example, a corn producer in Iowa might receive agri-environmental payments in return for a reduced nitrogen fertilization regime. However, a nearby swine CAFO might be willing to

---

[1] We do not consider new technological innovations that may allow animal producers alternative methods to curtail manure nutrient generation. Examples include supplements to livestock and poultry feed and alternative manure

purchase the right to spread manure on that farmer's fields at the greatest extent allowable under a nutrient standard. An additional complication is that manure nutrients are not packaged as uniformly as commercial fertilizers, contain pathogens, and are generally more difficult to handle (Risse et al). The willingness of crop producers to accept manure nutrients in lieu of commercial fertilizers is a critical parameter in understanding the economic and environmental potentials when adopting a carrot-and-stick approach for water quality improvement.

The potential interactions between and adjustments of crop and animal producers given these, sometimes competing, carrot and stick incentives will also generate secondary price impacts. In such cases, Berck and Hoffman suggest a sector-wide assessment of economic adjustments. Moreover, because the impetus for these carrots and sticks is to reduce adverse impacts on the environment from agricultural production, we conduct a regional and sector-wide assessment of potential economic and environmental implications.

The results from the empirical application suggest that, in general, the imposition of carrots and sticks results in decreased levels of crop and animal production, increasing food prices, and water quality improvements. These potential impacts are by no means homogenous across regions or sectors. In regions where there is relatively less cropland per ton of manure produced, adverse impacts of regulatory sticks will be more pronounced in the livestock and poultry sectors. These impacts are reduced as the willingness of crop producers to substitute manure nutrients for commercial fertilizers increases. However, the impacts on returns increase as more animal feeding operations meet nutrient standards.

Turning to the potential impacts on water quality, results indicate that agri-environmental payments can offset some unintended consequences of the nutrient standards. Specifically, by requiring certain AFOs to spread manure nutrients at agronomic rates there is the potential to

---

storage and treatment options that would serve to diminish the nutrient content of animal manure.

increase nitrogen leaching to groundwater and increase discharge of sediment and pesticides to surface water. However, when agri-environmental payments to crop producers are used to encourage the adoption of relatively benign production practices, the subsequent reduction in cropland discharge offsets any potential increases induced by the nutrient standards. Overall, nitrogen discharge to ground and surface water might be expected to fall by as much as 12.6 percent; phosphorus discharge might fall by more than 30 percent; sheet and rill erosion might fall by 6.7 percent; and pesticide discharge to surface waters might fall by more than 5 percent.

The next section discusses the parameters that this analysis focuses on in evaluating the potential impacts of carrot-and-stick approaches to managing water quality impairments from agricultural production. The third section describes the simulation model used to evaluate regional economic and environmental impacts of our scenarios. We then present results detailing the potential changes in market conditions, animal and crop sectors, and water quality. We conclude with a summary of findings and potential implications of key parameters for improving U.S. water quality.

Parameters

Nutrient standards require certain AFOs to spread the manure they generate on cropland at agronomic rates, or dispose of the manure in some other acceptable manner. When confined animal production within a region generates manure nutrients in excess of the assimilative capacity of the cropland, it can choose to find additional cropland for spreading, plant crops that consume more nutrients, raise animals that produce fewer manure nutrients, or reduce the number of animals produced. These adjustments will essentially increase the cost of producing animals, resulting in overall reductions in production. However, we might expect countervailing price effects and the provision of agri-environmental payments to reduce the market displacement that would have occurred after the imposition of nutrient standards. Furthermore, we expect that the net impacts would differ across regions and sectors, reflecting the heterogeneity inherent in crop and animal production across the U.S. Of the various parameters, which differ across regions and sectors and influence agricultural sector and environmental responsiveness to water quality regulation and agri-environmental payments, we constrain our analysis to three: nutrient standards (i.e., manure land application restrictions), agri-environmental payments, and manure substitution rates.

We first consider a case when only CAFOs meet nutrient standards.[2] These facilities represent 4.47 percent of the total number of AFOs in the U.S. However, the quantity of manure generated by CAFOs exceeds 200 million tons, more than 46 percent of the U.S. total from confined animal operations. Regional differences are also notable (Table 1).

Table 1. Operations with confined livestock and manure distribution

USDA Farm Production Region	Operations		Manure (Million Tons)		CAFO Manure Concentration (Tons/Acre)
	Total AFO	% CAFO	Total AFO	% CAFO	
Northeast	31,350	1.59	39	15.42	0.42
Lake	52,498	1.64	59	25.10	0.39
Corn Belt	71,252	3.18	73	39.55	0.29
Northern Plains	26,087	4.77	65	64.01	0.57
Appalachia	22,776	7.46	66	62.29	2.25
Southeast	12,635	10.79	23	43.31	1.33
Delta	12,252	7.48	19	39.04	0.42
Southern Plains	10,500	7.00	46	38.22	0.56
Mountain	7,780	8.43	33	69.31	0.80
Pacific	7,654	14.85	40	60.55	2.43
United States	254,784	4.47	462	46.36	0.64

Source: 1997 U.S. Census of Agriculture (USDA-NASS, 1997). Northeast = CT, DE, MA, MD, ME, NH, NJ, NY, PN, RI, VT; Lake = MI, MN, WI; Corn Belt = IA, IL, IN, MO, OH; Northern Plains = KS, ND, NE, SD; Appalachia = KY, NC, TN, VA, WV; Southeast = AL, FL, GA, SC; Delta = AR, LA, MS; Southern Plains = OK, TX; Mountain = AZ, CO, ID, MT, NM, NV, UT, WY; Pacific = CA, OR, WA.

[2] A CAFO is an AFO with more than 1,000 animal units (Gollehon et al.).

The percentages of CAFOs in the Southeast and Pacific regions are significantly higher than in other regions and in the Northern Plains, Appalachia, Mountain, and Pacific regions, CAFOs generate more than 60 percent of the region's manure on confined animal operations. We also consider the case when CAFOs and an additional 20 percent of the AFO manure nitrogen and phosphorus produced in a region voluntarily meet nutrient standards. This essentially reflects an increasing scope of the regulatory stick.[3] Table 1 illustrates the regions where meeting nutrient standards might be more difficult than in others. Appalachia, Southeast, and Pacific regions have greater manure generation per acre of cropland than do other regions. This indicates that possible changes in economic performance throughout these regions could be the largest when nutrient standards are imposed. We might also expect greater environmental improvement in these regions.

