River conservation, restoration, and preservation: rewarding private behavior to enhance the commons

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Abstract: Stream and river systems are a critical component of the world's commons, providing a public good that is essential to all life. Almost half the stream and river systems in the USA are in poor condition because thousands of institutions and millions of people have historically made—and continue to make—poor decisions about watershed stewardship. The widespread adoption of best management practices (BMPs) in homes, offices, farms, and factories would do a great deal to mitigate existing impairments and prevent further degradation. Recent advances in technology, which allow precise and relatively inexpensive measurements of BMPs' effectiveness, can provide an unprecedented level of accountability and make possible the use of incentives not previously available. We propose that incentivization can and should supplement education and legislation in promoting the adoption of BMPs, and we focus on rural and agricultural watersheds to explore how to incentivize BMPs to improve conservation, restoration, and preservation practices.
Key words: conservation, restoration, preservation, incentivization, best management practices

PICTURE A PASTURE OPEN TO ALL

In his renowned essay, "The Tragedy of the Commons", Garrett Hardin (1968) described a community pasture in which all herdsmen freely graze their cattle. Because each farmer gets the full value for each additional cow he grazes but pays only a fraction of the incremental cost, "the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all" (Hardin 1968, p. 1244).

The commons is slowly but inexorably destroyed because it creates a powerful incentive for each herdsman to put his private interest above the public good. As each individual appropriates just a little more grass for his own benefit, he undermines the community that has sustained him and his neighbors in the first place.

River systems are the world's ultimate commons. Their waters, which are essential to all life, provide food, water for drinking and bathing, transportation, irrigation, and hydropower. They also have been used throughout human history to carry off our waste, transporting our household, agricultural, and industrial effluents downstream. If we do not overload them, streams and rivers are capable of processing the pollutants we discharge into them while continuing to provide food, clean water, and habitat for wildlife.

Unfortunately, we have overloaded them dangerously: the most recent assessment of the USA's rivers and streams, e.g., found 46% in poor condition (USEPA 2016). Noting that "phosphorus, nitrogen, and streambed sediments in particular have widespread and severe impacts", the authors argued that "reducing levels of these constituents will significantly improve the biological health of rivers and streams". We must do so not just for ourselves. The authors con-

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cluded that we "need to address the many sources of these stressors—including runoff from urban areas, agricultural practices, and wastewater—in order to ensure healthier waters for future generations" (USEPA 2016, p. XV). We need, in other words, to reclaim the commons by recognizing that the cumulative effect of our individual actions can destroy the rivers that support all life. Polluted reaches of streams and rivers are like cancerous tumors that have their initial effect locally but will, if untreated, ultimately spread downstream to river, estuary, and marine habitat and poison the entire rivuarine system (Díaz and Rosenberg 2008).

Indeed, as the US Environmental Protection Agency (USEPA 2015, p. 6-1) concluded after reviewing 1200 peer-reviewed publications, "All tributary streams, including perennial, intermittent, and ephemeral streams, are physically, chemically, and biologically connected to downstream rivers via channels and associated alluvial deposits where water and other materials are concentrated, mixed, transformed, and transported". This finding strongly supports the central point of the River Continuum Concept, first proposed by Vannote et al. (1980), that activities in even the smallest stream reaches affect what happens downstream. Conversely, the development of models of the river and its water as a landscape or "riverscape" (sensu Schlosser 1991, Fausch et al. 2002), in addition to a continuum (Vannote et al. 1980), has led to the recognition of upstream–downstream–upstream connectivity (USEPA 2015) and the idea that "alterations to streams and rivers in their lower reaches can produce biophysical legacies in upstream reaches on levels from genes to ecosystems" (Pringle 1997, p. 425). Everyone, it turns out, lives downstream *and* upstream, and everything from the good characteristics of pristine streams to the bad aspects of our most polluted systems (i.e., Clean Water Act 303[d]-listed streams) cascades up and down the river continuum.

We know the ultimate source of these stressors is us: lots of us. Earth's population will reach 8 billion by 2024 (http://www.worldometers.info/world-population/), and each of us wants a little piece of a watershed for housing, business, food, and other needs. Consequently, the poor water quality in 46% of US streams and rivers (USEPA 2016) results from thousands of institutions and millions of people making decisions that impair the quality of their water and the health of their watersheds. That is the bad news. The good news is that we can make major advances in mitigating existing impairments and preventing further degradation by implementing best management practices (BMPs) in our homes, offices, farms, and factories. The key question is how to motivate people, e.g., individual landowners, to practice good stewardship.

