The Iowa Policy Project

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Solution to Pollution: It Starts on the Farm

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There is no doubt that an overabundance of the nutrients nitrogen and phosphorus is a leading cause of water pollution in Iowa and the nation.[1] However, discussion continues about the primary contributors to this problem. It is important to clearly identify the sources of water contamination so the discussion can move on to relevant, prioritized solutions.

This report provides background on nutrient pollution in the Mississippi River Drainage Basin, estimates the sources of nutrient pollution for Iowa, and discusses issues including application timing and ground cover that affect whether the nutrients are used for their intended purpose — increasing crop yield — or become unhealthy and costly water pollution.

Nutrient Pollution in the Mississippi River Basin

Nutrients, such as nitrogen and phosphorus, are essential for plant and animal life. However, in excess nitrogen and phosphorus are water contaminants that lead to the rapid growth of phytoplankton. These algae blooms contribute to a number of water quality problems. They diminish sunlight necessary for deep-water aquatic life to survive; create a foul taste and odor, as well as health hazards in drinking water supplies; and interfere with water-related recreational activities by creating unsightly scum and/or toxic water conditions.[2] As the algae in the blooms die, they sink and decompose. The decomposition process uses up large amounts of oxygen in the water (creating a condition known as hypoxia), which reduces available habitat for aquatic life, especially slower-moving or immobile bottom dwelling organisms.[3]

In addition to creating severe water quality problems in the states in which they are generated, excess nutrients have created an acutely toxic problem in the Gulf of Mexico.[4] Over-enriched streams and rivers in the Mississippi River Drainage Basin, including Iowa, have resulted in hypoxic conditions over a significant area in the Gulf of

Figure 1. Mississippi River Drainage Basin

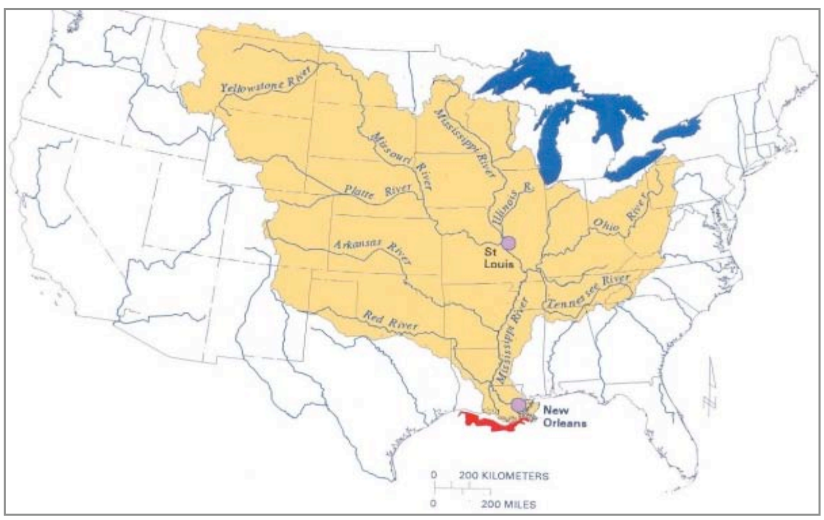

Image source: USGS

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Mexico, an area some refer to as the Dead Zone. This area of hypoxia is an area where the excess nutrients carried downstream have been deposited, resulting in an extremely low-oxygen environment. The size of this Dead Zone varies from year to year depending on conditions, but in 2008 and again in 2010 it has exceeded 7,000 square miles, an area approximately the size of New Jersey.[5]

Non-Point Source Pollution

Non-point source pollution — the source of more than half of water pollution in the U.S. — is contamination that occurs when rainwater, snowmelt, or irrigation washes off agricultural fields, city streets, or suburban yards.[6] As water runoff moves across the landscape, it picks up soil particles, nutrients and other pollutants such as pesticides and herbicides. Some of the polluted runoff seeps into the soil and may contaminate groundwater.[7] The majority of the runoff deposits the soil and pollutants in rivers, lakes, wetlands and coastal waters.[8]

Excess *nitrogen* in water is primarily due to non-point source pollution, such as agricultural runoff.[9] Fertilizer is the largest source of nitrogen input in the Mississippi River Basin and has increased more than six-fold since the 1950s.[10] The USGS estimates about 15.4 billion pounds of nitrogen from chemical fertilizers are applied annually in the Basin.