We next select a range of agri-environmental budgets to represent the carrot approach to inducing water quality improvements. To distribute payments to crop and animal producers based on EQIP provisions, we assume that 60 percent of the budget is allocated to offsetting fixed and variable costs of livestock and poultry producers incurred in complying with nutrient standards. This includes manure nutrient testing, nutrient management plan development, and manure hauling costs. The remaining 40 percent of the budget is allocated to crop producers to encourage the adoption of best management practices on their cropland. These practices include residue management, conservation rotations, and reduced nitrogen fertilization (Johansson, Claassen, and Peters). We examine three budget levels: $0, $250 million, and $1 billion.

Lastly, we choose two manure-nutrient substitution rates over which to conduct our scenarios. We define the willingness to substitute manure nutrients (*substitute*) as the percentage

[3] The adoption of nutrient standards by all AFOs is the stated goal of the USDA (see "Unified Strategy," USDA-EPA, 1999).

of a region's agronomic demand for nitrogen and phosphorus (based upon crop requirements in that region) met by manure nutrients. Currently 17 percent of corn producers and 9 percent of soybean producers supplement commercial fertilizer with manure as part of their crop fertilization regime (USDA 2000). It is unclear to what extent substitution rates might change as AFOs adopt nutrient standards, but it is not unrealistic to assume that this rate will increase, especially in regions facing binding nutrient standards. Increasing manure substitution could result from conservation programs such as EQIP or direct purchasing of spreading rights by livestock or poultry producers from crop producers. We allow this rate to vary between 20 and 30 percent to reflect a feasible range of possible substitution rates.[4]

Six scenarios illustrate the potential economic and environmental adjustments that may result from a carrot-and-stick approach to water quality improvement. Our baseline (*Base*) corresponds to the USDA forecast for crop and animal production in the year 2010, in the absence of any carrots or sticks. We then present results from the case when crop producers meet 20 percent of their nutrient needs using manure generated on CAFOs (*C20*). The next two scenarios build on *C20*, by offering agri-environmental payments at the $250 million and $1 billion levels (*C20-25* and *C20-100*), in line with EQIP funding expectations. Next, to reflect increased adoption of manure nutrient applications over time, we assume that crop producers are willing to meet 30 percent of the nutrient needs using manure generated on CAFOs in the presence of a $1 billion agri-environmental budget (*C30-100*). Lastly, holding manure substitution constant at 30 percent and the budget at $1 billion, we assume that an additional 20 percent of AFO nitrogen and phosphorus are spread according to nutrient standards (*AFO*) to correspond to an increasing scope of the stick.

---

[4] The most recent USDA-ERS survey of corn producers from 2001 (USDA-NASS, 2003) shows that approximately 26 percent of respondents report using manure on their fields.

Model

To evaluate the implications of meeting nutrient standards we employ a constrained partial equilibrium, regional optimization model, which seeks to maximize profits from livestock, poultry, and crop production in the presence of agri-environmental payments and nutrient standards:

(1a) $$\max_{xact_{rj}, xact_{ri}} \sum_j (P_j xact_{rj} - VC_{rj} - TC_{rj} - FC_r + AEP_{rj}) + \sum_i (P_i xact_{ri} - VC_{ri} + AEP_{ri}) - AVC_r,$$

subject to

(1b) $$\sum_j (\theta_{jr} \times man\_nut_{jrf}(xact_{rj})) \leq substitute \times Ag\_nut_{rf}(xact_{ri}), \forall r, f$$

(1c) $$\sum_r \sum_j \sum_i (AEP_{rj} + AEP_{ri}) \leq B.$$

Here $xact_{rj}$ represents regional production of livestock and poultry species *j* in region *r*; $xact_{ri}$ represents regional acres planted under cropping enterprise *i* (crop rotation and tillage regime) in region *r;* P_j and VC_j are equilibrium prices and variable costs for livestock and poultry products; P_i and VC_i are equilibrium prices and variable costs for crops. We also include fixed costs (*FC*) essential to meeting a nutrient standard, transportation costs (*TC*) associated with manure spreading, and additional variable costs (*AVC*) for soil testing and savings.

Aggregate agri-environmental payments for adopting environmental benign crop (AEP_{rj}) and animal (AEP_{ri}) production practices are constrained by an exogenously determined budget (*B*), where *B* takes on values of $0, $250 million, and $1 billion. There are many ways to structure these payments. We assume that crop producers are paid according to net environmental benefits generated from changing farm management practices. These benefits are broadly calculated to account for potential pollutant loading reductions to surface and groundwater (nutrients, pesticides, and sediments), reduced wind erosion, increased carbon sequestration, and increased soil productivity (Johansson, Claassen, and Peters). Further, because agri-environmental payments are not provided for land retirement under our assumptions, we solve the model in two stages. Acreage responses occur in the first stage, where the imposition of nutrient standards is modeled in the absence of agri-environmental payments. In the second stage, the model is re-evaluated in the presence of the agri-environmental payments, holding the acreage response constant.[5] Agri-environmental payments to livestock and poultry producers are assumed to offset fixed and variable costs of nutrient standards.[6]

Transportation costs are a function of the distance traveled and the quantity and type of manure transported. We use conventional estimates of commercial spreading and hauling charges (*Spread* and *Haul*) for tons of manure produced (*Ton*) by animal species within each region (Borton et al.; Pease, Pelletier, and Kenyon; Fleming, Babcock, and Wang):

(2a) $$TC_r = \sum_j Ton_{jr} \times (Spread_{jr} + Haul_r \times Mileage_{jr}),$$

where *Dis* is the average distance greater than a mile traveled to spread manure. To calculate the regional distance per affected AFO, we modify the Fleming, Babcock, and Wang methodology for search acreage:

(2b) $$Dis_r = \sqrt{\frac{Ac_r}{(1-\gamma_r) \times TO_r \times 640}} - 1,$$

where Ac_r is the total acres available for spreading manure, which is a function of the nutrient standards and the endogenous crop acreage choice ($xact_{ri}$), $\gamma \in (0,1]$ describes the spatial

[5] Additional acreage responses due to agri-environmental programs may occur at the farm-level. However, due to the regional scale of our model, we are unable to portray these adjustments here.
[6] At lower budget levels, EQIP payments to livestock and poultry producers are subsumed by increases in fixed and variable costs of compliance on CAFOs. We incorporate the effect of high conservation budgets by assuming that additional AFOs will voluntarily meet nutrient standards using EQIP payments (*AFO* scenario).

concentration of affected CAFOs within a region, and *TO* is the total number of AFOs in that region. Here, γ approaches one as the number of affected AFOs within a region increases, effectively centralizing the location of affected operations towards the middle of the region. This gets at the land competition effect, and allows the search algorithm to capture the greater distance needed to spread manure from a few highly concentrated operations.[7]

The nutrient standards (1b) require the sum of each manure nutrient generated by animal production activity *j*, within region *r* (man_nut_{jrf}) to be less than or equal to the product of the regional substitution rate and agronomic crop nutrient demand (Ag_nut_{rf}), where *f* indexes *nitrogen* and *phosphorus*, respectively.[8] θ_{jr} represents the affected AFO portion of available manure generation for each region and species. Note that man_nut_{jrf} and Ag_nut_{rf} are endogenously determined given optimal levels of animal and crop production.

We simulate this constrained optimization problem using the U.S. Regional Agricultural Sector Mathematical Programming Model (USMP). This is a comparative-static, spatial and market equilibrium model that incorporates agricultural commodity, supply, demand, environmental impacts, and policy measures (House et al.). This model has been applied to various issues, such as climate change mitigation (Peters et al.), water quality policy (Ribaudo et al.), wetlands policy (Claassen et al.), and sustainable agriculture policy (Faeth). The model permits the agricultural sector to adjust to the nutrient standards by substituting across production activities, and cropping and tillage practices with varying input requirements. This substitution is facilitated by nested constant elasticity of transformation functions that allow for interior solutions across activities and technologies.

---

[7] Because the farm production regions are already large, we assume that transportation of manure only occurs within a region.

Crop and animal production choices are linked to edge-of-field environmental variables using the Environmental Policy Integrated Climate Model (EPIC), which uses a daily time step to simulate weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, crop management and growth, and pesticide and nutrient movements with water and sediment (Mitchell et al). The movement of nutrients, pesticides, and sediment across the landscape is then calibrated to USGS estimates of regional pollutant loads (Smith, Schwartz, and Alexander).

Estimates of CAFO and AFO spreading practices on swine operations taken from Ribaudo, Gollehon and Agapoff allow us to account for prior land application of manure in the simulations. Accordingly, CAFOs are assumed to spread manure on the nearest 155 acres and the smaller AFOs are assumed to spread manure on the nearest 90 acres. While these numbers are not representative of the variety of animal operations across the U.S., we argue that these are reasonable for initial estimates of the environmental effects of excess manure utilization at the Farm Production Region scale. Because many livestock facilities have little or no land on which to dispose manure, the above levels provide a lower bound on our estimated benefits to meeting nutrient standards. Given the acres currently receiving manure nutrients, we calculate the quantity of manure nutrient in excess of the crop requirements on those acres. These excess nutrients are available for potential leaching into ground waters and/or transport across the landscape into surface waters.

Results

By simulating various manure nutrient substitution rates for commercial fertilizers, we obtain results portraying a potential range of national and regional changes in the U.S.

---

[8] Estimates of available manure nutrients by animal type are net the losses attributable to prevailing storage and handling technology (Kellogg et al.). Agronomic demand is calculated using crop uptake values for nitrogen and

agricultural sector following the application of agri-environmental carrots and regulatory sticks for water quality improvement. The results suggest that some of the cost of complying with nutrient standards will be passed along to consumers through higher retail food prices, with or without the presence of agri-environmental payments. In addition, changes in crop and animal production will vary regionally given pre-carrot and stick production levels. Environmentally, we expect that water quality improvements are intrinsically linked to changing crop and animal production levels and technologies, and therefore vary by region.

Prices & Quantities

Under all scenarios, livestock and poultry prices increase and quantities decrease (Table 2).[9] The largest price changes occur in the poultry sector (e.g., 6.3 percent increase in the price of eggs) and the greatest production changes occur in the swine sector (e.g., 3.2 percent decrease in production).[10] When agri-environmental payments increase, the individual sectors respond differently: amplifying the price and quantity changes in the poultry, dairy, and swine sectors, but muting the changes in the beef sector. When manure substitution rates increase, the impacts of nutrient standards on market conditions are lessened.

The accompanying price and quantity changes in the crop sector are not as large (less than 2 percent across all scenarios) nor as general as are those for the livestock sectors. This is in part due to the dual role of cropland as a sink for manure nutrients and a source of feed grains for livestock and poultry operations. This sink role creates an incentive to plant crops that consume

---

phosphorus, accounting for losses due to denitrification, subsurface flow, runoff, and leaching.

[9] These changes are relative to the USDA baseline projections for the year 2010 (USDA, WAOB 2001).

[10] Price changes will also be a function of the embedded elasticities underlying the USMP model. These elasticities are specified so that model supply response at the national level is consistent with supply response in the USDA's Food and Agriculture Policy Simulator (McDowell et al.) an econometric estimated national level simulation model of the U.S. agriculture sector.

relatively high quantities of phosphorus (assuming that the phosphorus constraint is more binding than the nitrogen constraint).

