Water Quality Protection and the Cost-effective Targeting of Riparian Buffers in Georgia

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Executive Summary

Contracting with private landowners for the maintenance of riparian buffers has become an important policy tool for protecting water quality worldwide. A riparian buffer is vegetated land along a stream, lake or reservoir that intercepts and sequesters polluting runoff. Given the limited budgets of government and non-government environmental agencies, cost-effective targeting of riparian buffers is of paramount importance. Cost-effective targeting means maximizing the environmental benefits of every dollar spent and requires an agency to consider both the costs and the benefits of establishing each potential buffer.

In a set of two papers, I seek to demonstrate two important points related to cost-effective conservation investment: (1) approaches that incorporate both biophysical and economic data are likely to generate much greater environmental benefits per dollar expended than approaches that consider only biophysical or economic data; and (2) sophisticated watershed models are not required to improve the effectiveness of current conservation investments. I illustrate both points using data from a riparian buffer contracting initiative in upstate New York.

In this first of two papers, I focus on the integration of cost and benefit information in conservation decision-making. I empirically compare different water quality investment approaches by using Geographic Information Systems data from a riparian easement contracting initiative in upstate New York. I demonstrate that failure to consider both costs and benefits in the targeting of riparian buffers leads to decisions that achieve as little as 11% of the benefits that could have been achieved had costs and benefits been simultaneously considered in targeting buffers in the watershed. In order to stretch limited water quality protection budgets as far as possible, riparian buffer initiatives must incorporate both biophysical and economic information.

I. Introduction

Imagine that you are interested in reducing the quantity of pollutants running off of the land into the Chattahoochee River in Georgia. You have been advised that one appropriate tool for achieving your goal is to pay riparian landowners (that is, landowners along the river) to protect vegetation along the river. The vegetated strip along the river, called a riparian buffer, serves as a filter that can reduce the quantity of pollutants that enter the river each year. You have a choice of creating a riparian buffer on Parcel A that will prevent 100 pounds of phosphorus runoff from entering the river each year or creating a riparian buffer on Parcel B that will prevent 50 pounds of phosphorus runoff from entering the river. Which parcel should you choose?

Parcel A provides twice the pollutant reduction that Parcel B provides and thus Parcel A might seem to be the best choice. What if the riparian buffer on Parcel A, however, costs $100 to acquire and the riparian buffer on Parcel B costs $25? This would mean that a riparian buffer on Parcel A can remove a pound of phosphorus for $1 and a riparian buffer on Parcel B can remove a pound of phosphorus for $0.50. Further imagine that you have only $20 with which to acquire riparian buffers along the river. In this case, spending your $20 budget to acquire a partial buffer on Parcel A would reduce phosphorus runoff by only 20 pounds, but spending it to acquire a partial buffer on Parcel B would reduce phosphorus runoff by 40 pounds. Thus, given a limited budget, you would do better to pay for a riparian buffer on Parcel B. Had you not considered both the environmental benefits **and** the economic costs of establishing each buffer, however, you would not have generated the "biggest bang for your buck."

Failure to consider both costs and benefits is common in many environmental initiatives, including those aimed towards improving water quality. Many initiatives focus solely on the benefits that each parcel contributes towards the policy objective, while other initiatives focus solely on acquiring land as cheaply as possible with no consideration of the benefits provided by each acquired parcel. In the following sections, I explore the conditions under which failing to consider both costs and benefits of conservation contracting would lead to large inefficiencies in a riparian buffer program. I demonstrate that considering both biological and economic data is particularly important in the context of watershed protection because the level of environmental amenities and the costs of obtaining the amenities are likely to be positively correlated. The greater the positive correlation between environmental benefits and acquisition costs, and the greater the spatial variability of costs compared with the variability of benefits, the greater are the gains that can be realized by considering both costs and benefits when making decisions on where to place riparian buffers.

In the next section, I briefly review existing water quality initiatives that pay private landowners to alter their land use activities. In Section III, I discuss various approaches that conservation agencies have adopted to guide their conservation investments. In Section IV, I describe the case study riparian buffer initiative in New York, and, in Section V, I present the results of the empirical analysis. In Section VI, I conclude the paper with a summary of the main findings of the analysis.

II. Conservation Contracting Initiatives

Concerns over the impact of private land use on water quality has led to an increasing global reliance on conservation contracting initiatives. The term “conservation contracting” describes the contractual transfer of payments from one party (e.g., government) to another (e.g., landowner) in exchange for land or land use practices that contribute to the supply of an environmental amenity (e.g., water quality improvements). Examples of conservation contracts include fee-simple title transfers, easements and short-term conservation leases.

The use of conservation contracts to achieve water quality objectives is becoming increasingly popular. For example, the New York City Watershed Management Plan will spend $250 million on conservation contracting with private landowners in the Catskill-Delaware watershed over the next ten years to protect the City's water supply and maintain its filtration waiver from the Environmental Protection Agency (NRC 2000: 213-239). Examples of other contracting initiatives for water quality include North Carolina's $30 million Clean Water Management Trust Fund and Costa Rica's $16 million per year effort to secure conservation contracts in, among other areas, the watersheds of municipal water supplies and hydroelectric dams.

