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(Theme Overview) Preserving Water Quality: Challenges and Opportunities for Technological and Policy Innovations

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Articles in this Theme

Nutrient pollution (Box 1) is a major environmental concern in the United States. Nitrates at levels harmful to human health are a growing problem in the surface- and groundwater used to supply drinking water. Degradation of freshwater, estuarine, and coastal aquatic ecosystem due to excessive levels of nitrogen and phosphorous is widespread. Recent headline-grabbing examples of nutrient pollution problems can be found in the Chesapeake Bay, the Des Moines River, the Gulf of Mexico, and Lake Erie. The U.S. nutrient problem is—to a very large degree—an agriculture problem. The productivity of the U.S. agricultural system is substantially fueled by large-scale nutrient flows that move nutrients from natural sources to fertilize crops and feed livestock. Because agricultural products do not fully remove nutrient inputs, flows of unused nutrients follow various pathways from fields and barnyards into ground and surface waters. Agriculture is responsible for a dominant share of the nitrogen discharges to surface water and leaching to groundwater. It is also a leading source of phosphorous in surface waters.

Box 1:
Nutrient pollution refers to water quality damages caused to water resources by various forms of nitrogen and phosphorous, which are essential nutrients for living organisms. Water pollution problems occur when the concentrations of these nutrients are elevated to harmful levels by human activity. Examples of this activity include densely populated urban areas, intensive agricultural production, and substantial energy production from fossil fuels.

The agricultural nutrient management problem is technologically, economically, politically, and institutionally complex. Nutrient flows from agricultural lands to water bodies are diffuse by nature, difficult to observe and measure at reasonable cost, and there is significant heterogeneity and weather induced stochasticity in the links between input use and polluting discharges. Policies for protecting water quality have therefore tended to focus on managing farming practices rather than environmental outcomes by encouraging the adoption of best management practices. But this highlights another key technological complexity, which is the tremendous spatial heterogeneity, at a sub-field level, in land quality, topography, and proximity to environmentally sensitive areas that exists in agricultural production. One result is tremendous fine-scale variability in cropping systems that can minimize nutrient losses to the environment while remaining competitive land uses. Another is high information, technology, and farm management requirements for such systems. A key economic complexity is that the U.S. agricultural economy is driven by multiple factors (consumer preferences, locations of high density populations, agricultural economic geography) to be nutrient intensive and to move nutrients to nutrient-sensitive environments.

While technological and economic complexities pose significant challenges, the greatest challenges are political and institutional. Agriculture's nutrient pollution problem is first and foremost a policy problem. Agriculture has been recognized as a leading cause of water quality problems for decades. That it remains so is not a consequence of a policy vacuum but that the policies that have been developed for agriculture have not been highly effective, especially considering the billions of dollars that have been devoted to addressing the problem. New water quality policies are needed for agriculture, but significant political and institutional constraints exist. Importantly, the political and institutional challenges extend beyond water quality policies for agriculture. Farm and energy policies have affected crop choices and crop acreage choices that are often detrimental to water quality. Solving nutrient pollution problems requires systemic change.

Emerging advances in precision technologies and the availability of "big data" have the potential to enable site-specific crop management and the development of more effective policies. Technologies for producing advanced biofuels from perennial grasses can lead to the diversification in crop production needed to reduce nutrient run-off. Growing recognition of the limits to relying on voluntary adoption of best management practices is leading to an interest in developing more performance-based and market-based policy approaches to incentivizing non-point pollution control. This includes designing policies that are better targeted to the sources of pollution and provide incentives related to environmental outcomes. It also includes developing markets for trading pollution credits between point and non-point pollution sources.

This special issue includes four papers that examine the challenges posed by current policies for protecting water quality cost effectively and role for technological and policy innovations in improving the effectiveness with which we do so. These papers were presented at the "Water Resources & Policy: Exploring the Risks, Benefits and Opportunities for Conservation" workshop on March 20, 2017, in Washington, D.C., organized by Mathew Interis, Madhu Khanna, Jerome Dumortier, Jonathan Coppess, Steven Wallander and Caron Gala on behalf of the Land, Water, and Environmental Economics Section of the AAEA. Funding and support was provided by the AAEA; the Economic Research Service; the Center for Behavioral and Experimental Agri-Environmental Research; the School of Public and Environmental Affairs, Indiana University-Purdue University Indianapolis; the Water Resources Research Institute, Mississippi State University; the Department of Agricultural and Consumer Economics, University of Illinois; and the Council on Food, Agricultural and Resource Economics.