Table 2. Commodity Changes

Commodity	Prices ($)					
	Base	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO-100***
Corn (Bu)	2.600	-0.040	-0.022	0.003	0.022	0.013
Soybeans (Bu)	6.300	-0.071	-0.054	-0.035	0.005	-0.017
Eggs (Dozen)	0.685	0.043	0.045	0.048	0.015	0.028
Fluid Milk (Cwt)	0.135	0.003	0.003	0.003	0.001	0.002
Fed Beef (Cwt)	335.424	1.887	1.695	0.816	0.343	0.585
Pork (Cwt)	262.995	3.837	3.874	3.607	0.769	1.623
	Quantities					
	Base	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO-100***
Corn (Bu)	11,235.38	-84.319	-122.691	-158.851	-93.088	-122.130
Soybeans (Bu)	3,245.038	35.319	17.238	-1.691	-16.951	-6.981
Eggs (Dozen)	7,585.812	-26.615	-27.983	-29.842	-9.465	-17.198
Fluid Milk (Cwt)	93,463.46	-517.482	-534.036	-542.379	-259.438	-431.414
Fed Beef (Cwt)	149.660	-3.404	-3.058	-1.471	-0.618	-1.055
Pork (Cwt)	189.824	-5.922	-5.979	-5.566	-1.186	-2.504

While not explicitly modeled, the sink incentives would be implicit in crop choices on land controlled directly by livestock and poultry producers, and by transfers from animal producers to crop producers. For example, the quantity of corn produced falls, as does its price. This market outcome occurs because the derived demand for corn as an ingredient in feed rations decreases more than the increase in demand for corn acreage as a means of disposal. The large decrease in poultry production, a major user of corn, further explains this result. In addition, corn production is associated with relatively high levels of sediment discharge, and increasing payments to crop producers in exchange for adopting environmentally benign production practices induces a movement away from corn rotations. This supply response to agri-environmental payments in turn lessens the decline in the price for corn. However, even though the price of hay and wheat fall, their production increases. One explanation for this result is that these crops are relatively high consumers of (i.e., sinks for) phosphorus, which outweighs the reduction in derived demand for livestock and poultry feed.

Regional Responses

Under most of the simulated scenarios, planted crop acreage declines marginally across the regions (less than one percent); however, cropland acres increase in the Southeast, Appalachia, and the Pacific regions (Table 3). These responses reflect our earlier expectation that those regions with relatively high levels of manure generation per acre of cropland would experience the greatest changes in production.

Table 3. Changes in Production

	Crops (Million Acres)					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	14.342	-0.082	-0.082	-0.082	-0.035	-0.058
Lake	38.097	-0.349	-0.349	-0.349	-0.143	-0.247
Corn Belt	99.043	-0.496	-0.496	-0.496	-0.195	-0.344
Northern Plains	72.794	-0.372	-0.372	-0.372	-0.154	-0.252
Appalachia	18.329	1.741	1.741	1.741	0.66	1.239
Southeast	7.566	0.967	0.967	0.967	0.37	0.772
Delta	17.394	-0.103	-0.103	-0.103	-0.043	-0.075
Southern Plains	31.733	0.209	0.209	0.209	-0.023	-0.039
Mountain	28.264	-0.084	-0.084	-0.084	-0.041	-0.061
Pacific	9.861	0.598	0.598	0.598	0.27	0.421
	Confined Livestock and Poultry (Million Animal Units)					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	2.451	0.215	0.221	0.22	0.071	0.116
Lake	6.069	0.589	0.627	0.623	0.176	0.313
Corn Belt	11.062	1.466	1.478	1.477	0.342	0.717
Northern Plains	16.93	0.235	0.818	0.769	0.236	0.348
Appalachia	8.929	-3.519	-3.579	-3.583	-0.974	-1.811
Southeast	0.46	-0.126	-0.129	-0.129	-0.035	-0.093
Delta	0.446	0.052	0.056	0.056	0.017	0.03
Southern Plains	10.233	0.112	-0.198	-0.182	-0.03	0.076
Mountain	6.537	-0.052	0.257	0.231	0.11	0.111
Pacific	3.808	-0.874	-0.904	-0.903	-0.344	-0.585

For regions that increase livestock and poultry production under the *C20* scenario, an initial increase in agri-environmental payments (*C20-25*) would further increase production. If agri-environmental payments further increased (a movement from *C20-25* to *C20-100*) production would begin to fall. The opposite response occurs for those regions that decrease animal production after the imposition of the initial nutrient standard.

It seems counterintuitive that providing agri-environmental payments to crop, livestock and poultry producers would, all else constant, lead to lower animal production. One explanation for this result is that the agri-environmental payments to crop producers for the adoption of environmentally benign production systems might induce movements towards crop rotations that do not consume large amounts of phosphorus and nitrogen. Movement to these alternative crop mixes would serve to make the nutrient application standards more difficult to meet for those affected AFOs, essentially decreasing the availability of manure nutrient sinks. However, at higher levels of agri-environmental payments crop producers appear to be adopting management practices, such as residue management, that do not focus as much on crop rotations. Hence, the production responses are marginal.

Sector Responses

The changes in national-level prices and quantities translate into differing regional responses. However, corresponding adjustments in net returns are not as straightforward. Table 4 shows the changes in net returns to crop, livestock and poultry sectors at the national and regional levels. Essentially, at lower manure substitution rates, the price impacts are sufficient to compensate aggregate decreases in livestock and poultry production. Nationally, net returns increase with increasing agri-environmental payments. However, when manure substitution rates are at 30 percent, the price effect no longer dominates the production (and carrot) effect and national net returns to animal production falls. However, by increasing the scope of the stick (*AFO* scenario), the price effect in conjunction with higher levels of agri-environmental payments is sufficient to re-generate increasing net returns (over the base scenario) for the livestock and poultry sectors.

The crop sector results are nearly opposite of the livestock and poultry sector results. Initially, aggregate net returns fall due to the decrease in prices, which are relatively larger than the increase in total acreage planted. However, as agri-environmental payments increase or as manure substitution rates increase, crop returns become positive. It is interesting to note that, under our assumptions, the agricultural sector as a whole might experience increases in net returns by amounts greater than the agri-environmental budget. However, we are quick to point out that this does not indicate that all sectors or regions will share in these increased returns. Furthermore, we do not include a number of adjustment costs that might be required of affected AFOs under alternative manure nutrient policies.[11]

Taking a closer look at the two sectors and ten regions, we note in many instances net returns are in fact falling, as the carrot grows and the scope of the stick widens. As before, livestock and poultry decreases are especially evident in the Southeast, Appalachia, and Pacific regions, and so do not seem to be affected by increasing availability of agri-environmental payments. Actually, initial offerings of agri-environmental payments appear to lead to marginally lower net returns. This indicates that in these regions, the agri-environmental incentives to produce crops using systems that consume relatively fewer nutrients is greater than the incentives to provide livestock producers with nitrogen and phosphorus sinks. Even at high

[11] For an in-depth discussion of additional adjustment costs see NRCS (2003).

levels of agri-environmental payments, net returns to animal production in the Southeast continue to fall.

