It's Time to Put a Price Tag on the Environmental Impacts of Commodity Crop Agriculture

by Linda K. Breggin, Bruce Myers, and Meredith Wilensky

Linda K. Breggin and Bruce Myers are Senior Attorneys and Meredith Wilensky is a Public Interest Law Fellow at the Environmental Law Institute.

This Comment examines what is known about the costs associated with environmental degradation resulting from the production of commodity crops—i.e., row crops such as corn, soybeans, and wheat—that are grown on large swaths of land. Much has been written about the environmental impacts of contemporary agriculture, and the critical need for conservation practices,[1] but far less is known about the cost of these impacts. Even less research has examined how those costs can be attributed to the various types of agricultural operations. This Comment provides a snapshot of the current state of the research and emphasizes the need for more cost data on impacts and for better public access to this information. The Comment draws on studies and information that were identified primarily through free, publicly accessible sources. It is certainly possible that additional studies exist and are available, for example, through discipline-specific, subscription-only databases. Such studies are not, however, readily available to policymakers and, therefore, do not appear to inform the public dialogue. Nevertheless, it is important to view this Comment as presenting a first step in the review of existing literature.

This Comment is not intended to express our views on how environmental harms caused by agriculture can best be addressed. Rather, our objective is to draw attention to the costs of environmental damage associated with pollution from commodity crop operations, because these costs currently represent a cost of production that is born not by the seller or the buyer of the crop, but by society. Such costs, which are described by economists as "externalities," often are not obvious—and in some cases go completely unnoticed. Where gaps in data prevent a comprehensive cost assessment, it is unsurprising that, at times, the costs are virtually invisible in the policy debate as well. Yet, the costs are real and extensive. At the very least, a reasonably complete accounting of these costs should be part of the public dialogue.

I. The Environmental Impacts of Commodity Crop Agriculture

In a forthcoming article in the *Harvard Environmental Law Review*, two of the co-authors of this Comment outline in detail the environmental impacts of commodity crop agriculture. The following discussion highlights some of these impacts.[2]

Agricultural production in the United States has in many ways become increasingly similar to other types of industrial production.[3] It is specialized, uses high volumes of chemical inputs, and employs sophisticated capital equipment. And it takes place on an ever-expanding scale: while the average size of individual farms has grown, the number of farms has decreased.[4] As a result, agricultural production today is concentrated in large, efficient operations that produce large yields.[5]

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1. *E.g.*, Marc Ribaudo & Robert Johansson, *Water Quality: Impacts of Agriculture*, *in* Econ. Research Serv., U.S. Dep't of Agriculture (USDA), Econ. Info. Bull. No. 16, Agricultural Resources and Environmental Indicators 33 (Keith Wiebe & Noel Gollehon eds., July 2006), *available at* http://www.ers.usda.gov/publications/arei/eib16/eib16_2-2.pdf; Michael Baker et al., An Urgent Call to Action: Report of the State-EPA Nutrient Innovations Task Group 17 (Aug. 2009), *available at* http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/2009_08_27_criteria_nutrient_nitgreport.pdf; Gregory McIsaac, *Surface Water Pollution by Nitrogen Fertilizers*, *in* Encyclopedia of Water Science 950 (Bobby Altman Stewart & Terry A. Howell eds., 2003); Robert J. Gilliom et al., The Quality of Our Nation's Water—Pesticides in the Nation's Streams and Groundwater, 1992-2001 (revised Feb. 15, 2007), *available at* http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291.pdf.
2. Linda Breggin & Bruce Myers, *Subsidies With Responsibilities: Placing Stewardship and Disclosure Conditions on Government Payments to Large-Scale Commodity Crop Operations*, 37 Harv. Envtl. L. Rev. 2 (forthcoming Spring 2013) (recommending reforms to the Farm Bill to better address pollution resulting from large-scale commodity crop operations).
3. Carolyn Dimitri et al., 20th Century Transformation of U.S. Agriculture and Farm Policy 2, 6 (June 2005), *available at* http://www.ers.usda.gov/publications/eib3/eib3.pdf.
4. Farms with sales less than $500,000 only comprise 3% of U.S. farms. U.S. Environmental Protection Agency (EPA), *Demographics*, EPA.gov, http://www.epa.gov/oecaagct/ag101/demographics.html (last visited Jan. 1, 2013).
5. *Id.*

Contemporary farming operations are highly efficient at producing commodity crops, but pollution is generated as a byproduct. In particular, impaired surface water quality—caused by nutrients, pesticides, and sediment—has become a major concern, as has agricultural contamination of drinking water. The downstream effects tend to be additive—with many farms contributing, as well as various nonagricultural sources. These impacts are briefly outlined below.[6]

Surface Water Pollution: Commodity crop production can contribute various pollutants to surface water, including nutrients, pesticides, and sediment. Nutrient pollution, in particular, has become a major national problem. Chemical fertilizers and manure are applied to promote plant growth, but crops cannot use all of the nitrogen and phosphorus made available to them—a problem that can be exacerbated by overapplication.[7] The unused fertilizer migrates to surface and groundwater when cropland becomes saturated from rainfall, snowmelt, irrigation, or flooding.[8]

Nutrients impair surface water in a variety of ways. For example, "dead zones" can form when nutrients (from crop production and other sources) cause growth of algal blooms that block sunlight, ultimately die off, sink, and are consumed by bacteria. The process uses up oxygen, resulting in hypoxia, or insufficient dissolved oxygen in the water.[9] Such conditions are not habitable for fish, shrimp, clams, and other aquatic organisms.[10] U.S. Geological Survey (USGS) research published in 2008 indicates that crop production contributes over 60% of the nitrogen and over 40% of the phosphorus affecting the Gulf of Mexico, for example.[11]