Education is probably the most important component of a long-term environmental strategy. However, creating a spirit of cooperative conservation among landowners has never been easy (Laubach 2014), and traditional approaches clearly have failed to stir enough people to act. Wals et al. (2014, p. 583) pointed out that the historic emphasis of environmental education has been based on the "ill-founded assumption that there is a simple linear relationship between knowledge, awareness, attitude, and environmental behavior". They propose that educators pay more attention to understanding "the learning processes and the capacities of individuals and communities needed to help resolve complex socio-ecological issues", which they think will encourage people to "(i) develop their own capacity to think critically, ethically, and creatively in appraising environmental situations; (ii) make informed decisions about those situations; and (iii) develop the capacity and commitment to act individually and collectively in ways that sustain and enhance the environment".

Legislation also has been, and will continue to be, a critical component for generating better stewardship practices. In particular, the Clean Water Act (1972), the US Environmental Protection Agency, and various departments of environmental enforcement across the USA have made a tremendous difference in cleaning up our rivers (see Karr and Dudley 1981 for a partial summary of early legislation). Yet, whereas legislation and regulation exist at national and state levels, enforcement has lagged behind because of budget limitations and a lack of political will. Thus, >40 y later, the USA remains well short of the water-quality goals laid out by the Clean Water Act.

Thus, education and legislation are necessary to spur landowners to protect water quality, but they are not in themselves sufficient to the task. They have provided the first 2 legs of a watershed stool, which needs 1 more leg to stand. We think that incentivization can and should play a larger role in supplementing education and legislation and, thus, provide the third leg of the sturdy stool required to uphold BMPs.

Incentivization (e.g., offering bonuses or other inducements to encourage superior performance) is used regularly in our economic system, but it rarely has been used to promote good environmental behavior. We have sought, instead, simply to educate people and provide them with the knowledge to implement BMPs and then assumed—hoped, really—that they would go out and do so. We also have passed laws and regulations intended to compel people to make better stewardship decisions and to penalize them, usually with fines, when they make bad choices. We have subsidized some BMPs through the US Department of Agriculture (USDA) and other programs, but such subsidies do not include incentives to maximize the outcome. Thus, we have fallen short. Recent scientific data and technological innovations now make it possible to use positive incentives, such as tax rebates, increased rental payments, and better programs for organic certification, to encourage better practices. In addition, we now know that good stewardship must go hand in hand with land conservation if we want to ensure maximum conservation benefits from permanently protected land. Below, we briefly explore some ways to incentivize BMPs to improve the quantity and quality of the water in US streams and rivers. We focus on rural and agricultural watersheds but suggest that the policy implications are applicable to other landscapes.

INCENTIVIZING STREAMSIDE FOREST BUFFERS

A streamside buffer is land set aside adjacent to a stream to: 1) intercept physical, chemical, and biological contaminants (e.g., excess sediment, pesticides, pathogens, respectively); 2) mitigate other habitat features (e.g., temperature, organic food input, flow regime) negatively affected by human activity (e.g., deforestation, urbanization, land development) and keep those activities from harming the stream; and 3) improve the integrity of the in-stream ecosystem so that it can more effectively process, sequester, or eliminate contaminants that do get into the stream (Welsch 1991, Sweeney and Blaine 2007). Unfortunately, buffers reduce the effects of human activity, but they fail to deal with the sources of the waste. Buffers are the last piece of an upland system, which includes terraces, grass waterways, cover crops, stormwater infiltration basins, level lip spreaders, and other structures or practices, the goals of which are to mitigate the effect of human land use on fresh water. All buffers provide some value, but the 2 primary factors in determining their effectiveness are type of vegetation and width of the buffer. The most effective buffers are forested and >30 m wide for streams and rivers with naturally forested riparian areas (Sweeney and Newbold 2014; Fig. 1, right side). Information about the effectiveness of buffers has long been available to landowners and many states have legislation to regulate their implementation, but the decision to create conservation buffers is still primarily voluntary, especially on farms. Moreover, many landowners continue to view land enrolled in certain BMPs (such as riparian forest buffers) as a loss to net agricultural production even though many agricultural BMPs improve both farm productivity and water quality.