Table 4. Changes in Net Returns ($Million)

	Crops					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	1,100.01	-22.46	-3.37	27.29	41.81	51.48
Lake	3,267.23	-90.60	6.55	138.19	170.15	174.31
Corn Belt	16,399.14	-429.36	-205.14	70.52	314.78	228.11
Northern Plains	5,119.94	-52.43	33.70	187.93	226.47	220.03
Appalachia	1,824.90	15.22	-17.29	13.74	94.28	67.14
Southeast	593.68	44.79	18.31	16.13	46.49	35.75
Delta	806.23	-11.71	17.10	68.64	79.27	87.12
Southern Plains	1,221.11	8.73	39.39	101.11	132.53	149.73
Mountain	1,610.96	6.00	23.71	55.27	66.49	67.73
Pacific	792.62	-65.03	-37.84	19.18	83.30	61.19
Total	32,735.82	-596.85	-124.86	698.01	1,255.57	1,142.58
	Livestock and Poultry					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	3,709.48	460.34	461.78	460.91	133.35	228.10
Lake	3,973.47	457.55	466.19	485.44	110.32	195.99
Corn Belt	3,608.07	770.20	779.30	796.34	128.26	325.47
Northern Plains	3,212.53	133.52	188.19	354.05	-7.55	48.31
Appalachia	3,183.93	-38.22	-40.99	-28.14	-6.96	-49.28
Southeast	3,008.05	-624.87	-636.70	-650.02	-133.96	-429.62
Delta	2,334.03	341.30	339.09	339.57	61.27	171.41
Southern Plains	3,641.18	239.72	205.74	146.18	79.93	177.44
Mountain	2,310.30	173.86	200.82	278.34	73.12	101.15
Pacific	4,490.48	-1,105.51	-1,105.57	-1,096.42	-487.88	-651.45
Total	33,471.53	807.88	857.85	1,086.23	-50.10	117.51
	Totals for Agriculture					
United States	66,207.35	211.04	732.99	1,784.24	1,205.46	1,260.09

This raises a question about the overall impacts of agri-environmental payments on net returns. Approximately 33 percent of the $150 million in agri-environmental payments to livestock and poultry producers (i.e., 60 percent of $250 million) results in actual increased returns to animal production (*C20-25*). The transfer percentage rises to 46 percent when $600 million in agri-environmental payments are provided (*C20-100*) to livestock and poultry producers. This implies that even though animal producers are being aided in compliance, the subsequent price effects mute their actual impact on returns. Conversely, the largest decreases in crop returns occur in the initial scenario (*C20*) in the absence of payments. As these payments become available to crop producers, the adverse impacts on net returns are lessened. At the highest levels of agri-environmental payments all regions would experience increases in net returns to crop production. In looking at the national totals, we note that a $250 million investment in our agri-environmental program would actually yield an increase in net revenues of more than $700 million when coupled with the regulatory stick at the lower manure substitution rates. At the higher budget, national net returns increase by more than $1.7 billion for agriculture as a whole. And, while at higher manure substitution rates and higher nutrient standard adoption rates, net returns are not as high as under the *C20-100* scenario, they still exceed $1 billion. We note that these estimates include the potential savings in commercial fertilizer costs, potential costs incurred in meeting nutrient standards and in providing agri-environmental benefits, potential impacts of price and production changes, and transfer effects of agri-environmental payments.

Environmental Impacts

The use of EPIC allows us to examine the environmental implications resulting from our policy scenarios. In particular, we estimate the potential quantity of nitrogen discharged into surface and groundwater, and the potential quantities of three additional contaminants discharged into surface water (phosphorus, sediment, and pesticides).

The changes in the potential discharge of nitrogen to surface waters and leaching of nitrogen to ground water listed in Table 5 reveals some unintended effects of the carrot-and -stick approach to improving water quality. Across all regions and scenarios, the amount of nitrogen discharged to surface waters falls from the pre-carrot and stick scenario. Nationally, these reductions range from 10 to 16 percent. Increasing the scope of the stick and the size of the carrots leads to larger reductions. However, increasing manure substitution rates mutes this response to a degree.

Table 5. Changes in Nitrogen Discharge (Million Lbs)

	Surface Water					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	193.694	-21.978	-25.493	-29.079	-27.738	-28.369
Lake	393.990	-40.262	-48.116	-59.085	-54.314	-56.484
Corn Belt	1,525.226	-50.136	-152.143	-180.703	-169.567	-175.514
Northern Plains	440.136	-38.827	-46.705	-55.268	-49.802	-52.158
Appalachia	358.144	-54.678	-60.279	-76.254	-79.098	-76.934
Southeast	182.572	-53.459	-54.781	-55.799	-64.276	-58.416
Delta	252.558	-12.081	-15.584	-21.010	-25.453	-26.454
Southern Plains	266.406	-12.821	-17.513	-23.655	-27.003	-32.043
Mountain	162.535	-44.084	-45.603	-47.858	-46.829	-47.188
Pacific	170.050	-77.450	-77.801	-79.169	-81.160	-80.207
United States	3,945.311	-405.776	-544.018	-627.880	-625.240	-633.767
	Groundwater					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	130.013	-1.334	-3.608	-8.127	-5.629	-6.706
Lake	357.332	-12.346	-30.965	-51.600	-38.974	-44.494
Corn Belt	234.604	-1.387	-8.124	-13.553	-12.485	-12.844
Northern Plains	112.647	-1.177	-4.657	-9.971	-8.444	-9.131
Appalachia	401.532	35.270	29.104	18.141	2.903	11.185
Southeast	182.631	19.399	16.459	14.104	2.404	10.444
Delta	141.203	-2.281	-8.600	-16.457	-13.523	-14.853
Southern Plains	62.902	0.801	-2.223	-6.258	-8.003	-8.688
Mountain	31.477	-0.119	-1.368	-2.884	-2.351	-2.547
Pacific	54.976	17.665	11.947	1.838	-6.239	-2.757
United States	1,709.317	54.491	-2.035	-74.767	-90.341	-80.391

