ABSTRACT

Title: USING PREDICTED MARKET VALUES FOR ECOLOGICALLY VALUABLE NATURAL LANDS IN LAND PRESERVATION PROGRAM OPTIMAL TARGETING SCHEME: APPLICATION TO MARYLAND'S GREENPRINT PROGRAM

Karen J Palm, Masters Degree in Agricultural and Resource Economics, 2005

Directed By: Loretta Lynch, Associate Professor, Department of Agricultural and Resource Economics

Thirty-eight U.S. states have programs to preserve land with ecological value yet few consider land acquisition costs in their selection criteria although targeting could improve the efficiency of these programs. To demonstrate this, a hedonic model is estimated on land characteristics including those that contribute to ecosystem services from recent arms' length market transactions. The estimated parameters are used to predict market values of parcels greater than 10 acres in three southern Maryland counties. The study compares targeting packages developed through overall benefits optimization, specific benefits optimization, and acreage optimization subject to projected budgets. The results suggest including market values permits Maryland's GreenPrint program, designed to protect ecologically valuable land, to preserve more acreage among parcels rated "excellent" for ecological characteristics. Comparing unconstrained parcel choice sets with the study's three county, unimproved parcel,

and 100+ acre parcel constraints highlights the benefits of developing targeting packages from unconstrained parcel choice sets.

USING PREDICTED MARKET VALUES FOR ECOLOGICALLY VALUABLE NATURAL LANDS IN LAND PRESERVATION PROGRAM OPTIMAL TARGETING SCHEME: APPLICATION TO MARYLAND'S GREENPRINT PROGRAM

By

Karen J Palm

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Masters in Agricultural and
Resource Economics
2005

Advisory Committee:
Professor Loretta Lynch, Chair
Professor Nancy Bockstael
Professor Erik Lichtenberg

Dedication

This thesis is dedicated to my parents, Paul and Mary Palm, for their ceaseless enthusiasm for my education through the years. This is also dedicated to my husband, Jason, who selflessly let me pursue my dream of a graduate education at the best resource economics school in the country.

Acknowledgements

This thesis truly would not have been possible without the dedication and guidance of my advisor, Dr. Lori Lynch. I am indebted to her for her time, her guidance, her suggestions, her understanding, and her encouragement. Her belief in my abilities as an economist and her success as a female economist in a male-dominated field have had a profound effect on my professional life. Thank you.

Table of Contents

List of Tables and Figures

Chapter 1: Introduction

Land conservation programs that preserve lands with ecological value can be found throughout the United States. At least 38 of the nation's 50 states have statewide land conservation programs (The Resources Agency of California, 2004). For example, Arizona implemented the Arizona Preserve Initiative in 1996. This program is designed to encourage preservation of select parcels for long-term benefits to humans and conservation of unique resources such as scenic beauty, wildlife, and plants. Maine's land preservation program, Land for Maine's Future, protects lands with exceptional natural or recreational value. Some 139,000 acres have been acquired, with another 53,000 acres in conservation easements. The Open Space Conservation Plan is New York State's comprehensive blueprint for land conservation. The program's goals include water quality protection, habitat protection, maintenance of wood products and fisheries industries, and open space preservation. The Florida Forever program's goals include restoration of damaged environmental systems, water resource supply, and increased protection of land through acquisitions and easements. This program builds on the Florida Preservation 2000 program, which preserved over 1.2 million acres in Florida.

The results of ballot initiatives in November 2003 across the country show strong support for land conservation programs. According to the Trust for Public Land (2004), 79 percent of local and state conservation ballot measures were approved in the November elections. Over $1.2 billion in funding was generated through these ballot initiatives alone for parks, open space, and farmland preservation.

To ensure ongoing public support for and funding of these preservation programs, the public's money could be directed most efficiently to achieve the greatest benefits from these preservation programs. In general, however, land conservation programs do not include land acquisition costs as a key element in their ranking and targeting protocols, though it is not clear why project costs are often omitted from program decision measures. For example, the Florida Forever program lists 38 performance measures by which potential projects are evaluated, but does not address project cost at all.

In the literature, economists have suggested that land values or land acquisition costs should be considered in addition to ecological benefits when targeting lands for ecological benefits or species conservation. Ando et al (1998) take land prices into account through county-level agricultural land values when selecting biological reserves for species conservation. They find that, even through county-level land values, it is important to consider economic factors in addition to ecological factors for efficient species conservation. Polasky, Camm, and Garber-Yonts (2001) use assessed land market values to demonstrate the relevance of including land cost differences in conservation decisions, though they caution that assessed land values are not always the same as market values.

This thesis focuses on potential improvements generated by employing alternative maximization techniques that incorporate predicted parcel market values based on recent arms-length transactions when ranking and targeting under a land conservation program. The methodology utilized to generate distinct targeting packages under various budget scenarios can be applied to any land conservation program. In the thesis, I specifically study one of Maryland's land preservation programs, GreenPrint. This program does not currently include land acquisition costs in the program's rankings.

The GreenPrint program, established in 2001, is designed to protect the most valuable remaining ecological lands in Maryland through land acquisitions and purchase of conservation easements. The Maryland Department of Natural Resources has identified two million acres of prime habitat that it would like to protect throughout the state. Given the State's limited funding for preservation programs, failing to account for parcel acquisition costs in the targeting protocol could decrease the GreenPrint program's effectiveness and efficiency.

This thesis uses econometric modeling with recent parcel level arms-length market transactions to predict the market value of land parcels that may be acquired for preservation and uses the predictions to compare targeting packages given limited program funding. The State of Maryland developed an assessment method to determine the ecological value of all land and uses this method to prioritize land for acquisition under the GreenPrint program. This comprehensive ecological ordinal ranking structure proxies for a systematic, scientific method of ecological valuation to which the economics of land acquisition can be added in the decision protocol. In addition to the ecological rankings for the GreenPrint program, a data set has been compiled specifically for the study with geocoded, up-to-date data from state and federal agencies. ArcView and ArcGIS Geographic Information Systems software programs extract and combine the data sources for geographically referenced land parcels. The geocoded data include structural characteristics of houses on land parcels, community and location characteristics, and land characteristics. The geocoded land data include land use measures and soil characteristics data. Public lands such as state parks and military installations and land encumbered with conservation easements were also identified.

The study area encompasses the three counties of Southern Maryland – Calvert County, Charles County, and St. Mary's County. The market value of each large land parcel is predicted based on a hedonic model of recent arms-length market transactions for land parcels. The hedonic technique models the extent to which the housing, community, and land characteristics influence a land parcel's sale price. Tests for heteroskedasticity and pooling data are conducted and out-of-sample predictions are investigated.

The hedonic model estimation results are used to predict the current market value of the land parcels. The predicted land parcel market values are then incorporated in alternative targeting packages for acquiring land parcels for preservation through the GreenPrint program. The targeting packages summarize the parcels that should be targeted for potential acquisition. The end result is a comparison of the current GreenPrint targeting package with the alternative targeting packages developed in the study. The results from the study can be applied across the entire state of Maryland. Additionally, the methodology can be applied to any land preservation program in the country that measures ecological benefits.

Chapter 2: Land Preservation Programs

Economic Rationale for Land Preservation Programs

Ecosystem services influence humans' utility, and therefore have value to humans. However, many of these services are not traded explicitly in markets. Because explicit market values are not available to determine society's valuation of ecosystem services, researchers derive willingness to pay estimates for ecosystem services using methods such as contingent valuation, hedonic models, and choice experiments. Results from such studies demonstrate that people positively value ecosystem services. For example, Pate and Loomis (1997) find that households are willing to pay between $67 and $215 for improvements in wetland habitat in the San Joaquin Valley, CA. Breffle, Morey, and Lodder (1998) estimate a median household willingness to pay of $234 to preserve undeveloped urban fringe open space providing scenic views and wildlife habitat in Boulder, CO. In a contingent valuation study in Wisconsin (Stumborg, Baerenklau, and Bishop, 2001), residents were asked about reducing phosphorus pollution to a local lake, presented in the form of a reduction in the frequency of algal blooms. Residents have a mean willingness to pay of $353 to reduce the frequency of algal blooms from once every other day to once every five days. Loomis et al (2000) report the mean household willingness to pay to simultaneously increase five ecosystem services – dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation – along a 45 mile stretch of the South Platte River in Colorado is $252 annually.

Natural lands cannot be replaced or returned to their original state after development without significant cost. Therefore, the conversion of these lands is often considered irreversible. Based on the cited studies, society has expressed some value for the ecosystem services that natural lands provide. As conversion is considered irreversible, society might want to evaluate whether it wishes to preserve these natural lands in their current state and if so, what is the optimal amount of natural lands to preserve. In the first-best world, the social planner could preserve the optimal amount of natural lands providing the optimal amount of ecosystem services. Government, as the social planner optimizing society's welfare, would know how every individual in the society values natural lands and ecosystem services and thus could determine the optimal amount of land to preserve. The government could also ascertain which natural lands provide society with the most welfare. Because the government has the authority to preserve the natural lands that maximize society's welfare by acquiring the lands from their private owners or prohibit its conversion while compensating owners for their loss, it is able to achieve a Pareto-efficient solution.

However, we do not live in a first-best world. There is no way to observe directly how every individual values goods and services. Since no one can observe every individual's valuation of natural lands and ecosystem services, government cannot costlessly and perfectly identify how much or which parcels it should preserve to maximize society's welfare.

In the second-best world, preservation of natural lands could be realized through the private land market. The competitive land market identifies the lands that are most valuable to individuals participating in the market. If natural lands producing ecosystem services are valued highly in the market, then these lands are retained in their present state through market interactions. Equilibrium prices in the market also reveal how various characteristics of the land are valued by individuals participating in the market. However, since land characteristics are not bought and sold as separate goods, there are no explicit prices for land characteristics. Instead, hedonic methods can be utilized to reveal the implicit marginal prices of natural lands' characteristics to determine how they are valued in the private land market.

The private land market may fail to preserve a socially optimal amount of natural lands, however the First Welfare Theorem ensures that a competitive equilibrium is Pareto efficient except when certain assumptions are violated.[1] In the private land market, the First Welfare Theorem does not hold because natural lands generate externalities and have public good characteristics. Natural lands produce ecosystem services that result in externalities for other land owners and the general public. These externalities, mostly positive, include erosion control, sediment retention, wildlife habitat, and recreation opportunities. Secondly, some ecosystem services have public goods characteristics. For example, filtering and cooling of water, carbon sequestration, cleaning air, and genetic resource preservation are non-excludable and

[1] The First Welfare Theorem requires that firms' and households' decisions are not affected by any other firms or households, and that firms face the same price vectors and households face the same price vectors. Pareto Efficiency indicates that no one in society could be made better off without making someone else in society worse off.

non-rival services. By non-excludability and non-rivalry, these services are not priced in the private land market. The private land market excludes the public value of such services from the equilibrium prices for natural lands.

Due to the presence of positive externalities and public goods characteristics, the private market will under provide these ecosystem services. Therefore, society's welfare may be improved by government intervention in the market to preserve natural lands and the ecosystem services they provide. Land acquisitions and the purchase of conservation easements by government and private organizations are common means through which natural lands are preserved. A voluntary preservation program encourages willing land owners to sell their ecologically valuable natural lands to the government for competitive market prices. Voluntary programs ensure that no land owner is left worse off after program implementation, as only those land owners whose welfare will increase from selling their land will participate in the program.

Government officials and experts develop protocols to identify, target, and acquire the most ecologically valuable natural lands for these preservation programs. One targeting option is to preserve the least expensive natural lands, thereby minimizing the total cost of preserving some number of acres. Another targeting option is to preserve the most ecologically valuable natural lands, regardless of their cost, until the preservation program funding is exhausted. A third option is to maximize total ecological value by targeting those natural lands that offer the highest ratio of ecosystem services to preservation/acquisition cost (Babcock et al, 1997).[2]

This thesis investigates how to best optimize society's welfare by comparing the outcomes of targeting packages under various budget scenarios to preserve natural lands. We apply these methods to Maryland's GreenPrint preservation program. The GreenPrint program's protocol for targeting potential projects does not include evaluation of the costs associated with potential projects' land acquisitions.[3] The current GreenPrint targeting protocol ranks natural lands of interest by an ordinal ecological index score. This targeting protocol is compared with other maximization equations, specifically maximizing acreage preserved and maximizing preservation of land with erodible soils subject to budget scenarios. The parcel costs that are needed to maintain the budget scenarios are estimated by predicting the market values of natural lands using the estimated coefficients from a hedonic model on actual market transactions. The thesis hypothesizes that alternative targeting packages provide more optimal packages for land preservation than under the current GreenPrint program targeting package. Investigating alternative targeting packages will allow the GreenPrint program to maximize the benefits achieved when selecting the natural land to preserve. This thesis could provide the State of Maryland with a comprehensive tool to target and preserve natural lands more efficiently through the GreenPrint program.