To date, efforts to expand the use of riparian forest buffers through incentives have proved inadequate. This situation is unfortunate because incentives work: the proportion of forest buffers relative to grass buffers in Pennsylvania increased dramatically when the state offered to match federal incentives for forest restoration on land en-

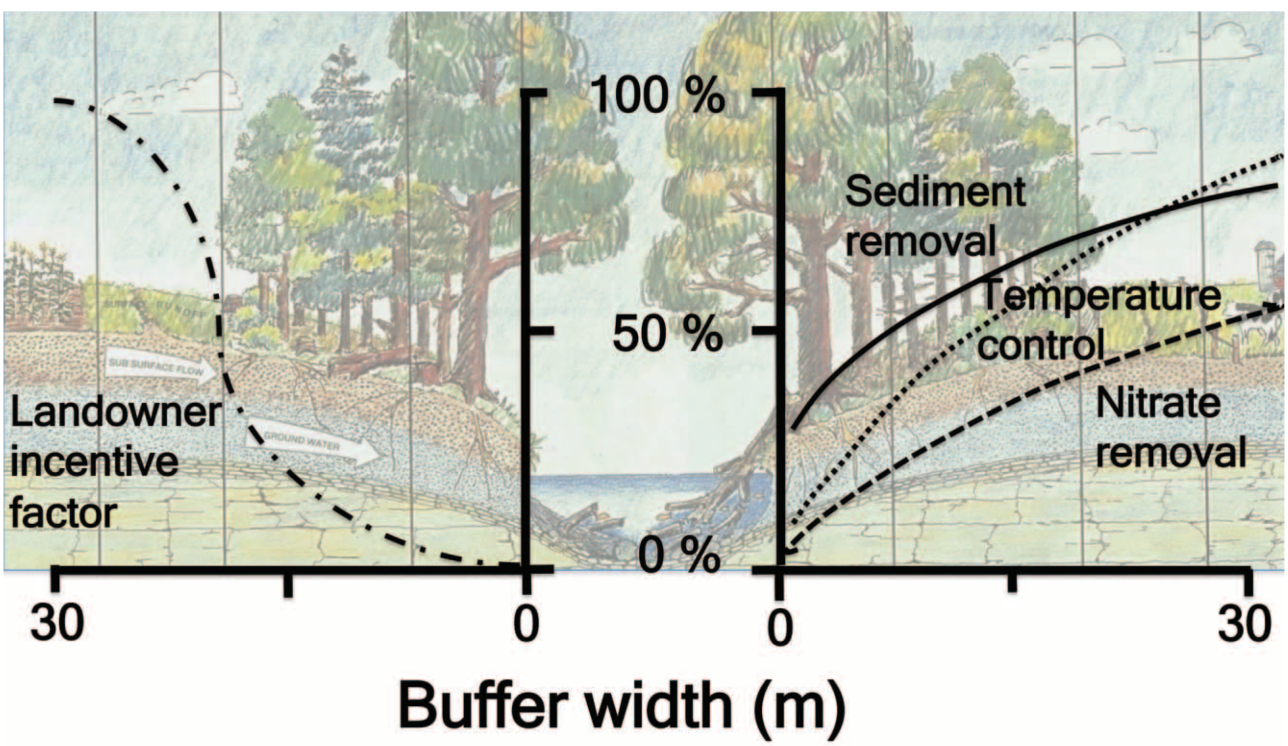

Figure 1. Illustration of how width of a riparian forest buffer helps avoid unnatural temperatures and keep unwanted sediments and nutrients (NO_3^--N) from entering the stream (right). The landowner's cost reimbursement can be increased in relation to buffer width to incentivize landowners to pursue wider buffers and the additional ecosystem services they provide (left). Sediment, NO_3^-, and temperature data are from Sweeney and Newbold (2014, figs 1, 3, and 4, respectively); line for the incentive factor drawn by eye. The vegetated buffer in the background was modified from Welsch (1991) and Sweeney (1992, 1993).

rolled in the USDA Conservation Reserve Program (CRP; or Conservation Reserve Enhanced Program [CREP]). However, despite the fact that scientific research now demonstrates the efficacy of wide forest buffers (Sweeney and Newbold 2014), the programs provide no incentive to increase buffer width beyond the minimum (other than to increase payments proportionately for a landowner's inclusion of more land area). This lack of incentives is inconsistent with the science. A 10-m-wide buffer will remove, on average, 65% of the sediment in farm runoff, most of which is coarse particles. Buffers ≥30 m wide are needed to remove the fine silt and clay particles that significantly degrade stream habitat (Wood and Armitage 1997, Ramezani et al. 2014). Filtration facilities that remove fine particles from drinking-water supplies are expensive to build and operate (e.g., in 2015, New York City completed a plant to filter 10% of its water supply at a cost of $3.2 billion; http://www.nytimes.com/2015/05/09/nyregion/croton-water-is-once-again-flowing-to-new-york.html).