Nitrogen leaching, however, increases under the *C20* scenario, but falls with increasing agri-environmental payments and increasing manure substitution. An increase of the scope of the stick from *Base* to *C20* or from *C30-100* to *AFO* results in a more binding nutrient standard, creating the incentive to increase cropland acres and grow crops that consume relatively more nutrients and leach more nitrogen, particularly in the Southeast, Appalachia, and Pacific regions. Because the phosphorus constraint is more binding than the nitrogen constraint, crop producers will have to supplement the new crop composition and acreage planted with additional commercial nitrogen fertilizer, which serves to undermine the reductions in manure production. For example, if we take a closer look at the potential adjustments occurring in the Pacific region, we see that there is a general increase in crop production across the scenarios, especially in corn and hay production. Both of these crops exhibit relatively high levels of nitrogen leaching. Furthermore, in certain areas in California there is a potential increase in cropland devoted to cotton-rice-barley rotations, which have very high levels of nitrogen leaching per acre. Nevertheless, the nitrogen prevented from reaching surface waters is of a greater magnitude than the relatively small increases in nitrogen leaching in all regions and across all scenarios. Overall, the reduction in nitrogen discharged to ground and surface waters ranges from 6.2 and 12.6 percent.

Turning to the other measures of potential water quality impairment, we see changes in phosphorus loading follow the same pattern as nitrogen discharged to surface water, with reductions in phosphorus ranging from 24.8 to 37.6 percent. The results indicate that increasing the scope of the stick, the size of the carrots, and the manure substitution rates all contribute to reducing phosphorus discharge. However, similar to nitrogen leaching, the quantity of sediment and pesticides discharged into surface waters increase in the absence of agri-environmental payments. As agri-environmental payments increase, discharge of sediment and pesticides fall. The changes in soil erosion range from -0.7 and 6.7 percent, and pesticide-loading changes range from -0.9 and 5.5 percent. Soil erosion is greatest at the lower manure substitution rate under the smaller scope of the stick (*C20-100*).

Table 6. Additional Changes to Surface Water Quality

	Phosphorus Discharge (Million Lbs)					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	17.734	-1.170	-1.323	-1.420	-3.617	-4.416
Lake	27.671	-3.384	-3.396	-3.325	-8.196	-9.952
Corn Belt	130.042	-9.608	-17.937	-19.908	-33.550	-35.964
Northern Plains	38.247	-9.336	-9.716	-9.565	-11.565	-12.824
Appalachia	56.333	-27.984	-28.400	-29.423	-28.442	-30.340
Southeast	32.315	-14.227	-14.325	-14.447	-12.033	-14.517
Delta	23.217	-2.444	-2.667	-2.932	-4.347	-5.655
Southern Plains	30.620	-5.842	-6.396	-7.359	-7.233	-9.532
Mountain	20.333	-10.932	-10.689	-9.865	-11.137	-12.333
Pacific	17.834	-12.956	-12.978	-13.011	-11.660	-12.887
United States	394.346	-97.883	-107.827	-111.255	-131.780	-148.420
	Sheet and Rill Erosion (Million Tons)					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	7.844	-0.040	-0.250	-0.459	-0.418	-0.436
Lake	20.298	-0.222	-0.650	-1.244	-1.021	-1.125
Corn Belt	101.869	-0.668	-8.449	-10.676	-9.800	-10.278
Northern Plains	14.849	-0.189	-0.616	-1.043	-0.826	-0.919
Appalachia	12.084	1.040	0.737	-0.478	-0.377	-0.345
Southeast	12.121	1.407	1.332	1.227	0.320	0.943
Delta	9.716	-0.052	-0.177	-0.341	-0.260	-0.297
Southern Plains	17.465	0.249	-0.111	-0.653	-1.071	-1.226
Mountain	12.007	-0.005	-0.200	-0.586	-0.457	-0.505
Pacific	4.554	0.059	0.023	-0.020	-0.035	-0.023
United States	212.807	1.579	-8.361	-14.273	-13.945	-14.211
	Pesticide Discharge (Million TPUs) [a]					
Region	***Base***	***C20***	***C20-25***	***C20-100***	***C30-100***	***AFO***
Northeast	8,538.5	-49.0	-131.7	-268.8	-201.1	-230.8
Lake	27,216.5	-354.5	-887.6	-1,451.5	-1,151.9	-1,292.6
Corn Belt	102,671.1	-938.3	-2,062.0	-3,168.4	-2,332.2	-2,675.3
Northern Plains	21,573.8	-534.6	-454.1	-344.2	-32.3	-178.3
Appalachia	24,024.0	253.6	-142.9	-739.9	-678.7	-636.0
Southeast	17,847.1	908.0	823.3	704.8	142.9	524.5
Delta	61,899.2	-67.8	-376.0	-271.0	-115.8	-162.8
Southern Plains	103,245.7	588.9	-5,094.3	-20,305.4	-21,047.5	-25,177.9
Mountain	108,813.3	-1,028.9	-2,526.6	-3,939.6	-3,112.5	-3,502.5
Pacific	54,172.6	5,933.1	5,954.2	6,017.4	2,738.9	4,219.0
United States	530,001.8	4,710.5	-4,897.7	-23,766.5	-25,790.2	-29,112.7

[a] TPUs refer to "toxicity persistence units" (Barnard et al., 1997). These refer to the sum of reference doses (maximum daily human exposure resulting in no appreciable risk) of the pesticides used for a particular cropping enterprise multiplied by the number of days each of those pesticides remain active in the environment. As a point of reference the number of TPUs in a pound of DDT = 4,443 million and in a pound of Borax = 103,872.

