Cost-effective Targeting of Riparian Buffers in Georgia when Water Quality Benefits are Difficult to Measure

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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. Although few would disagree that conservation agencies need to stretch their limited budgets as far as possible, determining the "optimal" conservation investment across the landscape is made difficult by uncertainty in the estimation of environmental benefits emanating from a buffer on given piece of land.

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 cost data are likely to generate much greater environmental benefits per dollar expended than approaches that consider only biophysical or cost 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 second of two papers, I focus on how one can rank the efficiency of land parcels in contributing to environmental quality when the important biophysical attributes have been identified (e.g., distance from drinking water intake pipes), but the way in which the attributes combine to produce environmental amenities (e.g., water quality) is not known. I argue that there is often inadequate scientific information for specifying an appropriate function that converts multiple biophysical attributes (or multiple pollutants) into a one-dimensional environmental benefit value. In such circumstances, policymakers attempting to incorporate biophysical and economic data into the decision-making process would do well to consider a nonparametric, distance function-based targeting approach. The nonparametric approach performs well against three common parametric benefit function specifications, yields land portfolios that dominate portfolios derived under other targeting rules (in terms of the amount of desirable biophysical attributes under contract), and provides information in a form that is easy to understand and appropriate for a complex decision-making environment that cannot be completely modeled.

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.

Although the example above clearly shows the need for integrating cost and benefit information into the buffer targeting decision, many natural resource agencies are being asked to make decisions with limited data on the benefits from a establishing a buffer on a given piece of land. What if, for example, it is too costly to develop a sophisticated hydrologic model of the watershed in which Parcels A and B are located and we have no idea exactly how much pollutant runoff would be removed by a riparian buffer on each parcel?[1] In many cases, we may be able to describe the biophysical characteristics of a parcel, such as land use, size, slope, soil type and distance from water use zones. We may not know exactly the way in which these characteristics affect pollutant runoff in the absence or presence of a buffer, but we may know whether a biophysical characteristic has a positive or negative impact on pollution – for example, we may know that, all other things equal, steeply sloped lands are likely to have more runoff.[2] In other words, biophysical data on land parcels are often available and can be categorized as "desirable" or "undesirable." I present a method for 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.

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 introduce the use of distance functions for ranking land parcels for inclusion in a riparian buffer. In Section IV, I discuss various approaches that conservation agencies have adopted to guide their conservation investments. In Section V, I describe the case study riparian buffer initiative in New York, and, in Section VI, I present the results of the empirical analysis. In Section VII, I outline other advantages of the distance function approach to targeting conservation investments and, in Section VIII, I discuss extensions to the approach. In Section IX, I conclude the paper with a summary of the main findings of the analysis.

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[1] Or what if we are concerned with multiple pollutants (e.g., phosphorus, nitrogen, pathogens, and chemicals), but have no idea how to measure each pollutant's contribution to water quality problems?

[2] In the case of multiple pollutants, we may not know how they combine to affect "water quality," but we do know that less of these pollutants is better than more.

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 of 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).[3] 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 acquisition (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 green space 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 begin to examine alternative ways of targeting limited conservation budgets to maximize environmental gains.

[3] 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. Distance Function Approach to Targeting Riparian Buffers

In many conservation initiatives, the biophysical attributes that are important in contributing to the desired environmental amenity are largely agreed upon by practitioners and advising scientists. However, the way in which these attributes (e.g., riparian exposure, drainage area) combine to produce the desired objectives (e.g., reduced sediment loading) is not simply a source of disagreement, but rather completely unknown in many circumstances. Instead of trying to approximate the environmental benefits from each parcel through a specific benefit function, it may be more appropriate to target parcels based on their efficiency in "producing" the desired biophysical attributes.

In any conservation contracting initiative, one wants to assess the desirability of contracting one parcel relative to contracting the other available parcels. To compare parcels, we can treat each parcel as a production unit that converts input -- the money and resources that are expended to obtain a buffer on the parcel -- into multiple joint outputs -- the parcel's biophysical attributes that contribute to the conservation goal. In effect, we are treating each parcel as if it were a manufacturing plant that produces "biophysical attributes." In such an approach to targeting, we are only concerned with the ability of a parcel to offer us maximal joint output (i.e., the parcel's biophysical characteristics) per dollar expended to obtain the output. We are assuming that we have identified the important biophysical attributes and that we prefer more of the desirable attributes to fewer of them.[4]

Economists have developed "distance functions" to describe multi-input, multi-output production processes when prices for some or all of the inputs and outputs do not exist or are unknown, or the behavioral objective of the decision-maker is unknown. For example, distance

[4] If more information is known about the relative importance of each characteristic, that information can also be incorporated. See Section VII.

functions have been used to assess the efficiency of hospitals and schools. Unlike most private firms, hospitals and schools are often not run to maximize profits and their outputs often have no observable market prices. These organizations would, however, like to produce as much of their desired outputs as possible (e.g., treated patients, educated graduates) with their current budgets.

In the context of riparian buffer contracting, we know the biophysical attributes that are desirable, but we cannot put them into a mathematical function that spits out a number that represents “water quality.” Distance functions allow us to compare different parcels on the basis of how cheaply they can “produce” the desired attributes. In the context of our introductory example, we may have decided that, all other things equal, parcels that drain bigger areas, have greater surface exposure to stream, have greater areas of hydrologically sensitive land (e.g., steeply sloped, highly erodeable land) and are closer to drinking water intakes are more desirable for establishing a riparian buffer. If we know that Parcel A drains 45 acres, has 900 feet of stream footage, has 15 acres of hydrologically sensitive land and is 1.4 miles from a drinking water intake pipe and we have similar information on Parcel B, we can use the distance function method to rank the two parcels based on how well each “produces” the desirable biophysical characteristics given the costs of acquiring a buffer on each parcel.

The productivity of a parcel in producing the desired biophysical attributes given its contracting cost can be measured by an input distance function. A land attribute “production frontier” is estimated through nonparametric programming methods. This may sound more complicated than it is. Suppose that there is only one biophysical attribute that we care about: stream footage (i.e., the number of linear feet of the parcel that touches surface water). Clearly we do not need to use a distance function to figure out which parcels give us the most stream footage per dollar spent; we just divide the steam footage of each parcel by its cost. We start with one attribute, however, because it will make it easier to understand how we construct a "production frontier."