Across the United States, freshwater lakes, streams, and rivers are impaired by nutrients. Based on data submitted by states to the U.S. Environmental Protection Agency (EPA) under the Clean Water Act (CWA),[12] nutrients are the third most common cause of river and steam impairment. State water quality criteria were exceeded in over 100,000 miles of assessed rivers and streams (27.8% of river and stream miles were assessed). And, over 3.5 million acres of assessed lakes, reservoirs, and ponds (45.5% were assessed) were impaired by nutrients, making nutrients the second leading cause of their impairment.[13]

Nutrient pollution from fertilizers is also linked to harmful algal blooms (HABs) that can be toxic to humans and wildlife. Consumption or exposure to HAB toxins is associated with illness and even mortalities. HABs also harm fish, birds, and mammals and degrade ecosystems and damage coral and seagrasses.[14]

Commodity crop production can also result in pesticide pollution in surface water. Although pesticides help maxi-

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6. Although this Comment focuses on water pollution impacts, other environmental and natural resource issues are associated with commodity crop agriculture—from potential loss of species habitat and biodiversity, to high levels of water consumption, to the uncertainties flowing from the use of genetically modified seeds, to climate impacts. The suite of harms resulting from global climate change is particularly important, as is the case with most sectors of the economy. Although agriculture as a sector exhibits features of both a greenhouse gas (GHG) emitter and a GHG gas sink, the sector is a net GHG emitter. *See*, *e.g.*, U.S. EPA, Doc. No. EPA 430-R-12-001, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*, at ES-12 to ES-13 (Apr. 2012), *available at* http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Main-Text.pdf. *See also* Renée Johnson, Congressional Research Service, *Climate Change: The Role of the U.S. Agriculture Sector and Congressional Action*, June 19, 2009 (providing a helpful overview of sources of agricultural emissions and sinks). Also attributable to the sector are GHG emissions associated with various off-farm operations and processes (e.g., the manufacture of chemical fertilizers and pesticides). However, accurately assessing the total GHG contribution of commodity crop operations—and then determining how to allocate that contribution across the myriad harms imposed by climate change—will be, at best, difficult and complex. Although any final price tag for the environmental harms attributable to commodity crop agriculture should account for climate impacts, this would be a challenging place to begin—both technically and politically. Further discussion of pricing the environmental impacts of commodity crop agriculture outside of the realm of water pollution is left for another day.
7. Mary Booth, Dead in the Water (Environmental Working Group, Apr. 2006), *available at* http://www.ewg.org/reports/deadzone; *see generally* Marc Ribaudo et al., *Nitrogen in Agricultural Systems: Implications for Conservation Policy*, USDA, Econ. Research Rep. No. 127 (Sept. 2011), *available at* http://www.ers.usda.gov/Publications/ERR127/ERR127.pdf (discussing overuse and misapplication of nitrogen fertilizers).
8. Nutrient-laden water can leave the land by way of runoff, soil erosion, leaching to groundwater, evaporation, and the drains that are used to keep the crops from becoming oversaturated. *See, e.g.*, Ribaudo et al., *supra* note 7, at 3.
9. Mississippi River Gulf of Mexico Task Force, Hypoxia 101, EPA.gov, http://water.epa.gov/type/watersheds/named/msbasin/hypoxia101.cfm (last visited Jan. 2, 2013); U.S. Geological Survey (USGS), The Gulf of Mexico Hypoxic Zone, USGS.gov, http://toxics.usgs.gov/hypoxia/hypoxic_zone.html (last visited Jan. 2, 2013).
10. *See id.*; Ecological Soc'y of Am., Hypoxia, *available at* http://www.esa.org/education_diversity/pdfDocs/hypoxia.pdf; La. Univ. Marine Consortium, What Is Hypoxia?, Gulfhypoxia.net, http://www.gulfhypoxia.net/Overview/ (last visited Jan. 2, 2013); Office of Wetlands, Oceans & Watersheds, U.S. EPA, Hypoxia 101, EPA.gov, http://water.epa.gov/type/watersheds/named/msbasin/hypoxia101.cfm (last visited Jan. 2, 2013); World Res. Inst., *Eutrophication & Hypoxia: Impacts*, WRI.org, http://www.wri.org/project/eutrophication/about/impacts (last visited Jan. 2, 2013); Interagency Working Group on Harmful Algal Blooms, Hypoxia & Human Health, *Scientific Assessment of Hypoxia in U.S. Coastal Waters*, WhiteHouse.gov 18-21 (Sept. 2010), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/hypoxia-report.pdf.
11. Nat'l Water-Quality Assessment Program, *Sources of Nutrients Delivered to the Gulf of Mexico*, USGS.gov (Jan. 28, 2008), http://water.usgs.gov/nawqa/sparrow/gulf_findings/primary_sources.html (last visited Jan. 2, 2013).
12. 33 U.S.C. §§1251-1387, ELR Stat. FWPCA §§101-607.
13. U.S. EPA, *Watershed Assessment, Tracking & Environmental Results/National Summary of State Information*, EPA.gov, Causes of Impairment in Assessed Rivers and Streams table, Causes of Impairment in Assessed Lakes, Reservoirs, and Ponds table, http://ofmpub.epa.gov/waters10/attains_nation_cy.control (last visited Jan. 2, 2013).
14. *See*, *e.g.*, Karen L. Bushaw-Newton & Kevin G. Sellner, *State of the Coastal Environment: Harmful Algal Blooms*, NOAA.gov 8 (1999), *available at* http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/hab.pdf; Harmful Algal Bloom Research, Dev., Demonstration & Tech. Transfer, National Workshop Report: A Plan for Reducing HABs and HAB Impacts 14 (Q. Dortch et al. eds., 2008), *available at* http://www.whoi.edu/fileserver.do?id=43464&pt=10&p=19132; Woods Hole Oceanographic Inst., Harmful Algae: What Are Harmful Algal Blooms (HABs)?, WHOI.edu, http://www.whoi.edu/redtide/ (last visited Jan. 2, 2013).

