Dirty Water, Degraded Soil

The Steep Costs of Farm Pollution, and How Iowans Can Fix it Together

Appendix

This technical appendix provides a detailed description of the data sources and methodology used to produce Figures 1 through 3 and other statistics presented in the report Dirty Water, Degraded Soil: The Steep Costs of Farm Pollution, and How Iowans Can Fix it Together.

https://www.ucsusa.org/resources/dirty-water-degraded-soil

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Calculating average number of pounds (lb) of nitrogen applied per harvested acre of corn for Iowa counties from 1982 to 2017

We compiled data from the US Department of Agriculture's (USDA) 1982 to 2017 Censuses of Agriculture and extracted the following variables, including observations for all counties in Iowa:

- State identifier (FIPS code=19)
- County identifier (County)
- Harvested corn for grain or seed (acres)

We merged these county-by-year-level data with the US Geological Survey's (USGS) National Water-Quality Assessment Program county-by-year-level estimates of commercial nitrogen fertilizer use on farms.

For census years 1982 to 2002 we estimated the rate of nitrogen applies per corn acre harvested by multiplying the acres of harvested corn for grain or seed per county per year times the lb of commercial nitrogen fertilizer used per county per year.

One major limitation of our methodology is that USGS nitrogen fertilizer use data are not crop specific. Consequently, our estimates assume that all nitrogen fertilizer used per county per year over the time period was applied to acres in corn production. However, studies of landcover data indicate that virtually all crop production in Iowa is in corn-soybean rotations. Similarly, our evaluation of the percentage of corn and soybean acres harvested out of total cropland acres harvested was between 85 percent in 1982 to 92 percent in 2017. We also assume that soybean acres in the contemporaneous census year are likely in a soy-corn rotation and that very little fertilizer nitrogen is used on the acres when they are planted in soybeans. Taken together, this information indicates that our rate of application per corn acres may be only a slight overestimation of the true amount of nitrogen applied to corn acres in the state.

Calculating total manure production per county per year for Iowa counties from 1982 to 2017

We extracted the following variables from the compiled 1982 to 2017 Census of Agriculture data:

- State identifier (FIPS code=19 for Iowa)
- County identifier (County)
- Beef cows (number)
- Milk cows (number)
- Hogs and pigs inventory (number)
- Broiler and meat chickens inventory (number)
- Layers or chickens > 3 months old inventory (number)
- Turkeys inventory (number)

We used the Midwest Planning Service manure management manual to calculate the amount of manure produced per animal type per day and the amount of nitrogen contained in that manure. Table 1 reports the estimated manure produced per animal head per day in lb and amount of elemental nitrogen in that manure, per animal head per day in lb. In some cases, we used the average value of manure produced by different animal sizes within the same type.

Table 1. Manure and Associated Nitrogen Produced per Animal Head per Day by Animal Type

Animal Type	Animal Type Details	Manure (lb/Head/Day)	Nitrogen (lb/Head/Day)
Dairy cattle big	Combination lactating and dry cow (1,400 lb)	140.8	0.924
Dairy cattle little		101.2	0.638
Dairy Cow Average		**121.00**	**0.781**
Beef steer/stock	Finishing cow (1,100 lb)	53.9	0.396
Beef feeder/heifer	Average of finishing cow (750 lb) and cow in confinement	63.8	0.308
Beef cow/calf pair	Sum of cow in confinement and 450 lb beef calf	139.7	0.55
Beef Average		**85.80**	**0.418**
Hog/pig big	Average of all swine > 300 lb	13.42	0.1122
Hog/pig medium	Average of 150 to 300 lb finishing swine	11	0.1276
Hog/pig large	Average of 25 and 40 lb nursery swine	2.42	0.0242
Hog/Pig Average		**8.95**	**0.088**
Turkey big	Male turkey (20 lb)	0.7392	0.011
Turkey little	Female turkey (10 lb)	0.4686	0.0077
Turkey Average		**0.60**	**0.009**
Layer		0.15	0.003
Broiler		0.19	0.002

To calculate the total manure produced per animal type for each county per year, we multiplied the total number of animals per animal type times the manure produced per day, times 365. The same calculation was used to estimate nitrogen produced per animal per day and year.