Some states currently recognize the benefits of wider buffers. In 2004, New Jersey enacted Administrative Code NJAC 7:8 and NJAC 7:13 to protect category-1 streams (i.e., streams of exceptional ecological significance as defined by http://www.state.nj.us/dep/wms/bears/c1dataneeds.htm) with 90-m buffers. Unfortunately, New Jersey's local property tax structure creates a disincentive to take land out of agricultural production to establish such buffers. A few states do have incentives to drive wider buffers. One is Pennsylvania, where a landowner can receive the additional 50% state cost share for enrolling in the federal CP22 CRP (USDA Farm Service) for forest buffers only if the buffer is >15 m. This requirement has greatly increased the implementation of wider buffers in certain parts of the state.

There are few other incentives to encourage wider buffers, such as scaling the level of reimbursement to buffer width, or disincentives to creating inadequate buffers, such as offering proportionately less credit for narrow buffers toward federal Total Maximum Daily Load requirements or toward the requirements of programs such as Pennsylvania's Municipal Separate Storm Sewer (http://www.stormwaterpa.org/ms4-program.html). We suggest that public and private institutions that fund conservation practices consider a sliding reimbursement scale, consistent with the latest scientific research, to give a landowner proportionately more money for adopting a wider forest buffer (Fig. 1, left side). The additional money also might help overcome nonfinancial issues, such as the additional trouble, time, and effort required to implement a better plan. Ways might exist to tie the scaling of incentives to the adoption of conservation practices aimed at reducing the runoff of water, nutrients, and sediment headed toward the buffer, e.g., shifting the response curve in Fig. 1 for the "landowner incentive factor" to the right or to the left depending on the presence or absence of a BMP, such as a no-till, multispecies-cover cropping system on all fields upland of the buffer.

INCENTIVIZING BMPS THROUGH MONITORING

Payments that reflect the environmental performance of BMPs are more effective than traditional regulatory approaches to conservation (Pattanayak et al. 2010). Consequently, economic incentives, such as paying the landowner for enhancing ecosystem services, are an important addition to education and legislation in motivating people to use BMPs to achieve sustainable conservation (Naeem et al. 2015). However, to date, payment for such ecosystem services has not been common practice because 1) assessing the value of the BMP service is challenging and 2) no effective system exists for appraising a BMP's performance. When landowners put in, e.g., stormwater detention basins, streamside forest buffers, terraced fields, grassed waterways, or multispecies-cover cropping, the assumption is that their actions improve water quality, and payments are based on generalized estimates rather than actual measurements of the level of service the BMP provides. To date, actual measurements of the BMP have been used only to guarantee its persistence (e.g., continuing the prohibition against cutting trees and tilling waterways) rather than its functionality (what the BMP is actually accomplishing). We think that if a landowner is willing to design, build, and maintain a good BMP and provide data that confirm its benefits, then he or she should be more highly rewarded than someone with a similar BMP whose actual functionality is unmonitored and, thus, unknown.

For example, a rapidly growing body of literature shows that cover crops can reduce erosion, improve soil health and C content, help control weeds and invertebrate pests, and enhance nutrient and moisture availability on farms (Dabney et al. 2001, Clark 2007, Kaspar and Singer 2011). In a review of the literature, Hoorman (2009) concluded that the use of cover crops may improve soil health and could reduce nutrient and pesticide runoff by ≥50%, soil erosion by 90%, sediment loading by 75%, and pathogen loading by 60%. Cover cropping can be practiced to varying degrees (e.g., single or multiple species, seasonal or continuous), which affect the level of reduction of runoff of water, sediment, and nutrients. We increasingly are able to model at least the potential return on investment from these improvements. For example, Kaspar (2009) used the Natural Resources Conservation Service modeling tool RUSLE2 and estimated that a rye cover crop would reduce erosion on no-till corn–soybean rotation by 2016 kg ha^{-1} y^{-1}, or 43%. Incentive payments could be tied to predictive models, but tying them to the BMP's actual pollution reduction would be better. Until recently, monitoring the functionality of BMPs has been labor intensive, expensive, unreliable, and without landowner incentives, but a new toolbox, "real-time monitoring", can now tie payments to landowners to measurable performance.