In Georgia, a recent report found that 85% of the streams and 99% of the lakes needed improvement in water quality (EPD 2000). In order to protect and improve the quality of Georgia's surface waters, environmental agencies are encouraging private landowners to establish riparian buffers and make other changes in their land management practices (EPD 2000; Board of Natural Resources 2001). There are a variety of programs in Georgia that use conservation contracts to encourage improved land management and the establishment of riparian buffers: the Conservation Reserve Program, the Conservation Reserve Enhancement Program, Environmental Quality Incentives Program, the Wetlands Reserve Program, the Altamaha riparian corridor initiative, the Georgia Buffer Initiative, the Georgia Greenspace Program and numerous local open space initiatives. The programs all have in common lofty goals and limited budgets.

The Georgia Greenspace Program, signed into law by Governor Roy Barnes in April 2000, is a good example of a conservation initiative that can benefit from cost-effective targeting of its limited funds. Designed to help fast-growing counties protect "connected and open greenspace which can be used for informal recreation and natural resource protection," the program has a budget of approximately $30 million a year for greenspace acquisition (DNR 2001).[1] One of the program's main objectives is to use greenspace protection, particularly in riparian areas, as a means to achieve water quality objectives. Riparian buffers on the Chattahoochee River, in particular, are singled out for targeting (DNR 2000). Although a budget of $30 million per year may seem large, land prices in fast-growing counties can quickly dissipate that budget. The coordinator of the Georgia Greenspace Program, Harvey Young, has stated, "…compared to the need, it's a small amount of money. The state this year has $30 million in greenspace money to allocate to all 40 counties. By comparison, Roswell, a city of about 70,000 people, is spending $19 million to buy park land." As another example of the severity of the budget constraint with which the Greenspace Program is working, consider that Gwinnett County, in 1999, spent $10.5 million to acquire only 217 acres along the Chattahoochee River (Tofig 2000).

In the next section, I compare popular approaches to targeting private lands for riparian buffer acquisition. I highlight the way in which their effectiveness in achieving the maximum water quality benefits per dollar expended varies depending on the way in which environmental benefits and acquisition costs are distributed across the watershed.

[1] The statute defines greenspace as permanently protected land and water, including agricultural and forestry land, that is in its undeveloped, natural state or that has been developed only to the extent consistent with, or is restored to be consistent with, one or more listed goals for natural resource protection or informal recreation.

III. Targeting Conservation Investments

In the discussion below, I will refer to the water quality benefit from a buffer on a given parcel (parcel *i*) as w_i. The measure w_i is a number that captures the perceived benefit from contracting for a riparian buffer on a given parcel of land. The measure w_i is often an index value or a measure of a key objective, such as reduction in tons of sediment. I will refer to the cost of acquiring a buffer on a given parcel as c_i. Acquisition cost is measured in dollars and includes the payment made to the landowner as well as the administrative costs in setting up and monitoring the contract (if payments and costs are incurred over many years, c_i is the discounted present value of all costs incurred).

When prioritizing land areas for water quality initiatives, biologists, hydrologists and conservation practitioners often use, explicitly or implicitly, a *benefit-ranking approach*, which I will refer to as the *B-rank* approach. The *B-rank* approach ranks parcels from the highest environmental benefits (w_i) to the lowest and acquires easements until the budget is exhausted. The *B-rank* approach can be viewed as the "crown-jewel" approach because it attempts to acquire the most biophysically valuable land in the watershed (Parcel A, in terms of the introductory example) while ignoring the costs of acquiring these jewels.

A narrow focus on environmental benefits, without consideration of the costs of securing those benefits, may lead policymakers to choose cost-inefficient conservation strategies. By incorporating costs into the decision-making, a conservation agency can identify the portfolio of riparian buffers that generates maximum environmental benefits per dollar expended. This cost-effective targeting approach, which I will refer to as the *E-max* approach, is equivalent to ranking parcels from highest to lowest based on their benefit-cost ratio ($\frac{w_i}{c_i}$) and accepting contracts until the budget is exhausted.

In my analysis, I will also consider two other approaches that are commonly used in conservation contracting initiatives. The first is referred to as the "acreage-maximization" approach, *A-max*, which maximizes the acres (a_i) acquired for every dollar spent. The *A-max* approach is like the *E-max* approach, except that parcels are ranked from highest to lowest based on their acres to cost ratio ($\frac{a_i}{c_i}$). The *A-max* approach is equivalent to achieving an acreage goal for the least amount of money. The *A-max* approach was formerly used by the U.S. Conservation Reserve Program (Reichelderfer and Boggess 1988) and it is equivalent to the current federal mandate for New York City's Watershed Management Plan to achieve a target of 335,000 acres in its conservation contracting activities (i.e., New York City would like to meet this mandate at least cost; NRC 2000).