That is, by relaxing the constraints on spreading manure nutrients (moving from *C20-100* to *C30-100*) less land goes out of production in regions with decreased production (e.g., the Corn Belt) and less land comes into production in regions with increased production (e.g., the Pacific). The relative changes in soil erosion rates across these regions would result in an addition 330,000 tons of sediment being discharged under *C30-100* than under *C20-100*. The amount of pesticide discharged to surface waters is expected to fall with increasing agri-environmental payments, with increasing acceptance of manure nutrients, and with an increasing scope of manure nutrient standards for AFOs. These reductions range between -0.9 percent under the *C20* scenario to 5.5 percent under the *AFO* scenario.

Summary of National-level Analysis

There are a number of efforts at the local, state, and federal level to reduce potentially adverse impacts of agricultural production on the environment in general and on water quality in particular. Some trends that are illustrative of these efforts include the increased level of support in recent Farm Bill legislation for crop, livestock, and poultry producers to implement environmentally benign production practices and the recently promulgated rules for CAFOs. To date, no national-level analyses have investigated the impacts of both these trends on U.S. agricultural production and water quality.

This paper represents an initial attempt to analyze the economic and environmental implications of this carrot-and-stick approach to improving the quality of U.S. water resources. We also examine how the willingness of crop producers to substitute manure nutrients for commercial fertilizers bears upon the changes brought about by the carrot and stick policies. These parameters form the basis of six potential scenarios depicting how agri-environmental payments, the scope of manure nutrient standards, and manure substitution rates might evolve in the U.S. First, we compare results when no payments or nutrient standards exist with the scenario where crop producers are willing to meet 20 percent of their crop nutrient demand using manure (*Base* to *C20*). Building on this scenario, we evaluate the effect of providing agri-environmental payments to crop and livestock producers, somewhat akin to the Environmental Quality Incentives Program. By increasing the budget from $0 to $250 million to $1 billion, we investigate the carrot effect (*C20* to *C20-25* to *C20-100*). We then examine two additional scenarios to see how increasing manure substitution rates and how increasing coverage of nutrient standards might differ from our earlier results (*C30-100* and *AFO*).

A wealth of regional and sector-level results emerges from these scenarios, illustrating how carrots and sticks might affect agricultural production and improve water quality in the U.S. In general, carrots and sticks result in decreased levels of crop and animal production and, given USDA estimates of demand and supply elasticities, increasing food prices. In particular, poultry and dairy products could see substantial price increases when substitution rates remain low. However, adverse impacts on net returns to both crop and animal producers are mitigated by providing increasing agri-environmental payments. For example, without agri-environmental payments (*C20*) six of ten regions experience decreasing returns to crop production, however by including $400 million in agri-environmental payments for crop producers (*C20-100*) all regions experience increasing returns to crop production. For those regions that experience adverse impacts on net returns to animal production (the Southeast, Appalachia, and Pacific), it appears that the willingness of crop producers to substitute manure nutrients has the most bearing on reducing these losses. Because net returns for crop producers also increase with increasing manure substitution, an avenue for future inquiry might concern using carrots to induce crop producers to use more manure nutrients to meet their crop needs.

Turning to the potential impacts on water quality, results indicate that agri-environmental payments can offset some unintended consequences of the nutrient standards. Specifically, by requiring certain AFOs to spread manure nutrients at agronomic rates there is the potential to increase nitrogen leaching to groundwater and increase discharge of sediment and pesticides to surface water in some regions due to changing crop levels and composition. However, when agri-environmental payments to crop producers are used to encourage the adoption of environmentally benign production practices, the subsequent reductions in cropland discharge offset any potential increases induced by the nutrient standards. Overall, nitrogen discharge to ground and surface water might be expected to fall by as much as 12.6 percent; phosphorus discharge might fall by more than 30 percent; sheet and rill erosion might fall by 6.7 percent; and pesticide discharge to surface waters might fall by more than 5 percent. These amounts are significant and have the potential to increase water quality in U.S. rivers, lakes, and estuaries. However, it is beyond the scope of this paper to place a value on these benefits.

In addition, this analysis cannot reveal how individual operations would benefit or suffer from these trends. If only the largest animal feeding operations meet nutrient constraints, the costs of compliance would fall on CAFOs and the benefits from secondary price effects will mostly accrue to the smaller AFOs. We see that when crop producers' substitution rates for manure nutrients remain at or near current levels (i.e., a 20 percent substitution rate), the secondary price effects are sufficient to compensate most livestock and poultry sectors for the costs of meeting nutrient standards. However, at higher substitution rates the increased costs of transporting manure, manure testing, soil testing, and developing a manure management plan outweigh compensating price effects and foregone commercial fertilizer purchases, resulting in reduced net returns for the livestock and crop sectors. However, at higher manure substitution rates consumers benefit from lower price increases and potential increases in water quality. We also note that the costs we have included in our analysis (namely, transportation costs, manure testing costs, soil testing costs, and nutrient management plan development) do not include all the costs livestock and poultry producers might face as they adjust to meet nutrient standards. Additional costs might include relocation costs, and investments in new storage and handling infrastructure.

References

Barnard, C., S. Daberkow, M. Padgitt, M.E. Smith, N.D. Uri. 1997. "Alternative Measures of Pesticide Use," *The Science of the Total Environment* 203: 229-244.

Berck, P. and S. Hoffman, 2002, "Assessing the Employment Impacts of Environmental and Natural Resource Policy," *Environmental and Resource Economics* 22:133-156.

Borton, L.R., C.A. Rotz, H.L.Person, T.M. Harrigan and W.G. Bickert. 1995. "Simulation to evaluate dairy manure systems," *Applied Engineering in Agric*. 11(2):301-310.

Claassen, R., Heimlich, R.E., House, R.M., and Wiebe, K.D., 1998. "Estimating the Effects of Relaxing Agricultural Land Use Restrictions: Wetland Delineation in the Swampbuster Program," *Review of Agricultural Economics,* 20: 390-405.