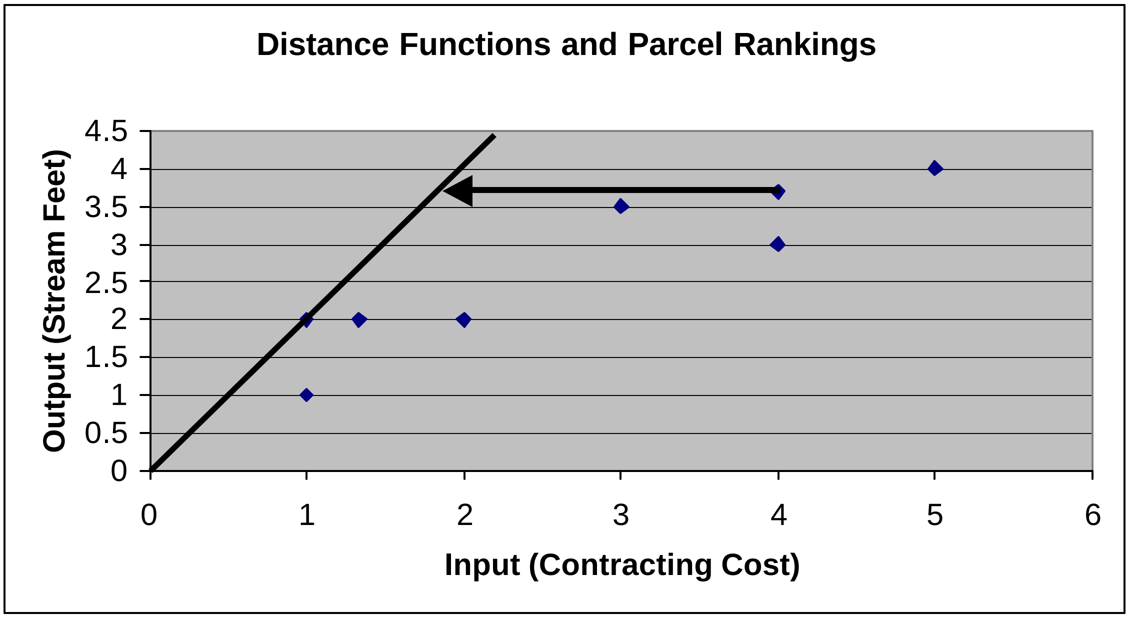


Figure 1. Distance Functions and Parcel Rankings

In Figure 1, each diamond represents one of eight parcels. Each is placed on the graph according to its cost and the stream footage it offers. The closer the parcel is to the vertical axis, the more steam footage per dollar the parcel offers. The parcel with a cost of $1 and two feet of stream exposure is the most productive parcel in that it offers the most stream footage per dollar spent. We can construct a "frontier" that establishes the maximum amount of stream footage per dollar that our set of eight parcels can produce. This frontier is represented by the dark straight line through the point (1,2). We can then rank each parcel by measuring its distance, in terms of cost, from the frontier. The further a parcel is from the frontier, the less desirable the parcel is (i.e., the less stream footage per dollar it can offer). For example, the parcel (4,3.7) sits a distance of 2.1 units from the frontier (in contract cost dollars), while the parcel (2,2) sits only 1 unit from the frontier. Parcel (2,2) is thus more desirable (you can check this by calculating the stream footage per dollar spent for each parcel).

The same sort of analysis that is represented by Figure 1 in two-dimensional space can be done in multiple dimensions. Using programming methods, one can place a frontier over the observed land parcels in the input-output space such that all parcels either lie on the surface of the cone or beneath it.[5] Parcels can be ranked based on relative cost-efficiency by considering their distance from the frontier. The most cost-efficient parcels are located on the frontier. Parcels not on the frontier are termed inefficient and their input distance measure provides a summary measure of the inefficiency, which, in the conservation contracting case, is the reduction in the contract cost required to put the parcel on the efficient frontier. One can incorporate as many attributes and costs as required.[6]

Using well-known nonparametric programming methods (Charnes et al. 2000), we will estimate a distance measure, θ, for each parcel. The distance measure θ will be less than or equal to one, with a value of one indicating that the parcel is on the frontier. In Figure 1, the point (1,2) yields a distance measure of $\theta = 1$ and is classified as "efficient." The remaining parcels, which are not on the frontier, are classified as "inefficient" and yield a distance measure that indicates the minimal reduction in contract cost required to project the parcel onto the frontier. For example, the parcel with coordinates (4,3.6) can be projected onto the frontier if the contract cost were reduced by a factor of $(1-\theta) = (1- 0.45) = 0.55$, or $1.62. The projected point is therefore (1.98, 3.6) and $\theta = 0.45$ indicates that the parcel is "45% of the way to the frontier." Parcels are ranked from the highest value of θ to the lowest.

[5] Technically, we place a linear, faceted conical hull (convex cone) over the land parcel cost and biophysical attribute combinations.

[6] One can define inputs more broadly to include costs about which a contracting agency is concerned but which cannot be easily converted into a dollar figure; for example, lost forestry jobs when old growth forest is protected from logging.

By using an input-oriented distance measure, we obtain an efficiency measure that is useful to a contracting agency that must negotiate with landowners: the distance function allows negotiators to evaluate the change in a parcel's relative ranking if the estimated contract cost changes during site visits and negotiation (see Section VII). The input distance θ also has the desirable property that the efficiency measure is units invariant (e.g., if one decides to measure stream footage in meters rather than feet, the distance measure does not change). In the next section, I describe the different targeting approaches that are empirically evaluated in Section V.

IV. 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 their 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 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. I will compare the *B-rank*, *E-max*, *A-max* and *A-rank* approaches to the distance function approach, which is referred to as *Nonparam*. The five possible targeting approaches are summarized in Table I.

Table I – Possible Targeting Approaches

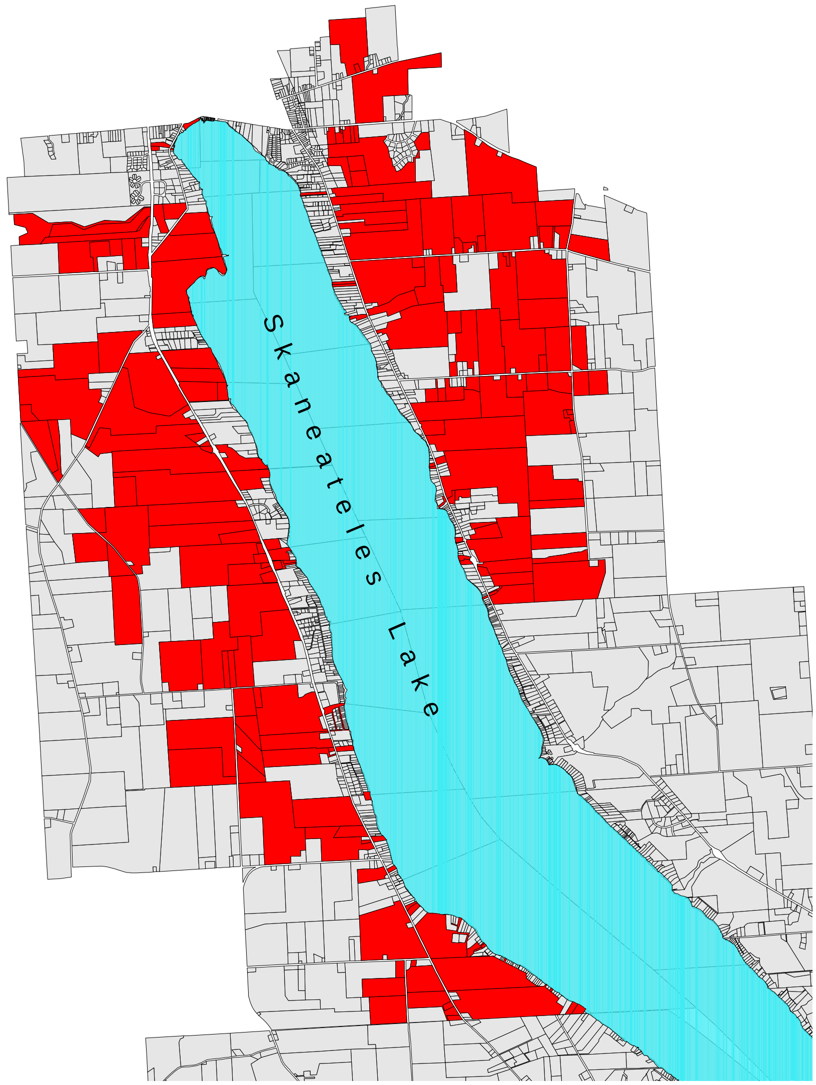
Approach	**Method of Ranking Parcels from Most Desirable to Least Desirable**
E-max (cost-effective targeting using scoring function)	By benefit to cost ratio of each parcel ($\frac{w_i}{c_i}$)
B-rank ("crown-jewel" targeting)	By total benefits of each parcel (w_i)
A-max ("cheap land" targeting)	By acreage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