With the advent of open-source electronics, small radio transmitters, and sophisticated sensors, BMPs can now be monitored almost continuously in real time, with good precision and accuracy, and at a much lower cost than was possible just a few years ago. Researchers at the Stroud Water Research Center recently deployed solar-powered sensor units near Chestertown, Maryland, to monitor water depth, temperature, conductivity, and turbidity in a cornfield's drainage ditch (Fig. 2A–F). The units take sensor measurements every 5 min and transmit the data in real time to the Internet with a solar-powered datalogger, equipped with a radio transmitter and cell phone technology, that was constructed for ~20% of the cost of a comparable commercial datalogger station. This technology for gathering, storing, and transmitting data (i.e., Stroud EnviroDIY MAYFLY™ Data Logger; Stroud Water Research Center, Avondale, Pennsylvania) combined with commercial sensors provides a cost-effective basis for measuring the success of future BMPs (e.g., multispecies-cover cropping) to reduce runoff of water, sediments, or nutrients from the cornfield. New incentive programs could reimburse or share BMP costs with the farmer and provide additional payments for measurable mitigation of target substances, such as nutrients, sediment, and runoff. Technological advances soon should enable similar installations to be positioned inexpensively in everything from stormwater basin outflows to the point discharge of community wastewater

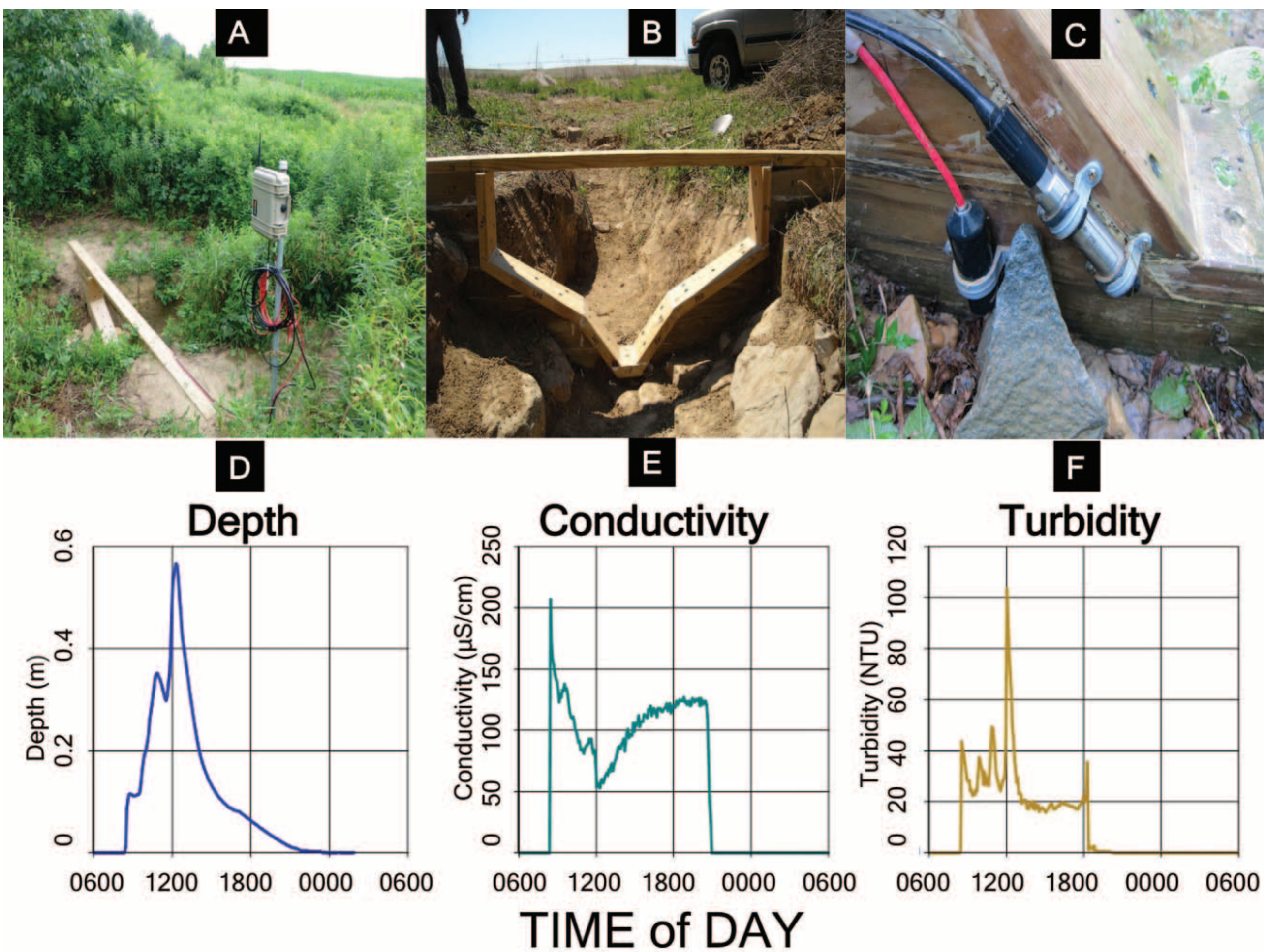

Figure 2. Solar-powered datalogger and transmitter (photograph by S. Hicks, Stroud Water Research Center) (A) positioned next to a wooden hydro-designed control structure (photograph by D. Montgomery, Stroud Water Research Center) (B) that has been inserted into the outfall ditch of an irrigated cornfield near Chestertown, Maryland, and outfitted (at the base of the control structure on the upstream side) with 2 continuously recording electronic sensor probes (photograph by BWS) (C). The structure and sensors enable real-time measurement of the quantity of water runoff (m^3/s) as measured by depth in m (D), the dissolved chemical content (conductivity µS/cm) of the water (E), and its turbidity in nephelometric turbidity units (NTU) (F). Recordings from the ditch (D, E, F) are for a small (0.8 cm) rain storm over a 24-h period 25–26 September 2014.

treatment plants. We think that this kind of infrastructure and data can and should play a key role in cost–benefit analyses of a BMP's ability to eliminate or mitigate streamwater contamination. These analyses, in turn, can serve as the basis for water funds (sensu The Nature Conservancy; http://www.nature.org/ourinitiatives/habitats/riverslakes/water-funds-investing-in-nature-and-clean-water-1.xml), whereby water users pay into a fund for clean fresh water, and the money is used to pay for watershed conservation and restoration practices that ensure a sustainable source of clean water.