mize yields,[15] when contained in runoff from crop operations, they can present a risk to human health and impair surface water quality, which in turn can harm freshwater and marine species and recreational and commercial fisheries.[16] EPA reports, based on state data submitted under the CWA, that pesticides impair thousands of river and stream miles assessed and hundreds of thousands of lake and pond acres assessed.[17] Similarly, the USGS reported in 2006 that pesticide compounds were found in 97% of stream samples taken in agricultural areas, and almost 10% of the streams had pesticide concentrations above the level at which there may be adverse human health effects. In addition, over 50% of the streams tested in agricultural areas had pesticide concentrations at levels that may have adverse effects on aquatic life.[18]

Commodity crop production can also contribute to sediment pollution in surface waters. According to the Natural Resources Conservation Service (NRCS), as of 2007, erosion from rainfall and runoff accounted for an average loss of 3.0 tons of soil per acre of cultivated cropland per year.[19] Wind erosion caused the loss of 2.5 additional tons of soil per acre per year from cultivated cropland.[20] State data reported to EPA under the CWA indicate that sediment impaired over 100,000 river and stream miles assessed, as well as over 700,000 of the assessed acres of lakes and ponds.[21] Not only does sediment transport other pollutants, such as nutrients and pesticides,[22] but it is associated with turbidity (i.e., water that becomes murky from suspended solids).[23]

Drinking Water Contamination: The same pollutants that impair surface water quality can also impair sources of drinking water. For example, nitrogen contained in runoff from commodity crops can pose health risks,[24] particularly for users of shallow wells located in agricultural areas.[25] "Blue baby syndrome," or methemoglobinemia, and adverse reproductive outcomes are among the problems associated with high nitrate levels in well water.[26] In addition, nutrients in drinking water can result in increased carcinogenic disinfection byproducts from the chlorinating of drinking water.[27] Furthermore, HABs can occur in drinking water sources.[28]

Pesticides from commodity crop operations can also contaminate drinking water. A USGS study of untreated groundwater from public supply wells found one or more pesticide compounds in over 40% of the samples.[29]

II. Accounting for and Attributing the Environmental Impacts

It is clear that commodity crop agriculture contributes to significant downstream environmental impacts. Far less clear, however, is the price tag that these impacts carry—or how best to attribute these costs to individual operations. This section surveys the existing literature on quantification of the environment-related impacts of commodity crop agriculture and highlights gaps in the research. This literature review was conducted by examining publicly available articles and information on government agency and nonprofit websites and through general web searches. Because this review was conducted without access to private database search tools, however, it may not reflect a comprehensive review of all research areas discussed and, therefore, represents only a first but important step in the review of existing literature.

Assigning a dollar value to the environmental harms associated with commodity crop agriculture can be done in several different ways. These include quantifying the overall impacts attributable to the sector, or to a particular type of crop; quantifying the impacts associated with a particular agricultural pollutant (e.g., one or more pesticides or

