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Innovations in Nonpoint Source Pollution Policy: Introduction

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JEL Classifications: K32, Q15, Q53
Keywords: Agriculture, Clean Water Act, Nonpoint Source Pollution, Stormwater Water Quality, Water Quality Trading

The recent 40th anniversary of the U.S. Clean Water Act (CWA) of 1972 was cause for celebration. Significant water quality improvements have been achieved as a direct result of that legislation. However, vexing water quality challenges remain, particularly those due to the management of land. This issue of *Choices* reflects on innovative approaches to addressing these "nonpoint sources" of pollution.

This issue was organized by the Natural Resources and Environmental Issues Blue Ribbon Panel of the Council on Food, Agriculture, and Resource Economics (http://www.cfare.org/). Affiliated with the Agricultural and Applied Economics Association, C-FARE supports public and private decision making on agricultural, rural, environmental, food safety and related societal issues.

The CWA nationalized the regulation of surface water quality, establishing the legal framework governing water pollution control in the United States to this day. Unlike pollution from industry, autos, and municipalities, contaminants from nonpoint sources were and remain largely exempted from federal and state regulation. These pollutants can concentrate in surface waters, diminishing aesthetic and recreational values, raising costs of treating water for drinking and industrial uses, diminishing stream and reservoir ecosystems, and creating nutrient-induced dead zones like those in the Gulf of Mexico, the Chesapeake Bay, and elsewhere along the Atlantic and Pacific coasts. Many of the remaining water quality problems in the United States are due to pollution from nonpoint sources. Federal and state authorities have tried to reduce pollution from nonpoint sources through voluntary programs offering incentives and assistance, but these programs have been no match for the scope of the problem and, in some cases, may have exacerbated it.

The 40th anniversary of the CWA is also an occasion for sober anticipation. Congress seems unlikely to enact new measures to address nonpoint source pollution. At the same time, market pressures are high for land use intensification to produce more food, fiber, biofuels, and urban growth. Progress in containing the environmental effects of intensive land uses is likely to depend on innovative new programs and strategies, many originating at state, tribal,

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and local levels, in other countries, or even within private supply chains.

This issue of *Choices* helps advance policy discussions on reducing harmful effects of nonpoint source pollution. The contributors describe and assess emerging innovations in its management and control.

Lara Fowler, Jamison Colburn, and Matthew Royer show how regulations under the CWA are being adapted to focus on basin-wide objectives, allow flexibility and state leadership in addressing individual dischargers, and extending authorities over stormwater and animal waste management. Cathy Kling reviews state-level initiatives surrounding nutrient pollution and, in particular, highlights Florida's successful regulatory efforts directed at nonpoint sources affecting the Everglades. Lisa Wainger and James Shortle report that a regulatory innovation—shifting from discharge limits to group caps on loading within a river basin—has enabled significant trading and cost-savings between point sources but few successes involving nonpoint sources. They view administered trading and pay-for-performance systems as the most promising approaches to control nonpoint source pollution. Sylvia Secchi discusses the application and contributions of a new-generation of integrated analytical tools to support policy innovations. Amy Ando and Noelwah Netusil report on new approaches to urban stormwater management emphasizing decentralized green infrastructure. Sara Aminzadeh, Linwood Pendleton, Sean Bothwell, Amy Pickle, and Ali Boehm discuss product bans, land acquisition, and financial incentives being used by states and local governments to reduce pollution to coastal waters. Finally, Jussi Lankoski and Markku Ollikainen review environmental conditionality within Europe's agricultural policy framework, required actions under the European Community's environmental directives, and Europe's mixed experience with financial incentives to manage nutrients.

Together, these papers present the state-of-the-art-in nonpoint source pollution policy and analysis. While the practical and political challenges are great, the experimentation described in these papers is encouraging.

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Addressing Death by a Thousand Cuts: Legal and Policy Innovations to Address Nonpoint Source Runoff

Lara B. Fowler, Matthew B. Royer, and Jamison E. Colburn.

JEL Classifications: K32, Q53.
Keywords: Agricultural Runoff, Clean Water Act, Nonpoint Source Pollution, Stormwater, Water Quality Trading.

Images of the Cuyahoga River burning in the 1960s have been replaced with headlines that read "Farm Runoff in Mississippi River Floodwater Fuels Dead Zone in Gulf"; "Manure, Fertilizer Part of Chesapeake's Problem"; or "Efforts to Address Agricultural Runoff Fail to Improve Iowa's Lakes." (Marder, 2011; Shogren, 2009; Peterka, 2013). After the passage of the Clean Water Act in 1972, substantial progress has been made in addressing pollution coming from point sources such as pipes. However, a huge challenge remains on how best to address the pollution coming from non-point sources: the death of a thousand cuts caused by runoff from farms, city streets and backyard neighborhoods.

A number of legal and policy innovations are underway to address nonpoint sources. Most of these involve innovative applications of the Clean Water Act that broaden its regulatory reach. Others, rooted in the Act, seek to incentivize regulated point sources to invest in less costly nonpoint source pollution control through economic drivers.

The Clean Water Act in Brief

The Clean Water Act is the primary law for addressing water pollution in the United States. Its general objective is to restore and protect the nation's waters. The Act seeks to meet this goal through two primary mechanisms: first, designating uses for particular streams and establishing water quality standards to meet those uses; and second, regulating point sources of pollution.

The Clean Water Act aims to protect and restore water quality to levels sufficient to protect aquatic life and recreation, known as the "fishable and swimmable" goal. (33 U.S.C. § 1251(a)(2)). States must designate uses for their waterways, and then establish water quality criteria based on those uses. (*Id.* 1313(c)(2)(A)). Under Section 303(d), states must also assess and list waters as "impaired" in a biennial report if water quality does not meet designated uses.

To clean up those impaired waters, states or the Environmental Protection Agency (EPA) must establish "total maximum daily loads" (TMDLs) for such listed streams to remedy the impairment and meet the water quality standards. (*Id.* § 1313(d)(1)(C); 40 C.F.R. § 130.7(c)(1)). The TMDL establishes pollutant load allocations for all sources contributing to the impairment which usually requires such sources to implement measures to reduce pollution. Under a TMDL, "Waste Load Allocations" are assigned to point sources such as wastewater treatment plants, while "Load Allocations" are assigned to nonpoint sources such as agricultural runoff.

The Clean Water Act regulates point and nonpoint sources differently. The definition of point sources includes a large list of discharges from a discrete conveyance, like a pipe. Nonpoint sources are everything else, and are essentially diffused sources of pollution such as runoff from farm fields. To discharge into waters of the United States, point sources are required to obtain National Pollution Discharge Elimination System (NPDES) permits which contain technology-based effluent limits.

Nonpoint sources are exempt from such permitting but are regulated indirectly through the Act's water quality provisions and TMDL processes. The legal differences between point and nonpoint sources can be tenuous, as the Supreme Court just confirmed in *Decker v. Northwest Environmental*

Defense Center (2013), holding that channeled stormwater runoff from logging roads was non-point source pollution under EPA's regulations, mainly because the EPA said so.

While the Act has achieved a level of success in regulating point sources through the NPDES permit process, many water bodies still do not meet water quality standards. Though many TMDLs have been developed, few have been successfully implemented. In many areas, progress towards addressing water quality impairment has been slow, largely attributable to the lack of teeth in the Act to address nonpoint source pollution.

There are, however, several recent approaches to implementing the Clean Water Act that hold promise for more success. Some may be described as top-down regulatory approaches; others as bottom-up approaches driven, in part, by economics, but allowed for in law and policy.

The Retooled Regulatory Hammer of TMDLs

The use of top-down regulation is certainly envisioned in the Clean Water Act, and the Chesapeake Bay offers a glimpse of what is to come. In 2010, the EPA issued a TMDL for the Bay, with 92 individual tributary segments for the entire 64,000-square-mile watershed, focused on three main pollutants: nitrogen, phosphorus, and sediment. The EPA required the six states in the watershed and the District of Columbia, also in the watershed, to create Watershed Implementation Plans (WIPs) with approaches for reducing pollution from both point and nonpoint sources to meet the TMDL. The EPA worked to develop a phased approach, with Phase I WIPs submitted in 2010, Phase II WIPs submitted in late 2011, and Phase III WIPs due in 2017. Each WIP is structured by its interim milestones and benchmarks tailored to the individual jurisdiction's priorities. Failure of a state to meet milestones and benchmarks may result in the EPA using additional regulatory authority or "backstops" to ensure that water quality goals are met. The EPA has long maintained that every TMDL for water impaired by both point and nonpoint sources afford "reasonable assurances" that the necessary load reductions will occur. The milestones, benchmarks, and backstops are an integral part of those assurances.

The Chesapeake TMDL and the requirements for states to develop and implement WIPs to address both point and nonpoint sources foreshadow a whole new approach to restoring impaired waters. Because scientists believe that it is the cumulative impacts of many small pollution sources that are now impairing most waters of the United States, a TMDL which starts with the largest receiving water (like the Chesapeake Bay) and works upstream by requiring state and local jurisdictions to develop and implement plans to meet load reductions has the potential to reorient this nation's water quality programs. It incentivizes states to act by ensuring others' accountability, and taps into each jurisdiction's comparative advantages in setting, policing, or optimizing pollution controls, including the use of state laws and regulations that do not draw their authority from the Clean Water Act. In the Chesapeake, problem areas are a mix of urban and agricultural sources and balancing the burdens placed on them can be politically tricky; this is putting pressure on local governments to address these issues. The WIP process allows states to customize their levels of stringency on sources, with water quality gains being maximized from that flexibility.

Despite the promise some see in the TMDL to move towards restoration, it is being fought by parties within the watershed. For example, the American Farm Bureau Federation (AFBF) and the National Association of Homebuilders have challenged the TMDL, arguing EPA lacks authority to set a TMDL for the entire Chesapeake watershed. A major blow to this challenge was dealt on September 13, 2013, when the U.S. District Court for the Middle District of Pennsylvania granted a summary judgment for the EPA, finding it has such authority under the Clean Water Act. The plaintiffs are evaluating their next steps.

Other challenges to the TMDL are pending. Friends of the Earth and other environmental nonprofits have challenged it for allowing water quality trading as one strategy of compliance for the states. Even local elected officials in Maryland have been lobbying their own state government to challenge the TMDL. As these challenges work their way through the courts and legislative processes, the EPA and the affected states continue to push on implementing the TMDL through the WIPs.

More Stringent Water Quality Standards from "Tribes as States"

In another set of developments, Indian tribes are using a provision under the Clean Water Act to set more stringent water quality standards, sometimes more strict than state or federal standards. This potentially subjects nonpoint sources upstream of Tribal waters to the rigors of a TMDL. The U.S. Federal 10th Circuit Court of Appeals, for example, upheld tribal water quality standards for ceremonial and recreational use that were stricter than both federal and state standards; these were enforced against the upstream City of Albuquerque, N.M. (*City of Albuquerque v. Browner 1996*; and Leisy, 2010). The Shoshone Bannock Tribes have also been working to develop standards in Southeastern Idaho which would similarly affect upstream, non-reservation activities. (EPA, 2008).

Casting a Wider Point Source Net Towards Agriculture and CAFOs

In other arenas, the EPA has shown a willingness to test the waters on what constitutes an "actual discharge." For example, recent case law clarified that only those Concentrated Animal Feeding Operations (CAFOs) with "actual discharges" from the production facility must obtain an NPDES permit. (*Waterkeeper Alliance v. EPA 2005*; *National Pork Producers Council v. EPA 2011*). In addition to other requirements, these cases require CAFOs to implement a nutrient management plan for manure applied to land under their control.

Following these decisions, the EPA is examining the potential to broaden the reach of point source regulation on smaller livestock farms that have not traditionally been regulated under the Clean Water Act. In a current case in West Virginia, for example, a poultry farmer sued the EPA over an enforcement order which required the farmer to obtain a CAFO NPDES permit because fan exhaust from the chicken houses emitted dust, dander, and manure particulates which settled on the ground and discharged into drainage ditches and eventually into a stream. (*Alt v. EPA 2013*). Even though EPA withdrew the order, the court declined to dismiss the case and the farmer, joined by the AFBF, continue to pursue the litigation.

While there is no case law on the point, EPA has reserved the right to exert its authority under a provision of its CAFO regulations to designate small animal operations with discharges as CAFOs in need of NPDES permits in the Chesapeake Bay TMDL if state controls over nonpoint source agriculture fail to meet load allocations. (40 C.F.R. § 122.23(c)).