[2] An identical targeting mechanism is purchasing natural lands that have the lowest marginal costs for providing ecosystem services.
[3] GreenPrint preserves natural lands through conservation easements in addition to land acquisitions. This thesis focuses on land acquisition costs.

GreenPrint Program

Maryland's Land Preservation Programs

The State of Maryland encompasses 6.2 million acres, stretching from the Atlantic Ocean to the Appalachian Plateau. It includes the diverse geologic provinces of the Coastal Plain, Piedmont, Ridge and Valley, and Appalachian Plateau. The Chesapeake Bay runs through the eastern portion of the State, isolating the Eastern Shore geographically from the rest of the State.

As of December 2002, developed lands represent 20 percent of Maryland's total land area and protected lands[4] account for another 19 percent of the State's land area. Despite ranking 42nd among states in total land area, the State ranks 13th in total acreage in state parks and recreation areas (259,000 acres) (U.S. Census Bureau, 2002). This leaves 61 percent of Maryland lands (3.8 million acres) in private, undeveloped land uses in 2002. One half of the undeveloped land is in agriculture and one half is in forest/natural cover.

In the 2000 Census, Maryland ranks eighth in the nation in percent of population in metropolitan areas (93 percent) (U.S. Census Bureau, 2002). Maryland's population grew by 30 percent between 1973 and 1997, resulting in the conversion of nearly 400,000 acres to intensely developed uses during that period. This represents a 49 percent increase in the amount of intensely developed land in the State (Maryland Environmental Trust, 2004). The State's population density rose 11 percent from

1990 to 2000, from 489 people per square mile to 542 people per square mile. Calvert County's population density rose most dramatically, increasing 45 percent during that same period (Maryland Department of Planning, 2001).

To slow the disappearance of natural lands, the State of Maryland has developed land preservation programs and smart growth initiatives. The State has passed legislation and appropriated funds to programs that support established communities and protect rural areas. In 1967, the State established the Maryland Environmental Trust to preserve open space through conservation easement donations. A conservation easement limits the landowner's right to develop and subdivide his or her land, both now and in the future. The land remains in the private ownership of the landowner, who often receives tax incentives for offering the conservation easement. In 1969, the State's Department of Natural Resources (DNR) created Program Open Space. Through this program, the State has amassed more than 250,000 acres for state and local parks throughout Maryland.

Maryland pioneered statewide purchase of development rights in the late 1970's with the Maryland Agricultural Land Preservation Foundation (MALPF), which was one of the first statewide farmland preservation programs in the country. To date, MALPF has preserved nearly 400,000 acres (Maryland Department of Agriculture, 2004). The Maryland Greenways Commission was established in 1990 to preserve natural infrastructure through corridors such as streams and mountain ridges. By the

---

[4] Protected lands include lands publicly owned at the federal, state, and local levels, as well as private preserves and privately owned lands with conservation easements.

late 1990's, Maryland had enacted a Smart Growth program including the Rural Legacy and Priority Funding Area initiatives, conservation incentives through programs such as the Conservation Reserve Enhancement Program, and wetlands and shoreline preservation regulations.

Adding to its suite of prominent land preservation programs, the State of Maryland recently instituted a new preservation program, GreenPrint. This program, established in 2001, is unique among Maryland's land preservation programs in that it specifically targets large land areas for acquisition. An initial $35 million allocation from the State provided GreenPrint with funding to finance the large-lot purchases anticipated under the program in 2001. Another $110 million were allotted at that time for the program to operate through June 2006, though State budget cuts have greatly reduced the funding. In fiscal year 2003, $16 million were expended through the program. In fiscal year 2004, only $4 million were authorized in the State budget for the program, while the funding should remain steady at $5 million per year for fiscal years 2005 through 2009 (Maryland Department of Legislative Services, Library and Information Services, 2004). The Maryland DNR states that the GreenPrint program will build upon existing conservation programs by providing additional funding to preserve lands and by conserving and connecting large contiguous land areas with multiple important natural resource features (Maryland DNR, 2003). The land preservation will occur through land acquisitions by the State and counties as well as purchases of conservation easements.

To implement the Greenprint program, scientists developed extensive ecological rankings specifically to determine which lands to target for acquisition using Maryland's extensive data and indexing of land characteristics throughout the state. Detailed scientific analyses of habitats and wildlife species have been undertaken as part of the land preservation efforts as well. These data and scientific assets, coupled with the State's rapid population growth and large amount of undeveloped lands, make Maryland an ideal setting for this study of the optimal targeting of natural lands for preservation.

GreenPrint Program Description

The primary goal of the GreenPrint program set forth by DNR is protection of the most valuable remaining ecological lands in Maryland. DNR has identified some two million acres of ecologically important habitat through its mapping and analysis efforts. These two million acres represent approximately one third of Maryland's total land area. The acreage encompasses 63 percent of Maryland's forest land, 87 percent of Maryland's unmodified wetlands, and 88 percent of Maryland's occurrences of rare, threatened, or endangered species (Weber, 2003). One quarter of the identified prime habitat is currently protected from development. The goal of the GreenPrint program is to increase the ratio of protected to unprotected land within these two million acres.

The State of Maryland reviewed the scientific literature to develop the motivation for and methodology of the GreenPrint program. The following quote summarizes this compilation:

> "Underlying the entire assessment of green infrastructure in Maryland is the growing concern, reflected in a substantial body of scientific literature, for the importance of entire ecosystems to supporting human use of the landscape and of the interconnectedness of all of the parts."
> (Maryland DNR CCWS, 2001)

The GreenPrint program emphasizes the conservation of entire ecosystems by focusing on the natural lands in Maryland that support the ecosystem services on which humans, as well as flora and fauna, depend. These services include cleaning the air, filtering and cooling water, storing and cycling nutrients, conserving and generating soils, pollinating crops and other plants, sequestering carbon, maintaining aquifers and streams, and providing forest products (Weber, 2003). The State emphasizes four types of ecological habitat for its GreenPrints program: large blocks of interior forest; large wetland complexes; rare species and migratory birds habitat; and pristine stream and river segments, especially those that support trout and mussels.

Between September 2001 and February 2002, over 9600 acres were protected from development through the GreenPrint program. This included 4,100 acres of land acquisitions described in Table 2.1.

Table 2.1: GreenPrint acquisitions between Sep. 2001 and Feb. 2002.

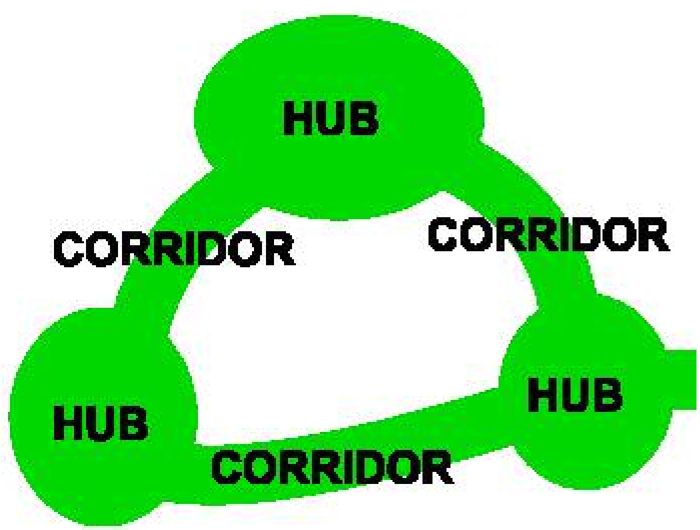
Property	Description	Acres	County
Jacoby Development Corporation	Addition to Jug Bay Wetlands Sanctuary that includes 321 acres within the critical area, and 200 acres of high quality marsh, scrub-shrub, and forested wetlands along the Patuxent River. Within a hub in the top 1%.	611	Anne Arundel
Douglas Point, PEPCO Property	High quality, mature forest along the Potomac River; includes 90 acres of wetlands and 1.8 miles of shoreline. Within a hub in the top 5%	715	Charles
Friends Meeting Quaker Camp Easement	Contains rare and endangered plants in a Wetland of Special State Concern, a well-buffered spring and first order stream (Buzzard Branch), and mature hardwood forest. Within the top-ranked hub in the Blue Ridge province.	382	Frederick
Douglas Point Wilson Farm	Contains 112 acres of high-quality, mature forest; 24 acres of wetlands; and 13,208 feet of stream. Within a hub in the top 5%.	509	Charles
Emmitsburg Watershed	Contains 306 acres of interior forest and 1,435 feet of streams.	520	Frederick
Chaney	Heavily wooded land adjacent to the Myrtle Grove WMA. Includes 31 acres of wetlands, 242 acres of interior forest. Within a hub in the top 5%.	313	Charles
Boyds-Bardon, Inc. property	Links more than 5,000 acres of protected land. Primarily forested, also has mineral resources and wetlands. Supports rare, threatened, endangered watchlist species found nowhere else in Montgomery County including the Mead's sedge and stellate sedge.	805	Montgomery
Rozalyn Carlson/ Feltman properties	Heavily wooded tracts that provide additional protection of 500 feet along Gashey's Creek (a rare habitat area) and 3,000 feet along Swan Creek.	202	Harford
Ridenour Swamp (Garden Property)	Located on Catoctin Mountain, one of the largest blocks of forest between Washington County and the Bay, and the top-ranked hub in the Blue Ridge province. Encompasses a forested wetland known as Ridenour Swamp, which is the headwaters of Middle Creek (designated as natural trout waters).	82	Frederick

(Source: Maryland DNR, 2003)

Within the Maryland DNR, the Watershed Services Unit (WSU) retains the responsibility to identify and assess the State's Green Infrastructure, or ecologically valuable habitat, for the GreenPrint program. The WSU utilizes a methodology called Green Infrastructure Assessment (GIA) to identify and rank the Green Infrastructure. The GIA, utilizing Geographic Information Systems (GIS) as its primary underlying technology, is a computer tool devised to provide a consistent approach to evaluating land conservation and restoration efforts in Maryland.

There are two components to Green Infrastructure – hubs and corridors. Figure 2.1 provides an illustration of the hub and corridor concept.

Figure 2.1: Illustration of Hubs and Corridors



(Weber, 2003)

Hubs are "unfragmented areas hundreds or thousands of acres in size, and are vital to maintaining the state's ecological health." (Weber, 2003). The hubs generally meet minimum parcel requirements of 250 acres. Hubs provide habitat for native plants and animals, protection of water quality and soils, and regulation of climate (Weber, 2003). The average size of hubs defined by the GIA is approximately 2200 acres. Intensive human land uses, including development, agriculture, and quarries, as well as major roads, were excluded from the hubs. Buffers were added around wetlands, streams, and shorelines within hubs. Some of the buffers may contain agriculture or other intensive human land uses.

Gaps are areas of intensive human alteration of the land from its natural state within or near hubs and corridors. Gaps include current land use in agriculture and mining, and clear-cut and built-on land within hubs and corridors. Gaps within Green Infrastructure may be targeted for restoration from human use to natural cover. Forest cover and wetland restoration are of particular interest. Restoration of forests and wetlands to a natural state would provide habitat for native flora and fauna. The opportunity cost of such restoration is the lost productivity of the land in its current use, whether it be agriculture or forest.

Corridors are linear strips of natural lands that allow plants and animals unrestricted movement, typically along stream valleys and mountain ridges. These corridors generally follow natural routes that bridge the gaps between hubs. Corridors are designed to "allow wildlife safe passage through their natural domain, facilitate seed and pollen transport helping plant life thrive across the state, and keep streams and wetlands healthy by protecting adjacent vegetation" (Maryland DNR, 2003). The corridors connecting hubs are at least 1,100 feet wide. The GIA uses a GIS technique called "least-cost" path analysis to determine the best ecological paths between hubs. The "cost" is measured by the difficulty for wildlife to traverse the landscape along a particular route. Therefore, the path with the fewest obstacles such as roads and development between two hubs is the "least-cost" path. GIS identifies the "least-cost" path as a line with no width, so the line is expanded to a corridor by including at least 550 feet on either side of the "least-cost" path line (Weber, 2003).

As of 2003, the Green Infrastructure comprises 2,030,472 acres, or 32 percent of Maryland's total acreage, of which 1,777,475 acres are in hubs and 252,997 acres are in corridors of natural land cover. Open water is excluded from these calculations. Altered open areas, including agriculture, lawns, quarries, and cleared lands, comprise an additional 375,546 acres in the potential Green Infrastructure land network (Weber, 2003).

Current GreenPrint Targeting Scheme

With one third of Maryland's total land area designated as Green Infrastructure, including large blocks of interior forest, large wetland complexes, rare species and migratory bird habitats, and pristine stream and river segments, a means for comparing such varied Green Infrastructure lands is required to facilitate the selection of hubs and corridors for preservation given limited funding. Maryland's GreenPrint program has invested significant resources in developing a comprehensive ecological scoring for all parcels in the state. One challenge found in the literature is the difficulty in quantifying ecological benefits from a preservation program. Maryland's detailed ecological scores provide an ordinal ranking scheme for quantifying the ecological benefits of different targeting protocols. Such a quantitative scoring thus enables the examination of different targeting strategies that include economic considerations.