V. Case Study: Lake Skaneateles Watershed Management Plan

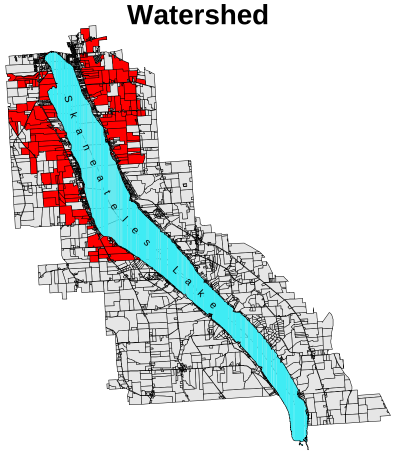
a. Location and Initiative

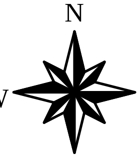
The City of Syracuse, New York (population 163,860) obtains its drinking water from Lake Skaneateles, which is 20 miles away and outside of the City's regulatory jurisdiction. The lake, pictured in Figure 2, is 16 miles long, less than one-mile wide on average, and has a 60 square mile watershed that covers three counties, seven townships, and one village. The population of the watershed is about 5000 residents, concentrated largely in the northern half of

Figure 2: Upper Skaneateles Lake Watershed



Skaneateles Lake Watershed





Map Legend

- Riparian Parcels
- Skaneateles Lake
- Other Watershed Parcels

Map Information

Data Sources:
Department of Water,
City of Syracuse
(Unprojected)

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 2). 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.[7] 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). The panel was able to agree that five biophysical attributes were important

[7] The exceptions were small, inexpensive parcels for which a change in transaction costs could have a large relative impact on contract cost.

in contributing to the City's policy objective, but they were not able to agree on the way in which the attributes combine to affect water quality.

In order to estimate the benefits from an individual land parcel, Syracuse policymakers ended up doing what many conservation groups and academic scientists have done (see, for example, Voogd 1983): they created an index for each parcel based on its biophysical attributes. Such indices are most often constructed through weighted linear functions of the attributes or by assigning points to each parcel based on the magnitude of its attributes. 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).

With the panel's assistance, the Department chose the following weighted linear function that assigns a score to each parcel:

$$\textbf{Environmental Benefit Score (EBS)} = 0.2\ \textit{Acreage} + 0.2\ \textit{Priority Zone} + 0.25\ (\textit{Distance to Intake})^{-1} + 0.25\ \textit{Acres of Hydrologically Sensitive Land} + 0.1\ \textit{Stream Length} \quad (10)$$

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 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-scale scoring equation. Two other scoring methods are also considered and are explained below.

VI. 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 3 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 distance function approach, *NonParam*, tracks the *E-max* curve quite closely, while the acreage-maximization approach, *A-max*, does a fair job of generating environmental benefits in a cost-effective manner. The two ranking approaches, *B-rank* and *A-rank*, perform poorly under most budgets. For example, with a budget of about $2.7 million, the *E-max* approach achieves 62% of the total benefits, while the *NonParam* approach achieves 51%, 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 4-8. Table II illustrates the overlap among the parcels chosen by each approach in percentage terms. Under a budget of about $5 million, the *E-max* approach achieves 85% of the total benefits, while the *NonParam* approach achieves 84%, 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*.