Announcement of a recent agreement between the EPA and the Chesapeake Bay Foundation indicates that further scrutiny of the Clean Water Act's application to livestock farms will be forthcoming. Under the terms of the agreement, EPA will conduct an audit of every Bay state's regulatory program related to CAFOs and other animal operations for compliance with the Act. Targeted inspections of such operations in four small Bay sub-watersheds were also to occur, as well as review of specific CAFO permits and nutrient management plans. The EPA indicates that the data gathered will help it determine whether yet another revision to its nationwide CAFO rule is required.

Regulating Stormwater Runoff as a Point Source

Nationally, the EPA is putting increased pressure on "municipal separate stormwater system" (MS4) pollution as well, which has been regulated by the Clean Water Act as a point source since amendments to the Act in the late 1980s. Many of the Phase II and Phase III WIP milestones in the Chesapeake Bay focus on MS4s where stormwater best management practices (BMPs) have been developing and improving for over a decade. Targeted areas will be under increasing pressure to set, verify, and enforce these BMPs.

Section 402 of the Clean Water Act requires the reduction of MS4 pollution to "the maximum extent practicable," a feasibility standard of relatively uncertain stringency. A recent petition by several environmental nonprofits called on EPA Region I to utilize residual authority under Section 402 to designate previously exempted urbanized areas and impervious surfaces as MS4s. Similar measures are listed among the federal "backstops" that EPA may employ in the Chesapeake if states' WIP goals are not met. Doing so would force these areas to seek permits, institute BMPs, and reduce their pollution to the maximum extent practicable like any other MS4, transforming unregulated nonpoint sources of stormwater into regulated point sources.

Another novel argument under Section 402 is that, in order to meet the "maximum extent practicable" standard, regulated MS4s must require all new development within its jurisdiction to meet low impact development (LID) standards. This is because LID standards constitute the scientifically acceptable method for controlling pollution from stormwater and, therefore, should be enforced by MS4 jurisdictions as construction and post-construction stormwater control measures. While one state administrative board has adopted this approach (*Puget Soundkeeper Alliance v. Washington State Dep't of Ecology, 2009*), there is not yet much legal precedent.

In the most recent round of MS4 NPDES permit renewals, the EPA began requiring MS4s that discharge into impaired waters with TMDLs to develop and implement plans for meeting the waste load allocations established in the TMDLs. Because regulated MS4 municipalities in the Chesapeake Bay watershed all ultimately discharge into impaired waters (i.e., the Bay), they must develop and implement pollution reduction plans to reduce pollutant loads from existing stormwater sources. Such requirements hoist costly compliance expectations upon often cash-strapped municipalities, particularly since urban stormwater retrofits are expensive nutrient reduction practices. Consideration of how to meet these obligations in a cost effective manner has led to some of the "bottom-up" innovations.

Another innovation has been the creation of proxy TMDLs. A proxy for measured, scientifically defensible pollutant loadings—which can be extremely difficult to obtain—is the amount of impervious surface area within a watershed. Impervious coverage has proven a surprisingly reliable indicator of aquatic environmental quality. Several states have experimented with these proxy TMDLs. The National Research Council—an arm of the National Academy of Sciences—has recommended them. Urban planners have found them more readily integrated into normal planning and land use controls. The legality of this approach is questionable, but its utility may well push the EPA to fight for them in court.

Bottom-Up Opportunities: Water Quality Trading

Water quality trading is a market-based method of reducing pollution from nonpoint sources by creating economic drivers for point sources to invest in nonpoint source pollution control. For example, point sources faced with costly nutrient removal technology upgrades to meet stringent NPDES permit limits (generally resulting from a TMDL) may decide to buy tradable nutrient credits from farmers who have earned the sellable credits by implementing much cheaper BMPs on farms. Water quality trading thus potentially provides point sources a more cost-effective way to achieve water quality standards required by the Clean Water Act.

Nutrient trading programs have been established in Pennsylvania, Virginia, and Maryland to facilitate cost-effective compliance with the Chesapeake Bay TMDL. A number of other pilot programs have been demonstrated in watersheds throughout the country, including in the Pacific Northwest where The Freshwater Trust is working to develop them.

Water quality trading programs must be developed carefully to address a number of legal and policy issues—including whether nutrient reductions from BMP projects are adequately calculated, certified, and verified—and whether adequate application and enforcement provisions exist within the NPDES permit to which credits are applied. The recent lawsuit filed by Friends of the Earth and other environmental groups against the Chesapeake Bay TMDL challenges the legality of the very concept of water quality trading under the Clean Water Act.

A Related Animal: Stormwater Offset and Trading Programs

As mentioned, requirements for MS4 municipalities to develop and implement TMDL and pollution reduction plans have, for the first time, resulted in serious consideration of pursuing stormwater retrofits to reduce pollution and how to pay the costly price tags. Among the innovative solutions for addressing this conundrum is the development of offset programs that would permit MS4s to fund less costly BMPs in more rural parts of the impacted watershed and receive credit toward MS4 pollution reduction requirements. Similarly, new developments—where site constraints make it infeasible to meet existing NPDES stormwater construction permit requirements—may benefit from options to implement or fund offset projects elsewhere in the watershed.

Development of offset or trading programs is already underway. For example, the Pennsylvania Department of Environmental Protection has convened a stormwater offset stakeholders workgroup to develop an offset policy to be released for public comment later this year. Legal and policy issues similar to those raised in trading programs will be at play. In addition, the District of Columbia recently promulgated a new stormwater rule that will require large construction sites to meet more stringent stormwater requirements, but allow them to meet these requirements by buying tradable "Stormwater Retention Credits" (SRCs). These credits would be generated by private landowners in the District, who could voluntarily retrofit their properties with practices such as green roofs and rain gardens in order to generate SRCs.

While offsets and trading can certainly result in implementation of additional practices that reduce nonpoint source pollution from agriculture and stormwater, such programs may not actually play a substantial role in remedying nonpoint source water quality problems, as the primary objective of trading is to reduce the cost of meeting water quality goals. Credits generated from nonpoint sources will be applied towards meeting point source NPDES permit limits that are, in themselves, necessary to meet TMDL goals. Unless sufficient mechanisms are built into offset and trading programs to ensure that such programs improve overall water quality in the watershed, the programs may be little more than pathways for point sources to more cheaply meet their Clean Water Act obligations.

An Uncertain Future for the Clean Water Act and Nonpoint Source Law and Policy

While the Clean Water Act has historically made little headway in addressing nonpoint source pollution, EPA has shown a recent willingness to revisit existing provisions of the Act to facilitate more proactive approaches. Among the most promising is the development of a more robust accountability framework to provide "reasonable assurance" of TMDL implementation. However, several of these approaches—including this one— are under legal challenge. Thus their ultimate success will depend on whether courts agree that the Clean Water Act provides sufficient legal authority EPA's more expansive view toward nonpoint source pollution.

The success of other economics-driven policy developments and approaches, such as trading, will depend on whether more mature markets than have been demonstrated to date will emerge. Even if they do, it is unlikely that they will become the panacea that will solve extensive and persistent water quality problems caused by nonpoint source pollution, since the primary market drivers will be point sources seeking cost effective options to meet their own regulatory requirements.

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State Level Efforts to Regulate Agricultural Sources of Water Quality Impairment

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The U.S. policy regarding water quality is codified in the 1972 Clean Water Act and amendments. The Act formally distinguishes between point sources and nonpoint sources of pollution entering waterways and assigns primary responsibility for controlling nonpoint source pollution to the states. Point sources—such as industrial facilities or wastewater treatment plants—fall under the National Pollutant Discharge Elimination System requirements of the Clean Water Act, and being so are subject to federal regulation and permitting requirements. A substantial reduction of emissions from point sources to waterways has occurred since the adoption of these requirements, leading to much improved water quality in many watersheds. However, in many agriculturally dominated watersheds, point sources contribute a relatively small percent of the overall nutrient load and, therefore, the restrictions on these sources have not achieved the desired improvements in water quality. The nutrients of primary concern in these watersheds are nitrogen and phosphorus, which cause excessive plant and algae growth resulting in water quality degradation.

Nutrient pollution from row crop agriculture is clearly identified as a nonpoint source in the Clean Water Act and, as such, its control is under state jurisdiction. States are free to develop regulations or enforceable standards on nonpoint sources including the agricultural sector, but until recently, few have chosen to do so. Instead, states have generally adopted a voluntary approach whereby conservation practices that reduce nutrient loss from fields—commonly called "best management practices" or BMPs, for short—are encouraged by extension agents and state agencies, sometimes in conjunction with cost-share programs provided by federal or state governments. A notable component of the cost-share programs is that, as the name implies, they typically cover only a fraction of the total cost of installing and maintaining conservation practices such that adopters of these practices do so at a cost. An important exception is the Conservation Reserve Program which pays landowners to remove land from crop production and plant native grasses or perennials.

As previous authors have noted (Shortle et al., 2012; and Kling, 2011), the reliance on voluntary adoption of conservation actions is inconsistent with the "polluter pays" principle and implies that the property rights to pollute rest with the polluter rather than society at large. As an overarching principle, the use of the "Pay the Polluter" principle (Shortle et al., 2012) is relatively rare elsewhere in U.S. pollution policy and does not generally apply to point sources of water pollution.

States are also responsible for developing goals for water quality improvement when agricultural nonpoint sources are important sources of impairment under the directive of the Total Maximum Daily Load—TMDL—program. Under this program, states are required to identify bodies of water that are too polluted to meet the purposes that the state would like them to meet such as being clean enough to provide drinking water or to support recreational fisheries. Once identified, states need to determine the origin of the pollutants and the "maximum load" of pollutants that could be allowed, and improve the quality enough to meet the designated purpose. Once this TMDL is identified, it is the responsibility of the states to develop plans for meeting those loads. For an excellent discussion and explanation of this process, see the National Research Council report on the Mississippi River (2008). The key point for discussion here is that the strategy for achieving the improvements in water quality lies with the states, and both regulatory and nonregulatory options are at their disposal.

The lack of improvement in water quality in agriculturally dominated watersheds has led to increased pressure for states to try new approaches. Water quality trading is being adopted in some areas and may yet prove quite helpful. However, there is a sizable portion of the continental United States where trading between point and nonpoint sources, as constructed in most current trading programs, cannot achieve notable improvements. This point is quantified indirectly by Ribaudo et al. (2008) who identify over 700 watersheds in the United States that have nitrogen impairments and wherein a water quality trading program in nitrogen might be possible. However, in over two-thirds of those watersheds, point sources contribute 10% or less of the nitrogen load, which means that even capping these sources at zero could achieve no more than a 10% reduction in loads. Faced with pressure to do more, a few states have begun to directly regulate some aspects of agricultural activity in an effort to reduce nutrient movement into waterways.

Environmental economists have historically considered two criteria—regulations or taxes—in evaluating policy instruments (Baumol and Oates, 1988). First, the policy instrument needs to achieve the environmental goal set forth by society. Second, the policy should achieve the goal at the least overall cost possible. This paper discusses the problem of water quality associated with nutrients from crop production, outlines a few regulations that states have adopted to address the issue, and considers a novel set of regulations adopted by Florida covering an agricultural region near the Everglades. The paper concludes with a discussion of the degree to which the Florida program satisfies the two goals of environmental policy commonly articulated by economists.

What is the Magnitude of the Problem?

The large hypoxic, or "dead," zone in the Gulf of Mexico has become something of a poster child for the problems of nutrient enrichment in agricultural watersheds across the Cornbelt and much of the Upper Midwest. Nutrients from this region flow into the Gulf each year causing excessive plant growth which, as it dies, depletes the oxygen levels to the point that most aquatic life cannot survive. In the summer of 2013, the size of this annually recurring area was nearly 6,000 square miles—about the size of Connecticut and the fifth largest on record (Hypoxia Report, 2013). The U.S. Environmental Protection Agency's (EPA) Science Advisory Board (2007) assessment of the science related to hypoxia suggests that both nitrogen and phosphorus loadings to the Gulf will need to be reduced by at least 45% each to achieve the targeted goal. The report also indicates that row crop agriculture in the central United States is the largest contributor of these nutrients.

While the large hypoxic zone is an easily identifiable and large ecosystem-wide effect, water quality throughout the entire Midwest is heavily impacted by nutrients. A summary of the EPA's findings from its freshwater lakes, wadeable streams, and coastal areas statistical surveys clearly outline the breadth of the issue:

More than 100,000 miles of rivers and streams, close to 2.5 million acres of lakes, reservoirs and ponds, and more than 800 square miles of bays and estuaries in the United States have poor water quality because of nitrogen and phosphorus pollution. (U.S. EPA)

In short, the hypoxic zone in the Gulf seems best viewed as the end result of a broad set of environmental damages that occur throughout the entire upstream ecosystem.