The streaming of data as described above will require significantly increased data infrastructure and staff time in an era of already tight budgets. The challenge of setting up a system to administer and track the data may seem onerous now, but it was not so long ago that monitoring individual purchases at supermarkets, gas stations, and department stores seemed equally onerous, and such programs are now widespread. We think the added value for conservation practices will pay off, so we propose that positive incentives tied to monitoring, such as greater rental payments for the land, higher levels of organic certification, and increased prices for produce, in conjunction with water funds, will make installation and maintenance of BMPs attractive to landowners. We envision a system that landowners will embrace, rather than one that merely penalizes them, which, if history is any guide, is a strategy doomed to fail.

INCENTIVIZING LAND PRESERVATION

To date, landowners have voluntarily installed many of the BMPs noted above under state and federal programs with contracts that last 10 to 15 y (e.g., USDA Environmental Quality Incentives Program or most BMPs or USDA CREP [buffers, warm-season grass strips]). However, if BMPs are to improve the quality of water permanently, they must be maintained in perpetuity. Currently in the USA, an owner can adopt a certain type of land use on his or her property (e.g., open space, forest, farm) through tax-reduction programs and permanently protect a certain type of land use through conservation-easement programs. Landowners in states having tax-reduction programs receive a tax rebate for agreeing to keep the parcel in a preferred state, usually forest or agriculture (e.g., the Clean and Green program of Pennsylvania). However, the programs currently are not structured to increase rewards for improved environmental performance provided by BMPs.

Because conservation easement (hereafter easement) programs permanently prohibit other types of land use, the land's market value is reduced. Consequently, the landowner is rewarded with tax benefits, direct cash payments, or both based on the lost-development value. The program is voluntary, and the money paid to landowners comes from both private (conservation foundations, land trusts) and public (municipal, county, state, federal) sources. Subsequently, the easements are held and administered by private land trusts or public agencies.

Often no requirement exists that an eased property have BMPs in place to ensure water quality, which means that a farmer can receive tax benefits or payments for an easement without having made any effort to reduce pollution. Prioritizing applicants willing to forego development and to conserve fresh water would enable the limited funds for such purposes to have a broader effect. In some regions of the USA, an easement that relinquishes development rights must be accompanied by a written conservation plan to qualify for incentive payments. However, the conservation plan may not contain all the possible BMPs available to mitigate water pollution because the plan is often tailored to the landowner's current operations. Moreover, often *no requirement exists that the conservation plan actually be implemented* once the payments have been disbursed, thereby nullifying the leverage of the incentive and perpetuating existing nonpoint-source pollution from that land parcel.