15. *See* Mark Goodwin Consulting Ltd., CropLife America, The Contribution of Crop Protection Products to the United States Economy (Nov. 2011), *available at* http://www.croplifeamerica.org/sites/default/files/node_documents/CLA_Socio_Econ120.pdf.
16. David Pimental et al., *Environmental and Economic Costs of Pesticide Use*, 42 BioScience 750, 756 (1992).
17. *See* U.S. EPA, *supra* note 13. These figures likely understate the true degree of pesticide pollution, given the great extent of the nation's waters that have yet to be assessed.
18. *See* Robert J. Gilliom et al., USGS Nat'l Water-Quality Assessment Program, Circular 1291, The Quality of Our Nation's Water—Pesticides in the Nation's Streams and Groundwater, 1992-2001, at 4, 6, 8 (revised Feb. 15, 2007), *available at* http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291.pdf.
19. Natural Res. Conservation Serv., USDA & Iowa State Univ. Ctr. for Survey Statistics & Methodology, Summary Report: 2007 National Resources Inventory 97 (Dec. 2009), http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri (last visited Jan. 2, 2013).
20. *Id.* at 110; *compare* Craig Cox et al., *Losing Ground*, EWG.org (2010), *available at* http://static.ewg.org/reports/2010/losingground/pdf/losingground_report.pdf.
21. U.S. EPA, *supra* note 13.
22. U.S. EPA Office of Water, Doc. No. EPA 841-B-03-004, National Management Measures to Control Nonpoint Source Pollution From Agriculture at 4-39, 4-75 (July 2003), http://water.epa.gov/polwaste/nps/agriculture/agmm_index.cfm (last visited Jan. 2, 2013).
23. Nat'l Estuarine Research Reserve Sys., Nat'l Oceanic & Atmospheric Admin., Turbidity and Sedimentation, http://www.nerrs.noaa.gov/doc/siteprofile/acebasin/html/modules/watqual/wmtursed.htm (last visited Jan. 2, 2013).
24. *E.g.*, Olga V. Naidenko et al., Envtl. Working Group, Troubled Waters: Farm Pollution Threatens Drinking Water 10 (Apr. 2012), *available at* http://static.ewg.org/reports/2012/troubled_waters/troubled_waters.pdf; James Robert Self & Reagan McTier Waskom, Colo. State Univ. Extension, Fact Sheet No. 0.517, Nitrates in Drinking Water (Oct. 2008), http://www.ext.colostate.edu/pubs/crops/00517.html (last visited Jan. 2, 2013); U.S. EPA, Basic Information About Nitrate in Drinking Water, http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm (last visited Jan. 2, 2013).
25. Neil Dubrovsky et al., USGS Nat'l Water-Quality Assessment Program, Circular 1350, The Quality of Our Nation's Waters—Nutrients in the Nation's Streams and Groundwater, 1992-2004 11 (2010), *available at* http://pubs.usgs.gov/circ/1350/pdf/circ1350.pdf.
26. Mary H. Ward & Jean D. Brender, *Nitrate in Drinking Water: Potential Health Effects*, *in* Dubrovsky et al., *supra* note 25, at 102-03; *see also* Naidenko et al., *supra* note 24, at 11-12.
27. Dubrovsky et al., *supra* note 25, at 22 (sidebar: "Concerns About Elevated Nutrients in Water").
28. Cary B. Lopez et al., Interagency Working Group on Harmful Algal Blooms, Hypoxia & Human Health, White House Council on Envtl. Quality, Scientific Assessment of Freshwater Harmful Algal Blooms 1 (July 2008), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/frshh2o0708.pdf.
29. Patricia L. Toccalino & Jessica A. Hopple, USGS Nat'l Water-Quality Assessment Program, Circular 1346, The Quality of Our Nation's Waters—Quality of Water From Public-Supply Wells in the United States, 1993-2007, Overview of Major Findings 31 (2010), *available at* http://pubs.usgs.gov/circ/1346/pdf/circ1346.pdf.

herbicides); or quantifying the impact of a particular form of pollution (e.g., nitrate contamination in drinking water, or injury to commercial fisheries caused by hypoxia) and determining what share of that impact is attributable to an agricultural activity. Indeed, it may be that a meaningful quantification of the harms at a sectoral level requires further efforts at aggregation of discrete studies.

Two factors add considerably to the difficulty here: first, various types of agricultural operations contribute to the same downstream impacts (e.g., row crop operations as well as animal agriculture); and, second, nonagricultural sources (e.g., municipal stormwater runoff) can also play a significant role. Given that downstream impacts can and likely do have multiple contributing sources, assigning a price tag to the harm is only the first step. The next step is to ascertain the extent to which a specific agricultural source, or category of sources, is responsible for the harm.

A. *Survey of the Literature*

An important 2004 study attempts to calculate fully the environmental impacts of agriculture. The study values externalities of crop production in the United States with respect to natural resources, wildlife and ecosystem biodiversity, and human health at roughly between $5 billion and $16 billion annually.[30] This figure reflects external costs of crop production at between $29 and $96 per hectare.[31] The study was conducted by aggregating existing valuation data from previous studies.[32] The authors conclude that crop production is associated with the following costs: at least $300 million in damage to water resources from nutrients and pesticides (while noting that this is not a complete review of all relevant impacts on water)[33]; $2 to $13 billion in damage to soil resources[34]; $283 million in damage to air resources[35]; $1.1 billion in damage to wildlife and ecosystem biodiversity[36]; and $1 billion in damage to human health due to pesticides.[37] The study does not break out the cropland data by type of crop.

This is precisely the type of study needed to characterize, in dollar amounts, the downstream harms attributable to agricultural operations. Yet, the utility of even this sweeping study is limited,[38] as the authors recognize that some of the data used is over one decade old (and the study is now nine years old) and that further research is needed to include a broader range of harms.[39] For example, the study does not consider community or property value impacts or ecosystem impacts of fertilizers.[40] Furthermore, the study refers to its assessment of wildlife harms as "far from comprehensive."[41]

Although there appears to be a dearth of comprehensive estimates of the environmental harms associated with commodity crop agriculture, there are studies that assess different facets of the total impact. For example, some studies have estimated the costs of nutrient pollution in the United States, but these studies are not tailored specifically to harm caused by commodity crops. Rather, these studies include additional sources of nutrient pollution such as urban stormwater runoff, which carries lawn fertilizers among other chemicals. For example, EPA estimates that nutrient pollution costs in the U.S. tourism industry alone are close to $1 billion each year, mostly through depressed fishing and recreational activities.[42] And, a 2009 study found that human-induced eutrophication of U.S. waters results in costs of approximately $2.2 billion annually,[43] including losses in recreational water usage, depressed waterfront real estate values, costs to recover threatened and endangered species, and treatment of drinking water.[44] The study was not comprehensive, however, in that it did not account for damage to rivers and for dead zones in the Great Lakes and in coastal areas.[45]

Other studies on the impacts of nutrient pollution include a study that estimates that Maui Coast, Kihei, Hawaii, seaweed overgrowth costs $20 million per year in reduced real estate values and lost recreational spending.[46] And, a study of hypoxia in the Barnegat Bay Estuary estimates the cost to New Jersey at $25 million per year in recreational fishing losses.[47]

One particular impact of nutrient pollution that has been more thoroughly examined is HABs.[48] According to a