A third region that has been heavily impacted by nutrient over-enrichment is the Chesapeake Bay. Like the Midwest, urban and point sources contribute to the problem, but row crop agriculture is the largest nonregulated contributor. More than 90 tidal segments along the Bay and dozens of streams, lakes, and rivers throughout the watershed are negatively impacted. Interested readers can find extensive literature on any of these regions, but these few summary statistics make clear that the problem of nutrient pollution from row crop production is pervasive, affecting all regions of the country with significant land use in agriculture.

State Regulations and Florida's Everglades Regulatory Program

A few states have begun to implement limited regulations on agricultural activities in order to reduce the nutrient export from the land. A few examples are outlined in Table 1. These are examples, not an exhaustive list; but, they serve to highlight the areas where states have begun to focus their attention. Maine, Maryland, Pennsylvania, and Vermont are all states that have chosen to impose some form of ban on winter application of manure or fertilizer despite the fact that such bans can raise storage costs. This is widely regarded as a fairly low-cost approach to reducing nitrogen loss. Minnesota and Pennsylvania have adopted setbacks or buffers near rivers and lakes in some locations. Wisconsin has a set of regulations that include setbacks and nutrient management plans.

A particularly interesting case of state-based regulation is the phosphorus reduction regulations in the Everglades Agricultural Area located southeast of Lake Okeechobee. The

Table 1: Examples of Regulations States have Adopted to Address Agricultural Nutrient Problems on Row Crop Production

State	Description	Year Regulation Was (or Will Be) Implemented
Florida[a]	Permits certifying the use of appropriate BMPs required for farming in Everglades Agricultural Area	1995
Maine[b]	Winter ban on manure spreading	2001
Maryland[c]	Organic nutrients must be incorporated within 48 hours Cover crops required when applying organic nutrients to fallow ground in fall 10′–35′"no fertilizer application zone" Nutrient applications prohibited November -March	2013–2016
Minnesota[d]	Vegetative buffer requirements 50′ from streams in shoreland districts	2007
North Carolina[e]	Mandatory BMPs or inclusion in local strategy in Neuse River Basin Nutrient Sensitive Waters	1998
Pennsylvania[f]	100′ setback from environmentally sensitive areas Winter application of manure banned on high-slope fields, fields without adequate residue or cover crops	2011
Vermont[g]	Winter ban on manure spreading	1995
Wisconsin[h]	Meet tolerable soil loss on cropped fields and pastures Develop and follow a Nutrient Management plan Use the Phosphorus Index Avoid tilling within 5 feet of bank surfaces	2011

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f. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=38446&folderId=209713&name=DLFE-15352.pdf
g.http://vermont.gov/portal/government/article.php?news=4004
h. http://dnr.wi.gov/topic/nonpoint/documents/farmersneed.pd

283,000 ha of land drain into the Everglades and are planted to sugar cane, winter vegetables, sod, and rice. With the passage of The Everglades Forever Act in 1994 came the requirement that growers in the Everglades Agricultural Area receive a permit indicating compliance with conservation actions in order to grow crops. Several novel components of this regulatory approach are worth emphasizing. First, while growers were required to have an approved plan of BMPs before being allotted a permit to farm, farmers are allowed to choose from a suite of practices to tailor the conservation actions to their fields and preferences. Thus, this is not a strict command and control regime with a completely top-down regulatory approach. Second, both farm-level discharges and basin-level monitoring were implemented so that the environmental gains from the actions could be adequately assessed. The implementation of a watershed scale set of BMPs in conjunction with a rigorous monitoring program associated with the drainage systems used to control water levels was a very valuable (and unique) component of this regulation as it allows a careful assessment of the policy's effectiveness.

Clearly the property rights have been reversed in the Everglades Agriculture Area: after passage of the law, landowners were not allowed to choose the level of pollution they chose. Likewise, the program is consistent with the "polluter pays principal" —financial support was not provided for growers to cover the cost of these practices up to the point where the 25% target was met. However, for phosphorus load reductions above the target, tax incentives are provided.

Did the regulation achieve the first goal of attaining society's target? Here the answer is a resounding "yes." The monitoring program shows that the target of a 25% reduction in phosphorus loads was exceeded in every year since full implementation of the program began in 1996—and averages over 50%. Did the regulation satisfy the second goal: to achieve the target at least cost? Here the answer is less clear. The fact that the regulation allowed farms to choose from among several conservation actions should be consistent with cost efficiency since farmers could choose the practices that best suited them, presumably those with the lowest cost or management and time costs. However, to be fully consistent with a least cost allocation of conservation efforts across the watershed, those efforts should be targeted to the locations that are most cost effective: this could mean additional conservation actions on some fields and no actions on others. Whether a more cost effective allocation could have been achieved is an empirical question, but it is worth noting that the permits could, in theory, have been made tradable, thereby allowing for implementation of a nonpoint-nonpoint water quality trading program.

Nutrient pollution from the nation's vast and productive agricultural lands is a challenge that will likely require a multitude of approaches to successfully address the problem. The apparent success of the Everglades program raises the question as to whether such a system could work in other states to achieve water quality goals and be a useful tool in meeting society's water quality goals.

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Local Innovations in Water Protection: Experiments with Economic Incentives

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JEL Classifications: Q15, Q18, Q53
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The ineffectiveness of traditional agricultural policies to reduce nutrient-related water quality impairments has prompted some states, local environmental and conservation agencies, and some nonprofit groups, to experiment with new approaches. This article examines innovations that make use of economic incentives to engage the agricultural sector in nutrient and sediment controls. It focuses on various forms of water quality trading, but also presents some other novel uses of incentives aimed at promoting cost-efficiency.

Weighing the Performance of Water Quality Trading

Water quality trading (WQT) is a major innovation in water quality protection policy that allows exchange of pollution credits among emitters to lower the costs of achieving a pollution cap. Such programs rely on a regulatory framework that compels polluters to participate and offers the flexibility necessary to conduct cost-saving trades. Under the Clean Water Act of 1972 (CWA), point dischargers are required to have National Pollution Elimination System (NPDES) permits to discharge into the nation's waters. Initially, the permits imposed technology-based effluent limits, developed by the U.S. Environmental Protection Agency (EPA), that were independent of water quality conditions affected by the discharges. Failure to achieve water quality standards through this regulatory mechanism led to lawsuits requiring the EPA to enforce the Total Maximum Daily Load (TMDL) provisions of the CWA. These provisions require state water quality authorities to establish pollution load limits and allocations for both point and nonpoint sources consistent with desired in-water uses, and to implement plans to achieve these limits.

Point source load allocations to meet TMDLs are enforced through water quality-based effluent limits that are in addition to the technology-based standards. In one form, WQT enables regulated sources to meet these additional effluent limits by acquiring environmentally equivalent (or greater) effluent reductions from other sources. In another, WQT replaces individual requirements with a "group" permit applicable to a set of regulated sources.

The economic rationale for WQT is that it can achieve water quality standards at a lower cost than traditional, non-tradable effluent standards or technology requirements. Such cost savings can occur when load reductions can be generated at lower cost from a substitute source or sources. The expectation that trading could lower the costs of water quality protection led to various experiments and demonstration projects beginning in the 1980s. Interest in the mechanism increased substantially beginning in the mid-1990s as the successes of the SO_2 trading program used to control acid rain became clear and EPA's TMDL initiatives were increasing in number and scope. Trading programs under the TMDL are created by states or substate entities subject to the states. These initiatives have been encouraged by the EPA since the late 1990s with policy guidelines, technical assistance, and funding for demonstration projects from the EPA and the U.S. Department of Agriculture (USDA). The federal interest was prompted, in part, by studies indicating that the costs of TMDL compliance to the nation could be substantially reduced by WQT (US EPA, 2001).

In their survey, Selman et al. (2009) identified 22 WQT initiatives with established rules, 19 under consideration or in development, and 10 that were complete or inactive. Several additional initiatives have been undertaken since this survey. WQT initiatives have been both ad hoc—with the terms of trades developed and agreed upon on a case-by-case basis between specific entities—and formal—with trade rules put in place to govern market trading between multiple, unspecified entities within specific geographic areas such as watersheds. In prominent ad hoc examples, Rahr Malting Company in 1997, and Southern Minnesota Beet Sugar Cooperative in 1999, each contracted for agricultural and other nonpoint source nutrient-pollution reductions to help industrial facilities on the Minnesota River meet permit requirements.

Among the formal trading programs, some are limited to point sources, while others enable trading between point and nonpoint sources. The most prominent point-point example is the Connecticut Nitrogen Credit Exchange Program, established in 2002 to allocate reduced nitrogen loads among 79 wastewater treatment plants discharging to the Connecticut River to comply with a TMDL for Long Island Sound. Highly visible programs allowing point sources to trade with agricultural nonpoint sources for nutrients have been developed over the last decade, mainly by states in the Chesapeake Bay watershed (Maryland, Pennsylvania, and Virginia), and in Ohio for the Greater Miami watershed.

Successful Trading Within Source Sectors

The success stories in water-quality trading have been programs that promoted trading among point sources. Within-sector trading overcomes many challenges to cross-sector trading, including the technical barrier of judging the environmental equivalence between nutrients emitted directly into the impaired body of water with nutrients emitted within the watershed. This trading has, therefore, been seen as carrying a lower risk of environmental harm and been more politically acceptable.

The innovation that allows within-sector trading is a move from individual, technology-based requirements for NPDES permits to a performance-based "group cap" that is shared among a group of permit holders. This approach provides flexibility in how to comply and has driven innovation where it has been used. Two of the country's oldest trading programs highlight the potential for within-sector trading to reduce the costs of compliance of achieving nutrient caps: Tar-Pamlico Sound and Neuse River

In both North Carolina programs, the point source dischargers have been able to meet and exceed nutrient caps. Trading gave flexibility to wastewater treatment plants (WWTPs) to follow their regular upgrade schedule because plants that upgraded first were able to generate enough excess capacity and credits to those waiting to upgrade. By phasing in upgrades, costs were substantially lower than those associated with simultaneous upgrades at all plants (Shabman and Stephenson, 2007). Further, the permit flexibility provided room for experimentation that led to new approaches to reducing nutrients through changes in the production process.

Although the caps were achieved and money was saved in the North Carolina basins, the water quality outcomes cannot be judged a success. Chlorophyll *a* levels in the Tar-Pamlico estuary remain high, and gage data and models in the Neuse suggest that nutrient loads have not been reduced. An explanation for the lack of response is that the caps were not sufficiently stringent to achieve water quality outcomes. However, a wide variety of alternative hypotheses including lags in estuarine response or problems with calculations are being considered.

The lack of environmental success despite achieving cost-effective compliance reinforces the necessity of engaging all sectors in achieving environmental goals. North Carolina has, perhaps, been most innovative in this regard by experimenting with a group cap for non-point source emitters in the Neuse basin. To achieve a 30% nitrogen reduction goal from agriculture, producers are required—under threat of civil or criminal penalties—to either individually implement a set of best management practices or join an association that will develop and implement a "collective local strategy" (North Carolina Environmental Management Commission, 1998). The effectiveness of this approach is not clear at this point.

In the case of the point source group cap, the program was successful at reducing costs of compliance because, instead of regulating how to comply, plants were told what reductions were needed. However, an important caveat to the point source success story is that trading has generally not been used to forgo major investments in technological approaches to reducing nutrients. Rather, it has been used largely to improve the efficiency of upgrading multiple plants at once by providing more time for compliance by all emitters.

Greater cost savings come from avoiding cost-inefficient technological investments. For example, it is generally less efficient to install state-of-the-art technology at small WWTPs because the relatively small reduction in nutrient loads from such investments comes at a high cost. In Virginia, multiple plants with a single owner can be given one effluent limit for all owned plants to avoid unneeded technology upgrades—demonstrating that even more flexible permitting rules can enhance cost-savings.

Point-Nonpoint Trading

As suggested above, WQT between industrial and municipal point sources and agricultural nonpoint sources is interesting because it offers the potential to integrate the control of point and nonpoint sources (Shortle and Horan, 2013). Pollution policies have historically addressed the two types separately. Such a separation is at odds with the "watershed-based approach" to water quality management thought to be most efficient by water quality scientists.

Equally crucial to realizing the potential economic gains from water quality trading is effective and efficient trading between point and agricultural nonpoint sources because it helps to achieve goals at the lowest cost. Economic assessments indicate that the incremental benefits of the CWA stopped exceeding the incremental costs sometime after the late 1980s (Olmstead, 2010). Two policy choices drove this flip (Shortle and Horan, 2013). One is that water quality goals have been pursued through increasingly stringent and costly point source controls rather than through lower-cost nonpoint source controls. Further, the diminishing returns to point pollution controls are exacerbated by the use of highly inefficient, technology-based, uniform effluent standards.