The final approach I consider is referred to as the "acreage-ranking" approach, *A-rank*, which ranks parcels from biggest to smallest according to acreage, and acquires easements until the budget is exhausted. The *A-rank* approach is like the *B-rank* approach, except that parcels are ranked from highest to lowest based on their size in acres. The four possible targeting approaches are summarized in Table I.

Using an example from upstate New York, I will demonstrate that the degree to which *E-max*'s riparian buffer portfolio is more cost-efficient than the portfolios chosen by *B-rank*, *A-max* and *A-rank* will depend on the spatial correlation between benefits and costs and the relative spatial variability of costs and benefits across the watershed. To understand why this is so, let us compare the *E-max* approach, which ranks parcels by their benefit-cost ratio, and the *B-rank* approach, which ranks parcels by their benefits.

Table I – Possible Targeting Approaches

Approach	**Method of Ranking Parcels from Most Desirable to Least Desirable**
E-max (cost-effective targeting)	By benefit to cost ratio of each parcel ($\frac{w_i}{c_i}$)
B-rank (“crown-jewel” targeting)	By total benefits of each parcel (w_i)
A-max (“cheap land” targeting)	By acreage to cost ratio of each parcel ($\frac{a_i}{c_i}$)
A-rank (“big parcel” targeting)	By total acreage of each parcel (a_i)

The greater the similarity in the way in which the *E-max* and *B-rank* rank the relative desirability of each available parcel, the greater the degree to which the *B-rank* approach comes close to the *E-max* approach in terms of achieving the “biggest bang for the buck.” The degree to which the two approaches rank parcels in the same way will depend on how closely w_i (the benefits from parcel *i*) and $\frac{w_i}{c_i}$ (the benefit-cost ratio of parcel *i*) are correlated across the watershed. If benefits and costs are, in general, negatively correlated (i.e., the higher the benefits from a parcel, the lower the costs of acquiring that parcel), then when w_i is large, $\frac{w_i}{c_i}$ will also be large. Thus the two approaches are likely to choose similar parcels for acquisition. If benefits and costs are, in general, positively correlated (i.e., the higher the benefits from a parcel, the higher the costs of acquiring that parcel) then when w_i is large, $\frac{w_i}{c_i}$ will **not** necessarily be large. In this case, the two approaches are likely to choose quite different parcels for acquisition.

Furthermore, the degree to which w_i and $\frac{w_i}{c_i}$ are correlated will also depend on the relative variability of benefits (w_i) compared to costs (c_i) across parcels. If w_i is much more variable than c_i, then the different values of $\frac{w_i}{c_i}$ are largely determined by the value of w_i and thus w_i and $\frac{w_i}{c_i}$ are likely to be similar. If c_i is very variable compared with w_i, then the different values of $\frac{w_i}{c_i}$ are largely determined by the size of c_i. In this case, ranking parcels according to w_i or $\frac{w_i}{c_i}$ can lead to very different parcel rankings depending on the correlation between w_i and c_i.

Thus, we would expect that the greater the positive spatial correlation between environmental benefits and acquisition costs, and the greater the spatial variability of costs compared with the variability of benefits, the greater are the gains that can be realized by considering both costs and benefits when making decisions on where to place riparian buffers.[2] With regard to the *A-max* approach, the degree to which *E-max* and *A-max* choose the same buffers for acquisition depends on the spatial correlation between acreage (a_i) and water quality benefits (w_i); both approaches take into account the cost of acquiring the parcel and thus if large parcels tend to have greater water quality benefits, the set of parcels chosen by *E-max* and *A-max* for acquisition would be similar. The degree to which the set of parcels chosen by *E-max* and the set chosen by *A-rank* are similar will depend on three things: (1) the spatial correlation between benefits and acreage, (2) the spatial correlation between benefits and costs, and (3) the relative spatial variability of benefits compared to the relative spatial variability of costs.

[2] It is important to note that even if costs and benefits were negatively correlated, but relative cost variability was much greater than relative benefit variability, there could be large differences in the parcel rankings of different targeting approaches.

IV. Case Study: Lake Skaneateles Watershed Management Plan

a. Location and Initiative

The City of Syracuse, New York (population 163,860) obtains its drinking water from Lake Skaneateles, which is 20 miles away and outside of the City's regulatory jurisdiction. The lake, pictured in Figure 1, is 16 miles long, less than one-mile wide on average, and has a 60 square mile watershed that covers three counties, seven townships, and one village. The population of the watershed is about 5000 residents, concentrated largely in the northern half of the lake. Land use is mainly a mix of agricultural land (48%), in which cropping and dairy farming are most common, and forest (40%).