Table 2.2 enumerates the steps the State of Maryland follows to achieve the final ordinal rankings and targeted parcels for GreenPrint acquisition. The Maryland DNR identifies hubs and corridors using GIS. The hubs and corridors are then scored on ecological and development risk indices and are ranked within physiographic region. The hubs and corridors ranking highest in the indices are pursued for potential land acquisition, along with other parcels whose owners are willing to sell their lands to the State. These identified lands are then evaluated at the individual parcel level and assigned Desktop Ecological Scores (DES) to rank parcels for acquisition.

Table 2.2: Process to Target Parcels for GreenPrint Acquisition via Desktop Ecological Scores in the Green Infrastructure Assessment

	Process Step	**Analysis Level**
1	Identify Green Infrastructure with GIS data	Hubs and Corridors
2	Develop composite ecological rankings	Hubs and Corridors
3	Develop composite development risk rankings	Hubs and Corridors
4	Develop fine scale ecological rankings with composite ecological rankings	Cell (0.314 acre)
5	Develop fine scale development risk rankings with composite development risk rankings	Cell (0.314 acre)
6	Identify Green Infrastructure with highest rankings from Steps 2-5 for GreenPrint acquisition targeting	Land Parcel
7	Develop Desktop Ecological Score (DES) for all parcels identified in Step 6	Land Parcel
8	Parcels with high DES have further field assessments	Land Parcel

One GreenPrint project can be a single parcel owned by a single landowner, multiple parcels that are part of a single protection project, or part or parts of a parcel or parcels. Potential GreenPrint projects are evaluated at the single parcel level for acquisition. If multiple parcels or parts of parcels are being considered for GreenPrint acquisition, some factors in the targeting schemes investigated here may not be accurate for those specific potential projects.

Following the identification of the Green Infrastructure (see Step 1 in Table 2.2), the Green Infrastructure Assessment (GIA) is used to rank the hubs and corridors for ecological value and development risk at the hub and corridor level (see Steps 2 and 3 in Table 2.2). The most detailed site comparisons are made at the cell level (see Steps 4 and 5 in Table 2.2). A cell is a square measuring 0.314 acres in area. This corresponds to the finest level of resolution in the satellite imagery land use data used in the GIA. The fine scale rankings are calculated for all cells in the state, not just for those that fall in the hubs and corridors. This permits the State to make comparisons between potential projects that may include land not defined as Green Infrastructure.

The fine scale ecological ranking (see Step 4 in Table 2.2) ensures that cells in hubs and corridors receive higher rankings than cells falling outside the Green Infrastructure, as the GIA has already determined that the Green Infrastructure lands are the most ecologically valuable lands at a larger scale. Therefore, the fine scale ecological ranking is based on the cell's local features score and the cell's landscape significance.

The formula for ranking cells by landscape significance is, according to Weber (2003): [5]

- score of cell within hub =100-[(hub composite ecological percentile)/2.5]
- score of cell within corridor=80-[(hub composite ecological percentile)/3.334]
- score of cell outside hubs and corridors=0,

where the hub composite ecological percentile is calculated in Step 2 of Table 2.2. These formulas are designed to give hub cells scores between 60 and 100, and corridor cells receive scores between 50 and 80. Cells outside the Green Infrastructure receive scores of 0 for landscape significance. This landscape significance score is combined equally with the local feature score,[6] which is also scaled from 0 to 100.

The fine scale development risk ranking (see Step 5 in Table 2.2) is developed for all cells in Maryland as well. The parameters used for the hub and corridor development risk rankings are used for this cell ranking.[7] Each parameter is reclassified to a 0 – 100 scale, with 0 being least likely to be developed and 100 being highly favorable for development. The reclassification is based on an equal area percentile distribution on all developable land in the State. The reclassified parameters are multiplied by importance weights and summed to create the cell development risk ranking.[8]

[5] Please see Appendix for details on the generation of the hub and corridor composite ecological rankings.
[6] Please see Appendix for details on local feature score.
[7] Please see Appendix for details on the hub and corridor development risk rankings.

Of particular interest in the context of this study is the market land value per acre parameter in the development risk rankings. This is the only parameter in the rankings that measures the market value of the land. However, this parameter is included in the development risk ranking not for its measure of acquisition cost, but for its proxy measure of development risk (see Weber, 2003). Land with higher market values are assumed to be at greater development risk.

The parameter data on market land value is created from a model using the 1997-1998 MDPropertyView database. Unimproved land value for a parcel is divided by total parcel acres to obtain a per acre land value. Parcel centroids are mapped in GIS and a land value surface is interpolated from the per acre land values assigned to the parcel centroids, creating a continuous price surface grid for the State. This method for determining land parcel values requires the unfavorable assumptions that land parcels are homogenous and that parcels have equal gradations in value between them. The land parcel value is given a weight of two in the development risk score, where the total weight is 25.

Weber (2003) writes "This model [interpolated cost surface] can help guide funds toward the most ecologically significant and most threatened areas, given a fixed budget." While the model produces an estimate of per acre land values across the State, it does not provide a systematic method for guiding funds toward the most ecologically significant and most threatened areas. The land parcel values were used to calculate the estimated costs in Table 2.3. Weber writes, "As Table [2.3] shows,

---

[8] Please see Appendix for details on the fine scale development risk ranking.

the areas more at risk of loss to development were also the more expensive per acre. Conversely, areas with higher ecological value tended to be less expensive per acre, as well as generally less at risk."

Table 2.3: Estimated cost of protecting portions of the Green Infrastructure

Portion of green infrastructure network	**Total land area in acres**	**Estimated cost**	**Estimated cost per unprotected acre**
Entire green infrastructure network	2,541,414	$5.8 billion	$3,071
All natural cover	2,114,233	$4.1 billion	$2,676
All 656 hubs	2,143,979	$3.7 billion	$2,425
Hubs (78 of 656) with top 10% ecological score	1,194,057	$1.2 billion	$1,376
Hubs in top 10% ecological score and top 33% development risk (9 hubs)	35,643	$89 million	$2,597
Hubs (6 of 656) in top 10% ecological score and top 20% development risk	20,145	$62 million	$3,164
Hubs (128 of 656) in top 20% development risk	120,543	$563 million	$4,859
Hubs (65 of 656) in top 10% development risk	57,179	$335 million	$6,042
All corridors (from Atlas)	409,077	$2.3 billion	$6,737
Corridor segments (182 of 1881) with top 10% ecological score	17,897	$45 million	$2,844
Corridor segments (35 of 1881) in top 10% ecological score and top 33% development risk	3,706	$15 million	$4,003
Corridor segments (18 of 1881) in top 10% ecological score and top 20% development risk	1,471	$8.5 million	$5,749
Corridor segments (373 of 1881) in top 20% development risk	52,654	$858 million	$16,544
Corridor segments (186 of 1881) in top 10% development risk	25,344	$647 million	$25,940

Source: Weber, 2003

What is perhaps most striking from Table 2.3 is that the available GreenPrint funding is sufficient to preserve only a small fraction of the Green Infrastructure deemed most valuable ecologically and most at risk from development. To further refine the protocol for GreenPrint acquisition of natural lands, the State uses the hub, corridor, and cell rankings to develop a targeting tool for comparing specific potential parcels for preservation. All three of these ordinal rankings relied on the scientific expertise of ecologists to determine what ecological characteristics are most important in maintaining natural lands' ability to provide ecosystem services. The scientific expertise is assumed to substitute for society's valuation of ecological characteristics.

Currently, Maryland evaluates the highest-ranking land parcels at the individual parcel level by assigning ordinal Desktop Ecological Scores (DES) to rank parcels for acquisition (see Steps 6 and 7 in Table 2.2). The DES is calculated from the parameters listed in Table 2.4. Note that the parcel's market value is not included in the DES calculation. Each parameter is assigned a rank – excellent, good, fair, or poor – and corresponding points – 4 for excellent, 2 for good, 1 for fair, and 0 for poor – according to the parameter's value. The ranks are listed in Table 2.4 by parameter value.

Table 2.4: Parameter ranks for Desktop Ecological Score

Parameter	**Excellent Rank**	**Good Rank**	**Fair Rank**	**Poor Rank**
Acres of Green Infrastructure in Parcel	> 65	32.1-65	18-32	<18
Percent of Green Infrastructure in Parcel	>90%	69-90%	34-68.9%	<34%
Mean Ecological Score for Green Infrastructure in Parcel	>85	76-85	66-75.9	<66
Nearby Acres of Protected lands	>434	152-434	5-151	<5
Percent Gain in Protection to Hub or Corridor	>10%	2.5-10%	1.0-2.4%	<1%

Then each parameter's points are weighted for significance by the weights field in Table 2.5.

Table 2.5: Parameter importance weights for Desktop Ecological Score

Parameter	**Weight**
Acres of Green Infrastructure in Parcel	2
Percent of Green Infrastructure in Parcel	1
Mean Ecological Score for Green Infrastructure in Parcel	3
Nearby Acres of Protected lands	1
Percent Gain in Protection to Hub or Corridor	1

The DES provides an ordinal metric that considers the importance of the parcel given its landscape context and the ecological values on the property. The DES is divided into four quartiles – excellent (DES 21 -32), good (DES 15-20), fair (DES 9-14), and least suitable (DES 0 – 8). A DES is calculated for every potential preservation parcel.

Potential projects that score well by DES are evaluated further. A field visit to the property is necessary to validate the GIA data, as well as to identify any restoration needs and assess the threat of development if the land is not promptly acquired. If the field visit indicates the potential property is favorable for investment of funds, a more detailed site assessment may be conducted. The field assessment researches the specific habitats present on the land and documents specific human disturbances. This study assumes the relative benefits generated for society by a parcel of natural land are accurately measured in the ordinal DES developed by Maryland's DNR. GreenPrint administrators use the ordinal DES rankings to prioritize land acquisitions.

Chapter 3: Theoretical Foundations

Land Market Valuation

After describing the Maryland GreenPrint, the focus turns to estimating land parcel costs. This section provides the foundation for using hedonic methods to estimate land parcel acquisition costs by examining land market valuation in the literature. Land parcel acquisition costs provide an important component of the targeting packages as the optimal targeting methods are subject to budget constraints.

Ecosystems services provided by land, such as wildlife habitat and flood control, influence people's utility, and therefore have value to people. However, many of these services are not traded explicitly in markets and do not have explicit market prices by which their values to society can be measured. Such services have public good attributes and produce externalities for other land owners and society.

Ecosystem services can be represented by their underlying ecological characteristics. The underlying ecological characteristics are characteristics of the land parcel itself, and, along with many other parcel characteristics, implicitly define the land parcel's market value. Ecological characteristics may increase or decrease the parcel's market value. In a competitive private land market,[9] the market value of a land parcel is equal to the net present value of returns to the land. This can be written as

$$PV = \int_{0}^{t^*} A(a_i, t)e^{-rt}dt + \int_{t^*}^{\infty} R(a_i, u)e^{-ru}du$$

where A is net agricultural returns and R is net residential rents, a_i is a vector of land parcel characteristics, and t* is the optimal date for development. With A and R defined as functions of the land parcel characteristics, it is clear that the usual model assumption of a homogeneous good does not hold for land. Land is a heterogeneous good containing a bundle of characteristics that defines its quantity and quality.

A hedonic model relates the price of a heterogeneous good to the attributes that comprise the good. Hedonic models are widely used in the residential housing market literature to estimate housing market values. Hedonic models have also gained popularity as a means to value non-market environmental goods whose values may be capitalized into the housing market. Ridker and Henning (1967) estimate one of the first hedonic models in the residential housing market to support the claim that air quality affects property values. Researchers use hedonic models to measure benefits from environmental improvements or losses from environmental degradations. Examples include Geoghegan, Lynch, and Bucholtz (2003), Irwin and Bockstael (2001), and Geoghegan, Wainger, and Bockstael (1997) for estimating the value of open space; Leggett and Bockstael (2000) for estimating water quality value; Palmquist et al (1997) for estimating negative externality costs from polluting industry; and Smith and Huang's (1995) meta-analysis of air quality valuation literature. Mahan et al (2000) use a hedonic model to measure the non-market value of wetlands in the Portland, Oregon housing market. They argue this method has advantage over other assessment techniques because the hedonic model uses observed

---

[9] The competitive private land market includes agricultural and residential lands lonely. Commercial, industrial, and institutional lands are excluded from this definition.

market values to build the valuation estimates for non-market goods and services.

Hedonic models also have been used extensively to estimate land values in the agricultural land market. Xu et al (1993) employ a hedonic model to estimate the value of various site characteristics on farmland. They write that, in land market hedonic models, the attributes act as proxies for the expected net return to the land, the driving force behind land values. The attributes in this hedonic model include barn characteristics, house characteristics, and machinery characteristics in addition to land and location characteristics.