The point-point trading programs implemented in Connecticut and more recently in Minnesota, North Carolina, and Virginia, suggest significant promise for water quality trading to efficiently allocate nutrient effluent reductions among point sources. However, the results, to date, for trading with agricultural nonpoint sources are generally disappointing. Most programs have shown limited participation by potential traders and a lack of trading activity. The reasons for these lackluster results include a lack of regulatory or economic conditions necessary for market development, high barriers to entry, high transactions costs, and regulatory uncertainty.

A number of unique challenges arise in developing programs that include agricultural nonpoint sources. First and foremost is that, unlike point source emissions, the movement of nutrients from farms to water resources cannot be metered. Thus, the uncertainty of agricultural best management practices (BMP) performance for controlling nutrient and sediment runoff has been a major challenge to water quality trading between point sources and the agricultural sector. This uncertainty scares off buyers who retain legal liability for the pollution reductions under trading. Further, the difficulty of verifying that reductions are occurring prompts regulators to propose trading ratios that dramatically reduce the supply of available credits and increase the costs to point sources of purchasing nonpoint reductions. For example, a 2:1 (nonpoint source:point source) trading ratio, at a minimum, halves the supply of nonpoint source credits and doubles the cost . This is sure to discourage some sellers from entering the marketplace. The contraction of supply further discourages buyers who need to secure large volumes of credits in perpetuity. Also important is that agricultural nonpoint sources are not commonly regulated, so ensuring that trading between regulated and unregulated sources results in real reductions generates the need for complicated rules that discourage farmer participation.

Administered Trading

Despite challenges, there have been outright and partial successes that indicate potential from well-designed, implemented, and administered programs. A particularly noteworthy outright success is not from the United States but Canada (Shortle, 2013). The South Nation River Total Phosphorus Management Program was established in eastern Ontario in 2000 to allow new and expanding industrial and municipal wastewater plants to meet stricter phosphorus limits by purchasing agricultural offsets at a trade ratio of 4:1 (nonpoint:point source phosphorus). Since the inception of the program, all of the point source operations have chosen to purchase offsets rather than upgrade treatment facilities. South Nation Conservation (SNC), one of 36 conservation authorities in Ontario, has leveraged an historic relationship with farmers to serve as a trading facilitator. Dischargers pay a price per credit that is intended to approximately cover the average cost of producing the credit. Payments to SNC are deposited in the Clean Water Fund, which is used, along with other funds, to finance agricultural projects that generate credits. Between 2000 and 2009, 269 phosphorus-reducing projects were established through the watershed's Clean Water Fund, and those measures reduced the amount of phosphorus discharged by an estimated 11,843 kg.

An example of a partial success is Ohio's Greater Miami Watershed Trading Pilot Program, established in 2005 as an incentive mechanism aimed at accelerating water-quality improvements. The program provides regulated point sources with the opportunity to purchase nutrient-reduction credits from agricultural sources under favorable terms, in advance of expected new regulations that would tighten in-stream nutrient criteria.

Enabling this program was an institution that was already managing water among relevant jurisdictions, namely the Water Conservation Subdistrict of the Miami Conservancy District (MCD). The MCD's original mission was flood control, but it now buys pollution-reduction credits from agricultural sources and transfers nutrient-reduction credits to point sources. They also conduct periodic reverse auctions to purchase credits and provide post-award oversight.

Several innovations may have promoted activity in this trading program. The program encourages early participation through trading ratios incentives. Point source dischargers that purchase credits before new, more stringent restrictions are imposed can, with some exceptions, do so at a ratio of 1:1. Once the new restrictions are imposed, the ratio increases to 3:1. To promote credit supply, the Soil and Water Conservation Districts (SWCDs) work with the farmers to develop projects and submit bids. Nine of the 14 SWCDs in the Greater Miami Watershed have been active in the program. The subdistrict obtains funds to purchase credits and operate the program from participating point sources and federal grants.

As of June 30, 2011, nine rounds of project submittals had been completed and 345 agricultural projects had been funded, generating more than one million credits over the life of the projects. Slightly more than $1.5 million will be paid to agricultural producers and $89,000 has been allocated to the SWCDs for assistance and oversight. The caveat that prevents declaring the Greater Miami program an outright success is that it has relied on federal grants to a significant degree to fund nutrient credit purchases. In addition, the expected tightening of water quality standards needed to sustain demand from the point sources has not occurred.

The two North Carolina watersheds that conducted point-point source trading also facilitate a type of point to nonpoint source—and nonpoint to nonpoint source—trading using an administered trading approach. This program works much like a traditional in-lieu fee system in which payments collected from regulated emitters are used to fund BMP and ecological restoration projects. The Ecosystem Enhancement Program (EEP) aims to make cost-effective investments by identifying restoration priorities and rating bids in terms of these goals.

The modest success of this program has been marred by criticism that it failed to fund projects in a timely manner and otherwise mismanaged funds. Clearly, centrally administered funds risk being inefficient due to their institutional structure. Further, the use of fixed fees within an in-lieu fee system risks creating gaps between needed and available funding as costs change. The EEP may have been particularly susceptible to institutional problems since it was largely a new institution created to administer this fund. Other programs have avoided similar problems by leveraging existing fee or payment programs to reduce administrative costs and learning time.

Paying for Performance in the Agricultural Sector

Regulators and buyers in water quality markets are concerned about environmental performance of BMPs while producers wonder how BMP adoption will affect yields or management costs. An innovative program developed by the American Farmland Trust sought to address concerns that could prevent BMP adoption. The "BMP Challenge" protected farmers from the risk of altering their practices through a yield guarantee. In this program, farmers were asked to adopt a management practice but also maintain an area of their field in their usual practices. In the mid-Atlantic region, the Challenge compensated farmers for any reduction in yield due to reducing N application to 15% below university-recommended rates.

The program succeeded in reducing N applications, but a portion of enrolled farmers were paid for yield losses. Yet, the direct program costs of $2.84/lb. N not applied (Wainger and Barber, 2012) was modest. If we apply a common rule of thumb that says that only a third of available nitrogen reaches a water body, the cost rises to a still-competitive $9.50/lb. N not delivered. These calculations are crude but suggest yield guarantee programs have the potential to be cost-effective, particularly if they are only needed initially to encourage adoption. In a follow-up survey, 59% of participants (nationally) said they would lower their nutrient application rates as a result of being involved with the Challenge. Thus, the program was successful at reducing the perception of nutrient reductions as risky in a majority of participants.

Spending in agricultural payment programs is typically backed by little to no evidence that pollution reductions are being achieved. The Florida Ranchlands Environmental Services Project (FRESP) sought to make more informed decisions and drive innovation by using the simple innovation of linking payments to measured performance. To achieve this end, it had to overcome multiple institutional, social, and technical barriers.

The payment for environmental services (PES) pilot project was initiated through a partnership between The World Wildlife Fund and a regional government agency (South Florida Water Management District) which jointly recognized that existing approaches to water quality management were not delivering desired water quality outcomes in Lake Okeechobee and downstream estuaries in Florida (Lynch and Shabman, 2011). The PES buyer was the state agency and the sellers were ranchers who were willing to modify the structure and management of existing water control devices. Modifications allowed higher water retention on fields and wetlands, and prevented phosphorus runoff.

Multiple innovations made this program possible. The program differed from similar efforts to control agricultural runoff because it provided flexibility to cattle ranchers to choose the level of action that was compatible with their site and operational goals. Most importantly, because the state was paying for outcomes rather than practices, ranchers had incentives to effectively implement the approach and to modify it to enhance performance.

From an institutional perspective, many innovations were needed. The local government shifted part of its resources to a payment program rather than continue to focus only on large, water retention structures. To minimize the transactions costs, the FRESP team created several streamlined procedures—such as development of a General Permit from the U.S. Corps of Engineers— and joint application procedures between state and federal agencies.

Moving Forward

Market-based water quality trading thus far appears to have been oversold as a way to cost-effectively manage water pollution from agricultural sources. Point source to point source trades show the potential for trading to reduce costs, but of all the successful WQT case studies that we highlight, only two have generated more than a handful of trades that involved reductions from the agricultural sector. These came about when local authorities developing the South Nation River and Greater Miami programs devoted considerable effort to develop a community of interest and acceptance for trading. They promoted acceptance by engaging traditional institutions that were trusted by farmers to facilitate trading and devised exchange mechanisms that farmers were willing to use. External funding also played a major role in one case.

Where we see the most success in lowering costs is where state programs have freed themselves from the tyranny of achieving perfect equivalence between point and nonpoint source reductions by using some form of administered trading. These programs, mostly in-lieu fee systems, offer the potential for benefits in terms of improved cost-effectiveness of payment through reverse auction approaches and verification of implementation and performance. However, centralized programs also run the risk of building in bureaucratic inefficiencies. Programs benefit from measuring performance where possible or by adopting realistic, feasible-to-administer, and "good enough" performance metrics to cost-effectively target payments, document performance, and begin to realize some of the efficiencies of engaging the agricultural sector in achieving water quality goals.

The pay-for-performance approach to agricultural nonpoint pollution control seems especially promising for innovation at state and local scales because, unlike trading with point sources, it allows program development outside of the confines of the CWA's emissions permitting structure. Emerging point-nonpoint trading programs are being developed on the basis of early forms of air emissions trading programs that required all sources to be regulated and emissions to be metered. Fitting this model to the unregulated and diffuse emissions of agriculture is like putting a round peg into a square hole. Thus, local innovators are making progress and providing lessons by creating and tailoring programs to the challenges and opportunities of agriculture.

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Integrated Modeling for Conservation Policy Support

Silvia Secchi

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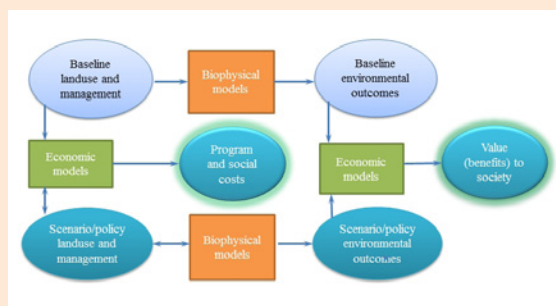
Keywords: Conservation Policy, Integrated Modeling, Water Quality

As public funds for conservation and environmental protection grow scarcer, and land prices increase, cost-effective policies become more and more important. Whether we have a given budget and need to determine how much conservation that money can buy, or legislation mandates a given level of environmental protection as a goal, the integration of biophysical science and socioeconomic analysis is crucial to good program design. This issue has become particularly important because, as Federal budgets shrink, U.S. conservation policy is broadening the variety of its environmental goals: soil productivity, air and water quality, wildlife habitat, and carbon sequestration. There may be trade-offs between some of these goals, and integrated modeling is crucial to quantify them. Further, integrated modeling can be used to assess the suite of activities, payments schemes, and range of benefits that policies can achieve, both in terms of social welfare and environmental quality.

Definition of Integrated Modeling

Integrated modeling refers to models that combine economic and environmental/hydrological elements. In the case of nonpoint source pollution (NPSP) analysis, such models are usually spatially explicit because pollution from an activity performed on different parcels of land is different depending on their location relative to where the pollution is measured, and other characteristics such as historical land use, soil, slope, and so on. Integrated models are characterized by the coupling of baselines and scenarios. Typically, integrated models have focused on the cost of pollution reduction activities and the associated benefits measured as decreases in pollutants—for example, reductions in sediment losses, nitrogen leaching, or pesticide run-off. However, it is possible to use these decreases in pollutants in revealed and stated preference studies to monetize the value of environmental quality improvements (Egan, Herriges, Kling, and Downing, 2009; Loomis, et al. 2000). As Figure 1 illustrates, such completely integrated models allow the estimation of both benefits and costs in monetary terms.

Figure 1: A Schematic Representation of a Fully Integrated Economic and Biophysical Suite of Models



There are many issues to be addressed in the process of model integration, from the harmonization of units of analysis in time and space to the creation of scenarios that models can process. A particularly important issue is the harmonization of the baseline, that is, the starting point land use and management practices from which the models determine changes (Figure1).