A permanent easement will maximize improvements in water quantity and quality in its watershed only if it assures that 1) the forest or farmland is protected in perpetuity and 2) a conservation plan is actually implemented. Therefore, we propose that landowners not be rewarded with public or private funds for easing their land until they have prepared a conservation plan and agreed to execute it within a satisfactory time frame. Otherwise, easements may simply perpetuate bad land-management practices, and polluted water will continue flowing into our streams (e.g., Fig. 3A–H).

To this end, conservation organizations, private land trusts, and public institutions that hold easements—and public and private funders of easement payments—must incentivize BMPs and land preservation. Only a landowner whose easement plan includes a conservation plan *and* a written implementation commitment should receive additional incentives for protecting water quantity and quality, and those incentives should be on a sliding scale that rewards their effectiveness.

Such a scaled incentive plan should lead to more effective partnering between land trusts that hold easements and conservation organizations that design and implement BMPs because few organizations have expertise in both land preservation and freshwater conservation efforts. The measure of success for a land trust (number or area of land parcels eased/y) is very different from that for a conservation organization (number or level of BMPs adopted and executed), and the 2 approaches actually may compete, especially within a single organization. For example, if a landowner receives no additional reward for an easement with BMPs, then he or she has no added incentive to incur the increased costs and burdens of implementing such practices. Conservation proposals that include a scaled incen-