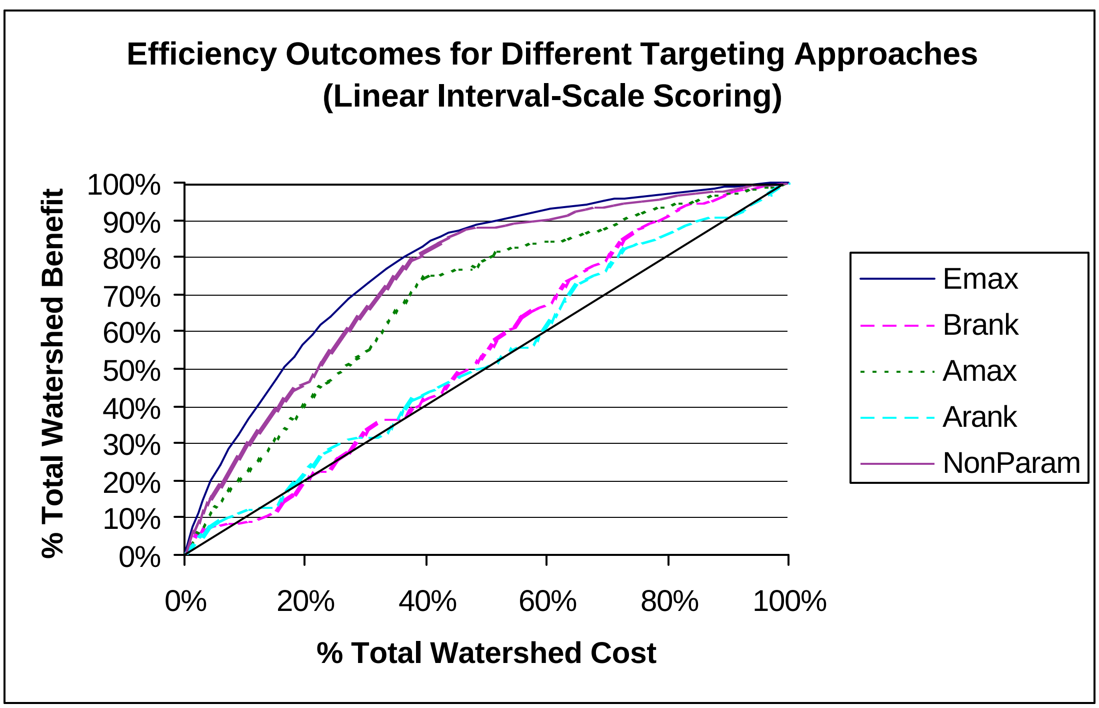
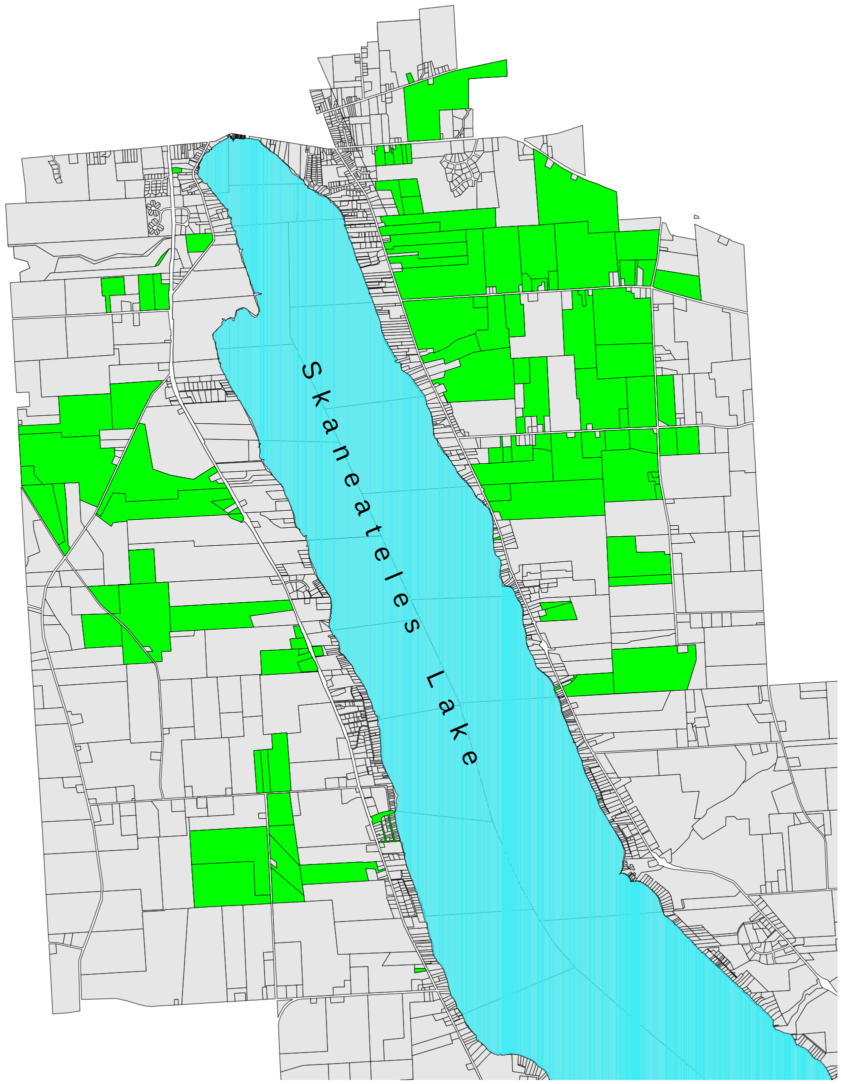
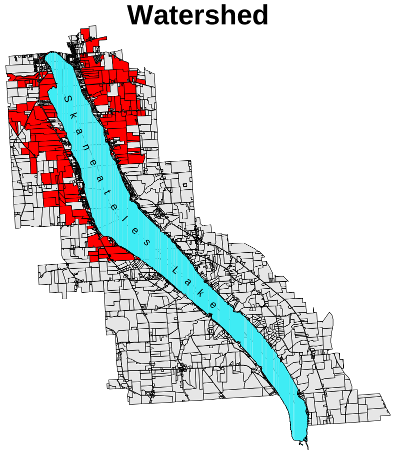


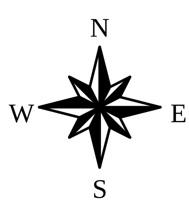
Figure 3. Efficiency Outcomes for Different Targeting Approaches (Linear Interval-Scale Scoring)

Figure 4. Contracted Portfolio, E-max ($2.6 Million)



Skaneateles Lake Watershed





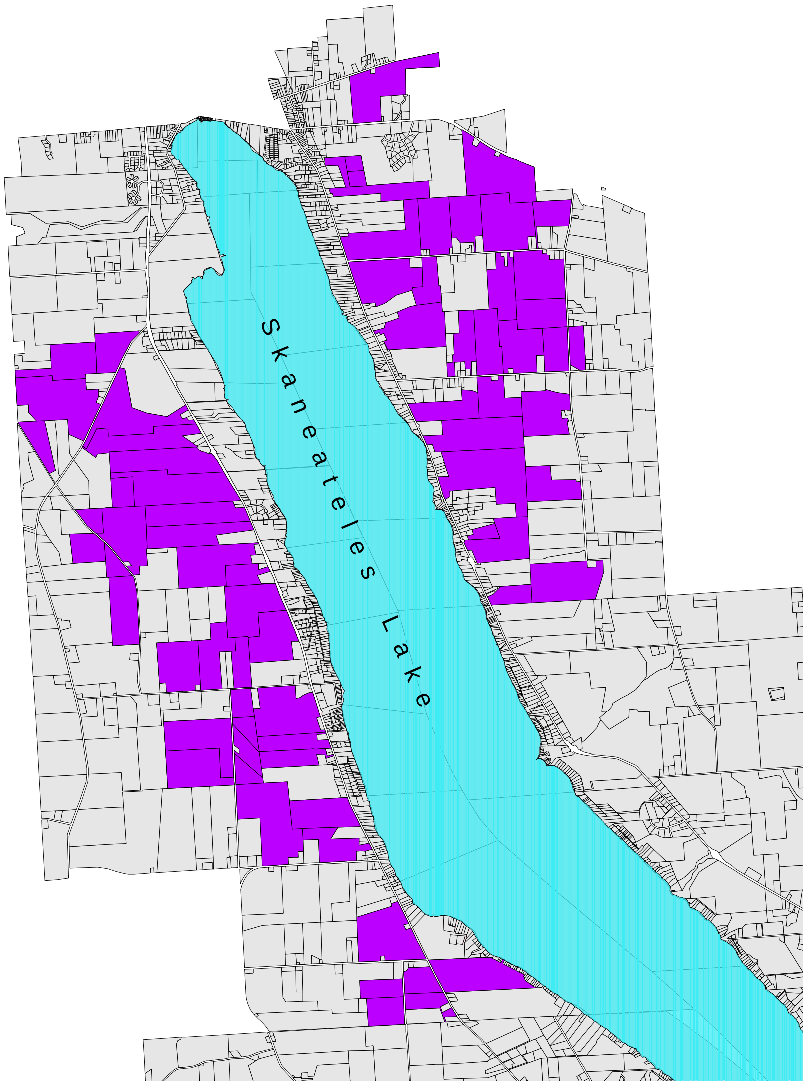
Map Legend

- Parcel Acquired
- Skaneateles Lake
- Other Watershed Parcels
- Riparian Parcels