The water from the lake is of exceptionally high quality (AA rating) and the City, using only disinfection by chlorination, meets drinking water standards without coagulation or filtration. In recent years, however, the City has come under increasing pressure to consider filtration in order to satisfy the provisions of the Environmental Protection Agency's Surface Water Treatment Rule. In 1994, the City signed a Memorandum of Agreement (MOA) with the New York State Department of Health that allows the City to avoid filtering water from the lake. The MOA requires that the City commit to a long-term watershed management program to reduce pathogen, chemical, nutrient, and sediment loading into the lake. An important part of the management program is a Land Acquisition Program, through which $5-$7 million will be spent over the next seven years to secure conservation easements on privately owned riparian parcels. Using easements, as well as subsidies for agricultural best management practices (not examined in this paper), the City hopes to avoid, or delay, the estimated $60-$70 million cost of a new filtration plant. The City must decide how to allocate its limited budget across the

watershed in a way that will have the greatest impact on maintaining and improving water quality in the lake (Myers et al. 1998).

The City of Syracuse identified both the *B-rank* approach and the *A-rank* approach as appropriate targeting strategies. As noted above, the *B-rank* is a popular conservation targeting approach worldwide. The analysis in the next section focuses on 202 riparian parcels in the upper watershed of Lake Skaneateles (see Figure 1). Biophysical and economic data on these parcels were obtained from the Geographic Information Systems database of the City of Syracuse's Department of Water. The southwestern end of the lake is mostly protected public land and is thus excluded from the analysis. Data on parcels in the southeastern end of the lake were not available at the time of analysis, but since these parcels are far from the City's intake pipes at the northern end of the lake, excluding these parcels has only a minor impact on the final results.

b. Case Study Cost Assumptions

A regional appraisal company estimated that easements around Lake Skaneateles would cost on average between 40% and 60% of the assessed land value of a parcel (Gardner 2000). In the analysis below, I use 50%. Altering the percentage used will not change the qualitative results for each targeting rule. A change in the percentage will affect only the number of parcels that can be acquired for a given budget, not the order in which the parcels are acquired. I also assume that for each easement, there is a transaction cost of $5000/easement. I varied the transaction cost from $2500 to $12,500 and did not observe dramatic changes in the parcel rankings.[3] Future analyses can incorporate new information on transaction costs and easement costs that practitioners are gathering in the course of contacting landowners.

c. Case Study Benefit Assumptions

Sophisticated hydrological models are not available for the Lake Skaneateles watershed. To measure the contribution of each parcel to Syracuse's water quality objectives, the Department of Water convened a scientific panel to help it develop a parcel scoring system (Myers et al 1998). With the panel's assistance, the Department chose the following weighted linear function that assigns a score to each parcel:[4]

$$\textbf{Environmental Benefit Score (EBS)} = 0.2\,\textit{Acreage} + 0.2\,\textit{Priority Zone} + 0.25\,(\textit{Distance to Intake})^{-1} + 0.25\,\textit{Acres of Hydrologically Sensitive Land} + 0.1\,\textit{Stream Length} \quad (1)$$

The attribute *Distance to Intake* measures the planametric distance from the geometric center of the parcel to a point exactly midway between the City's two water intake pipes. The closer to the pipes, the more desirable is the parcel of land (see appendix for a description of the attribute normalization). *Priority Zone* is a categorical variable, converted to a numeric scale that captures the development potential and land use intensity of the zone in which a parcel is found. *Stream Length* is the length of the stream frontage in each parcel, and *Acres of Hydrologically*

[3] The exceptions were small, inexpensive parcels for which a change in transaction costs could have a large relative impact on contract cost.
[4] Parcel scoring functions based on land attributes have been used in other watershed protection field initiatives (e.g., Lemunyon and Gilbert 1993) and in the multi-billion dollar conservation efforts of the U.S. Conservation Reserve Program (Feather *et al.* 1998), land trusts (e.g., The Nature Conservancy; Master 1991), international habitat protection groups (e.g., World Wildlife Fund; Olson et al. 2000), national wildlife protection initiatives (e.g., Partners in Flight; Carter et al. 1999), and farmland protection initiatives (e.g., American Farmland Trust).

Sensitive Land includes hydric soils, steeply sloped soil, frequently flooded soils and wetlands, all of which facilitate pollutant transport. In the next section, this parcel scoring equation is referred to as the Interval-Scoring equation. Two other scoring methods are also considered and are explained below.

V. Case Study Results

I analyzed the total Environmental Benefit Score (EBS) generated by the chosen land portfolios of each targeting approach at thirty-four budget levels, ranging from $0 to $11.8 million. The maximum budget level was equivalent to enough money to buy riparian easements across the entire Upper Watershed, given the assumed cost of contracting (i.e., one- half the assessed land value plus transaction cost). I refer to this amount as the Total Watershed Cost. If all the parcels were acquired, the total EBS for the watershed would be 70.95. I refer to this number as the Total Watershed Benefit.