Excess *phosphorus* in waterways comes from both non-point and point sources. Non-point sources of phosphorus include agricultural runoff, natural decomposition of rocks and minerals, stormwater runoff, erosion and sedimentation, atmospheric decomposition, and direct input by animals and wildlife.[11] Point sources for phosphorus include wastewater treatment effluent and permitted industrial discharges.[12]

The Upper Mississippi River Basin, including Iowa, is one of the most productive farming regions in the world with fertile soil and abundant rainfall. The intensive agriculture practiced here relies on fertilizer application to maximize crop yields and on land tiling and drainage to dry out fields, many of which were natural wetlands. The result is that nutrients from the synthetic and manure fertilizers largely bypass the cleansing and retention powers of healthy soil and instead are much more quickly transported to the Gulf of Mexico. Studies completed by the United States Geological Survey (USGS) have found agriculture to be the dominant source of nutrient delivery to the Gulf.[13]

In fact, the USGS estimates that agricultural sources contribute more than 70 percent of the delivered nitrogen and phosphorus to the Gulf of Mexico.[14] Iowa is one of nine states contributing a disproportionately large share of nutrients to the Gulf.[15] The nine states (in order of total contribution of nitrogen) — Illinois, *Iowa*, Indiana, Missouri, Arkansas, Kentucky, Tennessee, Ohio and Mississippi — collectively account for 75 percent of the total nitrogen and phosphorus delivered to the Gulf of Mexico. Yet, these nine states account for less than one-third of the Mississippi River watershed area.[16] Further, for nitrogen, the top two states — Illinois and Iowa — generate over 28 percent of the nitrogen that reaches the Gulf, but encompass only 9 percent of the watershed.[17]

Table 1 shows that urban sources, including fertilization of residential lawns and golf courses and wastewater treatment effluent, contribute a small percentage of the nutrients delivered to the Gulf. Specifically, 9 and 12 percent, respectively, of the total delivered nitrogen and phosphorus load to the Gulf of Mexico comes from urban sources.[18] Moreover, if only anthropogenic, non-atmospheric sources are considered, 82 percent of the nitrogen flux to the Gulf of Mexico comes from agriculture. This number understates the contribution of nitrogen from agriculture, however, since much of the atmospheric "natural" deposition of nitrogen is simply nitrogen that volatilized from farm fields.[19]

Table 1. Farm Sources Send Bulk of Nutrients Reaching Gulf of Mexico

	Agriculture		Urban[20]	Natural Processes[21]
	Crop[22]	Pasture[23]		
Nitrogen	66%	5%	9%	20%
Phosphorus	43%	37%	12%	8%

Source: USGS.[24]

Nutrient Application in Iowa

To better understand the contribution of urban and agricultural sources specifically in Iowa, this report examines the total acres in Iowa that are dedicated to each type of land use where nutrients are applied, the average annual application rates for both nitrogen and phosphorus, and the total amount of nutrients applied from each source. Seventy-four percent of Iowa's land area is dedicated to row-crop production, thus the first place to examine is the contribution of corn and soybean cropland to nutrient pollution.[25]

Industrial corn production requires extensive nitrogen additions to the soil. Thus, Iowa soils are subject to vast amounts of nitrogen fertilizer, most commonly in the form of anhydrous ammonia. In Iowa, nitrogen is applied to corn crops at the average annual rate of just under 130 pounds per acre, for a total of 1.6 billion pounds of nitrogen applied to Iowa-grown corn.[26] Of this, little more than half is ever used by the corn plants, as their nitrogen use efficiency (NUE) typically hovers around 50 percent, with the other half lost to other natural processes.[27] Assuming a 50 percent NUE means that over 800 million pounds of nitrogen fertilizer were applied to Iowa cornfields that were never used by the crop. Soybeans do not require any nitrogen application, but producers will apply some in order to boost yields. Soybean fields average 29 pounds per acre per year, for a total of 36.7 million pounds of nitrogen applied to Iowa soybeans.[28] (See Table 2).