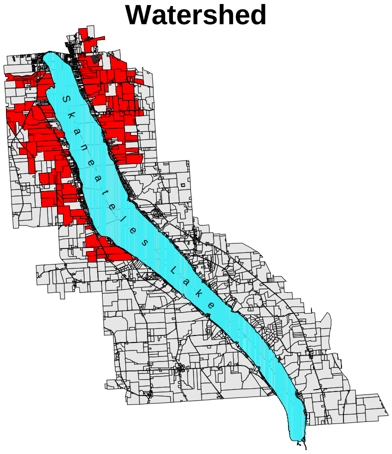
Map Information

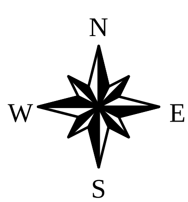
Data Sources:
Department of Water,
City of Syracuse
(Unprojected)

Figure 5. Contracted Portfolio, A-max ($2.6 Million)



Skaneateles Lake Watershed





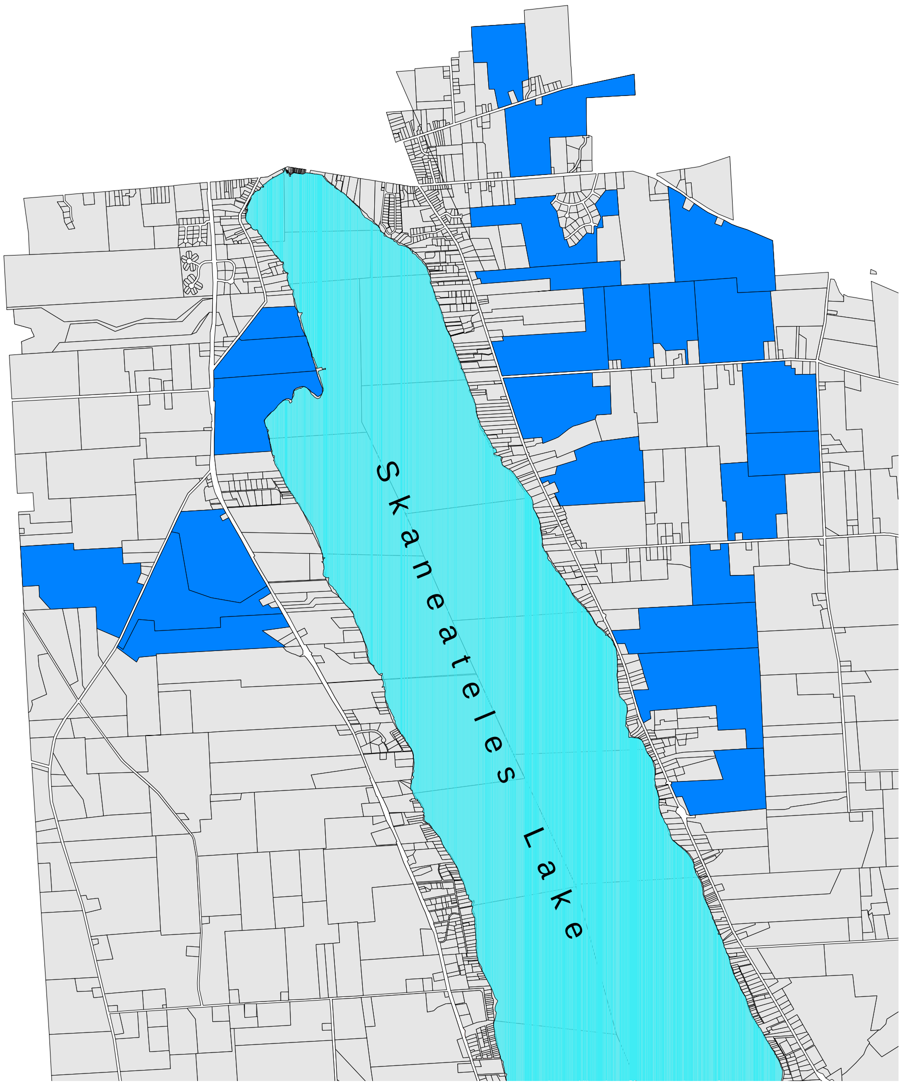
Map Legend

- A-max Portfolio
- Skaneateles Lake
- Other Watershed Parcels
- Riparian Parcels

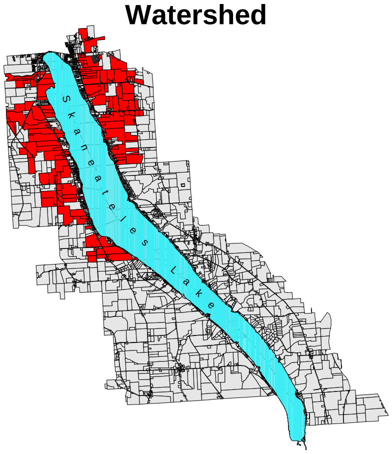
Map Information

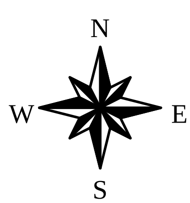
Data Sources:
Department of Water,
City of Syracuse
(Unprojected)

Figure 6. Contracted Portfolio, B-rank ($2.6 Million)