Determination of Baselines

The definition of a baseline, or how much conservation is occurring before a program is put in place, is a non-trivial enterprise both from a data collection and availability standpoint and from a program design perspective. Determining the level and location of conservation activities already being performed is difficult by definition in the case of nonpoint source pollution control because such activities are not easy to monitor. New technologies are reducing the uncertainty associated with nonpoint source activities by identifying land management practices accurately and cost-effectively, though these technological advances do not eliminate uncertainty in discharge and delivery. For example, remote sensing can be used to assess tillage levels (Watts, Powell, Lawrence, and Hilker, 2011) or to monitor the effectiveness of cover crops for nutrient uptake (Hively, et al. 2009). The first example illustrates the capacity to construct a baseline of management practices, while the second identifies potential environmental performance. Activities are good approximations of both baseline environmental quality and program performance only if they are closely correlated to environmental outcomes—for example, a reduction in tillage intensity by X increases carbon sequestration by Y.

In the future, remote sensing coupled with biogeochemical modeling could allow assessments of field-level environmental performance on a regular basis. In the meantime, however, we are able to only partially determine baselines and subsequently monitor changes in activity or performance. Therefore, program design has to take into account whether to allow for practices which are difficult to monitor, and whether the baseline levels of activities should be compensated. Integrated modeling plays a role in these decisions by allowing assessments of the costs to society and to the program, and of the range of benefits associated with specific policy choices. The decision may be made, say, for equity reasons, to reward good actors who have already implemented practices. This was the case of the 2002 Farm Bill Conservation Stewardship Program. Integrated models help evaluate trade-offs associated with program choices such as baseline/participant determination criteria, and the associated effects on environmental quality.

Models for Before and After Assessments

Integrated models can be used to design new policies—to determine the cost of a predefined program or to identify the most cost effective scheme. In particular, they can play a critical role in constructing targeting schemes, which allow more bang for the buck by focusing on the best lands and practices to include in conservation programs. For example, Yang, Khanna, Farnsworth, and Önal (2003) constructed an integrated, spatially explicit model to determine the best parcels to set aside from crop production in order to achieve sediment load reductions in a cost-effective manner (See Box). The Yang, Khanna, Farnsworth, and Önal study shows how economic models can be used to drive the construction of the scenarios to assess—hence the two-directional arrow in Figure 1. Alternative approaches start from the biophysical models or, in the more recent literature, use algorithms to determine the scenarios on the basis of both economic and environmental performance simultaneously (Rabotyagov, et al. 2009).

Definition of Efficacy and Cost Effectiveness

Efficacy refers to the capacity of a policy to achieve its stated goals, and models can be used to compare the scenario/policy environmental outcomes to the policy goals.

Cost effectiveness refers to the achievement of a goal or given amount of benefit(s) at the lowest cost among possible alternatives (Doering et al., 1999). Models can be used to determine which payment scheme is cheapest and still produces the wanted environmental outcomes/benefits.

In addition to these types of scenario analyses before a policy is implemented, models can also play an important role in program assessment after implementation. A notable illustration of this approach is the Conservation Effectiveness Assessment Program (CEAP), the first national effort to determine the environmental benefits associated with Federal farm bill conservation programs, and how to improve their effectiveness. Due to financial constraints and technological limitations, monitoring of conservation activities and environmental performance is still limited. Therefore, in CEAP, integrated models have been used extensively to study the efficacy and cost effectiveness of conservation programs both at a national scale and in selected watersheds (Duriancik, et al. 2008) (See Box).

The Role of Integrated Models in Innovative Policy for NPSP Control—Regulatory Drives

As implementation of the Total Maximum Daily Load (TMDL) provisions of the Clean Water Act progresses, interest in the different policy tools that could be used to limit nonpoint source pollution has increased. In particular, water quality trading mechanisms have been the subject of many studies because of their potential cost-effectiveness. In 2004, an Environmental Protection Agency (EPA) -sponsored project identified 40 initiatives and six state programs (Breetz, et al. 2004). The focus has historically been on point to point trading, in part because of the difficulty in determining the value of credits for nonpoint sources such as crop farmers. The potential for nonpoint sources to participate in trading schemes, however, appears high (Ribaudo and Nickerson, 2009). The large scale implementation of these programs will rely extensively on models. For example, the recent Chesapeake Bay TMDL and the policy-making process that led to it spurred a proliferation of model development and implementation studies and activities. The nonpoint source portion of the Chesapeake Bay states' water quality improvement programs rely heavily on models (Latane and Stephenson, 2011).

The Role of Integrated Models in Innovative Policy for NPSP Control—Role of Co-Benefits

Integrated models are crucial to assess the impact of a policy on multiple environmental goods and services and traditional commodities. As U.S. conservation policy has moved away from a focus on limiting soil erosion to a much wider set of goals—such as preserving water and air quality, enhancing wildlife habitat, and, more recently, sequestering carbon—the role of integrated models has become more crucial. This broadening is reflected in changes to the criteria for enrollment into the Conservation Reserve Program (CRP), the largest Federal land set-aside program, which have gone from a focus on soil conservation when it was instituted in 1985 to a broad Environmental Benefit Index in 1996. Since 2003, carbon sequestration has been added to the list of benefits. In an almost parallel fashion, in the early 1980s, the U.S. Department of Agriculture's Agricultural Research Service developed the Erosion Productivity Impact Calculator (EPIC), a field-scale environmental model which was first widely used in the 1985 Resources Conservation Act assessment. In the mid-90s, EPIC added components to assess water quality impacts, from nutrients to pesticides, and the model's name was changed to Environmental Policy Impact Climate. In 2004, carbon routines from the CENTURY model were incorporated in the model (Gassman, et al. 2005).

These changes in policy goals and the model's capacity to quantify them reflect our deepened understanding of the value and breadth of ecosystem services, and are likely to expand further in the future. Several studies show the potential for trade-offs and the need to account for a wide range of environmental impacts to avoid unintended consequences: growing trees for carbon sequestration may have potentially negative effects on water quantity (Jackson, et al. 2005), and increasing biofuel production for climate mitigation can decrease water quality (Secchi, et al. 2010). On the other hand, integrated models have also found double benefits—instances in which the production of one environmental good also improves the provision of another. Nelson et al. (2009) found that, in the Willamette River basin, preserving forests and increasing natural areas improves water quality, sequesters carbon, and also increases biodiversity, thereby showing a wide range of environmental benefits positively correlated with the same conservation activity. If payments for ecosystem services that include public, nonprofit, and private actors become prevalent, such accounting for the simultaneous provision of multiple environmental goods and services will become imperative. Since this is an empirical question that depends on the specific activities and socio-environmental systems at hand, models will be necessary to determine the signs and sizes of these relationships. For example, municipalities may be willing to pay for the reduction in flood risk associated with wetland restoration if such costs are lower than those of more traditional structural practices. However, because of the infrequency of flooding and its stochastic nature, such benefits will have to be quantified with models. Wetland restoration has a much wider range of benefits though, including carbon sequestration, nutrient cycling, and recreational benefits. Jenkins, Murray, Kramer, and Faulkner (2010) provide an example of their simultaneous quantification and monetization for the Mississippi Alluvial Valley, using models, as part of the CEAP project A complete assessment of the full range of environmental impacts associated with wetland restoration would require the coupling of carbon cycling, surface water quality, and hydraulics models such as those used by the U.S. Army Corps of Engineers for floodplain management. These would be linked with economic models of the value of recreation and the cost of conversion (Figure 1). In a landscape in which centralized Federal funding is low and there are several potential payers for specific benefits, not accounting for all benefits may result in the under provision of environmental goods and services (Banerjee, et al. 2013). Models play a key role in estimating the whole range of services associated with conservation practices and nonpoint source pollution control.

Challenges

Integrated, policy-driven modeling is still a relatively new research area. Therefore, many issues still need to be addressed. The most important ones, from a decision-making perspective, are related to the limited capacity of the models to address the full set of possible policy options. This can be true from a socioeconomic perspective—say, an economic model does not adequately capture a farmer's unwillingness to participate in a program for social or moral reasons—or from a biophysical perspective—a surface water model only coarsely captures effects on groundwater. Models developed for one purpose are often stretched to others, and though model development can help address initial inadequacies—as the evolution of the EPIC model illustrates—often the results of the integration are presented without emphasizing the uncertainties. For example, if water quality models calibrated and validated on the basis of sparse data are coupled with climate change models for the assessment of the future value of conservation practices, the uncertainty of each model component is compounded. It is important to recognize the limits of individual model components and how they affect the integration.

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A Tale of Many Cities: Using Low-Impact Development to Reduce Urban Water Pollution

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Over 80% of the U.S. population lives in urban areas, a number that is projected to increase to almost 89% by 2050 (United Nations, 2011). Increasing urbanization puts pressure on centralized stormwater systems, which are expensive to expand and focused on just one task—conveying stormwater to a treatment plant. Urban stormwater is, however, as polluted as untreated domestic wastewater and urban runoff is estimated to be responsible for 47% of the miles of impaired ocean shoreline, 22% of seriously polluted lakes, and 14% of seriously polluted rivers (U.S. Environmental Protection Agency (EPA), 2006; p. 4-23). In addition, many older cities have combined sewers that convey both sewage and stormwater; they were a significant improvement over the above-ground sewer ditches that existed before combined sewer systems were created in the mid-1800s, but many combined sewers discharge harmful waste when storms overload the system (Tibbetts, 2005).

Table 1: Benefits of LID Stormwater Management

- Less water pollution, better surface water quality
  - Fewer combined-sewer overflows (CSOs)
  - Lower levels of pollution flows during regular storms
- Improved aquatic habitat
- Reduced flooding
- Groundwater recharge
- Energy savings (if eco-roofs are used)
- Open space
- Wildlife habitat
- Improved air quality and reduced urban heat island effect
- Better human health

Green infrastructure projects—such as green roofs (or eco-roofs), bioswales, permeable surfaces, and rain gardens—are decentralized approaches that may generate multiple benefits such as the reduction of urban water pollution, provision of open space, reduction of air pollution, and improvements in human health. This article describes new approaches being used to control urban stormwater on public and private property, discusses insights from economic theory about optimal stormwater policy design, and provides examples of projects being implemented in several U.S. cities.

Costs and Benefits of Next Generation Stormwater Management

Many terms are used in discussions of modern stormwater management—often imprecisely—to refer to a suite of stormwater solutions. Low Impact Development (LID) approaches, green infrastructure, decentralized approaches, and best management practices (BMPs)—are all terms that appear in discussions of stormwater control alternatives to traditional, centralized, concrete, engineered "grey" infrastructure—sometimes interchangeably. The terms do, however, vary in connotation. For example, LID is a style of development that also includes design to reduce other facets of the environmental footprint of a building such as energy use (EPA, 2000), and green infrastructure can refer to projects such as wetland restoration that do not occur on developed lands themselves (Weber et al., 2004).

Research indicates that LID-style stormwater management can yield better outcomes than grey infrastructure for water quality and the quality of aquatic habitat

Table 2: Stormwater Management Definitions

Term	Definition
Low-Impact Development (LID)	A development approach that uses nature to manage stormwater by emphasizing on-site stormwater management.
Green Infrastructure	An approach for managing stormwater that uses natural systems or engineered systems that mimic the natural environment.
Grey Infrastructure	Engineered systems that manage stormwater, for example, pipes and gutters.
Best Management Practices (BMPs)	Structural or nonstructural measures taken to control the quantity and quality of stormwater runoff.
Bioswales	A long, narrow, shallow drainage course designed to capture stormwater runoff and treat it before release
Cistern (or rain barrel)	Container that collects and stores stormwater runoff from rooftops
Green Roofs (or eco-roofs)	Vegetated roof that is designed to reduce the volume and velocity of stormwater runoff
Permeable Surfaces (or porous pavements)	Surfaces that allow water to penetrate the ground; for example, pervious concrete
Rain Gardens	An area planted with vegetation to intercept and infiltrate storm-water runoff
Green Street	Street that is designed with vegetated areas (and sometime porous pavement) to intercept stormwater runoff

(EPA, 2000). A design that includes significant onsite stormwater use, treatment, and infiltration from features such as pervious concrete, green roofs, cisterns, rain gardens, and bioswales can greatly reduce stormwater flows during storms and, thus, reduce the introduction of pollution into local waterways from both combined sewer overflows and simple flushing of contaminants from the ground into water bodies via storm sewers. LID can also reduce the "flashiness" of stream flows, with better flow volume during dry times and less severe peaks of water flows during storms; this reduces streambed scouring and provides more stable aquatic habitat in rivers and streams (Williams and Wise, 2006).