Khanna describes the adverse impacts that agricultural production activities have had on water quality and soil carbon stocks, which have been exacerbated by renewable energy policies and commodity programs that have contributed to an expansion in cropland acreage and in land used to produce corn for food, feed, and biofuels. Various strategies can be used for reducing these adverse impacts, including adopting best management practices for nutrient management and switching from annual crops to perennials that have low input and tillage requirements. Emerging precision technologies and "big data" can enable site-specific crop management to tailor input applications to meet crop needs. The potential to produce advanced biofuels from perennial grasses could lead to cropland diversification and reduce run-off while providing low-carbon biofuels to displace fossil fuels. A mix of conservation, energy, and farm policies is needed to induce a switch to alternative production practices and crops beyond what might occur voluntarily. The paper discusses the challenges in designing cost-effective conservation policy due to the difficulties in measuring performance with non-point pollution, the need to prevent unintended consequences due to jointness of environmental impacts, and the need to consider behavioral factors that influence technology adoption decisions. It identifies several directions for future research including on the role of information technologies, big data, and data analytics coupled with integrated models in inform science-based conservation policy design.

Coppess discusses the history of conservation programs in the United States and the political and budget realities that have governed the size and composition of these programs, which have primarily taken two forms: land retirement programs and working land programs. The Conservation Reserve Program, which retires land from crop production, has historically been the largest program. The size of the program has varied over time, increasing in periods of low crop prices and decreasing in periods of high crop prices. There has been increased reliance on working land programs in recent years, but these programs are still relatively small in terms of cropland coverage. While the program has contributed to reducing soil erosion and sediment run-off, its effectiveness at reducing nutrient losses caused by tile-drained fields is likely to have been limited due to limited incentives for enrolling productive land in the program and retiring it from crop production. Working land programs that encourage adoption of best management practices for nutrient management on these lands have the potential to be more effective at reducing nutrient run-off from crop production. However, these programs are relatively small in scale. The paper discusses the budgetary constraints that affect conservation programs and alternative programs being considered by Congress to reduce the cost of achieving conservation goals.

Shortle describes the institutional structure of agricultural water quality policy in the United States as established by the Clean Water Act of 1972 and policy developments within that structure. The Clean Water Act nationalized the control of municipal and industrial point sources of water pollution and led to the establishment of strict regulations on these source that have been highly effective but also highly and unnecessarily expensive. The Act directed the states to take primary responsibility for the management of agricultural nonpoint source pollution and directed the USDA to provide technical and financial assistance for reducing agricultural nonpoint pollution. In contrast to the federal approach to point sources, states have largely pursued voluntary compliance programs that encourage and facilitate adoption of pollution control practices. Federal technical and financial assistance offered through USDA programs has been substantial, most notably through USDA's Water Quality Incentives program. While state and federal programs have had positive outcomes, they have not been up to the task of achieving established water quality goals, despite enormous spending. This is fundamentally a consequence of reliance on voluntary adoption of pollution controls incentivized by technical and financial assistance programs that do not direct resources in ways that get the most from public and private spending and that are subject to binding budget constraints. Shortle makes the case for policy innovations that introduce a mix of mandatory compliance strategies and better economic incentive mechanisms that target resources to practices and places within fields and watersheds and across watersheds to efficiently achieve water quality goals. He also argues that the water quality goals will be most effectively and cheaply achieved by policy innovations that integrate the control of point and nonpoint sources of pollution, in contrast to the existing structure, and suggests that water quality trading is a promising vehicle to attain the objective. The benefits of trading could include improved water quality and overall reductions in the costs of water pollution control.

Ribaudo parallels Shortle in identifying policy design flaws that limit the efficiency and effectiveness of agricultural nonpoint water pollution policies as a crucial problem and calling for policy innovations to improve the efficiency and effectiveness. Ribaudo focuses on specific strategies to improve the efficiency of USDA's voluntary participation programs for water quality protection. For better environmental outcomes given limited federal resources, Ribaudo stresses the importance of targeting funds to places and practices based on cost-effectiveness criteria, requiring resources devoted to water quality protection provide actual water quality improvements, the utilization of auctions to select program participants and their payments, and compliance incentives that make eligibility for participation in farm programs contingent on adoption of water quality protection practices. Ribaudo's requirement that resources devoted to water quality protection provide actual water quality improvements may seem an obvious need, but in it he recognizes flaws in current voluntary programs. One is that these programs provide assistance for adopting practices rather than for actual water quality improvements. This places the means before the ends. Farmers may sign up and implement practices in places that have little actual impact on water quality. A second flaw is that assistance is sometimes provided for actions a farmer might have taken without financial support. In this case, the assistance is fails an additionality test. To address these flaws, Ribaudo argues for shifting the focus of spending from practices to environmental performance and for formal consideration of additionality in the provision of technical and financial assistance.

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