Skaneateles Lake Watershed





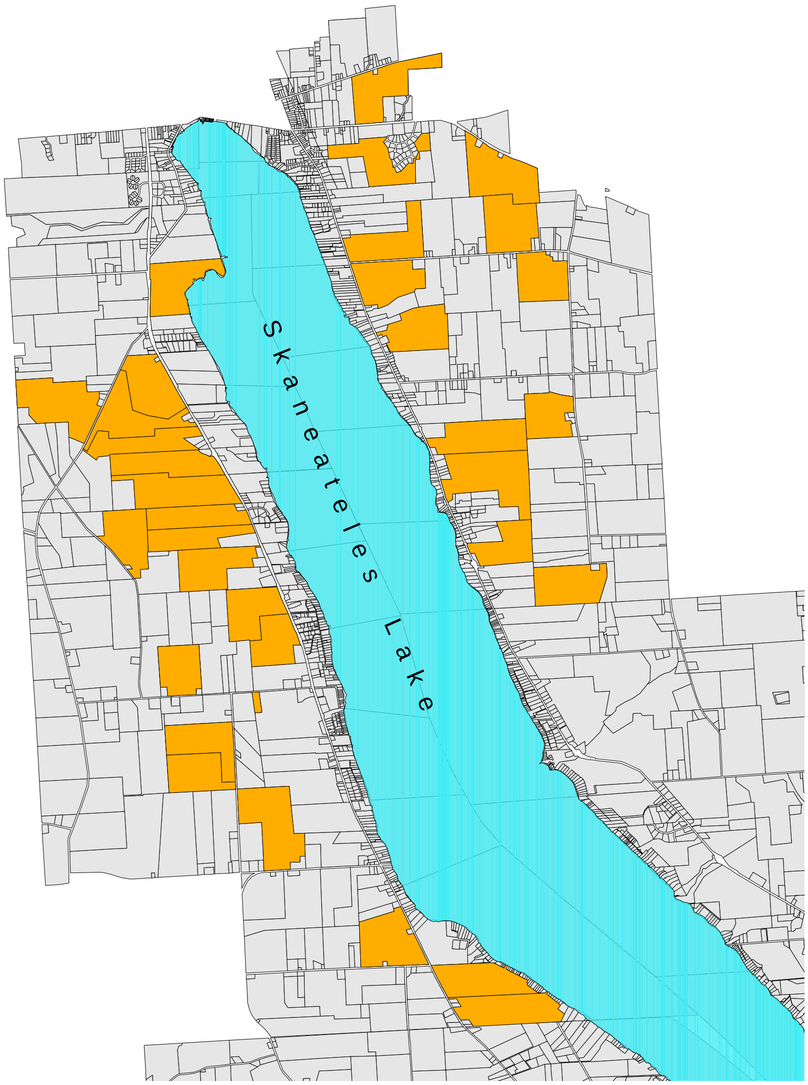
Map Legend

- B-rank Portfolio
- Skaneateles Lake
- Other Watershed Parcels
- Riparian Parcels

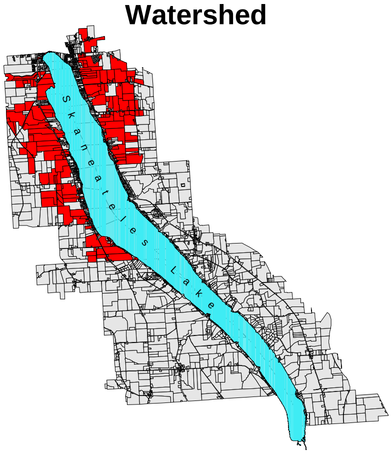
Map Information

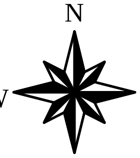
Data Sources:
Department of Water,
City of Syracuse
(Unprojected)

Figure 7. Contracted Portfolio, A-rank ($2.6 Million)



Skaneateles Lake Watershed





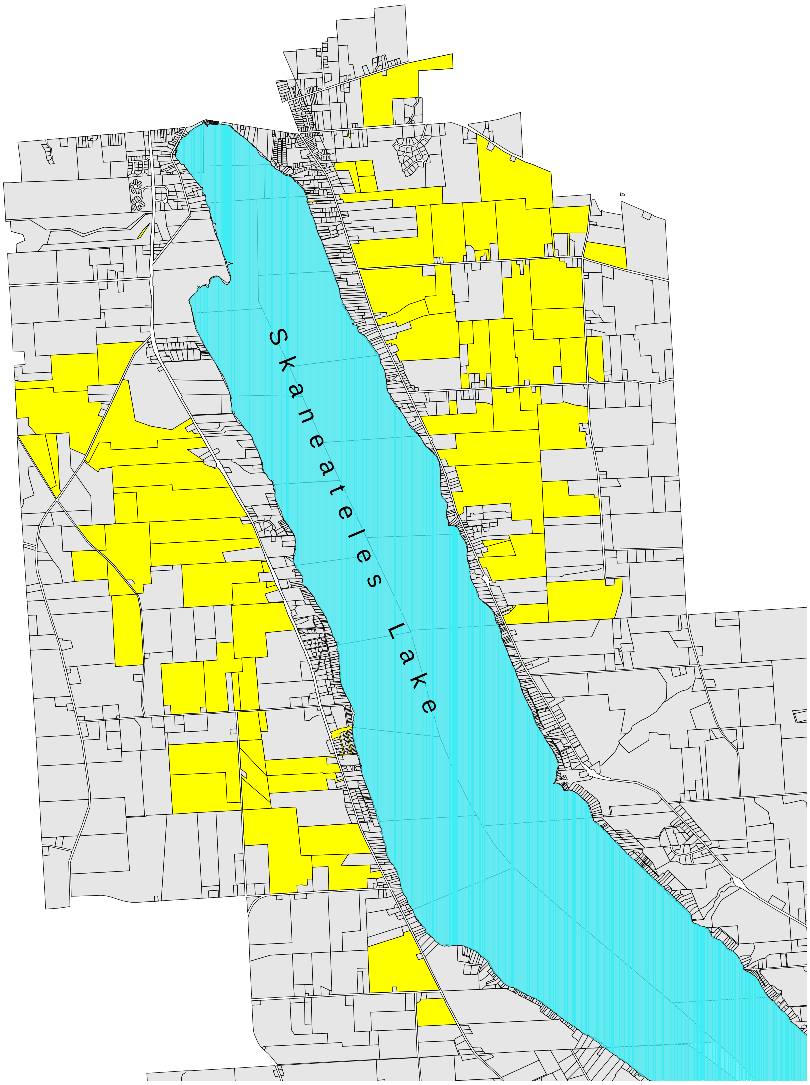
Map Legend

- Skaneateles Lake
- A-rank Portfolio
- Other Watershed Parcels
- Riparian Parcels

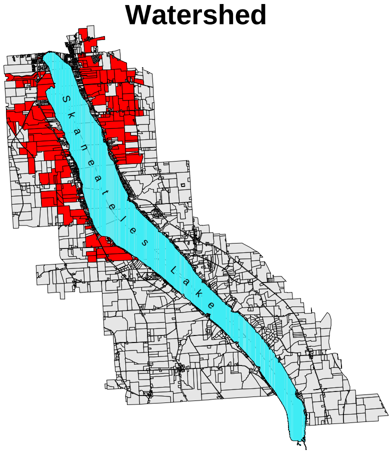
Map Information

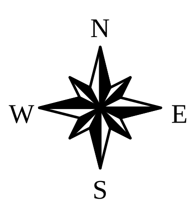
Data Sources:
Department of Water,
City of Syracuse
(Unprojected)

Figure 8. Contracted Portfolio, Nonparam ($2.6 Million)



Skaneateles Lake Watershed





Map Legend

- Nonparam Portfolio
- Skaneateles Lake
- Other Watershed Parcels
- Riparian Parcels

Map Information

Data Sources:
Department of Water,
City of Syracuse
(Unprojected)

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

	E-max	*A-max*	*B-rank*	*A-rank*	*Nonparam*	*NonParam* Coverage	*E-max Coverage*
E-max	113	50	17	17	67	59%	100%
A-max		73	19	30	68	93%	69%
B-rank			25	16	19	76%	68%
A-rank				34	28	82%	50%
Nonparam					85	100%	79%

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 column labeled "Interval-scale" 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. For explanations of why the *B-rank* and *A-rank* approaches perform so poorly in comparison to the other approaches, see Ferraro (2001).

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 that the satisfactory performance of the distance function approach (*Nonparam*) is robust to alternative ways of measuring environmental benefits.