Implementing LID management strategies can yield improvements for which the public has value, including open space (Lutzenhiser and Netusil, 2001); improved aquatic habitat (Cadavid and Ando, 2013); groundwater recharge (Cutter, 2007); reduced pollution and, consequently, improved surface water quality, and flood mitigation (Braden and Johnston, 2004). The private benefits of green roofs are sometimes sufficient to offset the added installation costs relative to a conventional roof; when public benefits are included, the net benefits are very often positive (Carter and Keeler, 2008). A survey of research on the expected costs and benefits of a national policy that would induce widespread adoption of LID stormwater solutions found that the benefits would exceed the costs by at least $34 million per year (Braden and Ando, 2012) and a review of case studies found that LID stormwater management yielded better environmental outcomes at an average of 25% lower costs than conventional infrastructure (EPA, 2007).

LID stormwater management is not a panacea. Many impediments slow adoption of sustainable stormwater management practices (Roy et al., 2007) including transaction costs in the process of changing local building codes and training personnel in the construction to make LID development possible (Braden and Ando, 2012). In places with existing construction, retrofits of LID solutions can yield benefits, but retrofits are usually more expensive than new LID construction (MacMullen and Reich, 2007). Decentralized stormwater management (especially if some elements are on private property) may necessarily entail decentralized and volunteer maintenance, with a range of problems associated with monitoring and enforcement (National Research Council (NRC), 2009; 450-452). The effectiveness of LID approaches is likely to vary across cities and with the nature of climatic conditions and soils in the area. Finally, stormwater engineers are sometimes reluctant to design a stormwater management plan with no grey infrastructure at all for fear that LID elements and green infrastructure alone might provide insufficient protection against flooding in major storms (EPA, 2000). However, the bulk of the evidence suggests that there would be net positive social benefits in many cities to controlling water pollution by increasing LID adoption.

Optimal Stormwater Policy

Evidence indicates that new development with impervious surfaces inflicts costs on society from pollution, flooding, and hydrological disruption, and those costs are not entirely borne by the developers or property owners. In other words, there is a negative externality from new, conventional development (Barnard, 1978). Conversely, in areas where old, established developments are already in place, retrofits of LID-style stormwater management can yield benefits to society by reducing pollution and other problems related to impervious surfaces; there is a positive externality to LID adoption. In the face of externalities, policy intervention can make society, as a whole, better off.

Cities could respond to stormwater pollution problems with a uniform regulation requiring that all new developments be designed to manage a minimum amount of rainfall from every storm onsite (for example, Chicago has an ordinance requiring that new construction manage the first inch of rainfall during a storm onsite). However, if the costs of stormwater abatement vary widely across the program area, this uniform approach will not be cost-effective (Thurston, 2006). Sites with high abatement costs will be forced to manage the same amount of stormwater as low-cost sites; total costs could be reduced by reallocating abatement among sites.

Theory in environmental economics (Tietenberg and Lewis, 2010) tells us that the optimal level of private stormwater management can be achieved with a tax on stormwater runoff (or a subsidy for LID installations) equal to the marginal external cost (MEC) associated with runoff (or the marginal external benefit to LID). Furthermore, runoff reduction will be distributed across the city in a manner that minimizes total costs—landowners for whom stormwater abatement is expensive will just pay the tax, while those who can abate at a low cost will do so to reduce their payments. A city could charge landowners a stormwater fee per unit of stormwater estimated to be produced by their property, where the fee is equal to the MEC of runoff. Landowners then have incentives to install retrofitted LID solutions on their previously developed property to reduce runoff (and their total fee) and to design new development to have efficient runoff levels. Many cities have used stormwater fees (Doll, Scodari, and Lindsey, 1998). However, those fees have typically been too low to accomplish socially optimal levels of stormwater controls (Thurston, 2006). Note that the level of the optimal fee is determined by the "polluter pays" principle and depends on the total costs to the community of the last unit of runoff (including the disamenities of water pollution, flooding, and degraded aquatic habitat), not on the costs to the city of putting in grey infrastructure to divert it.

An alternative, cost-effective policy design could be a system of tradable runoff permits. A quantity of permits equal to the total amount of runoff that is optimal for the area would be distributed to landowners, and landowners would have to make sure their properties did not produce more stormwater runoff than the number of permits held. Landowners with low abatement costs will have an incentive to reduce runoff more than they need to in order to sell the extra permits to landowners for whom abatement is costly. Efficient stormwater control will result if the total number of permits is set at the point where the MEC to society of the last unit of runoff is equal to the marginal cost to a landowner to abate it.

Various papers (Thurston et al., 2003; Thurston et al., 2004; Parikh et al., 2005; and Thurston, 2006) have explored and demonstrated the potential for both tradable permits and fee/rebate policies to accomplish efficient levels of stormwater abatement in a cost-effective manner. Economic incentive policies can be modified to accommodate situations where the damage done by stormwater varies across the program area, and they can be designed to minimize resistance from current landowners by giving out permits or using two-part fee/rebate programs to reduce payments from previously developed lots. However, municipalities face many challenges in trying to implement optimal stormwater incentive policies. A plan must be designed for ongoing monitoring and enforcement that is not so costly that it cancels out the benefits of the policy itself. It is also very difficult to estimate the MEC of stormwater to set the efficient fee and to gather the additional information about marginal stormwater abatement costs needed to set the efficient number of permits for a tradable permit scheme. It may be, as Feitelson and Rotem (2004) argue, that a stormwater fee levied on a subset of impervious surfaces equal to a subset of the external costs can have significant social benefits with the advantage of administrative simplicity.

Approaches Used by Cities

Many U.S. cities are aggressively incorporating green infrastructure techniques based on projected cost savings and the multiple benefits generated by some projects (EPA, 2010). Federal statutes generally support the use of green infrastructure to meet Clean Water Act stormwater management goals (EPA, 2008; and EPA, 2013a) and the EPA is actively promoting the use of green infrastructure as a "win-win-win approach and a fundamental component of the U.S. Environmental Protection Agency's (EPA) sustainable community efforts." (EPA, 2011; 1)

Portland, Ore., uses a combination of education, regulations, and incentive-based policies to reduce stormwater runoff. Ratepayers pay a separate stormwater utility fee to cover the cost of stormwater management, but the on-site management portion of the fee can be reduced up to 100% for residential property owners who manage runoff from roof areas and for commercial properties that manage runoff from roofs and paved areas (Environmental Services, 2013a). Payments from the Clean River Rewards program are guaranteed through June 2017.

Other green infrastructure projects in Portland include the installation of green street facilities, the purchase and restoration of open space, and a subsidy of 50% on the purchase of a tree (up to a maximum of $50) in target areas between September 1, 2013, and April 30, 2014 (Environmental Services, 2013b). An eco-roof program, which was discontinued at the start of the 2013 fiscal year due to a lack of funding, provided private developers with a subsidy of up to $5 per square foot and the potential to qualify for a building density bonus.

Philadelphia, Pa., has a Green City, Clean Waters program. It is a 25-year plan that is described as the largest green infrastructure program in the United States (Philadelphia Water Department, 2011). Major initiatives include the use of green infrastructure on public land, requirements and incentives to use green infrastructure on private land, a street tree program, open space acquisition, and stream restoration.

A new parcel-based stormwater fee, which was created in 2010, is based on a non-residential property's impervious area with discounts available for property owners who incorporate green infrastructure techniques. Residential properties are assessed a uniform monthly charge based on the average impervious area for residential properties. New regulations encourage infill to reduce the amount of impervious surface area and stormwater runoff in the region. A "triple bottom line" approach focusing on the environmental, social, and economic benefits of the program is being used with benefits from the program—which include reduced energy usage and greater employment, recreation, property values, air quality, water quality, and wildlife habitat—estimated to exceed costs after 45 years (Philadelphia Water Department, 2011).

Portland and Philadelphia have a combined sewer system, which is a driver for adopting green infrastructure. But cities without these systems are also adopting this approach. Project scales vary from specific sites—such as Pelham and Greenland, N.H. with LID projects in commercial and residential developments—to neighborhood projects—such as Burnsville, Minn., efforts to retrofit a suburban neighborhood with rain gardens. Citywide initiatives also exist—such as Kansas City, Mo., and its "10,000 Rain Gardens" and Orlando, Fla., with its use of wet ponds. Orlando also has a stormwater utility fee and a credit system that allows multifamily and commercial owners to receive credits (up to 42%) that reduce their stormwater utility fee by adopting an onsite management plan (EPA, 2013b; and Water Environment Research Foundation, 2013).

Next Steps

Research shows that LID can cost less than traditional approaches, but few studies have successfully investigated all the private and public benefits from these programs. In order to implement cost-effective, efficient, and equitable stormwater policies and programs, municipalities need to have access to key information on program benefits and how the costs (and benefits) of these programs are distributed among residents.

While cities are showing strong leadership in experimenting and implementing LID approaches, city finances can be volatile and may be more likely to change than policies set at the state or Federal level. Importantly, the decentralized nature of these projects means that cities are expecting residents to take a more active role in reducing stormwater runoff, so it is important to continuously educate residents about their central role in achieving stormwater objectives. With more time, urban efforts to use stormwater policy to control nonpoint urban water pollution could be facilitated by future research to understand how green infrastructure projects are performing and when an LID approach is the most efficient solution to urban water quality problems.

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U.S. Coastal and Estuarine Stormwater Management Approaches

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JEL Classifications: Q16, Q25, Q53, Q250
Keywords: Coastal, Estuarine, Polluted Runoff, Stormwater Management

Initial Clean Water Act implementation significantly reduced the discharge of pollutants to coastal waters and bays by improving sewage treatment and disposal practices and controlling industrial pollution that flows out of discharge pipes. However, polluted runoff (or "stormwater") remains a major source of contamination to coastal waters (U.S. Environmental Protection Agency (EPA), 1983; and EPA, 1993). In urban areas, paved areas and other impermeable surfaces impede the natural hydrologic cycle in which rainwater is filtered and absorbed into surface waterways and groundwater basins. Instead, stormwater flows across roads, buildings, and other "hardscapes," picking up pollutants including heavy metals, organic contaminants, nutrients, suspended solids, solid waste, and pathogens. Polluted runoff can enter coastal waters directly through muddy plumes near river mouths and storm drains or, in other cases, is transported through outfalls below the surface to the ocean.

Polluted runoff from improperly managed agricultural lands can also adversely affect water quality and is a significant contributor of contamination to estuaries, wetlands, rivers, and lakes (EPA, 2004). Like urban runoff, agricultural runoff can include sediment, pathogens, nutrients, pesticides, and metals. Erosion and sedimentation from improperly managed agricultural fields, forest lands, and concentrated animal feed operations deliver sediment attached to pesticides, fertilizers, and heavy metals, directly to rivers, lakes, and streams during rain events.

In previous decades, the large dilutive capacity of the ocean was seen as a natural solution to urban- and agricultural-polluted runoff and sewage pollution. However, the

Caption: Runoff from the San Dieguito River flows into the ocean at Del Mar dog beach in north county San Diego.
Credit Shannon Switzer.

EPA's 2000 assessment of severely impaired waters identified urban runoff as the primary source of impairment for more than a third of estuaries and more than half of ocean shorelines. The assessment identified agricultural runoff as the primary source of impairment for rivers and lakes, second largest for wetlands, and a major source for estuaries and groundwater. Polluted runoff impacts on coastal waters such as eutrophication, hypoxic "dead" zones, fish kills, and other damages are now well-understood and documented.

Contamination of coastal and bay waters can cause beach and shellfish area closures and health impacts to swimmers and consumers, amounting to significant direct and indirect costs to individuals, communities, and industries. Researchers (Ralston et al., 2011) estimate that, each year, over five million cases of gastroenteritis may be caused by swimming at contaminated U.S. beaches, with an annual health care cost of over $300 million. Polluted runoff also impacts the commercial fish and shellfish industries. Shellfish harvesting is prohibited or highly limited in 40% of existing harvest areas because of high bacteria levels primarily due to urban runoff discharges. In the Puget Sound, one harvest area lost $3 million in shellfish sales due to forced closures. Contamination and loss of aquatic species and habitats from polluted runoff cost the commercial fish and shellfish industry up to $30 million per year (National Oceanic and Atmospheric Agency (NOAA), 2000).