Palmquist and Danielson (1989) use hedonic techniques to determine the value of erosion control and drainage on farmland. Variables in the hedonic model include soil characteristics, land cover, community characteristics, and building characteristics. Faux and Perry (1999) estimate a hedonic model to estimate the implicit price of irrigation water on farmland in Oregon.

In a study of the effect of farmland preservation programs on agricultural land prices in of Maryland, Nickerson and Lynch (2001) employ a hedonic model on preserved and unpreserved agricultural land sales. The variable of interest is preservation status on the land parcel. The parameter in the hedonic model for preservation status indicates that preservation status does not significantly decrease land values. Nickerson and Lynch write that the hedonic approach is useful when one can observe parcel characteristics but not use values.

Lynch and Lovell (2003) study the private land market for both agricultural and residential use with hedonics. The study investigates whether values for parcel characteristics in the private land market are similar to the payment schemes developed by preservation programs. By subtracting assessed value of structures on the land from the total market value of the parcels, they estimate land characteristic values in the private land market through the hedonic model. The model included proxies for net agricultural returns to agricultural land and parcel characteristics that might affect the cost of and attractiveness of development on the land.

Studies also use hedonic models to analyze the value of unimproved land in the market. For example, Holway and Burby (1990) estimate a hedonic model for vacant floodplain parcels available for residential development to evaluate land-use policy decisions and their effects on the value of land in floodplains. Bockstael (1996) estimates a hedonic model to predict the value of land in residential use, excluding any structures on the land. These predictions of land values in residential use from the hedonic results are then included in a probit model predicting land use conversion to residential use.

These studies from the literature demonstrate the wide applicability of hedonic methods to land market valuation. The volume of peer-reviewed published studies using hedonic methods sets precedence for hedonic techniques in valuing housing, land, and environmental characteristics. A primary advantage of hedonic models over other valuation methods such as contingent valuation is that hedonic models use actual, not hypothetical, market transactions. This thesis will employ hedonic methods with market transaction data from Maryland to estimate the market values of natural lands.

Theory of Hedonic Models

Hedonic models are reduced form models that trace out the locus of equilibrium prices as a function of the attributes of a heterogeneous market good. Rosen's 1974 article is considered the seminal work on hedonic models. In the article, Rosen bases the hedonic model on a description of a competitive equilibrium in a plane of several dimensions on which buyers and sellers locate.

Underlying the hedonic model, a consumer maximizes utility (u) subject to his or her budget constraint,

$$\max u(x, a) + \lambda(y - P(a) - x)$$

where x is the numeraire good, a is a vector of land parcel attributes, y is the consumer's income, and $P(a)$ is the price of the parcel as a function of its attributes. According to Rosen (1974), each consumer has a bid function for land. The consumer's bid function represents the combination of bundles of parcel attributes a_j and quantity of numeraire x for which the consumer would be willing to pay to hold utility constant at the maximized level u^*. The bid function depends on attributes a_j, income y, and u^*:

$$\theta(a_1, a_2, \ldots, a_J, y, u^*) = y - x(a, u^*)$$

and u^*, the maximized level of utility subject to the budget constraint, is a function of x and the vector of attributes a.

Several assumptions must be met to justify use of the hedonic model for analysis of a market good. The first assumption is that the market good is a heterogeneous good. A land parcel is a heterogeneous good, composed of a bundle of attributes. These attributes include land cover, soil quality, structural characteristics of buildings on the parcel, and location characteristics. No two land parcels are identical, and therefore, their bundles of attributes are necessarily different. The hedonic model requires variation in each attribute across the land parcels for the hedonic model to estimate properly the implicit values of the attributes. Finally, a sufficient number of land parcels must be available in the market, so that the choice among bundles of attributes can be considered continuous.

The second assumption is that the heterogeneous good is a normal good. Land parcels meet this assumption, as more acreage or better soil quality will command a higher price for the parcel in the market.

The third assumption is that the consumer with the highest bid for the good will be able to purchase the good. In other words, the consumer's optimum choice is feasible. The hedonic model traces the locus of equilibrium points in the market.

Therefore, the market must be in equilibrium between buyers and sellers, such that no consumer wants to outbid any other consumer for a particular good.

Finally, the hedonic model assumes that the value of the good is an aggregation of the values of the individual attributes in the bundle. This heterogeneous bundle of attributes is sold as a single good – the land parcel – in the land market for which one price is negotiated in equilibrium between a buyer and a seller. The land parcel is sold as a single good because the bundle of attributes for a parcel cannot be decomposed, or untied as Rosen writes, and traded as individual attributes. For example, the parcel's soil cannot be separated from the parcel and sold to a different consumer than the consumer who pays for the rest of the parcel's attributes. The model assumes that each attribute of the heterogeneous good has an implicit price within the context of the bundle of goods. That is, each attribute's "price" can be derived as a function of the levels of all the attributes of the good.

From these assumptions, the price of the land parcel can be written as

$$P(a) = P(a_1, a_2, ..., a_J)$$

where a_j is the *j*th attribute of the land parcel and *P(a)* is the market clearing price for the land parcel in the market. This is the hedonic model. In general, *P(a)* is non-linear due to the increasing marginal costs of attributes and, more importantly, because it is not possible to untie the bundle of attributes.

At the optimum, the amount of money the consumer is willing to pay for the land parcel is equal to the minimum price he or she must pay in the market. That is,

$$\theta(a_1, a_2, ..., a_J, y, u) = P(a_1, a_2, ..., a_J).$$

At this equilibrium, differentiating utility with respect to a parcel attribute a_j results in the slope of the bid function being equal to the marginal rate of substitution between the parcel attribute and the numeraire, $\frac{\partial \theta}{\partial a_j} = \frac{\frac{\partial u}{\partial a_j}}{\frac{\partial u}{\partial x}}$. From derivation of the first order conditions of the utility maximization problem, one obtains $\frac{\frac{\partial u}{\partial a_j}}{\frac{\partial u}{\partial x}} = \frac{\partial P(a)}{\partial a_j}$ after simplification, where $\frac{\frac{\partial u}{\partial a_j}}{\frac{\partial u}{\partial x}}$ is the same marginal rate of substitution between the attribute a_j and the numeraire good. Therefore, the slope of the bid function is equal to the slope of the hedonic function at the land parcel market equilibrium. That is,

$$\frac{\partial \theta}{\partial a_j} = \frac{\frac{\partial u}{\partial a_j}}{\frac{\partial u}{\partial x}} = \frac{\partial P(a)}{\partial a_j}.$$

By this equality between the bid function and hedonic function at equilibrium, $\frac{\partial P(a)}{\partial a_j}$, which is the slope of the hedonic function, represents the marginal implicit price of attribute a_j.

Model Functional Form

There is no theoretical foundation for the choice of functional form for the hedonic model beyond the assumption that the hedonic function is generally non-linear (Rosen, 1974). If the hedonic function is estimated linearly, as

$$P(a) = \alpha + \beta_1 a_1 + ... + \beta_J a_J + \varepsilon$$

then every consumer in the market faces the same marginal implicit prices. This is an arbitrary constraint on consumer preferences and one that most economists are not willing to make.

Because the hedonic theory does not explicitly identify a proper functional form, the researcher is faced with an ad hoc choice among functional forms. Popular functional forms include the semi-log, inverse semi-log, log-log, and Box-Cox specifications. The semi-log model takes the form

$$\ln P(a) = \alpha + \beta_1 a_1 + ... + \beta_J a_J + \varepsilon$$

where the dependent variable is transformed by taking the natural log of market value. Examples of this specification in the literature can be found in Nickerson and Lynch (2001), Bockstael (1996), and Lynch and Lovell (2003) with the natural log of the market value per acre as the dependent variable. The natural log of total parcel market value is the dependent variable in Mahan, Polasky, and Adams (2000) and Palmquist and Danielson (1989), among others.

The inverse semi-log model specification is

$$P(a) = \alpha + \beta_1 \ln a_1 + ... + \beta_J \ln a_J + \varepsilon .$$

Holway and Burby (1990) use an inverse semi-log form, in which the dependent variable is linear and the continuous independent variables are logged. This is also often referred to as the linear-log specification. This form is justified by the authors in that it measures the decreasing, positive slopes of most marginal implicit price curves.

The log-log, or double-log, form is specified as

$$\ln P(a) = \alpha + \beta_1 \ln a_1 + ... + \beta_J \ln a_J + \varepsilon .$$

Examples of this in the literature include a flexible form correcting for spatial autocorrelation by Geoghegan, Lynch, and Bucholtz (2003), Irwin and Bockstael (2001), and Geoghegan, Wainger, and Bockstael (1997).

The Box-Cox specification is often chosen for estimation because the data is used to choose the best functional form for the model. A classic Box-Cox model transforms only the dependent variable (Faux and Perry, 1999), though the Box-Cox specification may transform the dependent variable or the independent variables. Each variable can be transformed separately, but it is more common to use the same transformation for all of the variables. The Box-Cox specification can be used directly for the hedonic model estimation. Alternatively, the Box-Cox model can be used to test for and choose among various functional forms, including linear, semi-log, and log-linear forms.

Some researchers choose to report results from multiple functional forms. For example, Leggett and Bockstael (2000) report estimation results from linear, semi-log, log-log, and inverse semi-log forms. Palmquist and Danielson (1989) use Box-Cox techniques to select between the linear, semi-log, log-linear, and inverse semi-log specifications. They find the semi-log form is the best specification through minimization of the residual sum of squares for the transformed data.

The researcher can plot the distributions of the variables to assist in choosing a functional form for the hedonic model. If the variable distributions appear normal, then a linear functional form is likely most appropriate. If the variable distributions are right-skewed, then transformations such as logarithms and square roots may normalize the distributions for some or all variables.

Furthermore, as the purpose of the model in this study is to predict land parcel market values for use in the creation and analysis of targeting packages, it is important to choose the functional form that makes the best predictions. One method by which comparisons can be made across functional forms is the out-of-sample prediction. The out-of-sample prediction mimics the prediction process, as the parcel values being predicted by the model algorithm are not in the data set on which the model is being estimated. The out-of-sample prediction measures the error between the true parcel values and the predicted parcel values. The data set is randomly split into two groups – a training set with a large proportion of the observations and a validation set with the remaining observations. The model is estimated with the training set observations only. This ensures that the predictions are made for observations that are not included in the modeling sample. The parameters from the model estimation are then applied to the validation set to predict the parcel values. The differences between the predicted parcel values and the true parcel values are calculated to determine how well the model predicts the true parcel values.

Econometric Considerations

Heteroskedasticity

In a hedonic model, the error terms are assumed to be homoskedastic with

$$Var(\varepsilon_i) = \sigma^2, E(\varepsilon\varepsilon') = \begin{bmatrix} \sigma^2 & 0 & 0 \\ 0 & \sigma^2 & 0 \\ 0 & 0 & \sigma^2 \end{bmatrix}.$$

Under heteroskedasticity, the variance on the model error terms may be different for every observation, or

$$Var(\varepsilon_i) = \sigma_i^2, E(\varepsilon\varepsilon') = \begin{bmatrix} \sigma_i^2 & 0 & 0 \\ 0 & \sigma_i^2 & 0 \\ 0 & 0 & \sigma_i^2 \end{bmatrix}.$$

If heteroskedasticity exists but the model does not correct for it, ordinary least squares remains unbiased and consistent but is no longer efficient. The parameters' standard errors will be incorrect, leading to incorrect t-statistics and significance results.

The White's Information test, the Goldfeld-Quandt test, and the Breusch-Pagan test check for the presence of heteroskedasticity. The Breusch-Pagan test is preferred over the other tests because it incorporates multiple variables that may drive the heteroskedasticity, whereas the Goldfeld-Quandt test requires the hypothesis that only one variable drives the heteroskedasticity and White's test can be inefficient. If heteroskedasticity is present, but the form of the heteroskedasticity is unknown, White's heteroskedasticity-consistent covariance matrix can be used to obtain the correct standard errors and t-statistics. If the form of the heteroskedasticity is known, then generalized least squares or feasible generalized least squares will offer efficient model estimates.

Spatial Autocorrelation

Spatial autocorrelation originates from omission of spatially correlated variables from the model. The overall effect of omitted variables is captured in the model's error term. When the omitted variables are spatially correlated, the error term is spatially correlated. A spatially correlated error term violates the independence assumption in the standard assumption of an identically and independently distributed error term, $\varepsilon \sim N(0, \sigma^2 I)$. There is no longer zero covariance between the errors. Model results remain unbiased and consistent but are inefficient, leading to inaccurate t-statistics and significance levels (Anselin and Griffith, 1988).

Numerous studies have found no qualitative or quantitative differences between spatially corrected and ordinary least squares models.[10] Due to the application of the hedonic model estimates in predicting parcel market values where unbiased and

[10] See, for example, Geoghegan, Lynch, and Bucholtz (2003), Lynch and Lovell (2003), and Leggett and Bockstael (2000).

consistent results are most important, as well as due to previous studies' results, the hedonic models are neither tested for nor corrected for spatial autocorrelation.