Figure 2 illustrates the results. The x-axis represents the budget levels in percent of the Total Watershed Cost. The y-axis represents the environmental benefits achieved as a percentage of the Total Watershed Benefit. By definition, the optimal *E-max* approach achieves the maximum benefits per dollar expended, and thus, its curve is on the outside. The acreage-maximization approach, *A-max*, does a fair job of generating environmental benefits in a cost-effective manner, but the two ranking approaches, *B-rank* and *A-rank*, perform poorly under most budgets. For example, with a budget of about $2.7 million (18% of the Total Watershed Cost), the *E-max* approach achieves 62% of the total watershed benefits, while the *A-max* approach achieves 44%, the *B-rank* approach achieves 22%, and the *A-rank* approach achieves

26%. Maps of the land portfolio chosen under each targeting approach are shown in Figures 3-6. Table II illustrates the overlap among the parcels chosen by each approach in percentage terms. Under a budget of about $5 million (42% of the Total Watershed Cost), the *E-max* approach achieves 85% of the total benefits, while the *A-max* approach achieves 76%, the *B-rank* approach achieves 43%, and the *A-rank* approach achieves 45%. In general, the greater the budget available for easement acquisition, the smaller the efficiency losses associated with choosing a targeting approach other than *E-max*.

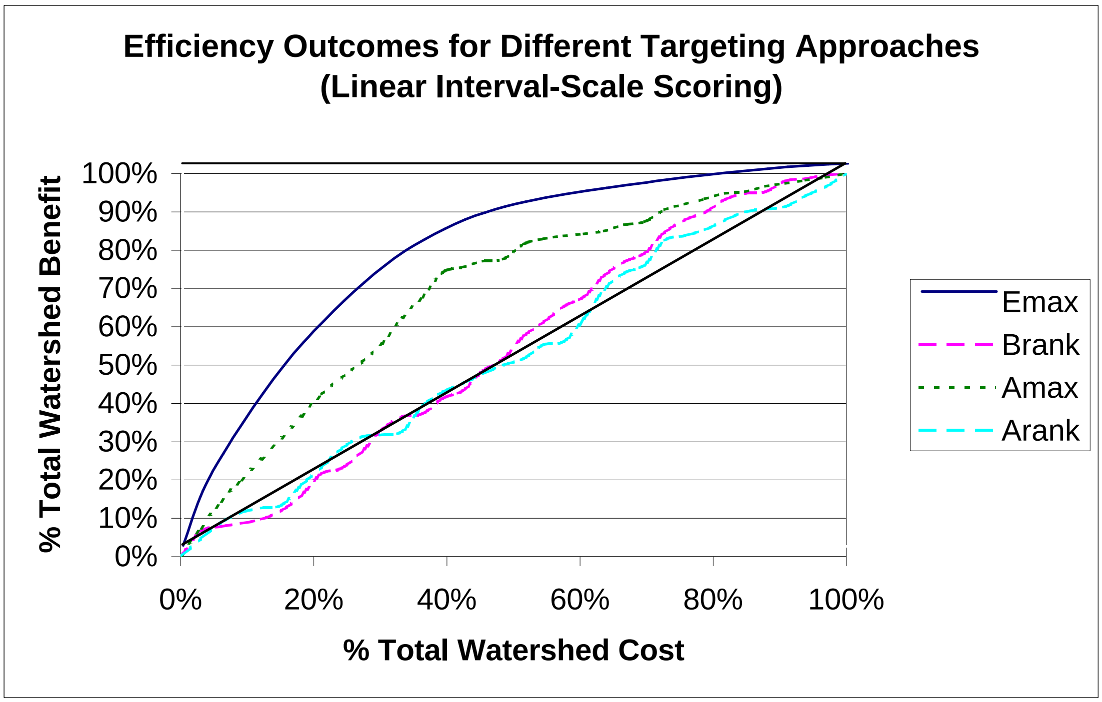

Figure 2. Efficiency Outcomes for Different Targeting Approaches (Linear Interval-Scale Scoring)

Table II. Overlaps among Portfolios (Interval-Scale Scoring Equation; Budget = $2.7 million)

	E-max	*A-max*	*B-rank*	*A-rank*	*E-max Coverage*
E-max	113	50	17	17	100%
A-max		73	19	30	68%
B-rank			25	16	68%
A-rank				34	50%

To consider the differences in the cost-effectiveness of the approaches over all budget levels, one can compare the areas under the curves and above the 45ë line in Figure 3 (Babcock et al. 1996): the bigger the area, the greater the cost-effectiveness of the approach (i.e., the bigger the area, the more benefits one has obtained). I estimate an area equal to twice the size of the area under a given curve and above the 45ë line by using trapezoids at each of the thirty-four budget intervals. The greater the difference between the measured area under the *E-max* curve and the equivalent area under the other curves, the greater the loss in efficiency from using a targeting approach other than *E-max*. The areas under the curves are listed in Table III. For example, the area under the *E-max* curve is 0.55, while the area under the *B-rank* curve is 0.09. This means that the *B-rank* approach is only 16% as efficient as the *E-max* approach in achieving the greatest amount of benefits per dollar expended.