Table III. Areas under Curves in Benefit-Cost Space

Targeting Approach	**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%
Nonparam	0.48	0.57	0.48
Nonparam Efficiency (% Emax)	87%	88%	90%

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).

$$\textbf{Environmental Benefit Score (EBS)} = 0.27\ \textit{Acreage} + .27\ \textit{Priority Zone} - 0.27\ \textit{Distance to Intake} + .33\ \textit{Acres of Hydrologically Sensitive Land} + 0.13\ \textit{Stream Length} \quad (2)$$

In the column labeled "Ratio-scale" in Table II, I present efficiency results of the different targeting approaches under the assumption that equation 2 accurately measures environmental benefits from buffers on each parcel in the watershed (as was done for equation 1). The distance function approach continues to perform well.

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. In the column labeled "Categorical" in Table II, I present efficiency results of the different targeting approaches under the assumption that categorical scoring method accurately measures environmental benefits from buffers on each parcel in the watershed.

More insights into the relative performances of the five targeting approaches can be obtained by comparing land portfolio characteristics generated for each approach at a given budget level. For purposes of illustration, I choose a budget of $2.7 million and summarize the portfolio characteristics in Table IV. The qualitative results are maintained over all budget levels.

In almost all of the attribute categories,[8] the distance function-based approach, *NonParam*, dominates the other portfolios, including the "optimal" *E-max* approach.[9] In terms of average parcel distance from the intake pipes, the *NonParam* portfolio is slightly higher than the *E-max* and *B-rank* portfolios, but lower than the two acreage-oriented portfolios. The *NonParam* portfolio also requires fewer contracted parcels than the *E-max*, which was considered desirable by the City of Syracuse policymakers. Furthermore, recall from Table II that a greater overlap exists between the *NonParam* and ranking portfolios than between the *E-max* and ranking portfolios. For practitioners and policymakers accustomed to using benefit-ranking targeting approaches, a greater overlap between the cost-efficient portfolio and the

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[8] Although acres of riparian buffer are considered important to reducing pollutant loading, the area that is drained (*Acreage*) and the amount of exposure a parcel has to surface water (*Stream Feet*) are more important and are highly correlated with acres of buffer. Thus, the scientific panel did not include acres of riparian buffer in the parcel scoring equation.

[9] Not surprisingly, *Amax*, which attempts to maximize acreage per dollar spent, dominates in acreage, but by less than 100 acres. As the budget increases, the difference in acreage shrinks (e.g., at $5 million, the approaches differ by less than 25 acres).

traditionally targeted portfolio will make for easier acceptance of cost-efficient conservation targeting.

Table IV. Portfolio Characteristics

Interval-Scale Scoring Equation (Budget = $2.68 million)							
	%Total EBS	*StreamFT*	*Acres*	*AcHSL*	*AcBuff100*	*AvDistMi*	*Parcels*
E-max	62%	177,3010	3034	1041	398	2.04	112.5
B-rank	22%	92,022	1953	771	224	1.59	24.7
A-max	44%	188,122	4204	1136	437	2.70	72.3
A-rank	26%	118,817	3054	815	283	2.56	33.8
Non-Param	51%	205,722	4112	1193	470	2.40	84.7

Ratio-Scale Scoring Equation (Budget = $2.68 million)							
	%Total EBS	*StreamFT*	*Acres*	*AcHSL*	*AcBuff100*	*AvDistMi*	*Parcels*
E-max	72%	185,509	3309	1134	422	1.77	86.9
B-rank	41%	103,941	2178	833	250	1.68	28.2
A-max	56%	188,122	4204	1136	437	2.70	72.3
A-rank	39%	118,817	3054	815	283	2.56	33.8
Non-Param	66%	205,722	4112	1193	470	2.40	84.7

Categorical Scoring Equation (Budget = $2.68 million)							
	%Total EBS	*StreamFT*	*Acres*	*AcHSL*	*AcBuff100*	*AvDistMi*	*Parcels*
E-max	61%	183,066	3010	983	411	2.09	112.1
B-rank	26%	94,888	2078	753	232	1.52	29.1
A-max	45%	188,122	4204	1136	437	2.70	72.4
A-rank	26%	118,817	3054	815	283	2.56	33.8
Non-Param	56%	205,722	4112	1193	470	2.40	84.7

The *NonParam* approach, by virtue of its ability to achieve maximal attributes at minimal cost, is likely to be cost-efficient across many plausible scoring functions.[10] An *E-max* portfolio

[10] The ability to perform well under many plausible benefit functions may be facilitated by the positive correlation among attributes, but simulations using constructed data for which the heterogeneity of and correlation among

chosen under one scoring method, however, may not remain cost-efficient if its parcels' *true* (unobserved) environmental values are reflected best by another scoring method. For example, consider using the ratio-scale scoring Equation 2 to generate an *E-max* portfolio for a given budget level. Now imagine that the interval-scale scoring Equation 1 is really the more accurate scoring method. Does the *E-max* portfolio I chose using Equation 2 still perform best at every budget level when all parcels are scored by Equation 1? As one can see in Figure 8, the portfolios derived under the *NonParam* approach can be superior to the *E-max* portfolios when all parcels are scored by Equation 1. Moreover, Equation 12 attributes scores of zero to some parcels, which ensures that they are never part of the *E-max* portfolio at any budget. The *E-max* portfolio thus cannot achieve the total benefits available in the watershed.

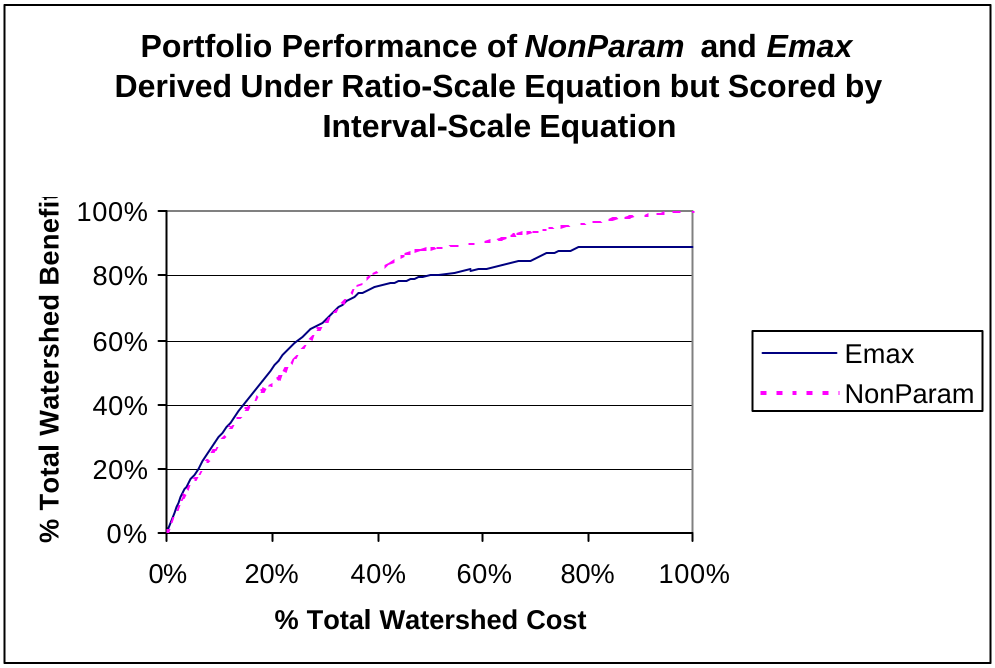

Figure 8. Portfolio Performance of *NonParam* and *Emax* Derived Under Ratio-Scale Equation but Scored by Interval-Scale Equation

attributes can be altered suggest that the moderate amount of attribute heterogeneity across the landscape may be more important than the positive spatial correlation among attributes.