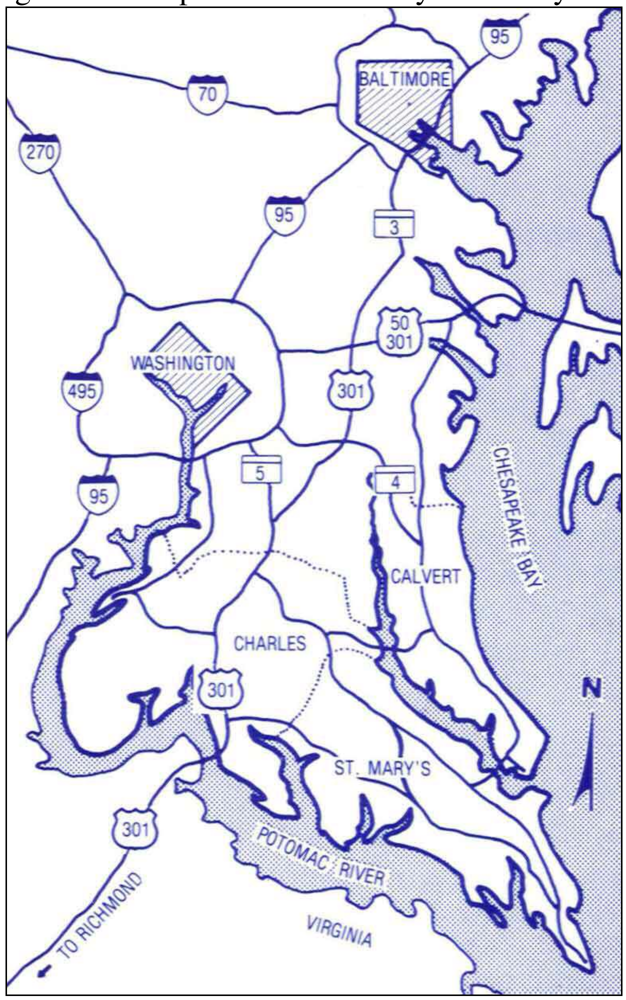
Chapter 4: Data

Definition of the Land Market

The first step in the data collection process for the hedonic model estimation is the definition of the extent of the land market. Similar to choosing a functional form for the model, this process has no firm theoretical foundation in the literature. The extent of the market can vary greatly from one place to another. Consumers may have limited search ranges and supply is somewhat fixed. Geoghegan, Wainger, and Bockstael (1997) write that, if the market is defined larger than individuals actually choose from, the model results will be biased, while defining too small a market will lead to inefficient results due to the loss of information from omitted transactions in the true market. In the context of predicting parcel values from hedonic model results, it would be better to have inefficient results than biased results. Therefore, it is inappropriate to estimate one hedonic model for the entire state of Maryland for this study.

Defining a smaller market for this study, the hedonic model estimation is restricted to parcels in Charles, Calvert, and St. Mary's counties in Maryland. These three counties comprise what is known as Southern Maryland. By estimating the hedonic model with these three counties, it is assumed that they comprise one land market. Given the geography of the region, demographics of the counties' residents, and economic interdependencies in the area, this is a reasonable assumption. For example, regional planning and development is coordinated across the three counties through the Tri-County Council for Southern Maryland.

Figure 4.1: Map of Southern Maryland Study Area



Source: Tri-County Council for Southern Maryland (2004)

Charles County, with 452 square miles, borders the Potomac River to the west and the Patuxent River to the east. Calvert County, lying east of Charles County, borders the Patuxent River to the west while its eastern boundary is the Chesapeake Bay. Calvert County is the smallest county, at 213 square miles. St. Mary's County lies south of Charles and Calvert counties, bounded by the confluence of the Potomac and Patuxent Rivers with the Chesapeake Bay, and is 373 square miles. The counties are within 2 hours of both Washington, D.C. and Baltimore, MD.

The 2002 median household income is $69,350 in Charles County, $77,100 in Calvert County, and $58,650 in St. Mary's County (St. Mary's County Maryland, 2004). The proportion of residents with bachelor's degrees is 20 percent in Charles, 22.5 percent in Calvert, and 22.6 percent in St. Mary's (Maryland Department of Business and Economic Development, 2004). The cost of living index, when compared with a national average of 100, is 98 in Charles, 97 in Calvert, and 90 in St. Mary's (Maryland Department of Business and Economic Development, 2004).

Population growth in all three counties in the five year period from 1996 to 2001 outpaced both Maryland's growth rate and the country's growth rate.[11] Southern Maryland's economy, and especially St. Mary's County's economy, is dominated by the U.S. Navy's installations and affiliated high-tech defense contractors. In the early 1990's, the Department of Defense reassigned hundreds of jobs to the area, facilitating rapid population growth in the once-rural region (Southern Maryland Association of Realtors, 2004).

The hedonic model estimation is designed to reflect the land market from which parcels may be selected for conservation. The GreenPrint program specifically targets large lots for purchase. Therefore, the hedonic model must estimate market land values for the large parcel land market. Only parcels in excess of ten acres are included in the model parcel population.

Furthermore, the parcels must have been sold in the private non-commercial land market. All publicly held lands are omitted from the parcel population, as are commercial, exempt, exempt commercial, and industrial land uses. These lands could be purchased under the GreenPrint program, but are fundamentally in a different land market than residential and agricultural lands. Commercial and industrial land, for example, may be more expensive than residential or agricultural land. Data on improvements for commercial, industrial, and exempt land parcels is sparse at best, making it difficult to estimate a hedonic model to predict land market values for such parcels. Parcels with any level of development restriction are excluded from the hedonic model estimation. These include Environmental Trust Easement parcels, Private Conservation Properties, MALPF parcels, and parcels in Rural Legacy.

Without a clear a priori definition of what is considered a 'large' parcel in this land market, empirical analysis provides insight into the extent of the market. The land of interest includes both unimproved and improved agricultural and residential parcels in excess of ten acres with forests, wetlands, and agriculture. Therefore, the hedonic model estimation must include the site characteristics that affect the value of unimproved land parcels as well as the structure characteristics that contribute to the value of improved land parcels. However, improved and unimproved parcels likely have different markets with different buyers and sellers. For example, a buyer looking to relocate to a larger house may not consider unimproved land a substitute

---

[11] The percent change in population between 1996 and 2001 was 17.6 percent in Calvert County, 10.1 percent in Charles County, and 9.2 percent in St.Mary's County. The percent change was only 6

for improved land. To ensure that the hedonic model estimation results are good predictors of land market values, the hedonic model is estimated separately for improved and unimproved land. The hypothesis of separate markets for improved and unimproved land parcels is tested with an F test for joint significance of community and land variables interacted with a dummy variable for improved parcels. The F test for joint significance tests the null hypothesis that the parameters on the interaction terms are jointly equal to zero. Rejection of the null hypothesis indicates that the marginal values for the community and land characteristics are different for the improved and unimproved parcels, and therefore separate models should be estimated for the improved and unimproved parcels.

Parcels are restricted to those sold in arms-lengths transactions in 1999, 2000, 2001, or 2002. The model population is restricted to parcels sold from 1999 through 2002 to ensure that market conditions are most recent while maintaining a sufficient quantity of parcels. The full population of parcels cannot be used because they do not have recent market prices. A survey of recent hedonic model studies found the time period for parcel sales included in the models ranged from one year to five years.[12]

Every parcel's market value is adjusted for inflation. The owners' equivalent rent of primary residence from the Consumer Price Index – All Urban Consumers for Washington-Baltimore, MD-DC-VA-WV (Bureau of Labor Statistics, 2003) scales the market values for parcels sold in 2000, 2001, and 2002 to 1999 dollars. With

percent nationwide and 4.8 percent across Maryland. (St. Mary's County Maryland, 2004)

1999 as the base year at an index of 100, the index is 103.033 in 2000, 107.867 in 2001, and 112.607 in 2002.

Model Variables

The hedonic model is written as

$$P(a) = f(s, c, l) + \varepsilon$$

where s is a vector of structural characteristics, c is a vector of community characteristics, l is a vector of land characteristics, and ε is an independent and identically distributed error term. *P(a)* is the inflation-adjusted parcel market value.

The s vector includes structural characteristics on which the market value is hypothesized to depend. The market value of the parcel is expected to depend positively on the size of the structure, SQFTSTRC, measured as the square feet of the foundation. The structure's age is expected to relate negatively to the market value. The variable, HOUSEAGE, is measured as the inverse of the age of the structure.[13] New homes will have values closer to 1, while older homes will have values closer to zero. The estimated parameter is expected to have a positive sign. New homes have larger square footage, on average, than older homes so an interaction term is included in the model to account for this. The interaction term is AGESQFT, and is calculated by multiplying SQFTSTRC with HOUSEAGE. This interaction term is expected to have a negative estimated parameter, as it provides a correction to the positive effects of SQFTSTRC and HOUSEAGE on the algorithm's slope.

[12] See, for example, Bockstael (1996), Palmquist et al (1997), Moran et al (2000), Bell and Bockstael (2000), and Geoghegan, Lynch, and Bucholtz (2003).
[13] The age of the house is capped at 103 years.

Higher quality construction of a structure is expected to increase the market value. CONSTGOODP is a dummy variable for structures of good, very good, excellent, and luxury construction quality. CONSTRAV corresponds to average construction quality. CONSTRAV and CONSTGOODP are expected to have positive effects on market value, compared to the omitted category for structures of low cost, economy, and fair construction quality. The total number of full and half bathrooms, TOTBATHS, is expected to have a positive sign. Each full bathroom is given a value of 1 and each half bathroom is given a value of 0.5 in the summation for TOTBATHS. The market value is also expected to depend on non-essential housing amenities. A structure with at least one fireplace, as measured by the dummy variable FIREPLACE, is expected to sell for a higher price, all else being equal. Similarly, presence of a basement, BASEMENT, may increase the market value of the parcel. GARAGE is a dummy variable for presence of an attached or detached garage. This is also expected to have a positive effect on market value.

Community characteristics in the *c* vector explain that portion of parcel market value that is attributable to neighborhood and location. Waterfront parcels are distinguished by the dummy variable WATERFRONT, which is expected to have a positive parameter. A dummy variable for St. Mary's County controls for differences between this county and Charles and Calvert Counties, such as the distance to Washington, D.C. and Baltimore and zoning regulations that might impact market value.

The vector of land characteristics *l* includes ACRES, which measures the parcel's total acreage. The parameter is expected to be positive. The land use variables are measured as the percent of total parcel acreage, minus any acreage in water, in each land use category. PERCROP measures the percent of parcel acreage in cropland, and PERPASTURE measures the percent of parcel acreage in pasture. The omitted category is percent of parcel acreage in development or in forested land. Cropland is expected to carry a higher net return than pastureland, on average, because cropland is indicative of good soil conditions. Pastureland may or may not have soil conditions suitable for conversion to cropland.

Four variables capture soil characteristics of the land parcels. The slope of the land parcel is captured in S_SLOPE_M_H, percent of parcel with slope greater than 8 percent. Steeper slopes are expected to reduce the parcel market value, as the land becomes more difficult to develop or cultivate as the slope increases. Therefore, relative to the omitted category, percent of parcel with slopes less than 8 percent, S_SLOPE_M_H is hypothesized to have a negative parameter. Soil erodibility is measured in two variables for the percent of soils with moderate erodibility, S_ERODEM, and with high erodibility, S_ERODEH. Soil erodibility is not desirable in the market place although it is valued in the GreenPrint program's ranking of ecological characteristics, so both parameters are expected to be negative relative to the low erodibility category. Finally, S_FLOOD measures the percent of parcel with floodplain soils. These soils have marginal value for agricultural land and have severe limitations for urban development (Maryland Department of State Planning,

1973) and the estimated parameters are expected to be negative.

As mentioned with the soil erodibility, some of the variables described above are also attributes that the GreenPrint program considers in its parcel rankings. The land use variables, soil erodibility, and waterfront access are attributes that directly impact the GreenPrint program's ecological and development risk rankings, which are discussed in Chapter 2. Some of these variables may actually decrease the market value of the parcel, while being valued ecologically by the GreenPrint program. For example, steeper slopes are expected to reduce parcel market value but are desired in lands targeted for GreenPrint acquisition. These variables carry special importance toward the goal of achieving greater benefits per dollar spent for the preservation program.

Data Sources

The model variables include land parcels' structural, land, and community characteristics. This section describes the process used to compile the data for this study. The compiled data is used first for the hedonic model estimations, secondly for the parcel land market value predictions, and thirdly for calculating parcels' GreenPrint Desktop Ecological Scores. The data set creation relies on the ArcView 3.2 and ArcGIS 8.2 Geographic Information Systems (GIS) software programs to extract and combine data for geographically referenced parcels. The compiled data set contains one record for each parcel in the State of Maryland at least 3 acres in area, with geocoded parcel-level attribute data for each parcel.