30. Erin Tegtmeier & Michael Duffy, *External Costs of Agricultural Production in the United States*, 2 Int'l J. Agric. Sustainability 1 (2004).
31. *Id.* at 13. The study separates out the costs of impacts attributable primarily to livestock production.
32. *Id.* at 2.
33. *Id.* at 6.
34. *Id.* at 9.
35. *Id.* at 10.
36. *Id.* at 11-12.
37. *Id.* at 13-14.
38. *Id.* at 3.
39. *Id.* at 1, 3.
40. *Id.* at 7.
41. *Id.*
42. U.S. EPA, The Facts About Nutrient Pollution (May 2012), *available at* http://water.epa.gov/polwaste/upload/nutrient_pollution_factsheet.pdf.
43. Walter K. Dodds et al., *Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages*, 43 Envtl. Sci. & Tech. 12, 18 (2009), *available at* http://pubs.acs.org/doi/full/10.1021/es801217q.
44. *Id.* at 12.
45. *Id.* at 16. Similarly, the costs of nutrient pollution in Europe have been studied. One report estimated the social and ecological damage caused by freshwater nutrient pollution in England and Wales to be $105-160 million per year. Jules N. Pretty et al., *Environmental Costs of Freshwater Eutrophication in England and Wales*, 37 Envtl. Sci. & Tech. 201 (2003), *available at* http://pubs.acs.org/doi/abs/10.1021/es020793k. Another paper estimated that groundwater pollution from nitrates and pesticides costs the drinking water sector in the Upper Rhine Valley, France, approximately 21.8 million Euro per year (drinking water utilities assessed at 1.8 million Euro per year and households' averting behavior costs at 20 million Euro per year.). Jean-Daniel Rinaudo, *Assessing the Cost of Groundwater Pollution: The Case of Diffuse Agricultural Pollution in the Upper Rhine Valley Aquifer*, 52 Water Sci. & Tech. 153 (2005).
46. National Oceanic and Atmospheric Administration (NOAA), *State of the Coast* (revised May 23, 2012), http://stateofthecoast.noaa.gov/hypoxia/impacts.html (last visited Jan. 2, 2013) (citing Pieter van Beukering & Herman S.J. Cesar, *Ecological Economic Modeling of Coral Reefs: Evaluating Tourist Overuse at Hanauma Bay and Algae Blooms at the Kihei Coast, Hawai'i*, 58 Pac. Sci. 243 (2004).
47. *Id.*, citing Suzanne Bricker et al., Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change, NOAA Coastal Ocean Program Decision Analysis Series No. 26, National Centers for Coastal Ocean Science, Silver Spring, Md. 322, http://stateofthecoast.noaa.gov/hypoxia/impacts.html (last visited Jan. 2, 2013).
48. Center for Disease Control and Prevention, Harmful Algal Blooms (HABs), CDC.gov, http://www.cdc.gov/nceh/hsb/hab/default.htm (last

2012 Woods Hole Oceanographic estimate, HABs cost the United States nearly $50 million annually,[49] including $20 million in public health costs, $18 million in losses for commercial fisheries, $7 million in losses from the recreation and tourism industries, and $2 million in management and monitoring.[50] In contrast, a 2006 National Center for Coastal Ocean Science study estimates that HABs cost the country $82 million per year,[51] due in part to much larger estimates for fishery and public health impacts.[52] Both the Woods Hole Oceanographic Institute and the National Center for Coastal Ocean Science consider their estimates to be conservative.[53] In fact, a 1998 study found that HABs had resulted in $100 million in losses annually in the preceding 25 years.[54]

As HABs are readily observable and of limited duration, their impacts tend to be conducive to valuation. They can lead to measurable economic damage in the form of, for example, lost tourism, reduced fishery productivity, and depressed property values. This is reflected in Table 1, which contains examples of studies that quantify the costs associated with particular HAB events. These studies report millions of dollars of losses annually across the United States due to HABs. Other studies examine costs over time from a specific species or a specific geographic location. For example, one study reports that *P. parvum,* since its first documented outbreak in 1985, has caused 41 fish kills, killing over 18 million fish worth an estimated $7 million in losses.[55] Another study estimates that *Heterosigma akashiwo* blooms in Washington have caused losses of $4 to $5 million per year to harvesters of wild and penned fish.[56] A 2000 study estimates that HABs caused by cyanobacteria cost the U.S. catfish industry $60 million dollars annually (in 1998 prices).[57]

Another important cost associated with nutrient pollution is contamination of drinking water. Between 1998 and 2008, nitrate exceedance violations in U.S. waters nearly doubled.[58] As nutrient pollution has worsened, installation of expensive drinking water treatment equipment has become increasingly necessary across the country. While there are few estimates of the damages caused by nutrients in water sources, the costs incurred by localities to remedy this impact provide a ready shorthand for the economic impact. For example, in 1991, Des Moines Water Works installed a $4 million ion exchange facility to remove nitrate from drinking water. This system costs Des Moines nearly $3,000 per day.[59] In Fremont, Ohio, an estimated $15 million reservoir must be constructed due to high levels of nitrate in the Sandusky River.[60] According to one estimate, the removal of nitrates alone from drinking water costs the United States more than $4.8 billion annually.[61] In addition to water treatment systems, water contamination results in increased spending on bottled water. One study found that odor and taste episodes result in approximately $942 million in bottled water purchases each year.[62]