Table 2. Corn, Soybean Acres Account for Almost All Annual Nitrogen Application in Iowa

Nutrient Source	Total Acres Receiving Nitrogen Application[29]	Application Rate (lbs/acre)	Total Applied (lbs)	Percent of Total Applied
Corn	12,484,333	129.7[30]	1,619,218,033	96.0%
Soybean	756,700	29.2[31]	36,669,360	2.2%
Residential Lawns	154,064	156.0[32]	24,033,965	1.4%
Golf Courses	49,172	154.0[33]	7,572,488	0.5%
Total			1,687,493,846	

Source: USDA and author calculations

Phosphorus, like nitrogen, is used abundantly in Iowa. Fertilizer used on row crops primarily contains nitrogen, but also includes phosphorus. In addition, much livestock feed is phosphorus-rich, so manure generated by livestock that are fed a diet with excess phosphorus will contain high phosphorus levels.

In Iowa, phosphorus is applied to both corn and soybeans at an annual average rate of just over 60 pounds per acre, for a total of 558 million pounds of phosphorus applied to Iowa corn crops and 76 million pounds applied to soybeans annually.[34] (See Table 3).

Table 3. Corn, Soybean Acres Account for Almost All Annual Phosphorus Application in Iowa

Nutrient Source	Total Acres Receiving Phosphorus Application[35]	Application Rate (lbs/acre)	Total Applied (lbs)	Percent of Total Applied
Corn	9,201,333	60.7	558,520,933	86.2%
Soybean	1,255,800	60.7	76,227,060	11.8%
Residential Lawns	154,064	65.0[36]	10,014,152	1.6%
Golf Courses	49,172	65.0	3,196,180	0.5%
Total			647,958,325.21	

Source: USDA and author calculations

Residential lawns and golf courses constitute 1.9 percent of the total nitrogen applied (vs. 98.1 percent for corn and soybean production) and just over 2 percent of the total phosphorus applied in Iowa (vs. 98 percent for corn and soybean production). While on average, households and golf course operators apply both nitrogen and phosphorus at greater rates per acre, their impact is minimal due to the small amount of acreage receiving applications. There are opportunities to reduce fertilizer usage on residential lawns and golf courses, but our calculations and the USGS data show that in Iowa, agriculture contributes the vast majority of nutrients to the Mississippi River Drainage Basin.

While this report focuses exclusively on the chemical fertilizers, it should be noted that manure applications occur on just over 10 percent of Iowa fields and add significant amounts of both phosphorus and nitrogen to the fields and some of this contributes to water quality problems.

Factors Affecting Whether Applied Nutrients Become Pollution

Timing of Nutrient Application Relative to Crop Use

Properly timing nutrient applications can reduce nutrient losses to ground and surface water.[37] A number of studies have found that fertilizer is most efficient when it is applied after crop seedlings emerge from the soil.[38] Nutrient applications that occur in the fall after harvest and spring before planting can lead to substantial losses of nitrogen due to the time lag between application and use by the crop.[39]

In Iowa, a significant percentage of corn and soybean acres are treated with nutrients before planting, and over half of the total acres planted for corn and soybeans are treated with fertilizer in the fall. In addition, Table 4 shows that a majority of corn acres are treated in the spring before the crop is planted.[40] Some acres will be treated again at planting or after planting. Unfortunately, data were not available for the number of acres treated at and after planting. Approximately 40 percent of corn acres are treated with nitrogen more than once a year.[41] This is notable because the average application rate per acre is higher when fertilizer is applied more than once a year.[42]

Table 4. Most Iowa Corn and Soybean Acres Treated with Nutrients Before Planting

	Nitrogen			Phosphorus		
	Fall	Spring	Average # of Treatments / Acre[43]	Fall	Spring	Average # of Treatments / Acre[44]
Corn	51.5%	68.7%	1.40	54.7%	35.6%	1
Soybeans	59.7%	NA	1	70.3%	NA	1

Source: USDA

Seasonal Timing of Nutrient Application

Fall and spring nutrient applications are also at greater risk of loss through runoff and leaching because of snowmelt and considerable precipitation during the late winter, spring and early summer.[45] A study completed by agricultural scientists at the University of Illinois found that heavy precipitation contributed to increased water flow through drain tile, resulting in significant increases in nitrate flow.[46] Indeed, 95 percent of nitrate flow in field tile occurs in winter and spring.[47] The loss of nitrogen through drain tiles becomes a significant contributor to nitrogen in the Gulf of Mexico.[48]

Ground Cover

In addition to variances due to the timing of application, the amount of vegetation present when nutrients are applied makes a difference in how much nitrogen and phosphorus is absorbed and used and how much runs off unused. Areas with complete ground cover throughout the year are the least susceptible to runoff.[49] In Iowa, urban lawns and golf courses have some vegetative cover throughout the year, whereas cropland can be essentially bare for six months of the year.