There are two reasons that the *E-max* and *A-max* approaches do relatively well, while the two ranking approaches, *B-rank* and *A-rank*, do not: (1) the correlation between parcel costs and parcel benefits is positive; and (2) the spatial variability in costs is greater than the spatial variability in benefits.

The correlation coefficient between parcel costs and parcel benefits is $\rho = 0.18$; in other words, the high benefit parcels tend to be the high cost parcels. The EBS equation gives higher scores to large parcels with water frontage that are near the town center of Skaneateles, where the intake is located; these are also likely to be expensive parcels. The *B-rank* and *A-rank* approaches do not consider costs and thus are likely to target parcels that are expensive relative to the amount of benefits they provide.[5] The *E-max* and *A-max* approaches consider costs in the targeting decision. Although the *A-max* approach only focuses on a single attribute (i.e., acreage), its portfolios perform fairly well because acreage is highly correlated with the EBS (ρ=0.66).

Table III. Areas under Curves in Benefit-Cost Space

Targeting Approach (see Table I for details)	**Interval-Scale (1)**	**Ratio-Scale (2)**	**Categorical**
E-max	0.55	0.65	0.54
A-max	0.37	0.51	0.39
A-max Efficiency (% E-max)	67%	79%	72%
B-rank	0.09	0.37	0.11
B-rank Efficiency (% Emax)	16%	57%	20%
A-rank	0.06	0.28	0.08
A-rank Efficiency (% Emax)	11%	43%	15%
Correlation (benefit/parcel-cost/parcel)	0.18	0.21	0.23
Benefit Variability (area under spatial concentration curve)	0.26	0.41	0.28

[5] Despite ignoring both benefits and costs, the acreage-ranking approach performs as well as the benefit-ranking approach because of the positive correlation between parcel score and parcel size (0.66).

Figures 7 and 8 illustrate the spatial heterogeneity of costs and benefits. In Figure 7, land is ranked on the basis of environmental benefits (high to low). In Figure 8, land is ranked on the basis of cost (low to high). The greater the curvature of the curves, the greater is the variability of costs and benefits (or, equivalently, the greater the spatial concentration of costs and benefits). A curve that follows the 45ë line depicts a situation in which benefits or costs are uniformly distributed across riparian parcels.

The degree of variability can be represented by twice the area between the curves and the 45ë line; the larger the area, the greater the variability.[6] The area under the benefit curve is 0.26, and the area above the cost curve is 0.55. Thus, relative cost variability is greater than relative benefit variability. With greater relative cost variability, approaches that seek out the least expensive lands first will tend to perform better than approaches that ignore costs.

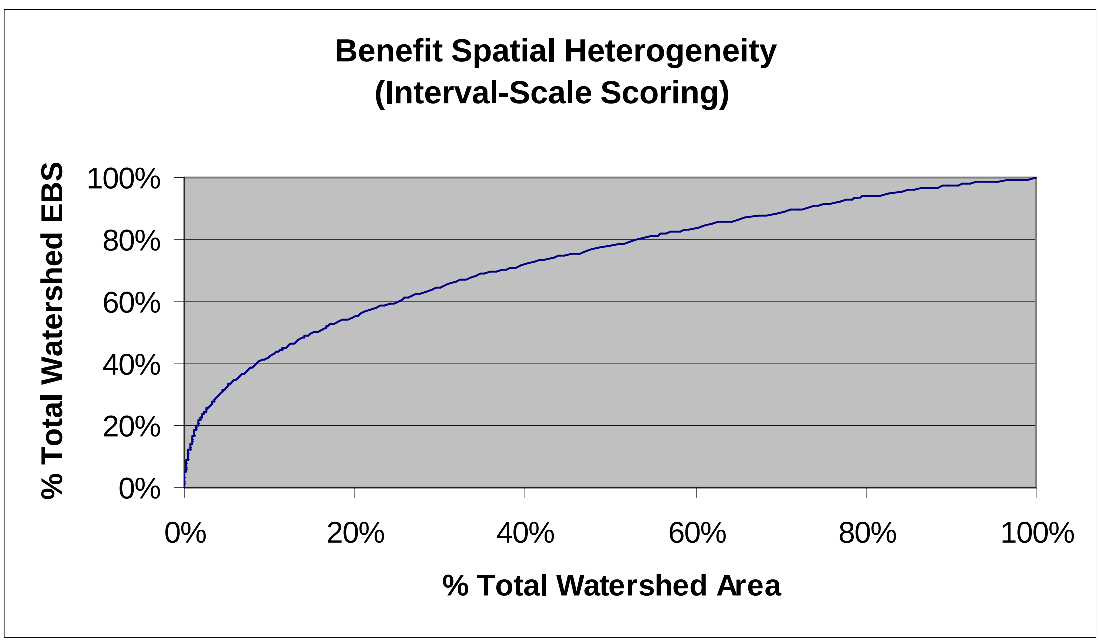

Figure 7. Benefit Spatial Heterogeneity (Interval-Scale Scoring)

[6] One can also represent relative variability by the coefficient of variation, which is the standard deviation divided by the mean. The greater the coefficient of variation, the greater the relative variability.