The primary data set containing the parcel location and size data for the analysis is

MDPropertyView 2002. The MDPropertyView 2002 Database (MDPVD) is created by the Maryland Department of Planning as a series of county level files. The files include data updated through October 2002 from the State's Department of Assessments and Taxation. The files are spatially referenced for use in GIS, allowing the data to be utilized in conjunction with other state and federal spatially referenced data sets.

The MDPVD supplies information on parcel ownership, valuation, land characteristics, and structural characteristics for every land parcel in Maryland. The parcels are spatially referenced by the x and y coordinates in NAD83 meters Maryland State Plane Coordinate System. Each parcel is also identified by a unique account number that allows parcel-level links between the various MdPropertyView 2002 data files and parcel-level data sets created by other State agencies. The Computer Assisted Mass Appraisal (CAMA) database, which is part of MDPropertyView 2002, provides additional residential housing characteristics for non-commercial parcels in the Database. These characteristics cover features such as fireplaces, full and half bathrooms, porches, and garages. The CAMA data matches to the Database parcel information by the unique account number as it is also obtained from the State's Department of Assessments and Taxation.

A wealth of data characterizing Maryland lands is linked to the MDPVD land parcels spatially through GIS techniques. For the most part, the land characteristics data is stored in maps that have been digitized by the State of Maryland. To extract this data for the specific land parcels in the MDPVD, buffer parcels are created as proxies for the true parcel boundaries.[14] A buffer parcel is a circular area with center at the land parcel centroid and total area equal to the land parcel's acreage. The MDPVD contains the exact location of each parcel centroid as spatially referenced x and y coordinates. ArcView 3.2 GIS software uses these x and y coordinates to map the parcel centroids across Maryland. Each land parcel's size in acres, as measured in MDPVD, is used to calculate the parcel's radius in meters according to the formula $radius = [(acres * 4046.87)/3.1416]^{1/2}$. With the radius and the parcel centroid for each land parcel, the Buffer Selected Feature command in ArcView creates noncontiguous circular buffer parcels. These buffer parcels intersect with spatially referenced data to extract land characteristics for the MDPVD land parcels. One refers to this process as buffer parcel extraction.

Several data sets obtained from State agencies provide spatially referenced, detailed data on the characteristics of Maryland's land. The Maryland Office of Planning compiles detailed land use data from satellite and aerial photography taken as recently as 2002. Land uses are categorized into Urban Areas, Agriculture, Forest, Water, Wetlands, and Barren Land. Urban Areas includes the sub-categories low-density residential, medium-density residential, high-density residential, commercial, industrial, institutional, extractive, and open urban land uses. Agriculture includes cropland, pasture, orchards, vineyards, and agricultural buildings and storage. Forest includes deciduous, evergreen, and mixed forests as well as brush. Water and

[14] Exact land parcel boundaries are preferred to buffer parcels, but are currently available only for

Wetlands refer to open water and intermittently wet areas, respectively. Finally, Barren Land includes beaches, bare rock, and bare ground. ArcView is used to extract the land use data for each buffer parcel as the percent of the parcel in each land use category. These land uses sum to 100 percent.

Soil data comes from the Maryland Department of State Planning's 1973 work to classify and map all Maryland soils, completed in conjunction with the U.S. Department of Agriculture Soil Conservation Service. The two agencies developed the Natural Soil Groups classification system. Soils are grouped by productivity, erosion potential, permeability, stoniness and rockiness, depth to bedrock, depth to water table, slope, stability, and susceptibility to flooding. The authors define these factors as most significant for land use planning purposes. The Natural Soil Groups Technical Report (Maryland Department of State Planning, 1973) provides estimated chemical and physical properties for each soil group. Each soil group is classified according to categories for each of several soil properties. ArcView is used to extract the natural soil groups present on each parcel as the percent of the parcel in each soil category, and the categories are used to derive interpretable data for modeling. The categories define soil slope, soil erodibility, and floodplain soils, which affect the extent of potential development on the land and agricultural returns.

Easements and preservation acquisitions made by state, local, and private organizations are compiled in several data sets. Some of these data sets are spatially referenced, while others use the unique account number that can be matched to the

---

Montgomery County, Maryland.

MDPVD to obtain spatial references. Maryland Environmental Trust Easements are perpetual land agreements between landowners and the Trust that ensure the properties will not be developed beyond some agreed upon limit. The Maryland Agricultural Land Preservation Foundation (MALPF) preserves agricultural lands through perpetual easements. Parcels with Environmental Trust Easements and MALPF easements are identified by unique account number. Forest Legacy Easements are perpetual conservation easements from willing landowners on private forest land. These parcels are identified by ArcView via buffer parcel extraction, as are Rural Legacy Areas. Rural Legacy Areas have been deemed among Maryland's best remaining rural landscapes and natural areas by local communities. Some parcels in these Rural Legacy Areas have been protected from development through purchase of land or conservation easements. In addition to the government easement programs, private conservation groups and organizations hold ownership to land or development rights for some parcels in the state. The Private Conservation Properties database, maintained by the State, is a collection of such properties. These parcels are identified by buffer parcel extraction.

Lands currently owned and maintained by public agencies are identified through the MDPVD and buffer parcel extraction. Natural Heritage Areas are 32 land areas owned by the State to protect endangered and threatened species. Greenways and Water Trails are natural corridors set aside to connect larger areas of open space and to provide for the conservation of natural resources and offer opportunities for recreation. Stream valley parks in urban areas are an example of greenways and water trails. Currently, Maryland has over 1,500 miles of protected greenways (Maryland Greenways Commission, 2000). Counties and the Maryland DNR own and maintain parks, state forests, wildlife management areas, natural resource management areas, natural environmental areas, and fish management areas. Finally, federal lands in Maryland include U.S. Military lands, U.S. Park Service lands, U.S. Department of Agriculture lands, and U.S. Fish and Wildlife Service lands.

The model variables are listed in Table 4.1 with their descriptions, means, standard deviations, and expected effects on the parcel inflation adjusted market value.

Table 4.1:Description of Model Data

Variable	Description	Improved Parcels Mean (Std Dev)	Unimproved Parcels Mean (Std Dev)	Effect
SALEPRICE	Parcel inflation adjusted market value	$228,198 ($141,316)	$124,337 ($112,062)	
SQFTSTRC	Foundation square footage	2162 (1232)		+
HOUSEAGE	1/Age of Structure	0.26 (0.45)		+
AGESQFT	1/Age * SQFTSTRC	779 (1342)		-
CONSTRAV	Construction Grade Average	0.29 (0.45)		+
CONSTGOODP	Construction Grade Good through Luxury	0.11 (0.31)		+
BASEMENT	Basement	0.39 (0.49)		+
GARAGE	Attached or detached garage by CAMA	0.45 (0.50)		+
TOTBATHS	Total number of bathrooms by CAMA	1.69 (1.20)		+
FIREPLACE	Fireplace by CAMA	0.46 (0.50)		+
WATERFRONT	Waterfront property	0.07 (0.25)	0.05 (0.21)	+
STMARYS	St. Mary's County dummy	0.47 (0.50)	0.41 (0.49)	?
ACRES	Acres	31.90 (34.4)	38.07 (41.6)	+
PERPASTURE	Land Use: % in Pasture	0.03 (0.14)	0.01 (0.07)	?
PERCROP	Land Use: % in Cropland	0.28 (0.33)	0.19 (0.30)	?
S_SLOPE_M_H	Soil % Acres with Slope Greater than 8 Percent	0.28 (0.37)	0.32 (0.39)	-
S_ERODEHIGH	Soil % Acres with High Erodibility	0.49 (0.44)	0.44 (0.43)	-
S_ERODEM	Soil % Acres with Moderate Erodibility	0.24 (0.37)	0.26 (0.38)	-
S_FLOOD	Soil % Acres with Floodplain Soil	0.23 (0.36)	0.27 (0.38)	-
		N=268	N=195	

Chapter 5: Hedonic Model Results

Without an *a priori* reason to choose a particular functional form, empirical analysis is used to determine the functional form for the hedonic model. By using the parcel market value as the dependent variable, which includes the structure as well as community and land characteristics, there is an implicit assumption that the structure value is additive with the value of the community and land characteristics. Therefore, the dependent variable is not transformed. However, some independent variables are hypothesized to have nonlinear relationships with parcel market value, leading to empirical analysis of two model specifications.

Table 5.1 presents the results of hedonic model estimations using ordinary least squares for two model specifications. The dependent variable is parcel inflation adjusted market value, SALEPRICE, in all model specifications. Separate models are estimated for the improved and unimproved parcels, where the only difference in the model specification is the omission of structure variables in the model with unimproved parcels. Model 1 has the inverse semi-log functional form with SQFTSTRC and ACRES transformed by natural logarithm. Model 2 has the nonlinear functional form with the square root of SQFTSTRC and ACRES. The square root transformation allows SQFTSTRC and ACRES to have decreasing positive implicit price curves while allowing greater variation than would be found with the natural log transformation. All other variables remain linearly related to the dependent variable.

Table 5.1: Hedonic Model Estimation Results

	Model 1: Inverse Semi-log		Model 2: Non-linear	
	Improved	Unimproved	Improved	Unimproved
Variable	Parameter (StdDev)	Parameter (StdDev)	Parameter (StdDev)	Parameter (StdDev)
INTERCEPT	-44656 (49036)	152219** (65397)	46651 (39944)	257586*** (57382)
SQFTSTRC^#	5988** (2727)	-	1407*** (429)	-
HOUSEAGE	990138*** (258848)	-	146432** (0.191)	-
HOUSEAGE* SQFTSTRC^#	-148593*** (32740)	-	-6292*** (1260)	-
CONSTRAV	79867*** (16927)	-	68729*** (16790)	-
CONSTGOODP	175936*** (24172)	-	163933*** (24056)	-
BASEMENT	34614** (13885)	-	30108** (13460)	-
GARAGE	32086** (14257)	-	31886** (13924)	-
TOTBATHS	11258 (7233)	-	8675 (7076)	-
FIREPLACE	56640*** (16030)	-	54483*** (15754)	-
WATERFRONT	71890*** (24907)	23485 (32221)	73442*** (24416)	24634 (31681)
STMARYS	11894 (13252)	-17430 (14980)	5748 (13004)	-20394 (14736)
ACRES^#	70235*** (8993)	66896*** (8897)	22611*** (2737)	20756*** (2578)
PERPASTURE^	-78656* (45204)	64689 (93303)	-82832* (44055)	61842 (91747)
PERCROP^	49268** (19957)	19951 (23370)	46711** (19511)	23311 (23016)
S_SLOPE_M_H	-18931 (20838)	-29940 (22399)	-17862 (20300)	-31322 (22012)
S_ERODEHIGH	-62006* (32543)	-221459*** (55873)	-52609* (31858)	-222424*** (54889)
S_ERODEM	-83908** (36757)	-214964*** (58284)	-71406** (35979)	-216284*** (57230)
S_FLOOD	-92954*** (34299)	-304745*** (56085)	-87585*** (33554)	-306282*** (55112)
Adjusted R^2	0.58	0.33	0.60	0.35

Note: Parameter significance tested with $H_0 : \beta = 0$, $H_1 : \beta \neq 0$.

* indicates rejection of the null hypothesis at the 0.10 significance level;

** indicates rejection of the null hypothesis at the 0.05 significance level;

*** indicates rejection of the null hypothesis at the 0.01 significance level.

^ SQFTSTRC, ACRES are transformed by natural logarithm in Model 1: Inverse semi-log.

\# SQFTSTRC, ACRES are transformed by square root in Model 2: non-linear.

The results of the two model specifications generally follow the hypothesized effects laid out in Table 4.1, as none of the significant coefficients have perverse effects on parcel market value. The variables with significant parameters are significant across the two model specifications for the improved parcels. Similarly, the same variables have significant parameters across the model specifications for the unimproved parcels.

Across the improved models, an additional square foot adds to the market value as expected. House age significantly affects the parcel market value, as newer homes have larger market values than older homes. The marginal cost of an additional square foot is significantly lower for newer homes than for older homes. This is expected since newer homes have more square footage, on average, than older homes. Average and good-luxury construction grade lead to higher market values than low quality construction. Basements, garages, and fireplaces add significant value to the market value of a parcel. The total number of bathrooms has no significant effect on the market value.

Waterfront location commands a premium on market value for improved parcels. The county designation of St. Mary's County has no significant effect on market value. As the parcel acreage increases, the market value increases as expected. Additional pasture land lowers the market value while additional cropland raises the market value for improved parcels. Highly and moderately erodible soils as well as floodplain soils significantly lower parcel market values while steeper slopes do not significantly affect parcel market value.

Among the models for unimproved parcels, waterfront location and county have no significant effect on the market value. As parcel acreage increases, the market value increases significantly as expected. Pasture and cropland do not significantly affect the unimproved parcels' market value. As expected, highly and moderately erodible soils as well as floodplain soils significantly lower parcel market values. Steeper slopes do not significantly affect parcel market value.