However, in some cases relatively few farms for each animal type operate in a particular county. In these cases, USDA does not disclose the number of animals per county, in order to avoid disclosing the identity of farms or operations. For these counties, we estimate manure produced per county per year using the following equation:

$$Manure\ produced_{p,i,t} = (manure\ per\ head\ per\ day * 365_p) \times (farms_{p,i,t}\ /farms_{\ p,t})(\textstyle\sum_i^n animals_{p,t} -\ animals_{\ p,t})$$

where p is the animal type (beef cow; milk cow; hogs and pigs; broiler and meat chickens; layers or chickens >3 months old; turkeys), i is an individual county in Iowa that did not disclose the number of animals produced, and t is the census year. $farms_{p,i,t}$ / $farms_{p,t}$ represents the ratio of farms producing animal type p in county i in year t to the total farms in Iowa producing animal type p in year t. $animals_{p,t} - \sum_i^n animals_{p,t}$ the total number of animal type p in year t produced in Iowa minus the sum of animal type p in year t raised in counties with disclosed animal inventory data, which equals the sum of animals type p in all counties not disclosing inventory data.

Calculating cost per person for treating nitrates in drinking water

Data on the cost to treat drinking water for nitrates using two technologies—reverse osmosis (RO) or ion exchange (IX)—were obtained from a 2018 report by researchers at Iowa State University (Tang et al. 2018, Table 2.1, page 12). For each sized water system (very small, small, medium, large) we found the midpoint value between the high and low estimate of the population served by each system type. We then multiplied the estimated average total flow of water (in gallons) for each sized system times the total annualized cost of treating drinking water for nitrates per gallon for each technology type. This product was then divided by the midpoint population value for each system to get an estimate of the cost per person per year for each of the different sized systems. We present a range of estimates on a per person basis to capture the variability that exists in the capital, operating, and maintenance costs of treating drinking water using both RO and IX systems and the variability that exists in costs based on the size of the system (i.e., very small, small, medium, large). We also present costs per person that both include and exclude annualized capital expenditure costs estimated on a per gallon basis.

Because cost information for very large systems (serving 100,001 to 250,000 people each) was not available, we extrapolate the costs per gallon of these systems by taking a ratio of the midpoint of the population served by large and very large systems (e.g., large systems serve 45,000 people and very large systems serve 75,000 people at the midpoint) and multiplying this ratio times the cost per gallon and by the water flow values for the large system size.

Detailed calculations can be found in Spreadsheet 1.

Calculating cost of treating drinking water for nitrates in Iowa from 2021 to 2025

We applied the same cost data from Tang et al. 2018 to forecast the cost of treating drinking water in Iowa for nitrates from 2021 to 2025. To calculate total treatment costs ($193 million in 2020 dollars), we assumed no new treatment plants would be built over the five-year period, so the forecasted cost would include only the cost of operation and maintenance of the 58 treatment plants in operation according to the Environmental Protection Agency Safe Drinking Water Information System data from 2020 quarter 3. We also used the midpoint value for operation and maintenance costs derived from Tang et al. 2018 to represent the average projected cost of treating water of the five-year period. The full range of costs for the five-year period is $47 million to $338 million (in 2020 dollars).

In Figure 1, we present the full range of costs broken down by system size, and we present both the capital and operation and maintenance costs separately. The blue bars were calculated using the midpoint cost values by system type from Tang et al. 2018. The error bars show the low- and high-cost estimates.

Detailed calculations can be found in Spreadsheet 1 at www.ucsusa.org/resources/dirty-water-degraded-soil.

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