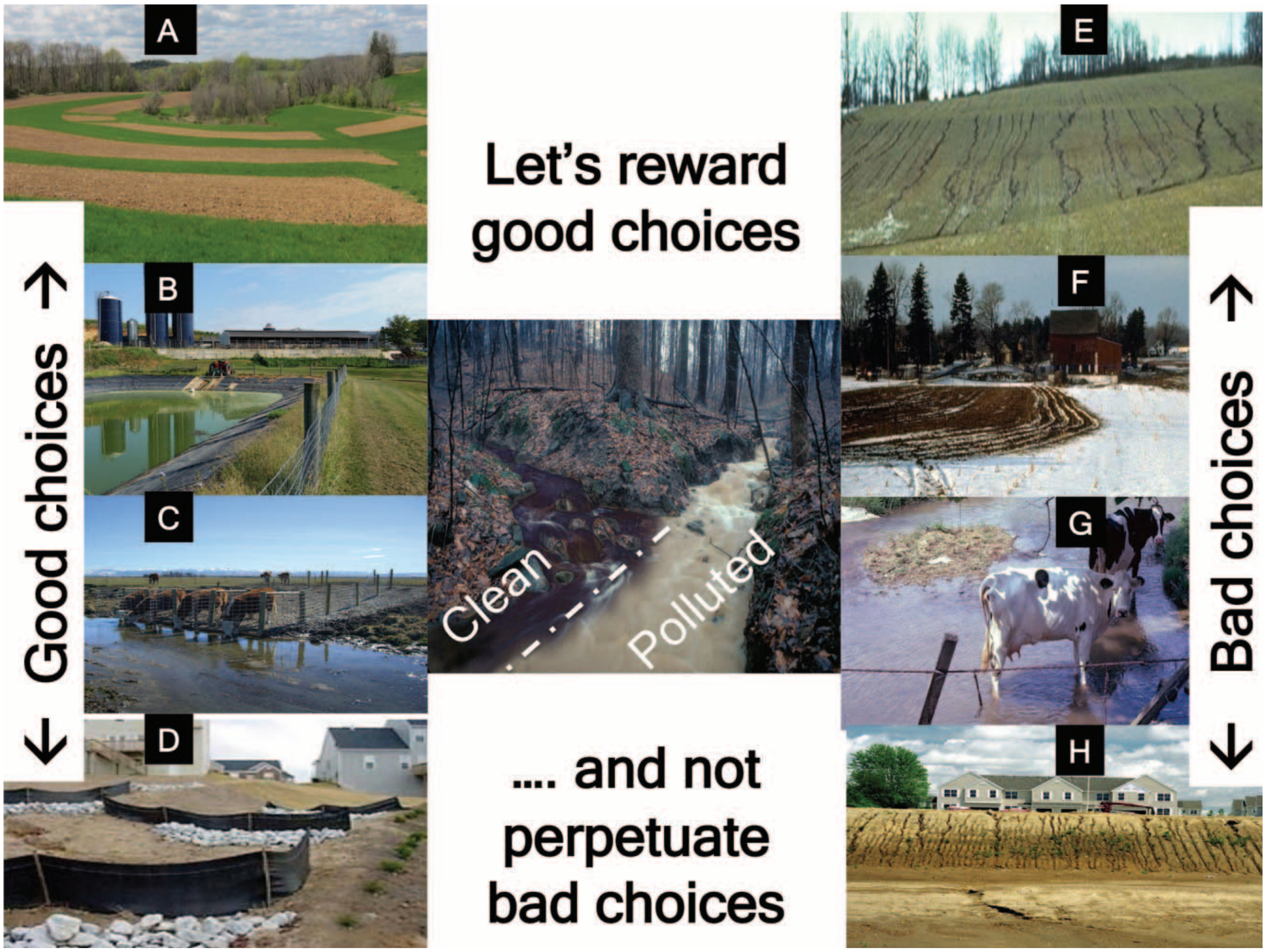

Figure 3. Good landuse choices like grass waterways, terracing, and contour planting (photograph by BWS) (A), manure storage lagoons (photograph by D. Arscott, Stroud Water Research Center) (B), cattle-watering structures (photograph by A. Sigler, Montana State University) (C); and sediment erosion controls (photograph courtesy Natural Resources Conservation Service [NRCS]) (D) result in clean water in nearby streams (center; left tributary). Poor landuse choices, such as farming up and down steep slopes (photo BWS) (E), spreading manure on frozen fields (photograph by R. Vannote, Stroud Water Research Center) (F), allowing cattle to access streams (photograph by BWS) (G), and improper erosion controls on construction sites (photograph by L. Betts, NRCS) (H) result in highly turbid, polluted water in nearby streams (center; right tributary). Center photograph by D. Funk, Stroud Water Research Center.

tive plan for BMPs, on the other hand, provide additional incentives for the landowner to come to the table, which would help reduce in-house and inter-institutional conflicts that currently result in eased land with inadequate water conservation measures.

RECLAIMING THE COMMONS

Recent studies indicate that incentivization is a complex process, in which "the direct extrinsic incentives . . . can crowd out intrinsic motivations in the short run and the long run . . . [depending] on how they are designed, the form in which they are given (especially monetary or nonmonetary), how they interact with intrinsic motivations and social motivations, and what happens after they are withdrawn. Incentives do matter, but in various and sometimes unexpected ways" (Gneezy et al. 2011, p. 206). Therefore, any expansion in the incentivization programs for BMPs must be based on good economic, social, and physical science.

We are not proposing that a landowner be compensated for behavior that he or she should practice in the first place, such as refraining from polluting the streams that cross or abut his or her land. For that kind of behavior, he or she should be educated or punished. Nor are we advocating that a landowner be paid simply for enhancing the value or beauty of his or her own land. Projects that produce purely private benefits have no call on public funds.

We are arguing that a landowner should be compensated for private actions that measurably increase the public good. Such actions go beyond simply obeying the laws and abiding by the regulations, and their benefits are not confined to the particular property on which they are implemented. The ultimate aim of such actions is to reclaim a bit of the commons by protecting the water, its ecosystem, and the watershed that sustains them. We think it reasonable and appropriate to use public funds to purchase services that increase the quality and quantity of fresh water in the nation's rivers and thereby enhance the public welfare. Governments do it all the time. A landowner should be rewarded for the verifiable and measurable value that he or she has added for the benefit of all—for his or her actions have not merely helped diminish the tragedy of the commons, they have begun to reverse it. We think it at once hopeful and ironic that a powerful incentive system, which has in the past done much to destroy our rivers, and the commons in general, may in the future help to revive them.

CONCLUSIONS

Incentivizing the implementation of BMPs for watershed stewardship may provide much-needed help in the ongoing effort to clean up streams and rivers in the USA. We propose a different approach from the current cost-share, subsidy, and grant programs that help pay for BMPs but do not incentivize performance improvements. A case can be made that, even though humans respond more readily to incentives than to penalties, the former have yet to play a critical role in the adoption of BMPs. Incentives give individual landowners a material stake in the measurable value of their improvements by evaluating their BMPs and rewarding their effectiveness. This, in turn, should encourage landowners to design, implement, and maintain BMPs more diligently. Incentives can lead not only to a greater willingness to adopt and improve BMPs but also to a greater understanding of the system-wide consequences of individual actions. We suggest that incentives for landowners can take many different forms, from providing extra money for wider conservation buffers, to rewarding BMPs based on their effectiveness, to making payments for preservation easements contingent on their comprehensiveness. Incentives work in most forms of business and most walks of life. They need to be part of our toolbox for advancing environmental conservation, restoration, and preservation.

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