With respect to pollution costs associated with pesticide use, a 2012 study estimates that impacts from pesticide pollution cost the United States $9.645 billion per year.[63] The study takes into account public health effects, domestic animal health effects, destruction of natural beneficial predators and parasites, honey bee and pollination losses, pesticide resistance, harm to wildlife, fishery losses, water contamination, crop losses, and governmental regulation to prevent damage.[64] The authors explain that their assessment was challenging to develop because of the "scarcity of data" and "complexity of issues." For example, they note the challenge of accurately measuring certain costs, such as the difficulty of placing a monetary value on wildlife. They also explain that "many costs" were not included in the estimate.[65]

Studies on the cost of sediment pollution from commodity crop agriculture are limited. For example, a 1988 study estimates that erosion due to agriculture results in between $458 million and $661 million in damages to water treatment systems each year.[66] A more comprehensive erosion study from 1989 reported that agriculture results in between $2 billion and $8 billion in sediment damages annually.[67] This estimate includes costs associ-

visited Jan. 2, 2013).

49. Woods Hole Oceanographic Inst., Harmful Algae: Economic Impacts, http://www.whoi.edu/redtide/page.do?pid=15315 (last visited Jan. 2, 2013).
50. *Id.*
51. National Center for Coastal Ocean Science, Economic Impacts of Harmful Algal Blooms, *citing* Porter Hoagland, and Sara Scatasta, *The Economic Effects of Harmful Algal Blooms*, Ecology of Harmful Algae: Ecological Studies 391 (E. Graneli and J.T. Turner eds. 2006), *available at* http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf.
52. Commercial Fisheries Impacts: $38 million/year; Public Health Costs of Illness: $37 million/year; Recreation and Tourism Impacts: $4 million/year; Coastal Monitoring and Management: $3 million/year. *Id.*
53. National Center for Coastal Ocean Science, *supra* note 51; Woods Hole Oceanographic Inst., *supra* note 49.
54. Donna D. Turgeon et al., NOAA, NOS, NCCOS, Center for Coastal Monitoring and Assessment, Status of U.S. Harmful Algal Blooms: Progress Towards a National Program 22 (1998).
55. Woods Hole Oceanographic Inst., Harmful Algae: Aquaculture Losses, http://www.whoi.edu/redtide/impacts/aquaculture-losses (last visited Jan. 2, 2013).
56. Rita A. Horner et al., *Harmful Algal Blooms and Red Tide Problems in the U.S.*, 42 Limnology & Oceanography (1997).
57. Cary B. Lopez et al., Scientific Assessment of Freshwater Harmful Algal Blooms, Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology (2008) (*citing* Craig S. Tucker, *Off-Flavor Problems in Aquaculture*, 8 Rev. Fisheries Sci. 45 (2000)).
58. State-EPA Nutrient Innovations Task Group, An Urgent Call to Action (Aug. 2009), *available at* http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/2009_08_27_criteria_nutrient_nitgreport.pdf.
59. *Id.*
60. *Id.*
61. Naidenko et al., *supra* note 24.
62. *Id.* This figure is in 2008 dollars.
63. David Pimental et al., *Environmental and Economic Costs of the Application of Pesticides Primarily in the United States*, *in* Integrated Pest Management: Innovation-Development Process 89 (Rajinder Peshin & Ashok K. Dhawan eds., 2009).
64. *Id.*
65. *Id.* at 107.
66. Thomas Holmes, *The Offsite Impacts of Soil Erosion on the Water Treatment Industry*, 64 Land & Econ. 356 (1988).
67. Marc Ribaudo, *Chapter 2.3 Water Quality Impacts of Agriculture*, *in* Agricultural Resources & Envtl. Indicators: Water Quality Impacts of Ag-

Table 1: Cost Estimate of HAB Events Across the United States

Year	Bloom	Location	Cost (Millions)	Impacts
1987	*Chaetoceros*	Washington	>$0.5	Deaths of 250,000 salmon[a]
1987-1988	*Gymnodimium breve*	North Carolina	$37.6	Negatively affected fish harvests, tourism, and recreational impacts[b]
1991	Domoic acid	Washington	$15-20	Losses in tourism and oyster industry[c]
1997	*Pfiesteria*-like organisms	Chesapeake Bay and tributaries	$43	Negatively affected boat charters, seafood sales, dealers, restaurants, and watermen; Prolonged belief the Bay was unsafe[d]
2000	Red tide	Galveston	>$9.9 in Galveston County alone; loss of over 300 jobs	Commercial oyster fishery closures, lost tourism, and costs of beach cleanups[e]
2002-2003	Domoic acid	Washington and Oregon	$10-$12	Yearlong closure of razor clam fisheries[f]
2005	Red tide	Maine	$14.8 in lost sales; $7.9 in lost income	Closure of shellfish harvesting[g]
2005	*Alexandrium fundyense*	New England	$18 in Massachusetts; $4.9 in Maine	Closures of shellfish harvesting to prevent paralytic shellfish poisoning[h]

a. Donald Anderson et al., Woods Hole Oceanographic Inst., Harmful Algae: Aquaculture Losses, http://www.whoi.edu/redtide/impacts/aquaculture-losses (last visited Jan. 2, 2013).

b. Donald Anderson et al., Woods Hole Oceanographic Inst., Estimated Annual Economic Impacts From Harmful Algal Blooms in the United States 45 (Sept. 2000).

c. JoAnn Burkholder & Howard B. Glasgow, Pfiesteria piscicida *and Other* Pfiesteria*-Like Dinoflagellates: Behavior, Impacts, and Environmental Controls*, 42 Limnology & Oceanography 1052 (1997).