Cooper, J.C., and R.W. Keim. 1996. "Incentive Payments to Encourage Farmer Adoption of Water Quality Protection Practices," *Amer. J. Agr. Econ.* 78(1): 54-64.

Faeth, P., 1995, Growing Green: Enhancing the Economic and Environmental Performance of U.S. Agriculture, World Resources Institute, Washington, DC.

Fleming, R., B. Babcock, and E. Wang. 1998. "Resource or Waste? The Economics of Swine Manure Storage and Management," *Review of Agricultural Economics*, 20(1): 96-113.

Food and Agricultural Policy Research Institute (FAPRI). 2001. "FAPRI's Analysis of the EPA's Proposed CAFO Regulations," University of Missouri, FAPRI-UMC Report No. 06-01, Columbia, MO (July).

Gollehon, N., M. Caswell, M. Ribaudo, R. Kellogg, C. Lander, and D. Letson. 2001. "Confined Animal Production and Manure Nutrients," Econ. Res. Serv., USDA, Agriculture Information Bulletin No. 771, Washington, DC.

Horan, R.D. and R. Claassen. 2001. "The Welfare Sensitivity of Agri-environmental Instruments," *J. of Agri. and Res. Econ.* 26(2): 368-86.

House, R.M. McDowell, H., Peters, M. and R. Heimlich, 1999, "Agriculture Sector Resource and Environmental Policy Analysis: An Economic and Biophysical Approach," in

Environmental Statistics: Analyzing Data for Environmental Policy, John Wiley and Sons: New York.
Johansson, R.C., R. Claassen, and M. Peters. 2002. “New Conservation Initiatives in the 2002 Farm Bill,” selected paper presented at the AAEA Annual Meetings, Long Beach, CA (August).
Kellogg, R.L., Lander, C.H., Moffitt, D.C. and N. Gollehon. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States*, Natural Resource Conservation Service, Economic Research Service, USDA, Washington, DC.
McDowell, H., R. Kramer, A. Randall A., and M. Price. 1989. “An Analysis of U.S. Farm Income Policies: Historical, Market-Determined, and Sector-Wide Stabilization.” *Southern Journal of Agricultural Economics* 21(2): 1-11.
Mitchell, G., R. H. Griggs, V. Benson, and J. Williams. 1998. *Environmental Policy Integrated Climate Model*, available on at http://www.brc.tamus.edu/epic/. Washington, DC (September).
Pease, J., B.A. Pelletier, and D. Kenyon, 2001. “Poultry Litter Transport Alternatives for Land Application in Virginia,” selected paper presented at the Annual Southern Agricultural Economics Association meetings, Ft. Worth Texas (January 29-31).
Peters, M., J. Lewandrowski, R. House and H. McDowell. 2001. "Economic Impacts of Carbon Charges on U.S. Agriculture," *Climatic Change*, 50: 445-473.
Ribaudo, M., N. Gollehon, and J. Agapoff. 2002. “Land Application of Manure by Animal Feeding Operations: Is More Land Needed?” *J. of Soil and Water Cons.*(forthcoming).
Ribaudo, M. Heimlich, R., Claassen, R. and M. Peters, 2001, “Least-Cost Management of Nonpoint Source Pollution: Source Reduction vs. Interception Strategies for Controlling Nitrogen Loss in the Mississippi Basin,” *Ecological Economics*, 37: 183-197.
Risse, L.M., M.L. Cabrerea, A.J. Franzluebbers, J.W. Gaskin, J.E. Gilley, R. Killorn, D.E. Radcliffe, W.E. Tollner, and H. Zhang. 2001. “Land Application of Manure for Beneficial Reuse,” National Center for Manure and Animal Waste Management white paper.
Roe, B., Irwin, E.G. and J.S. Sharp. “Pigs in Space: The Spatial Structure of Hog Production in Traditional and Nontraditional Production Regions,” *American Journal of Agricultural Economics* 84(2) (May 2002): 259-278.
Smith, R.A., G.E. Schwarz and R.B. Alexander. 1997. “Regional interpretation of water-quality monitoring data,” *Water Resources Research* 33: 2781-2798.
U.S. Department of Agriculture (USDA) and U.S. Environmental Protection Agency (EPA). 1999. “Unified National Strategy for Animal Feeding Operations,” joint policy statement, Washington, DC, available online at: http://www.epa.gov/npdes/pubs/finafost.pdf.
USDA, National Agricultural Statistical Service (NASS). 2003. “Corn Production Practices and Costs Report (ARMS 2001),” Washington, DC.
_____. 1997. *Census of Agriculture – 1997*, Washington, DC, available online at http://www.nass.usda.gov/census/.
USDA, Natural Resources Conservation Service (NRCS). 2003. “Costs Associated with Development and Implementation of Comprehensive Nutrient Management Plans: Part I. Nutrient Management, Land Treatment, Manure and Wastewater Handling and Storage, and Record Keeping," USDA Report,Washington, DC.
_____. 2002a. “Fact Sheet: Environmental Quality Incentives Program,” available online:

http://www.nhq.nrcs.usda.gov/CCS/FB96OPA/eqipfact.html.
_____. 2002b. “Costs Associated with Development and Implementation of Comprehensive Nutrient Management Plans,” Review Draft, USDA, NRCS, Washington, DC (August).
USDA, Soil Conservation Service (SCS). 1994. “Summary Report: 1992 National Resources Inventory,” Washington, DC.
USDA, World Agricultural Outlook Board (WAOB), 2001. USDA Agricultural Baseline Projections to 2010. Staff Report WAOB-2001-1, U.S. Department of Agriculture, Office of the Chief Economist, Washington, DC.
United States Environmental Protection Agency (EPA). 2001. “Environmental and Economic Benefit Analysis of Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Animal Feeding Operation,” Office of Water: EPA 821-R-01-002, Washington, DC.
_____. 2002a. *2000 National Water Quality Inventory*, Office of Water Report EPA-841-R-02-001.
_____. 2002b. “Concentrated Animal Feeding Operations (CAFO) – Final Rule,” Available online: http://cfpub.epa.gov/npdes/afo/cafofinalrule.cfm.