Choosing a Functional Form

While two model specifications are presented in Table 5.1, the robustness of the results across the model specifications indicates that one model can be chosen to make predictions of the land parcels' market values in Southern Maryland. The results from the tests below determine which model specification is used to predict the land parcels' market values.

The assumption that there are separate markets and, therefore, separate models, for improved parcels and unimproved parcels is tested with an F test for joint significance. A model is estimated with the improved and unimproved parcels, including a dummy variable for improved parcels and interaction terms for each of the community and land characteristics with the improved parcels dummy variable. An F test for joint significance tests the null hypothesis that the parameters on the interaction terms and the dummy variable for improved parcels are jointly equal to zero. Rejection of the null hypothesis indicates that the marginal values for the community and land characteristics are different for the improved and unimproved parcels, and the intercepts for the improved and unimproved parcels are different, and therefore separate models should be estimated for the improved and unimproved parcels.

For both models, the null hypothesis that parameters in the interaction terms and dummy variable for improved parcels are jointly equal to zero is rejected at the 95 percent confidence level. The $F_{(10,434)}$ value for Model 1 is 1.95. The $F_{(10,434)}$ value for Model 2 is 1.98. These results confirm that the markets for the improved and unimproved parcels have different marginal values for community and land characteristics. The models for improved and unimproved parcels are estimated separately.

The Bruesch-Pagan Lagrange Multiplier test for heteroskedasticity is conducted for each model specification in Table 5.1. Table 5.2 presents the test results.

Table 5.2: Breusch-Pagan Lagrange Multiplier Heteroskedasticity Test Results

	LM Statistic	Probability[15]
Model 1 Improved	200.6	0.140
Model 1 Unimproved	78.0	0.000
Model 2 Improved	197.4	0.191
Model 2 Unimproved	61.3	0.154

[15] Under the null hypothesis of homoskedasticity, the LM Statistic is distributed chi-square with degrees of freedom set at the number of regressors in the model (Hansen ,2001).

For improved parcel models, the null hypothesis of homoskedasticity cannot be rejected at the 95 percent confidence level for either model specification. However, the null hypothesis of homoskedasticity can be rejected for the Model 1 unimproved model. This model includes the natural logarithm of acreage. The null hypothesis of homoskedasticity cannot be rejected for the Model 3 specification, which includes the square root of ACRES.

Out-of-sample predictions compare the predictive quality of the models. Table 5.3 presents the results of 25 percent holdout sample predictions for each of the model specifications.

Table 5.3: Out-of-sample Predictions –
Mean of Actual minus Predicted Market Value

Model	Mean
Model 1 Improved	$9209
Model 1 Unimproved	$10025
Model 2 Improved	$6457
Model 2 Unimproved	$10728

Model 2 has the smallest mean difference between the actual and predicted market values for the improved parcels. Among the unimproved parcel models, Model 1 has the smallest mean difference between actual and predicted market value.

The results from the Breusch-Pagan tests and out-of-sample predictions suggest that Model 2: Non-linear has the best model specification. Model 1 exhibits heteroskedasticity in the unimproved parcel model. The Model 2 specification that transforms ACRES by square root rather than by natural logarithm does not have heteroskedasticity. The out-of-sample predictions reveal that Model 2 has the smallest mean difference in actual versus predicted market value for the improved parcel model. Therefore, the Model 2: Non-linear specification is chosen to make the parcel market value predictions.

Prediction of Parcel Market Values

The results from the Model 2 hedonic model estimations are used to predict parcels' market values in the study area of Charles, Calvert, and St. Mary's Counties, Maryland. The predictions are based on parcels sold in the market from 1999 through 2002, rather than the full population of parcels because the full population does not have recent market prices or market prices at all.

Predicted market value (PMV_i) is calculated as

$$PMV_i = \alpha + \beta * s_i + \delta * l_i + \gamma * c_i$$

where α is the estimated intercept. The vectors s_i, l_i, and c_i contain parcel i's characteristics, and the β, δ, and γ vectors contain the corresponding hedonic model parameter estimates. Specifically, the improved parcels' predicted market values are calculated as

PMV_i = 46651 +
(sqrt (sqftstrc) *1407) +
(houseage * 146432) +
(agesqft * -6292) +
(constrav * 68729) +
(constrexc * 163933) +
(basement * 30108) +
(garage * 31886) +
(totbaths * 8675) +
(fireplace * 54483) +
(waterfront * 73442) +
(stmarys * 5748) +
(sqrt(acres) * 22611) +

(perpasture *-82832) +
(percrop *46711) +
(s_slope_m_h *-17862) +
(s_erodehigh * -52609) +
(s_erodem * -71406) +
(s_flood * -87585).

For unimproved parcels, the predicted market values are calculated as

PMV_i = 257586 +
(waterfront * 24634) +
(stmarys * -20394) +
(acres * 20756) +
(perpasture * 61842) +
(percrop * 23311) +
(s_slope_m_h * -31322) +
(s_erodehigh * -222424) +
(s_erodem * -216284) +
(s_flood * -306282).

Market values are predicted for all parcels at least ten acres in size that have designated agricultural or residential land uses in the three counties.[16] Table 5.4 presents the predicted land market values in 1999 dollars for improved and unimproved lands.

Table 5.4: Median Predicted 1999 Land Market Values

Parcel Type	Number of Parcels	Mean Predicted Market Value	Median Predicted Market Value
Unimproved	2,648	$146,949	$124,121
Improved	4,358	$267,611	$252,847

[16] The land use designation comes from Land Use Code in the Maryland PropertyView 2002 database.

Chapter 6: Targeting Schemes

Targeting Schemes in the Literature

This section outlines targeting tools found in the literature. Studies in the literature investigate optimal targeting methods for farmland easement programs, CRP conservation, and biodiversity and species protection. No studies were found that specifically investigate targeting schemes for ecologically valuable land preservation through land acquisition. However, the methodologies and findings from other studies can provide significant insight to the optimal targeting of ecologically valuable natural lands.

Babcock et al (1996) recommend maximizing environmental benefits by purchasing land with the highest benefit to cost ratios. They show that choosing projects based on the benefit to cost ratio is more efficient than choosing projects based on benefits alone. In a 1997 paper by the same authors (Babcock et al, 1997), they compare three targeting methods in an empirical analysis using Conservation Reserve Program contracts. The targeting methods rank projects from low to high by cost per acre, rank projects from high to low by benefit per acre, and rank projects from low to high by the ratio of cost per acre to benefit per acre. This last ranking method, considered optimal by the authors, is equivalent to ranking projects by marginal cost. The study measures benefits in the form of acres enrolled and proportion of available benefits targeted for four indicators – water erosion, wind erosion, groundwater vulnerability to pesticide leaching, and wildlife habitat. The marginal cost targeting method yields the highest proportion of available benefits across all four indicators. This method yields the second highest amount of acreage for a given budget total, second to the cost per acre method which yields the lowest proportion of available benefits. Wu, Zilberman, and Babcock (2001) also find that the benefit to cost ratio is more efficient at providing environmental benefits than benefit or cost targeting.

Polasky, Camm, and Garber-Yonts (2001) find cost effective strategies that represent a maximum number of species for a given conservation budget. Recognizing that the opportunity cost of designating a site as a biological reserve is the average per acre land value, they solve a budget-constrained maximal covering location problem that has the form

$$\max \sum y_i \text{ subject to } \sum x_i \geq y_i \text{ and } \sum x_i b \leq B$$

where y_i is 0 or 1 for species present at site i, x_i is 1 if the site is chosen for conservation and 0 otherwise, b is the land value of the site, and B is the total budget constraint. The cost of covering 350 species under this maximization solution is less than 10 percent of the cost of a maximization solution that is site-constrained rather than budget-constrained.

As an example of a different method by which targeting can be achieved, Khanna et al (2003) minimize costs for a targeted level of sediment abatement. The authors use linear programming to solve for the optimal land acquisitions for conservation. This method of targeting is especially relevant when the preservation program is designed to achieve a very specific conservation goal.

It can be difficult to define the 'value' for benefits from ecosystem services for any targeting methodology. In this study, the hedonic model estimation results cannot be used to proxy for ecological benefits as the marginal values are negative in the land market for such characteristics as erodible and floodplain soils. The GreenPrint program's Desktop Ecological Scores (DES) assigns an ordinal 'value' to a parcel that is a measure of the parcel's benefits. The State assigns scores for various ecological characteristics, weighs these scores by relative values, and then adds the weighted scores together to obtain the final DES. This score provides an ordinal ranking so the GreenPrint program manager knows whether one parcel is relatively better or worse than another parcel with respect to ecological benefits. However, the score does not provide a cardinal measure to reveal how much better one parcel is than another. Therefore, the targeting packages presented in this study show the number of parcels that have each DES score as a means to quantify the ecological benefits of the targeting packages.

Definition of GreenPrint Targeting Packages

The GreenPrint program maximizes the ordinal DES per parcel subject to the funding constraint imposed by the State legislature. Again, the DES is assumed to represent the benefits achieved from each parcel. This optimization problem is written as

$$\max \sum_i DES_i * p_i \text{ subject to } \sum_i c_i p_i \leq B,$$

where DES_i is the measure of benefits for parcel *i*, p_i equals 1 if parcel *i* is acquired and 0 otherwise, c_i is the cost of acquiring parcel *i*, and *B* is available GreenPrint funding. The solution is obtained by ranking all pursued parcels from high to low with respect to the ordinal DES, and, beginning with the highest ranked parcel, acquiring parcels until the available funding is exhausted. These targeting packages are termed "Benefits" targeting.

The current GreenPrint targeting protocol may not provide optimal allocation of the program's scarce funding resources because it targets parcel benefits only. This study presents two alternative targeting packages for comparison with the current GreenPrint targeting packages. The first alternative targeting packages are built on maximization of the total acreage targeted for acquisition subject to the budget constraint imposed by the State. This is written as

$$\max \sum_i ACRES_i * p_i \text{ subject to } \sum_i c_i p_i \leq B,$$

where $ACRES_i$ is parcel i's acreage, p_i equals 1 if parcel i is acquired and 0 otherwise, c_i is the cost of acquiring parcel i, and B is available GreenPrint funding. This is equivalent to minimizing costs, or

$$\min \sum_i (c_i / ACRES_i) * p_i$$

for a given budget constraint, where $(c_i / ACRES_i)$ is the parcel's cost per acre. Empirically, this maximization is obtained by ranking the parcels from lowest cost per acre to highest cost per acre until budget constraint is reached. These targeting packages are termed "Acreage" targeting.

The second set of alternative targeting packages focuses on a specific benefits metric that the GreenPrint program has deemed ecologically important. Each parcel's area of highly erodible soils is measured and weighted in both the hub level and cell level ecological scores.[17] A gauge of the area of a parcel's highly erodible soils is found in the hedonic model's S_ERODEHIGH variable, which measures the percent of the parcel with highly erodible soils. This variable's parameter is found to be significantly negative in the hedonic models, indicating that more highly erodible soils on a parcel leads to a lower market value for that parcel. Therefore, targeting this ecologically important characteristic could help GreenPrint minimize costs. The targeting packages' optimization problem can be written as

$$\max \sum_i S\_ERODEHIGH_i * p_i \text{ subject to } \sum_i c_i p_i \leq B,$$

where S_ERODEHIGH is the percent of parcel *i* with highly erodible soil, p_i equals 1 if parcel *i* is acquired and 0 otherwise, c_i is the cost of acquiring parcel *i*, and *B* is available GreenPrint funding. Empirically, the parcels are ranked from high to low with respect to S_ERODEHIGH and targeted until the scarce funding is exhausted. These targeting packages are termed "Erodible Soils" targeting.

Results of GreenPrint Targeting Packages Under Various Budget Scenarios

The State of Maryland calculates Desktop Ecological Score (DES) rankings only for parcels pursued for preservation, though all parcels can be scored and ranked with the DES. Ranking all parcels does not change the relative rankings of any specific parcels that may be targeted by the State. Therefore, this study calculates the DES for

[17] Please see Appendix for details on the ecological scores.

every parcel at least ten acres in size with designated agricultural or residential land use. The State-provided GIA data identifying the Green Infrastructure and ecological scores were combined with the parcel acreage data to calculate the DES for each parcel. The DES calculation followed the rankings and weightings listed in Tables 2.4 and 2.5.

Those parcels with an "Excellent" DES rank – scores ranging from 21 to 32 – are evaluated for inclusion in the targeting packages. This allows comparison across targeting packages for the most ecologically valuable lands of the GreenPrint program.