Farming practices can be adjusted to leave more ground cover on crop fields and reduce runoff. On cropland, reduced- and no-till systems may increase infiltration on some soils and lead to less runoff. In fact, using conservation tillage, where at least 30 percent of the residue from the previous crop is left on the field, runoff can be reduced significantly. Conservation tillage can reduce runoff by 82 percent on cornfields and 42 percent on soybean fields.[50] Conservation tillage can be effective at increasing infiltration, however heavily tiled fields where conservation tillage is practiced are susceptible to an increased loss of nitrogen through leaching. The use of cover crops can reduce this leaching.

In Iowa, the practice of conservation tillage has been gaining steadily in recent years. As of 2007, conservation tillage was practiced on nearly 45 percent of corn ground and nearly 83 percent of soybean fields. This is a vast improvement in terms of reducing runoff over the recent past. Still, 55 percent of Iowa corn ground is more rigorously tilled, and nearly 22 percent is left with between 0 and 15 percent residue.[51] This means that over 5,000 square miles, an area larger than Connecticut, of Iowa corn and soybean fields were intensively tilled and most at risk for sediment and nutrient runoff.

Table 5. Conservation Tillage Gains Acceptance in Iowa, 2007

	Conservation Tillage (> 30% residue)	Reduced-Till (15-30% residue)	Intensive-Till (0-15% residue)
Corn	44.7%	33.6%	21.7%
Soybeans	82.9	13.0%	4.2%

Source: Conservation Technology Information Center

Further, depending upon soil moisture, tilling may occur in either the spring or the fall. In many cases producers will till in the fall in case weather conditions in spring do not permit. This means a portion of Iowa cropland is freshly tilled and loosened prior to lying bare for a number of months and thus more susceptible to runoff.

Nutrient Testing

Understanding how much phosphorus and nitrogen are necessary to promote optimal plant growth is another important factor in reducing nutrient pollution. If more nutrients are applied than are necessary, the excess can pollute waterways. While we do not have data to compare how common it is to test soils before applying nutrients for lawns or golf courses, we do know that in 2005, the soils in almost 87 percent of corn fields were not tested for nitrogen before nutrients were applied; and in 2006, roughly 94 percent of soybean acres were not tested.[52] These data are only for a soil test for nitrogen and other types of tests, such as the late season corn stalk nitrogen test, may be used to determine the amount of nutrients required.

When the soil is tested for nitrogen, the average amount of nitrogen applied per acre is significantly reduced. On corn acres, where the soil was tested to determine the amount of nitrogen present, 108 pounds per acre of nitrogen were applied on average. On acres that were not soil tested, 146 pounds per acre were applied on average.[53] The difference in application rates suggests that soil tests could be effective in reducing nutrient pollution and producers' costs. Soil tests are inexpensive with most being around $10 per sample, with a recommendation of one sample for every 20 acres, resulting in a much lower cost than purchasing unneeded fertilizer.[54]

Climate Change

Climate change has the potential to increase nutrient pollution. The United States Global Change Research Program, an initiative that integrates the research of 13 federal departments and agencies, stated that one of the effects of climate change in Iowa and the Midwest will be an increase in the frequency and intensity of rain falls, such as those experienced in Iowa during the summer of 2010. Higher precipitation can increase nutrient runoff in several ways. More nutrients will be transported with the increased volume of stormflow overland; higher precipitation can cause greater nutrient leaching from soils into tile drains and ditches; and higher streamflow decreases the amount of time nutrients can be filtered by aquatic plants and riparian vegetation.[55] Thus climate change could result in more water pollution and an expanded Dead Zone in the Gulf of Mexico.[56]