VII. Other Advantages of the Nonparametric, Distance Function-based Targeting Approach

Prendergast et al. (1999) note that despite decades of research on conservation targeting, mainly by biologists, practitioners have not adopted sophisticated targeting methods. They argue that practitioners often have a "general antipathy toward what is seen as a prescriptive approach to conservation….(p.484)." The *E- max* approach tends to generate results that practitioners perceive as too prescriptive, and it does not allow practitioners to easily compare parcels relative to one another. The *E-max* approach generates rankings in units of EBS divided by contract cost, a measure not easily interpreted when the EBS is an artificial index. In contrast, the distance function approach generates rankings in terms of contract costs, which are more easily understood. Moreover, the concept of maximizing artificial index numbers is not easily communicated, whereas the concept of trying to obtain as many of the desirable biophysical attributes as possible given a fixed budget is clearer. Furthermore, the distance measures allow for more intuitive categorizations of parcels by comparing all parcels to a reference set of efficient parcels.

The distance function approach also has advantages in conservation initiatives, including the Lake Skaneateles program, in which no mechanism exists to simultaneously elicit all landowners' bid prices for accepting a conservation contract on their land (e.g., procurement auction). Practitioners often use two cost discovery methods: (1) wait for a landowner to express interest in a conservation contract and then negotiate over the contract price (often the approach used by land trusts); or (2) estimate *ex ante* the likely willingness-to-accept of each landowner and then negotiate with landowners sequentially by parcel rank. Thus, practitioners often need a way of assessing the implications of new information on contract costs without having to continually update and re-solve a programming model. I argue that the results from the distance function-based approach are easier for practitioners to adapt in the field and will lead to more accurate conservation targeting.

Assume, for example, that the contracting budget is $2.7 million and consider Parcel A that is in both the *E-max* solution for Equation 10 and the *NonParam* solution. A riparian easement on Parcel A is estimated to cost $12,000. Now assume that, after negotiating with the landowner, the contracting agent has discovered that the contract cost is higher than originally estimated. To consider a contract cost change in the *E-max* approach, one would need to minimize the portfolio contracting cost subject to a portfolio EBS target in order to derive the allowable increases and decreases in contract cost under which the current basis remains optimal.[11] The minimization procedure reveals that the contract cost could increase by as much as $15,985 without a change in the optimal basis.

Using the distance function approach, the contracting agent would know that Parcel A was 96% of the way to the frontier (θ=0.96). Through simple arithmetic,[12] the agent can calculate that if the contract cost of Parcel A were to increase by $15,985, the parcel would move away from the frontier to a point about 41% of the way to the frontier. In this case, ten other parcels that formerly were not part of the solution would have higher efficiency scores and would be considered preferable to Parcel A. When more than one contract cost changes, the ease with which relative rankings can be updated using the distance function approach is even more important.[13]

[11] Practitioners may not even understand what the results of this minimization procedure imply.
[12] Divide the parcel's "target" cost of (0.96*$12,000) = $11,520 by the new contract cost of $27,985.
[13] This statement assumes that no parcel becomes less expensive enough to greatly transform the surface of the frontier. Such a transformation is most likely to occur with changes in contract costs for parcels found close to the frontier and near the area of increasing returns to scale on a <u>convex</u> hull over the data. It is in this area of the attribute-cost space that small absolute changes in contract costs can have a large impact on a parcel's relative

VIII. Extensions

A nonparametric programming approach to targeting has the advantage that only the biophysical attributes of the landscape need be considered. Knowledge about the way in which the attributes combine to produce the desired environmental amenities is not needed. What if, however, practitioners and scientists have some knowledge about the relative importance of the different attributes in contributing to the environmental objective?

A priori knowledge can be incorporated into the nonparametric programming approach through the use of constraints on the multipliers, which are typically only restricted to be non-negative. Restrictions on the multipliers will alter the surface of the frontier and thus alter the estimated efficiencies of the parcels. Proposed techniques for implementing multiplier restrictions include placing upper and lower bounds on individual multipliers (Dyson and Thanassoulis 1988; Roll et al. 1991); imposing bounds on the ratio of multipliers; appending multiplier inequalities (Wong and Beasley 1990); and requiring multipliers to belong to given closed cones (Charnes et al. 1989, 1990).

The classification of "Priority Zone" as an output in the distance function targeting approach may strike some readers as objectionable. An alternative way of dealing with a variable like *Priority Zone* is to treat it as a categorical variable that partitions the set of parcels. Specifically, the set of decision-making units $D = \{1,2,\ldots,N\} = D_1 \cup D_2 \cup \ldots \cup D_L$ where $D_k = \{i | i \in D$ and category value is $k\}$ and $D_j \cap D_k = 0$, $j \neq k$. Each parcel is evaluated with respect to the frontier determined for the units contained in its category and all preceding categories. It is not difficult to specify a model that allows a decision-maker to evaluate all units $l \in D_1$ with

position in attribute-cost space. The parcels in such areas can easily be identified *ex ante* through a modification of the original programming model.

respect to the units in D_1, all units $l \in D_2$ with respect to the units in D_1 (D_2, and so on. Of course, this approach rests on the assumption that there is a natural nesting or hierarchy of the categories, but this is exactly what the priority zones are about. We would want to compare all Zone A (high pressure-high use) parcels with Zone A parcels, all Zone B parcels with Zone A and Zone B parcels, etc. Note, however, that if we remove *Priority Zone* as an output, six of the eight original efficient parcels fully define the frontier, the efficiency scores of ninety parcels do not change, the scores of one hundred and thirty-one parcels change by less than 0.01, and the scores of one-hundred and seventy-five parcels change by less than 0.05. Not one score increases.

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. In many circumstances, however, measuring the environmental benefits of different land parcels may be difficult. Environmental agencies may ask: "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)?"

I demonstrate that in the absence of a widely agreed upon specification for an environmental benefit function, policymakers may do well to consider a non-parametric distance function-based approach to conservation targeting. The distance function approach to conservation targeting ranks 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. The distance function approach has a strong potential to make cost-efficient conservation targeting more effective and more attractive to decision-makers.

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. Methods that help 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-$\text{Score}_{\text{distance},j}$) 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 (14)

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,

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