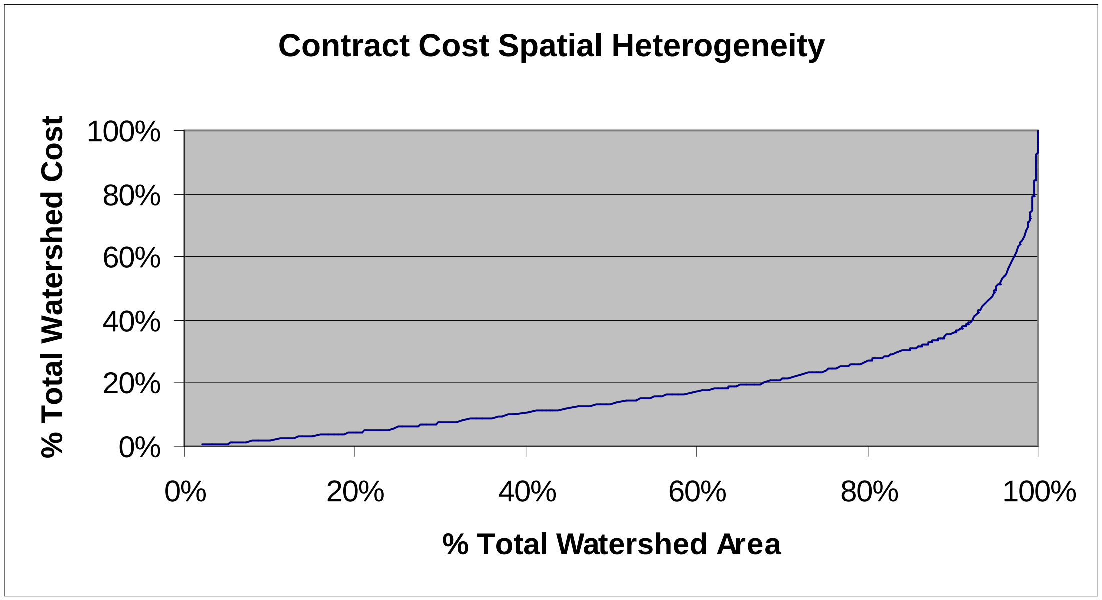

Figure 8. Contract Cost Spatial Heterogeneity

If Equation 1 perfectly captures the water quality benefits provided by a parcel, then the *E-max* portfolio derived above for any given budget is the optimal portfolio. Equation 1, however, is only one of many reasonable ways to estimate the relative environmental benefits generated on each parcel. I therefore consider two additional scoring functions: (1) a ratio-scale standardized scoring function and (2) a categorical scoring function. I introduce these scoring functions to demonstrate further that the degree to which the *E-max* approach is superior to the other targeting approaches is determined by the spatial correlation and variability of costs and benefits. In the second paper on targeting riparian buffer contracts, I introduce an alternative way to compare parcels that does not require weights on the biophysical attributes and a linear scoring specification (Ferraro 2001).

A ratio-scale standardized scoring function was considered by the City of Syracuse for use in its targeting efforts (see appendix for normalization). The ratio-scale scoring uses weights similar to that in Equation 1, but its form is different. Excluding the *Distance to Intake* weight, all the weights sum to one. Each parcel is then penalized for its distance from the intake (represented by a negative coefficient on *Distance to Intake*). All parcel scores are assumed to be greater than or equal to zero (a parcel that generates a negative score from the ratio-scale scoring function is scored as zero).

Environmental Benefit Score (EBS) = 0.27 *Acreage* + .27 *Priority Zone*
- 0.27 *Distance to Intake* + .33 *Acres of Hydrologically Sensitive Land* + 0.13 *Stream Length* (2)

Under Equation 2, the correlation between costs and benefit is positive and greater than in Equation 1: 0.21 versus 0.18. Cost variability has not changed because costs are not affected by the nature of the benefit function. As was done in Figure 7 for Equation 1, the spatial heterogeneity of benefits under Equation 2 can be expressed graphically (graph not pictured), and the area between the benefit curve and the 45ë line can be calculated. The estimated area under the curve in benefit-area space is 0.41. Thus the relative variability of benefits using Equation 2 is much greater than that observed under Equation 1. Although the cost-benefit correlation is slightly higher under Equation 2 in comparison to Equation 1, the benefit variability is far greater under Equation 2. One would therefore expect the *B-rank* and *A-rank* targeting approaches to perform relatively better in generating benefits per dollar expended than they did under Equation 1. This prediction is confirmed by the results reported in Table II.