Conclusion

The data are clear: the fertilizers applied for corn and soybean production are the largest sources of nutrients in Iowa and the leading cause of water pollution in Iowa's rivers and streams. Given the history of nutrient pollution and potential for even greater nutrient losses, the time for change is now. While farmers and others are taking steps to reduce the amount of pollution from nutrient applications to agricultural fields and urban settings, more needs to be done. Policy makers must consider options that include requirements or significant incentives for the planting of cover crops, nutrient testing, conservation tillage and the development of nutrient management plans that are followed. The improvements needed to reduce non-point source pollution require the initiative and cooperation of farmers, improved financial incentives, enforcement of existing laws and significant new regulations. To address this problem and begin to create cleaner waters in Iowa and address the devastating consequences in the Gulf of Mexico, Iowa should not ignore the nutrient problems originating in our urban areas. However, state environmental policy must focus on the main culprits, nitrogen and phosphorus applied to agricultural land.

[1] U.S. EPA. December 2006. Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams. EPA 841-B-06-002. Available at www.epa.gov/owow/streamsurvey.
[2] Sprague, Lori, David Mueller, Gregory Schwarz, and David Lorenz. 2009. Nutrient Trends in Streams and Rivers of the United States, 1993-2003. United States Department of Interior and USGS Scientific Investigations Report 2008-5202. Available at http://pubs.usgs.gov/sir/2008/5202/pdf/SIR08-5202.pdf. Also see www.iowapolicyproject.org/2009docs/091217-cyanobacteria.pdf, www.cdc.gov/hab/about.htm and www.cdc.gov/hab/cyanobacteria/about.htm#bg.
[3] United States Geological Survey. 2010. The Gulf of Mexico Hypoxic Zone. Available at http://toxics.usgs.gov/hypoxia/hypoxic_zone.html.
[4] Alexander, Richard, Richard Smith, Gregory Schwarz, Elizabeth Boyer, Jacqueline Nolan, and John Brakebill. 2008. Differences in Phosphorus and Nitrogen Delivery to The Gulf of Mexico from the Mississippi River Basin. Environ. Sci. Technol. 42, 822-830. Available at http://water.usgs.gov/nawqa/sparrow/gulf_findings/index.html. And the National Science and Technology Council and the Committee on Environment and Natural Resources. 2000. An Integrated Assessment of Hypoxia in the Northern Gulf of Mexico. Washington, DC. Available at http://oceanservice.noaa.gov/products/hypox_final.pdf.
[5] In 2008 and 2010 the hypoxic zone exceeded 20,000 square kilometers, surpassing the previously largest hypoxic zone ever measured in 1999. See August 1, 2010. 2010 Dead Zone – One of the Largest Ever http://www.gulfhypoxia.net/Research/Shelfwide%20Cruises/2010/PressRelease2010.pdf and USGS. June 22, 2009. Nutrient Delivery to the Gulf of Mexico Among Highest Ever Measured. ScienceDaily. Available at http://www.sciencedaily.com /releases/2009/06/090620162540.htm. And Goolsby, Donald A. and William A. Battaglin. December 2000. Nitrogen in the Mississippi Basin – Estimating Sources and Predicting Flux to the Gulf of Mexico. United States Geological Survey Fact Sheet 135-00. Available at: http://ks.water.usgs.gov/pubs/fact-sheets/fs.135-00.html.
[6] State of Nevada. Department of Conservation & Natural Resources. Division of Water Resources. Water Words Dictionary – A Compilation of Technical Water, Water Quality, Environmental, and Water-Related Terms. Available at http://water.nv.gov/WaterPlanning/dict-1/ww-index.cfm.
[7] State of Nevada. Water Words Dictionary.
[8] State of Nevada. Water Words Dictionary.
[9] Goolsby, Donald A. and William A. Battaglin. December 2000. Nitrogen in the Mississippi Basin – Estimating Sources and Predicting Flux to the Gulf of Mexico. United States Geological Survey Fact Sheet 135-00. Available at: http://ks.water.usgs.gov/pubs/fact-sheets/fs.135-00.html.
[10] Goolsby et al. 2000.
[11] Oram, Brian. Phosphates and Water Quality. Wilkes University. Center for Environmental Quality, Environmental Engineering and Earth Sciences. Available at http://www.water-research.net/phosphate.htm.
[12] Oram. Phosphates and Water Quality.
[13] Sprague, Lori, David Mueller, Gregory Schwarz, and David Lorenz. 2009. Nutrient Trends in Streams and Rivers of the United States, 1993-2003. United States Department of Interior and USGS Scientific Investigations Report 2008-5202. Available at http://pubs.usgs.gov/sir/2008/5202/pdf/SIR08-5202.pdf. And Alexander et al. 2008.
[14] United States Geological Survey. Nutrient Delivery to the Gulf of Mexico. Frequently Asked Questions. Available at http://water.usgs.gov/nawqa/sparrow/gulf_findings/faq.html#13.
[15] Alexander et al. 2008. Data available at http://water.usgs.gov/nawqa/sparrow/gulf_findings/ES&T_states.pdf
[16] Alexander et al. 2008.
[17] Alexander et al. 2008. According to U.S. Census figures Iowa's land area is 55,869 square miles and Illinois' land area is 55, 584 square miles. The Mississippi River basin is 1,245,000 square miles according to the EPA.
[18] Alexander et al. 2008.
[19] Libra, R.D., C.F. Wolter and R.J. Langel. 2004. Nitrogen and Phosphorus Budgets for Iowa and Iowa Watersheds. Iowa Geological Survey Bureau Technical Information Series 47.
[20] Urban sources include nutrient inputs from lawn fertilization (both residential and commercial) and wastewater treatment effluent.
[21] Natural processes include atmospheric deposition and natural land.
[22] Crop refers to corn and soybean crops as well as other crops which constitutes a minimal portion.
[23] Pasture refers to non-recoverable animal manure which is manure from unconfined animals and manure lost during the collection, storage, and treatment of wastes from confined animals including concentrated animal feeding operations.
[24] USGS data available at http://water.usgs.gov/nawqa/sparrow/gulf_findings/primary_sources.html
[25] USDA. 2007. National Agricultural Statistics Service, Census of Agriculture.
[26] Application rates were calculated by taking an average of nitrogen and phosphorus applications from 2000-2007 based on yearly chemical input data obtained from the United States Department of Agriculture's National Agriculture Statistics Service. These same data also provided the average percentage of fields receiving fertilizer applications each year. A simple average calculation was used relying on this data as well as data on total acres of planted corn and soybeans that was also obtained from USDA's NASS for the years 2005-2010. The USDA's NASS for Iowa is available here:

http://www.nass.usda.gov/Statistics_by_State/Iowa/index.asp#.html and here: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1000.

[27] Raun, William R. and G. J. Johnson. 1999. Improving Nitrogen Use Efficiency for Cereal Production. J. Agronomy. 91:357-363. Available at http://www.nue.okstate.edu/Index_Publications/Improving_NUE.pdf

[28] See footnote 26 on application rate calculations.

[29] Corn and soybean total acres data were calculated using 2005-2010 average from National Agriculture Statistics Service. Available at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1000 and average acres receiving fertilizer application.

Total acreage for residential lawns was calculated accordingly:1,232,511 housing units in Iowa (2000 US Census) multiplied by the national average of 50% of households who participate in lawn fertilization multiplied by 0.25 average acre lot size = 154,064 acres of residential lawn subject to fertilization.

Golf Course total acreage was calculated by taking the average acreage of a golf course under turf management (and therefore subject to nutrient inputs) given by the Golf Course Superintendents Association of America (GCSAA) as 111.5 acres per course and multiplying that by the total number of golf courses in Iowa which is 441.

[30] See footnote 26 on application rate calculations.

[31] See footnote 26 on application rate calculations.

[32] Relying on formulas and data found through Florida State University's Fertilizer Task Force, we calculated the 156 pounds per acre per year of applied nitrogen on Iowa residential lawns as such: Of the 50% average of US residents who fertilize their lawns, 75% are do-it-yourself (DIY) homes and 25% rely on professional lawn services. The average DIY homeowner applies 2.78 pounds of nitrogen per thousand square feet per year and, estimating on the high-end, a professional lawn service company will apply 6 pounds of nitrogen per thousand square feet per year. We then took a Weighted Average Pounds of Nitrogen Calculation = (75% X 2.78 pounds nitrogen per thousand square feet) + (25% X 6 pounds of nitrogen per thousand square feet) = 3.58 pounds of nitrogen per 1,000 square feet per year. In order to convert the 1,000 square feet application rate to an acre, we multiplied 3.58 pounds of nitrogen per 1,000 square feet X 43.56 thousand square feet per acre (conversion) = 156 pounds per acre per year. This figure falls into the range of residential nitrogen application rate data we came across in our research.