d. Woods Hole Oceanographic Inst., *Harmful Algae: Economic Impacts*, WHOI.edu, http://www.whoi.edu/redtide/page.do?pid=15315 (last visited Jan. 2, 2013).

e. Garen Evans & Lonnie Jones, Economic Impact of the 2000 Red Tide on Galveston County, Texas a Case Study, TPWD No. 666226. Texas Parks and Wildlife (2001), *available at* http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/redtide/media/report/economicimpact.pdf.

f. Woods Hole Oceanographic Inst., Harmful Algae: Aquaculture Losses, WHOI.edu, http://www.whoi.edu/redtide/page.do?pid=15317 (last visited Jan. 2, 2013).

g. Kevin Athearn, Economic Losses From Closure of Shellfish Harvesting Areas in Maine (2007), *available at* http://www.umm.maine.edu/assets/docs/appliedResearch/eco_losses_shellfish_jan08.pdf.

h. Di Jin et al., *Economic Impact of the 2005 Red Tide Event on Commercial Shellfish Fisheries in New England*, 51 Ocean & Coastal Mgmt. 420 (2008), *available at* http://www.sciencedirect.com/science/article/pii/S0964569108000070.

ated with navigation, reservoirs, recreational fishing, water treatment, water conveyance systems, and industrial and municipal water use.[68]

This sampling of valuation data, much of it specific to nutrient pollution, highlights the cost and extent of the human and ecological impacts. We know that agricultural operations—and certainly commodity crop agriculture—is a significant cause. But a comprehensive quantification of these harms is lacking.

B. Discussion

Although it is clear that pollution results from commodity crop production, data quantifying the harms from this pollution—either in the aggregate, by type of pollution/harm, or relative to particular kinds of agricultural operations—remains limited.[69] Based on this initial review of the literature, there are myriad data gaps on the cost of virtually every type of pollution associated with commodity crop agriculture. More—and more recent—data are needed, as well as a more thorough assessment of the existing literature.

For example, the 2004 study, discussed above, that attempts to aggregate cost data on various types of pollution from crops is now 20 years old and did not take into account key harms, such as ecosystem damage from nutrient pollution. The studies on specific types of pollution provide useful but not comprehensive, up-to-date cost data. For example, the studies on sediment pollution are dated, and the author of the key study on pesticide pollution recognizes that the study underestimates the costs.

There are a larger number of studies on the costs of nutrient pollution generally, which indicate that the overall costs are substantial—but the studies do not separately consider the costs attributable to commodity crop agriculture. Furthermore, in some cases, the cost estimates do not

riculture 6 (2000), *available at* http://www.ers.usda.gov/media/873632/waterquality.pdf (*citing* Marc Ribaudo, Water Quality Benefits From the Conservation Reserve Program, USDA, Econ. Res. Serv., AER 606 (1989)).

68. *Id. See also generally* LeRoy Hansen & Marc Ribaudo, Economic Measures of Soil Conservation Benefits: Regional Values for Policy Assessment, USDA, Econ. Res. Serv. (Sept. 2008) (describing the per-ton values of various types of soil conservation benefits; methodology involves examination of certain types of economic damage caused by sediment).

69. Relevant to these considerations is an effort currently underway at EPA. The Agency's Science Advisory Board has been asked by the Office of Water to evaluate the value of water to the U.S. economy and provide a resource for future decisionmaking. *See* U.S. EPA Science Advisory Board, Estimating the Value of Water to the U.S. Economy, *available at* http://yosemite.epa.gov/sab/sabproduct.nsf/0/26ED6423F450CDA2852578F7004BA0E6?OpenDocument. *See also* Paul Quinlan, *Water Policy: Panel Weighs Water's Economic Impact as EPA Girds for Political Combat*, Greenwire, Jan. 23, 2012 (noting political fight over panel's work and predicting a final report by the end of 2012).

include key harms, such as dead zones in the Great Lakes or damage to rivers. Finally, there are individual studies that estimate the cost of hypoxia in specific water bodies, but little in the way of national-level, comprehensive estimates.

There are data on the national annual average costs of HABs and on the costs resulting from individual HABs. The estimates indicate that the costs are significant, but the range varies dramatically, indicating that additional work may be needed to further refine the estimates. The costs associated with drinking water treatment of nutrient pollution are well-documented in some municipalities, but a comprehensive national study has not been conducted.[70]

To take one important example of the need for more data, even as the dead zones in the Northern Gulf of Mexico and the Chesapeake Bay have become well-understood from a scientific perspective, the sweep and depth of their economic impact remains undocumented. Various questions remain to be considered. For example, what is the full cost imposed by a dead zone on all impacted commercial fisheries—in terms of lost catch, lost time, and additional expense as fishermen must seek more productive fishing grounds? What is the cost in terms of undersized shrimp or fish? What are the recreational costs—i.e., in terms of foregone tourism dollars due to fouled summer waters? What is the cost in terms of other damages to our aquatic ecosystems? We may never have a complete answer to all of these questions, but the more data we have, the clearer the picture becomes.

Understanding the dollar value of environmental harm associated with a sector—i.e., commodity crop agriculture, or even corn production—would allow for further determinations that could assist policymakers. For example, where commodity crop operations are a significant (i.e., non-negligible) contributing source of pollutants to the environment, and thus bear a share of the responsibility for any resulting environmental damage, one might ideally characterize the cost of the harm on a per-crop, per-acre basis—or by some other similar, suitable metric. It would be helpful to know that, on average, 100 acres of conventionally produced corn or soybeans correlates to downstream harm quantifiable in a particular dollar amount.