Four Noteworthy Approaches

Clean water laws and permitting frameworks have had limited success in addressing polluted runoff. Polluted runoff sources are often widely dispersed, thus making it difficult to identify responsible parties and incentivize engagement from private actors. However, in some cases, the existence of regulatory obligations has prompted the development of new approaches to meet Clean Water Act requirements and reduce polluted flows to estuaries and coastal areas. Many of these approaches may require long-term commitments and deeper collaboration between dischargers and regulators, but can also yield a suite of benefits for coastal and estuarine ecosystems and communities. Many pollution reduction techniques capture and collect water for local use, among other community benefits. Here we examine four approaches aimed at changing the fundamental behaviors and dynamics that contribute to polluted runoff, with a focus on solutions suitable for coastal and bay communities. For each approach, we provide a brief overview and then present different applications of the approach, with an emphasis on five criteria:

1) Pollution Reduction. What is the reduction in pollutant load to coastal areas and estuaries?
2) Multi-purpose. Does the project or policy provide multiple environmental benefits (e.g., water capture, groundwater recharge, recreational opportunity, habitat creation, flooding mitigation)?
3) Economic Costs and Benefits. What are the costs and benefits of implementing the project or policy?
4) Scalability & Potential Application. Can rural and agricultural stakeholders, or other individuals and agencies, implement the project, or a modified version of the project?
5) Potential for innovation and change. How does the policy drive meaningful change in behaviors and practices (as opposed to those that are legally required or imposed)?

Pollutant Trading Programs

Pollutant trading programs are increasingly employed throughout the country to address excessive nutrients, phosphorous and sediment. Trading programs set a pollution limit, distribute the allowable pollution across "polluters," and allow them to trade with each other. In most cases, the regulatory driver has been the establishment of a Total Maximum Daily Load (TMDL) or "pollution budget." Polluters with higher pollution control costs can meet their regulatory obligations by purchasing pollution reductions from another polluter who reduces pollution at a lower cost. Trading programs are voluntary, especially for agricultural communities, but provide permit holders with an alternative approach to meet their regulatory obligations through a market-based strategy. There are approximately 21 active and pilot water quality trading programs in place in Colorado, Idaho, Maryland, Michigan, Ohio, Oregon, Pennsylvania, Vermont, and Virginia (Fisher-Vanden and Olmstead, 2013).

In 2001, the EPA estimated that expanded use of water quality trading could reduce compliance costs associated with TMDL regulations by $1 billion or more annually between 2000 and 2015. However, critics point out several fundamental challenges with water pollution trading programs that must be resolved before they can function effectively. One overarching concern with pollution trading, in any context, is the implied assignment of "rights to pollute." Additionally, the scientific models that underlie the development of TMDLs or pollution budgets are often subject to controversy and legal challenge, thus undermining the validity and "buy-in" to subsequent trading programs. Further, pollutant trading doesn't eliminate localized concentrations of pollution and can lead to the development of pollution hot spots. Nonetheless, some commentators maintain that pollution permit trading systems can meet or exceed environmental goals at lower costs in certain circumstances (Fisher-Vanden and Olmstead, 2013).

Chesapeake Bay: According to the EPA, an average rainfall year causes over 250 million pounds of nitrogen and almost 20 million pounds of phosphorus to drain into the Chesapeake Bay. The situation became so critical that, in 2010, the EPA intervened and developed a TMDL, or "nutrient diet," for the Chesapeake. The TMDL sets a watershed-wide annual limit on the amount of nitrogen, phosphorous, and sediment that can be discharged. To reduce the cost of the regulated sector in meeting their requirements, a mix of regulatory and voluntary approaches are being used to meet the TMDL. Although it is premature to determine the effectiveness of these programs, each state believes it will achieve the TMDL's mandate of a 25% nutrient reduction by 2025. The trading programs also reduce TMDL compliance costs and can stimulate the development of innovative new polluted runoff management practices. The projected direct financial savings to dischargers are expected to be significant, and the programs help protect the Chesapeake's ocean-based economy. Maryland and Virginia's commercial seafood industry alone realizes $3.39 billion in sales and produces over 34,000 jobs with a combined income of $890 million.

Rebates for Retrofits

Some local municipalities have started offering rebates to commercial and residential landowners who implement low-impact development strategies to alleviate coastal and estuarine stormwater runoff impacts such as replacing turf lawn with native plants, building green roofs, and substituting impermeable surfaces with permeable pavements. Rebate programs incentivize green infrastructure projects which reduce polluted runoff flows to inland and coastal waterways, and provide a host of environmental benefits, including flood mitigation, reduced water consumption, increased groundwater recharge, increased wildlife habitat, reduced energy costs to heat and cool a property, and increased property value. The following examples are widely applicable to both shoreline and inland communities.

Lawn Removal in Los Angeles, Calif. The Los Angeles Department of Water and Power (DWP) offers landowners rebates for removing their lawns and installing water-efficient landscape equipment such as weather-based irrigation controllers. So far, 1.5 million square feet of lawn has been replaced and water use is down 20%. Following a dry 2013 winter, DWP increased rebates from $1.50 to $2 per square foot of lawn. This program is innovative in its goal of addressing polluted runoff at its source through the integration of private property and public right-of-way improvements (Belden et al., 2012).

Green Roofs in Portland, Ore. The city of Portland offers landowners rebates for installing "green-roofs." Green roofs use vegetation and soil to capture rain, filter and slow runoff, and reduce the volume of runoff flowing into sewers and streams. The city offers $5 per square foot of green-roofing, and expects to reach its goal of 43 acres of coverage by late 2013.

Permeable Pavement in Montgomery County, Md. Montgomery County landowners receive rebates for installing permeable pavements, a standard hot-mix asphalt with reduced sand. Unlike traditional surfaces used for driveways, roads, parking lots, and patios, permeable pavements allow water to filter into the ground, thereby reducing the volume and rate of stormwater runoff and pollutant concentrations. The County offers $4 per square feet for laying down permeable pavements (with a minimum 100 square feet and a maximum rebate of $1,200).

Land Acquisition Programs

Land acquisition programs buy large swaths of land to protect riparian corridors and coastal ecosystems from pollution, improve water infrastructure systems, and subsidize environmentally sound economic development. Programs can also utilize conservation easements, an option for a landowner to sell specific development rights while retaining the right to use the land for other agreed-upon purposes.

New York: The Catskills watershed in New York City covers nearly 2,000 square miles with 19 reservoirs and aqueducts providing 1.2 billion gallons of drinking water daily to 9 million New Yorkers. To combat polluted runoff, the N.Y. Department of Environmental Protection (DEP) had to choose between building an $8-10 billion filtration plant or spending $1.5 billion on watershed restoration and riparian buffering in the upper watershed to prevent polluted runoff. The DEP choose the latter and, in 1997, created the Land Acquisition Program, which protects undeveloped, environmentally sensitive watershed lands through property acquisition and conservation easements, primarily on vacant land associated with wetlands. As of June 2009, DEP has protected 143,212 acres of land within New York City's watershed, encompassing the Delaware, Catskill, and Croton watersheds. The Land Acquisition Program also aided in postponing the construction of a massive treatment plant and made substantial investments to modifying agricultural practices in the region.

Florida: In 2002, Florida identified Wakulla Springs, a critical drinking water source and one of the largest artesian wells in the world, as impaired by nitrate pollution due to urban runoff, polluted runoff combined with wastewater overflows, and agricultural runoff. Florida responded by creating the Wakulla Springs Protection Zone that required over 10,000 acres of land be protected to reduce polluted runoff impacts to the watershed. Studies were conducted to confirm the sources of polluted runoff and to prioritize riparian lands for acquisition (Harrington et al., 2010). As a result of these studies, Florida approved $1.5 million to acquire over 600 acres to protect critical riparian zones and reduce nitrate applications from inorganic fertilizers from agriculture and lawns, animal waste, domestic waste water, and residential land use that impacts the state's coastal waters and bays.

Source Control Measures

To complement traditional management strategies, local and state governments have begun to pass source control bans on pollutants commonly found in urban and agricultural runoff. These measures require society to reduce reliance on environmentally harmful products and prompt manufacturers to develop innovative substitutions. Source control strategies reduce management and treatment costs by reducing pollutant inputs to the runoff cycle.

California: Copper is often detected in urban runoff and is highly toxic to aquatic species. Copper from brake pads accounts for more than half of the human-generated copper in polluted runoff. Washington and California have enacted legislation to reduce copper in brake pads. In 2010, California passed Senate Bill 346, the Copper Brake Pad Ban, to require brake pad manufacturers to use pads composed of 0.5 percent copper or less by 2025. Other states are considering similar bans, which shifts the responsibility of copper contamination from municipal permit holders to brake pad manufacturers.

New York: Phosphorous pollution is a serious threat to waterbodies. Excessive amounts turn waterbodies green with algae, impacts drinking water supplies, and kills fish due to a lack of oxygen. Detergents and fertilizer are only two sources of phosphorous pollution, but detergent is the source of up to 34% of municipal water's phosphorous levels, and fertilizers account for up to 50% of the levels in polluted runoff. In 2010, the New York Legislature addressed the issue by banning household dishwater detergents that contain phosphorous. Similar bans have been enacted in 16 other states, forcing detergent makers to redesign their products to produce low-phosphate formulas. In 2012, New York also joined 11 states to ban phosphorous fertilizers.

Table 1: Policy Criteria and Stormwater Policies

Stormwater Policy	Direct Pollutant Reduction	Rural/Ag Focus	"Carrot" or "Stick"	Increase Water Supply[1]	Voluntary
Nutrient Trading		X	C		X[2]
Retrofit Rebates	X		C	X	X
Land Acquisition	X	X	C		X[3]
Storm Control	X		S		

[1] Both the land acquisition program and the fertilizer fee created more clean drinking water, but did not necessarily create an additional water supply.

[2] While the permittees must comply with the TMDL, no permittee was required to participate in the trading program that was voluntary.

[3] It's not voluntary for NYC, but is voluntary for riparian landowners to sell property.

Concluding Observations

State and local governments are initiating new policies designed to change behavior and address polluted runoff's negative economic and health consequences—many in coastal and estuarine areas. We highlight a small handful of those policies that seek to create incentives to remove pollutants at the source or to take steps to restore the natural ability of watersheds to do so. By focusing on both behaviors and technical solutions, these policies reduce polluted runoff while also reducing costs of implementation and creating additional benefits beyond pollution mitigation. The promise of these new policies provides extensive societal benefits, more flexibility, and even benefits for the polluter, either through financial incentives or by encouraging behaviors that yield local as well as watershed and coastal benefits. These policies include both "carrots" and "sticks" (Table 1) and other incentive structures that reward good behavior and are able to achieve stormwater goals.

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Innovations in Nonpoint Source Pollution Policy—European Perspectives

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Keywords: Fertilizer Tax, Nutrient Surplus Tax, Agri-environmental Payment, Conservation Auction

Agriculture is an important source of nutrient loading—nitrogen and phosphorus—into surface and groundwater in Europe. Phosphorus is the most common cause of eutrophication in fresh waters, such as rivers and lakes, while nitrogen loading promotes eutrophication of coastal waters. Several valuation studies show that Europeans value clean water and agricultural landscapes, which often exhibit high historical and cultural values as well as biodiversity. Traditional emphasis of the European agri-environmental policies has been on landscapes and biodiversity.

Over time the role of agriculture in water pollution has been recognized. Indeed, agriculture contributes generally 50-80% of the total nitrogen and phosphorus loading to Europe's fresh waters. The same holds true for sea waters. For example, in the Baltic Sea catchment area, nonpoint source loading represents 71% of nitrogen and 44 % of phosphorus loads. No wonder the need to develop policies to reduce nonpoint source nutrient loads has emerged.

By the gradual increase of the number of its member states, the European Union (EU) has become the key European player in environmental and agricultural policies targeting nutrient loads from point and nonpoint sources. The key means of the EU environmental policies are the legally binding environmental directives, such as the Water Framework Directive, Marine Strategy Directive, Urban Waste Water Treatment Directive, and Nitrates Directive. Member states are required to implement the directives within their jurisdiction and choose the most appropriate means to do so. Furthermore, member states are allowed to impose stricter policies than directives require if they want to do so.

The *Common Agricultural Policy* (CAP) provides the basis for agricultural nonpoint source policies. CAP consists of partly decoupled farm income support with environmental conditionality, so called environmental cross-compliance, and voluntary agri-environmental policies in member states. While in most member states voluntary agri-environmental policies focus more on biodiversity and landscapes, Denmark, Finland, and Sweden have developed ambitious voluntary nonpoint source policies.

Agri-environmental policies in the EU and the United States differ in some respects. While agri-environmental policy in the EU primarily addresses positive environmental externalities, such as landscape features and biodiversity, the emphasis in the United States is more on the reduction of negative externalities. As regards policies targeting negative environmental effects, the EU focuses more on negative environmental effects brought on by intensification of farm input use—fertilizer, manure, and pesticide—whereas extensification-related effects—cultivation of erosion-prone and other environmentally sensitive land— are addressed in the United States. Third, agri-environmental payments in the United States are mostly targeted towards environmental performance, such as those based on the environmental benefit index. However, in the EU, they are based on the adoption of environmentally friendly cultivation practices (Baylis et al., 2008). Finally, there are also differences as regards environmental regulatory approaches between these two regions.