[33] Nutrient application for golf courses was obtained through a report commissioned by The Environmental Institute of Golf. Available at http://www.eifg.org/programs/nutrientsurvey.asp#use.

[34] See footnote 26 on application rate calculations.

[35] See footnote 26 on acreage calculations.

[36] There was no readily available data on phosphorus application rates on residential lawns. One Maryland study listed 15 pounds per acre per year for DIY households but had no data available for professional lawn care services. Therefore we decided to apply the same application rate to residential lawns as golf courses. Considering this figure is 50 pounds per acre per year more than the 15 pounds we found in the Maryland study, it is likely a gross overestimate. Either way, the impact is minimal at less than 1 percent.

[37] Environmental Working Group. February 1996. Pouring It On: Solving the Nitrate Problem. Available at http://www.ewg.org/node/7715.

[38] Pereira, L.S. and J.Q. dos Santos. 1991. Fertilizer and water application, and control of nitrate pollution: Management issues in Nitrate Contamination: Exposure, Consequence, and Control. NATO ASI Series, Vol. G30. Bogardi, et al., eds. Springer Verlag. Berlin. and Peterson, G.A. and W.W. Frye. 1989. Fertilizer Nitrogen Management. Nitrogen Management and Groundwater Contamination, R.F. Follett, ed. Elsevier Press. Amsterdam.

[39] Pereira and. dos Santos. 1991. And Verlag et al. 1989.

[40] The same could likely be said for soybeans, however, the data either did not comply with USDA's Economic Research Service (ERS) disclosure limitation practices or was not available. Data obtained from the USDA – Agricultural Resources Management Survey.

[41] Average number of treatments per acre was calculated using data from the USDA's NASS Agricultural Chemical Usage report for the state of Iowa; the figure was calculated by taking an average of the average number of treatments per acre for all years of available data from 2000 to the present.

[42] Environmental Working Group. 1996.

[43] See footnote 41 on average number of treatments per acre calculations.

[44] See footnote 41 on average number of treatments per acre calculations.

[45] National Science and Technology Council and the Committee on Environment and Natural Resources. 2000. An Integrated Assessment of Hypoxia in the Northern Gulf of Mexico. Washington, DC. Available at http://oceanservice.noaa.gov/products/hypox_final.pdf.

[46] University of Illinois at Urbana-Champaign. July 10, 1998. Study Of Fertilizer Runoff Suggests Changing Time Of Application. ScienceDaily. Available at http://www.sciencedaily.com /releases/1998/07/980710081028.htm.

[47] University of Illinois at Urbana-Champaign. 1998.

[48] University of Illinois at Urbana-Champaign. 1998.

[49] Gilley, J.E., L.M. Risse, and B. Eghball. 2002. Managing runoff following manure application. Journal of Soil and Water Conservation. Vol 57 No 6. Available at http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1139&context=biosysengfacpub.
[50] Gilley, J.E., L.M. Risse, and B. Eghball. 2002.
[51] Conservation Technology Information Center. 2007. Crop Residue Management Iowa Summary.
[52] United States Department of Agriculture, Agricultural Resources Management Survey. Crop Production Practices Data. Nutrient Use by Manure Application and Soil Test, for Corn, by All Acres, for Iowa, for 2005 and Nutrient Use by Manure Application and Soil Test, for Soybeans, by All Acres, For Iowa, for 2006. Available at http://www.ers.usda.gov/Data/ARMS/CropOverview.htm. Data for soybeans were noted as statistically unreliable due to small sample size
[53] United States Department of Agriculture, Agricultural Resources Management Survey. Crop Production Practices Data.
[54] Indiana Natural Resources Conservation Service brochure on soil testing. Available at http://www.in.nrcs.usda.gov/smallscalefarmers/Small%20Farms%20Soil%20Testing%20(IN)-web.pdf
[55] National Science and Technology Council and the Committee on Environment and Natural Resources. 2000. An Integrated Assessment of Hypoxia in the Northern Gulf of Mexico. Washington, DC. Available at http://oceanservice.noaa.gov/products/hypox_final.pdf.
[56] National Science and Technology Council and the Committee on Environment and Natural Resources. 2000.