Admittedly, such an estimate would be imperfect and fail to account for the wide range of local and regional variations that are inherent in agricultural production. Growing conditions vary dramatically for crops produced in different parts of the country, and differences in climate, crop rotations, proximity of fields to surface waters, and many other factors influence the amount of runoff that finds its way downstream. Similarly, runoff will contain different types and amounts of pollutants—from pesticides to chemical fertilizers—some of which will make their way into surface waters, and some of which will not.

Another complicating factor is that environmental harms resulting from agricultural pollution may be attributable not only to commodity crop operations, but also to runoff from concentrated animal feed operations and from sources unrelated to agriculture (e.g., municipal stormwater or lawns). This means that even when rigorous work has been performed to place a dollar value on the resulting environmental impact from a pollutant, one faces the complex task of attributing that harm to types of sources—agricultural and nonagricultural. Nevertheless, and notwithstanding the difficulties of allocation, even reasonably supported dollar estimates that link row-crop production to specific kinds of downstream environmental harm can provide a valuable new tool for both better explaining harms to the public and for informing and improving policymakers' decisionmaking with respect to environmental effects from agriculture.

The data would also allow for consideration of questions that are not now part of the policy debate. For example, more robust cost data would allow for consideration of issues such as: Should the U.S. Congress take into account the net societal costs of federal farm subsidies in making subsidies authorization and appropriations decisions?; Is there a role for voluntary reporting of information on pollution from agriculture?; and, Would private firms increase the use of supply chain requirements to foster conservation practices if more is publicly known about the costs of environmental harms? Policymakers may ultimately decide that the economic costs externalized by industrial agricultural production are properly borne by the taxpayer. Or, they may conclude that those who receive the greatest financial benefit from this production (which could be producers or those who purchase the goods) should internalize these costs. But to ignore the costs is unacceptable.

Placing a meaningful dollar value on the cost of a public health problem has in other contexts helped inform the public policy dialogue. For example, to support his anti-obesity measures in New York City, the mayor cited and the media reported on the estimated $4 billion in health costs each year associated with obesity in New York City.[71] Similarly, other local governmental entities have cited obesity cost data in seeking behavior change.[72] At the national level, there are myriad examples of government officials and advocates referencing the cost of obesity.[73]

In addition, it is important to emphasize that the cost of the harms is only part of the missing data that may be needed to formulate a response to addressing the harms. A detailed discussion of these other data gaps is beyond the scope of this Comment, but one example is lack of information about current conservation practices and the extent

70. Ribaudo, *supra* note 67, at 10 (stating that there have been "few" estimates on costs of water treatment).

71. *Combating Obesity*, MikeBloomberg.com, http://www.mikebloomberg.com/index.cfm?objectid=B7EE3B90-C29C-7CA2-FE35C0860A2075BD (last visited Dec. 26, 2012).

72. *E.g.*, *The Costs of Obesity*, AgingFlorida.com, http://www.agingflorida.com/index.php?option=com_content&view=article&id=225:the-cost-of-obesity&catid=3:newsflash (last visited Jan. 2, 2013) (stating $19.39 in added health care costs for every overweight pound).

73. *E.g.*, Dan Glickman et al., *Lots to Lose—How Obesity Is Costing America*, The Hill, June 4, 2012, http://thehill.com/opinion/op-ed/230831-lots-to-lose-how-obesity-is-costing-america- (last visited Jan. 2, 2013) (citing $147 billion per year direct costs and $300 billion indirect costs such as lost productivity).

to which there is room for improvement. Of course, many farming operations do take steps to mitigate the environmental consequences of commodity crop agriculture, as a result of receiving conservation subsidies, satisfying supply chain requirements, or simply as a matter of engaging in good stewardship of the land. Some data are available on the use collectively by all sizes of farms, but the publicly available data cannot be used to determine the use of conservation measures by size or profitability of farm. It would also be informative to understand more fully the drivers for implementing stewardship measures and the relative influence, for example, of cost savings (e.g., less fertilizer use), as compared to other factors such as supply chain requirements (e.g., processor requirements for suppliers' use of conservation measures).[74]

III. Conclusion

In summary, more, and more up-to-date, information is needed to enhance understanding of the environmental harms associated with commodity crop production—to foster the formulation of sound, practical agro-environmental policy over the long term. Accordingly, Congress through the Farm Bill and the U.S. Department of Agriculture (USDA) in implementing agricultural laws and policies should encourage and support comprehensive efforts to quantify, inventory, and make publicly available cost data on the environmental impacts associated with commodity crop agricultural operations. In addition, researchers and the philanthropic community should undertake initiatives to do the same. These data will provide resources to policymakers, environmental and public health advocates, and the agricultural industry that we currently lack—and will inform the development of a more sound agricultural policy in the United States.

74. James M. McElfish et al., *Inventing Nonpoint Controls: Methods, Metrics, and Results*, 17 Vill. Envtl. L.J. 87 (2006). Another is the need to learn more about the benefits of conservation measures. The USDA's effort to quantify the benefits and costs of key programs such as the Environmental Quality Incentives Program report useful data about the benefits of conservation measures. In part because these data are presented in the context of a specific program, however, they are not transparent in terms of linking specific conservation practices to quantifiable benefits. Furthermore, the methodology is such that it is difficult to apply or extrapolate the benefits assessments more generally. Nevertheless, indications are that the benefits can be substantial.