Keeping the key role of the EU in mind, we review both past experience and current policy initiatives for nonpoint source pollution. We start with the features of the CAP.

Past Policy Experiences Addressing Agricultural Nutrient Pollution

EU's CAP policy addresses nutrient pollution from agriculture via three channels: farm income support policies coupled with environmental cross-compliance, environmental regulations, and agri-environmental payments.

Agricultural Policy Reforms, Decoupled Income Support, and the Development of Environmental Conditionality

Since the 1992 MacSharry CAP reform, there has been a gradual shift from production, trade, and environmentally distortive coupled support payments towards more decoupled income support payments to EU farmers and increased environmental conditionality of general agricultural support payments as well as increased use of specific agri-environmental payments. The CAP reform has increased the coherence of agricultural policies with overall water policies in the EU. While direct measurement of loads is missing, a decline in nutrient surpluses for EU15 from 1990 to 2009 is evident (Table 1). This has reduced the overall nutrient loading pressure on watercourses.

Environmental Regulations

The 1991 EU *Nitrates Directive* forces EU member states to reduce the nitrate loading from agriculture to groundwater and surface water. Member states need to assign areas that are vulnerable to nitrate leaching—Nitrate Vulnerable Zones (NVZ). These are areas where surface water and groundwater contain nitrate concentrations that may exceed 50 mg. per liter if preventative action is not taken. In 2007, 40% of the area of the EU27 was designated under NVZs and 10 member countries have designated their whole national territory as an NVZ.

Within NVZs mandatory measures are established regarding sufficient manure storage capacity, timing and location of manure application, and maximum application limits of 170 kg N/ha. Effectiveness of the Nitrates Directive in reducing nitrate loading has varied among member states. The EU-wide report on the implementation of the Nitrates Directive found that the gross nitrogen balance at the EU15 level in 2000—55 kg/ha—had decreased by 16% compared to 1990, with the range from 37 kg/ha in Italy to 226 kg/ha in the Netherlands. However, a number of challenges remain in the implementation of the Nitrates Directive. Most notably, several member states have failed to comply with requirements related to manure storage capacity, manure application limits, and manure application periods. Oenema et al. (2009) estimated that the costs of reducing nitrogen surplus through balanced fertilization in the context of the Nitrates Directive in the EU27 is € 4 per kg N surplus, which is € 25 per ha.

Table 1: Nitrogen and Phosphorus Balances in the EU15 from 1990 to 2009 (OECD 2013)

Years	Average N-balance, thousand tonnes of N	Average P-balance, thousand tonnes of P	Average N-balance, kg/ha	Average P-balance, kg/ha
1990-92	9 966	1 399	109	14
1998-2000	8 529	812	93	9
2007-09	6 567	239	65	3

Experience from Fertilizer Taxes

Before their joining to the EU, Austria, Finland, and Sweden generated experience from using fertilizer taxes for fiscal purposes. Rougoor et al. (2001) analyzed the impacts of fertilizer taxes on fertilizer use in these three countries. Tax burdens varied between 10% and 72% of the fertilizer price. The price elasticity of fertilizer varied between countries and years from -0.1 to -0.5. Administrative costs of these taxes were low, representing, on average, about 0.75% of the tax revenues.

Unfortunately, the reviewed experience does not provide extensive evidence of the effectiveness of fertilizer taxes in reducing nonpoint source pollution. Calculations based on the Finnish data show that tax rates on nitrogen fertilizer need to be high to have an effect on nitrogen fertilizer use and nitrogen runoff. With a 15% tax rate the use of nitrogen would decrease only 4-5% and nitrogen runoff by 4-5%, while a 100% tax rate would decrease use by 22-34% and nitrogen runoff by 28-32%. A 15% tax rate reduces farm income by € 15/ha and 100% tax rate by € 85/ha.

Tax on Nutrient Surplus

The Dutch approach to the Nitrates Directive was to implement the Mineral Accounting System (MINAS). MINAS combined farm-level nutrient accounting with a tax on nutrient surplus. The accounting was based on a farm gate balance approach in which nutrient outputs in animal products and crops leaving the farm were reduced from nutrient inputs entering the farm in chemical fertilizer, feed, and organic and livestock manure. Some nutrient losses were allowed so that there was a levy-free surplus and only the surplus above that level was taxed on a per kg N and per kg P basis. Standards related to levy-free surpluses were progressively lowered between 1998 and 2003. For example, the P standard for arable crops was lowered from 40 kg/ha to 20 kg/ha, while the N standard was lowered from 175 to 100 kg/ha on clay soils (Wright and Mallia, 2008).

Despite the perceived advantages of a nutrient surplus tax over a uniform manure application standard or uniform fertilizer tax rate, the MINAS system failed and was replaced in 2006. Wright and Mallia (2008) examined reasons for this failure. First, the Dutch government thought that with the implementation of MINAS it was possible to avoid strict, and possibly costly, manure application standards mandated by the Nitrates Directive. However, the EU Commission was unsatisfied with the system and considered it insufficient to protect groundwater from nutrient pollution and took legal action against the Dutch government. Indeed, in 2003, the European Court of Justice ruled that the Dutch government had failed to fulfill obligations of the Nitrates Directive. Second, the MINAS was considered unfair towards intensive pig and poultry farms with very little arable land for the application of manure produced on the farms. These farmers had to bear the cost of transporting manure off the farms to crop farms. Moreover, the surplus levies were considered extremely high representing 5 to 10 times the price of nitrogen fertilizer and 50 times the price of phosphorus fertilizer.

Ondersteijn et al. (2002) assessed the impact of MINAS on individual farms by using detailed financial and nutrient bookkeeping data of 194 farms distributed over five different farm types and covering the years from 1997 through 1999. Their study shows, among other issues, that farm-specific nutrient surplus taxes can vary a lot, ranging from € 179/ha for arable farms to € 404/ha for mixed dairy and intensive livestock producers. On average, these taxes would reduce gross margin by 8%.

Agri-environmental Payments

Agri-environmental measures were introduced in 1992 for all EU member states as an "accompanying measure" to the Common Agricultural Policy reform. For the EU27 the total expenditure in agri-environmental measures from 2007 to 2009 was about € 6 billion annually, around 7% of the total agricultural support. Agri-environmental measures are designed to encourage farmers to protect and enhance the environment on their farmland. Farmers receive payments in return for carrying out agri-environmental measures that involve more than the application of usual good farming practice or environmental cross-compliance. Farmers sign a contract with the administration and are paid for the additional cost of implementing the measures and for income losses, for example, due to reduced production which the practices entail.

Practice based payments have been a dominant means in the EU agri-environmental programs and they have been successful in regards to voluntary participation by farmers. Agri-environmental programs covered 22% of the utilized agricultural area of the EU27 in 2009. However, several studies have indicated that their environmental performance has been poor and thus, they may not provide value for the money invested by European taxpayers. Hence, there has been an increasing interest in performance based payments—also called results based or outcome-based payments. In Europe many experimental projects have utilized performance-based payments over the last decade, and calls for a stronger connection between agri-environmental payments and environmental outcomes are growing (Burton and Schwarz, 2013).

Agri-environmental measures can be designed and implemented at national, regional, or local levels so that they can be tailored to the particular farming systems and environmental conditions, both of which vary greatly throughout the EU. An obvious drawback in the EU system is the fact that crop area payments and some other instruments promote increasing farm land expansion and regional concentration of livestock production. While this further increases the need for spatial targeting and tailoring of the agri-environmental measures, it also may contribute to partial failures of national voluntary programs. Finland provides a striking example.

Lankoski and Ollikainen (2013) find that the Finnish agri-environmental program has failed to achieve its water protection-related goals, which was a 30% reduction of both nitrogen and phosphorus loading from 1995 to 2007: nitrogen loads from agriculture have even increased by 14% and phosphorus loads have decreased only 4%. Their counterfactual analysis helps to trace the mechanisms behind this failure. First, the CAP has modified the incentives provided by the Finnish agri-environmental program. Crop area payments and the current single farm payment invite new land in cultivation. Second, relative prices have favored land allocation towards more fertilizer-intensive land use forms, thus leading to increased use of nitrogen. Third, environmental support is also an area-based payment. Due to the fact that payment levels over-compensates farmer's compliance costs, it further invites more cultivated land to agriculture and keeps low productivity lands in cultivation. Thus, due to overcompensation the policy instrument works against its water protection aims.

Novel Practices and New Policy Approaches

Europe is increasingly aware of the need to find more efficient ways to reduce nonpoint source loads. The search is going on for instruments that could provide stronger and more flexible incentives for reducing nutrient runoff. Interestingly, water quality trading in nutrients has not received similar attention as in the United States, although some proposals and studies have been made. Instead, active research and pilot projects have been conducted regarding environmental auctions. Also alternative manure handling systems have been under scrutiny and practice.

Conservation Auctions

A pilot auction on applying gypsum to reduce phosphorus runoff in the Nurmijärvi area in Southern Finland was carried out in 2010 (Iho et al., 2011). The pilot was based on an environmental benefit index describing the expected phosphorus runoff reduction based on three factors: soil phosphorus levels, field parcel slope, and location of the field parcel with respect to ditches or surface water. Application of gypsum was used as a measure to reduce phosphorus loading and farmers were asked to offer their field parcels with associated bids to spread gypsum in the fields. According to Finnish studies, four tons per ha of a gypsum amendment decreases particulate phosphorus runoff by 57% and dissolved reactive phosphorus runoff by 29%. The pilot auction was successful as it enrolled the parcels providing the highest environmental benefits—reductions in dissolved and particulate phosphorus runoff—from among the parcels for which bids were submitted. The key factor that separated the enrolled targets from rejected ones was soil P-status: it was four times higher for accepted bids. What is more, the auction format attracted some of the most environmentally sensitive parcels in the area. This was shown by a comparison to data on P-status in the whole study area.

Novel Manure Management Technologies

It is well-established that manure application is often excessive at both farm and regional levels and is one of the major causes of nutrient loads. Manure contains, from an agronomic viewpoint, too much phosphorus in relation to nitrogen and thus leads to a very high soil phosphorus content. Moreover, manure is very expensive to transport. Much work has been done in separating liquid manure into phosphorus-rich solid fractions and nitrogen-rich liquid fractions. This facilitates field application of nitrogen in optimal amounts per ha even in the presence of tight P-standards in environmental regulations and provides a relatively cheap option to transport phosphorus from nutrient-surplus regions to deficit regions, that is from areas dominated by livestock to crop production regions. Transportation of manure from surplus regions to deficit regions reduces the need for mineral phosphorus fertilizer by 30-50%. Total nitrogen runoff can decrease by 10%, total phosphorus runoff by 6%, and dissolved phosphorus runoff by 13% (Luostarinen et al., 2011).

Greening of CAP Support

Political agreement has been achieved on the CAP 2014-2020. In this reform so called “greening” has been introduced to the Pillar 1 payments, that is single farm payments, and 30% of the farmers’ direct payments are now focused on the environment. Under the Commission’s proposals, 30% of Pillar 1 national envelopes were to be used to fund three environmental measures as follows: (i) crop diversification—at least three different crops; (ii) maintain 95% of the area of permanent grassland on the farm as declared in 2014; and (iii) 7% of the farm must be managed as ecological focus areas, examples of which include landscape features, fallow land, and buffer strips.

No assessment of the potential impacts of these measures on water quality has been conducted, but some preliminary critique has been provided that the overall environmental value added by the reform may be small. We would like to mention one possibility, however. The greening of CAP supports may increase crop rotation with legumes as biological fixers of nitrogen. This reduces the need for mineral fertilizers and some preliminary estimates indicate that this would reduce nitrogen runoff on average by 2-4 kg/hectare per year over the crop rotation length.

Way forward

Due to historical and cultural reasons, landscape and biodiversity conservation have had the dominant role in the European agri-environmental policies with the exception of Nordic countries. This state of affairs is now changing. Nonpoint source pollution policies receive increasing attention throughout Europe. More efficient and targeted policies and policy instruments are both under research and underway in practice.

A dominant feature of the European policies is the interplay between EU-wide and voluntary national policies. The CAP policy creates a framework for member states’ voluntary programs and sometimes may even work against CAP’s specific goals. This stresses the need for careful designing of more ambitious national water policies in the member states. We find Europe has still much to do in coordinating various policies and developing more efficient instruments suited well for the European environment.

At the moment, much of the innovative work on more efficient policies is being made in the member states. But there is a long road to a nutrient-smart agriculture sector, which recycles nutrients and uses them efficiently in production so that nutrient loads are considerably lowered.

For More Information

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