The categorical scoring function is similar to what the U.S. Department of Agriculture uses in its Conservation Reserve Program (CRP). For each parcel, the CRP scoring system assigns points to a parcel's attributes. The total amount of points achievable for each attribute is determined by relative weights (e.g., up to 10 points can be awarded for proximity to wetlands and up to 15 points can be awarded for endangered species habitat). I use a similar point-scoring system for each land attribute listed in Equation 1. I separate each attribute into three or four categories (e.g., 0-10 acres, 11-50 acres, 50+ acres) and allow up to 300 total points to be allocated to each parcel. The maximum amount of points possible for each attribute is determined by the same weights used in Equation 1.

As reported in Table II, the correlation between benefits and costs increases slightly under the categorical scoring function in comparison to the correlation under Equation 1. This increase tends to make the *B-rank* and *A-rank* approaches perform worse. However, the benefit variability under the categorical scoring system is higher than the benefit variability under Equation 1 (0.28 versus 0.26). Greater relative benefit variability improves the performance of the benefit-ranking approach (*B-rank*). Although the increase in benefit variability is small, it counteracts the negative impact of increasing the positive correlation between benefits and costs.

VI. Conclusion

Policymakers and conservation practitioners in Georgia seek flexible tools that permit the integration of biophysical and economic data into cost-effective water quality protection plans. I empirically compare commonly used water quality investment approaches by using GIS data from a riparian easement contracting initiative in upstate New York. In this empirical application, I use data available to decision-makers, explicitly consider actual approaches used by decision-makers, and approach the problem at the geographic scale at which decisions are being made.

I demonstrate that efficient conservation investment, defined as conservation investment that achieves the greatest benefit per dollar expended, requires the simultaneous consideration of biophysical and economic data. Ignoring either costs or benefits can lead to ineffective conservation investments. The integration of biophysical and economic data is particularly important in the context of watershed protection because the level of environmental amenities and the costs of obtaining the amenities are likely to be positively correlated. The greater the positive correlation between environmental benefits and acquisition costs, and the greater the spatial variability of costs compared with the variability of benefits, the greater are the gains that can be realized by considering both costs and benefits when making decisions on where to place riparian buffers.

In a follow-up paper (Ferraro 2001), I consider the question that many natural resource agencies ask when faced with an environmental mandate: "What if we have no idea how much pollutant runoff would be removed by a given riparian buffer, or what if we are concerned with multiple pollutants (e.g., phosphorus, nitrogen, pathogens, chemicals)?" In the follow-up paper, I present a method for ranking the desirability of different land parcels by converting multiple biophysical and economic attributes into a one-dimensional measure of a land parcel's contribution towards the cost-effective achievement of environmental quality objectives.

Effective riparian buffer initiatives will incorporate biophysical and economic information to ensure that limited buffer acquisition funds generate as many water quality benefits as possible. Clearly, the design of riparian buffer initiatives requires consideration of issues other than simply evaluating the tradeoffs between benefits and costs across a watershed. These other issues include the best ways to design the physical features of the riparian buffers, to measure the benefits from different buffers, to negotiate contracts with landowners, and to monitor and enforce agreements over time. Georgian government and non-government organizations, however, are already acquiring riparian buffers. Simple advice that helps us spend our scarce conservation budgets more effectively can go a long way towards ensuring that we achieve the laudable goal of protecting Georgia's freshwater treasures, now and into the future.

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Appendix

A1. Attribute Normalization in Interval-Scale Scoring Equation (1)

In order that parcel attributes can be meaningfully compared to each other and that the units of measurement do not affect the scores, each attribute is scaled so that the least favorable observed value generates a score of zero and the most-favorable observed value generates a score of one. For example, the smallest parcel in the data set was .17 acres, and thus this parcel received a standardized score of zero for the acreage attribute. The largest parcel was 136 acres and thus received a standardized score of one for the acreage attribute. Intermediate values receive a standardized score based on the relative position between the high and low values:

$$Interval - Scale\, Score_{ij} = \frac{OBS_{ij} - Min_{ij}}{Max_i - Min_{ij}}$$

The standardized score of attribute *i* for parcel *j*, called an Interval-Scale Score, derives from subtracting the minimum observed value for the attribute from the observed value and dividing this number by the difference between the maximum and minimum values for attribute *i*. A standardized score of .33 for stream footage, for example, indicates that the parcel's stream length falls one-third of the way between the shortest stream length and the longest stream length. In Equation 1, more of any attribute is desirable to less. Since parcels *farther* in distance from the intake are considered *less* desirable for the EBS, we use (1-$Score_{distance,j}$) for this attribute; thus the *closer* the parcel is to the intake, the *higher* the standardized score for the *Distance to Intake* attribute.

A2. Attribute Normalization in Ratio-Scale Scoring Equation (2)

Each attribute is scaled so that the most-favorable observed value generates a score of one and every other parcel is compared to that parcel; i.e., for the *j*th parcel and the *i*th attribute,

$$Ratio - Scale\, Score_{ij} = \frac{OBS_{ij}}{MAX_i}$$