The comparison among targeting packages is made under four budget constraints. These budget constraints - $4 million, $5 million, $16 million, and $25 million – are four project budget scenarios based on past funding scenarios from the State. In fiscal year 2003, the state allocated $16 million for the Greenprint program. In fiscal year 2004, this fell to $4 million, with projections for $5 million in funding per year for 2005 through 2009 for a total of $25 million over 5 years.[18] Under each projected budget, the targeted parcels include full parcels for which sufficient budgeting is available to purchase the entire parcel.[19] If a highly ranked parcel cannot be purchased in entirety under the allocation budget, the parcel will not be targeted. Rather, the next ranked parcel that can be purchased in its entirety under the budget

[18] Under each projected budget scenario, the assumption is that all Greenprint targeting is limited to Calvert, Charles, and St. Mary's Counties.

allocation will be targeted. The targeting packages include both improved and unimproved land parcels, except for the packages that exclusively target unimproved parcels in Tables 6.6a – 6.6c. An improved parcel's full market value is used in the rankings for the parcel's land acquisition cost, including the value of the structure on the parcel.[20]

Overall Targeting Packages

Table 6.1a - c presents the overall targeting packages for the three Southern Maryland counties in this study – Calvert, Charles, and St. Mary's. Table 6.1a presents the targeting packages under the Benefits DES maximization. Table 6.1b presents the targeting packages under the Acreage maximization/cost minimization. Table 6.1c presents the targeting packages under the Erodible Soils maximization. The metrics in the tables serve to compare the outcomes of the three targeting packages for each projected budget. The number of parcels targeted under each scenario is displayed in the # of Parcels row. Total acres and total cost summarize the extent of the targeting packages' reach in land area and funding terms. The Mean Predicted Parcel Market Value can be compared across packages to assess the relative costs of land acquisition under the three targeting packages. The Mean % of Parcel with Highly Erodible Soils measures the reach of highly erodible soils among the targeted parcels. Finally, the

[19] The DES score is calculated for full parcels only. To appropriately compare benefits between targeting schemes, partial parcels must be excluded as their parcel DES scores do not accurately measure the ecological benefits of the partial parcel.

[20] In the GreenPrint program, developed lands called "gaps", which are areas of agriculture, mining, or development such as lawns and residential structures, are targeted for restoration to natural land cover if they are located in a hub's interior. Gaps are included in the DES scores as acres of Green Infrastructure. Restoration could include converting to wetlands, reforesting interior forest, closing roads and restoring them to natural conditions, and abandoning houses and other facilities (Weber, 2003).

DES Score rows 32 - 21 count the number of targeted parcels with each of the "excellent" DES scores from 32 to 21 to quantify the ecological benefits of the targeted land parcels through the DES.

Table 6.1a: Overall Targeting Package for GreenPrint – **Benefits**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	15	20	50	89
Total Acres	1933	2542	9222	13971
Total Cost	$3,959,398	$ 4,948,411	$15,945,128	$ 24,976,946
Mean Predicted Parcel Market Value	$ 263,960	$ 247,421	$ 318,903	$ 280,640
Mean Parcel Market Value per Acre	$ 2,049	$ 1,946	$ 1,729	$ 1,788
Mean % of Parcel with Highly Erodible Soils	23.5%	28.8%	26.5%	34.4%
DES Score 32	4	4	4	4
DES Score 30	11	14	23	23
DES Score 29	0	0	16	17
DES Score 28	0	2	7	44
DES Score 27	0	0	0	0
DES Score 26	0	0	0	0
DES Score 25	0	0	0	1
DES Score 24	0	0	0	0
DES Score 23	0	0	0	0
DES Score 22	0	0	0	0
DES Score 21	0	0	0	0

Table 6.1b: Overall Targeting Package for GreenPrint – **Acreage**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	8	10	31	55
Total Acres	5511	6590	16790	23943
Total Cost	$3,944,005	$ 4,963,244	$15,966,232	$ 24,970,064
Mean Predicted Parcel Market Value	$ 493,001	$ 496,324	$ 515,040	$ 454,001
Mean Parcel Market Value per Acre	$ 716	$ 753	$ 951	$ 1,043
Mean % of Parcel with Highly Erodible Soils	47.1%	45.5%	39.7%	39.2%
DES Score 32	0	0	0	0
DES Score 30	0	0	2	3
DES Score 29	1	1	4	4
DES Score 28	1	2	5	13
DES Score 27	0	0	2	3
DES Score 26	0	1	6	8
DES Score 25	0	1	2	5
DES Score 24	3	3	4	7
DES Score 23	1	1	3	3
DES Score 22	2	1	3	6
DES Score 21	0	0	0	3

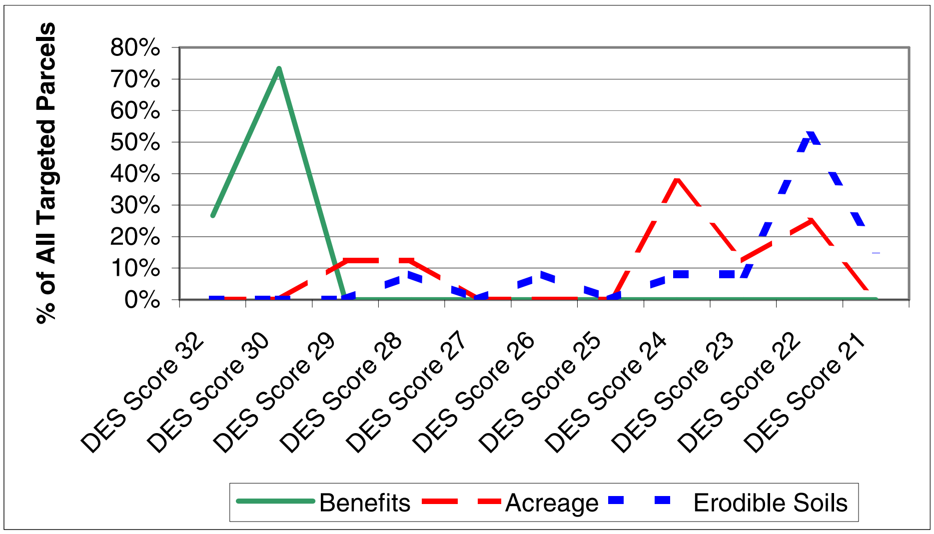
Table 6.1c: Overall Targeting Package for GreenPrint **– Erodible Soils**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	25	31	71	104
Total Acres	989	1346	5911	10484
Total Cost	$3,897,550	$ 4,985,027	$15,978,459	$ 24,690,638
Mean Predicted Parcel Market Value	$ 155,902	$ 160,807	$ 225,049	$ 237,410
Mean Parcel Market Value per Acre	$ 3,943	$ 3,703	$ 2,703	$ 2,355
Mean % of Parcel with Highly Erodible Soils	100.0%	100.0%	100.0%	96.3%
DES Score 32	0	0	0	1
DES Score 30	0	0	1	1
DES Score 29	0	0	0	3
DES Score 28	2	4	12	16
DES Score 27	0	0	2	2
DES Score 26	2	2	6	8
DES Score 25	0	0	3	3
DES Score 24	2	4	12	18
DES Score 23	2	2	2	6
DES Score 22	13	13	23	31
DES Score 21	4	6	10	15

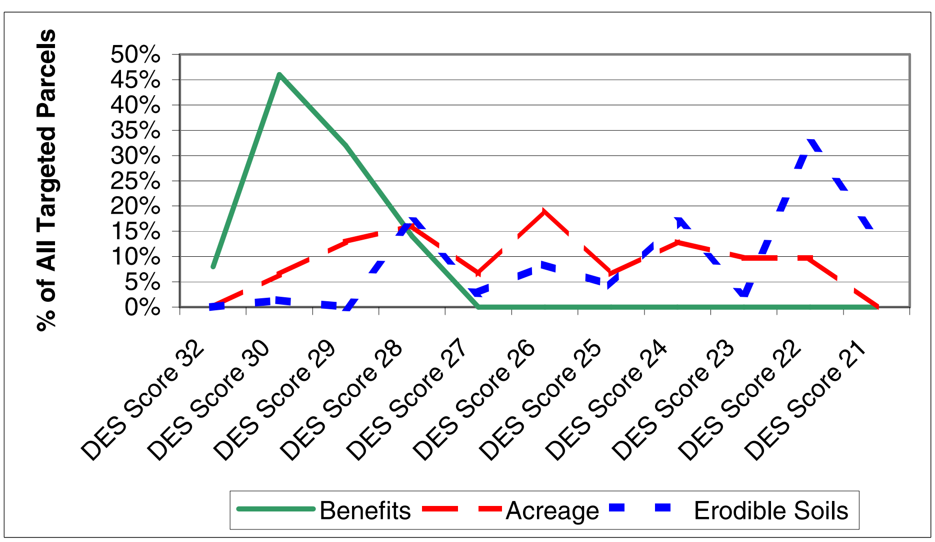
The Erodible Soils packages target 15 to 66 percent more parcels than the Benefits packages and 200 to 300 percent as many parcels as the Acreage packages target. As expected, the Acreage packages include the most acreage. The Benefits packages include more acreage than the Erodible Soils packages, which is likely a result of the large weight for acreage in the DES ordinal rankings. The mean predicted parcel market value is highest for the Acreage packages, as the Acreage packages target the parcels with the lowest per acre parcel market values and therefore the most acreage and largest parcels on average. This is expected as the marginal value of an acre decreases as acreage increases, such that the parcel per acre cost is lower for larger parcels with greater market values due to the positive effect of acreage on market value. The Erodible Soils packages have the lowest mean predicted parcel market values. As expected, the mean percent of parcel with highly erodible soils is highest in the Erodible Soils packages. This measure is also higher in the Acreage packages than in the Benefits packages.

Finally, the Benefits packages have the greatest number and proportion of parcels with the top ranking DES ordinal scores such as 32 and 30. To compare the parcel DES scores across the three targeting packages, the graphs below show the percent of parcels with each DES score across the three optimization metrics. Graph 6.1a compares the distribution of DES scores for targeted parcels under the $4 million budget scenario. Graph 6.1b shows the distribution of DES scores for targeted parcels under the $16 million budget scenario. Graph 6.1c shows the distribution of DES scores for targeted parcels under the $25 million budget scenario. From these graphs, it is clear that the Acreage packages target a greater proportion of parcels with the highest DES scores than the Erodible Soils packages target. This suggests that optimizing one ecological metric may create a relative deficit in other ecological metrics, as measured here by the comprehensive DES ordinal scores.

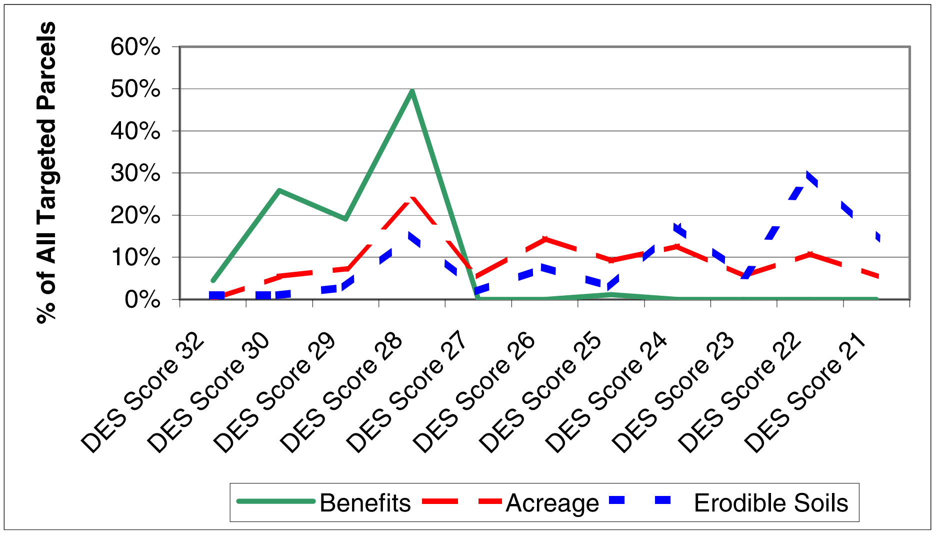
Graph 6.1a: Overall Targeting Package for GreenPrint – **$4 Million Budget**



Graph 6.1b: Overall Targeting Package for GreenPrint – **$16 Million Budget**



Graph 6.1c: Overall Targeting Package for GreenPrint – **$25 Million Budget**



County Specific Targeting Packages

Tables 6.2a – 6.2c present the Benefits targeting packages for each of the three Southern Maryland counties separately. These demonstrate how the overall targeting packages change under a scenario in which counties, rather than the state, are responsible for identifying and preserving lands under GreenPrint. Under this funding scheme, the total GreenPrint funds are split equally between the counties.

Table 6.2a: **Calvert County** Targeting Package for GreenPrint – **Benefits**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	4	5	16	26
Total Acres	758	926	3056	4546
Total Cost	$1,319,270	$ 1,635,199	$ 5,258,602	$ 8,291,913
Mean Predicted Parcel Market Value	$ 329,817	$ 327,040	$ 328,663	$ 318,920
Mean Parcel Market Value per Acre	$ 1,741	$ 1,766	$ 1,721	$ 1,824
Mean % of Parcel with Highly Erodible Soils	1.3%	6.7%	2.8%	1.8%
DES Score 32	2	2	2	2
DES Score 30	1	3	6	6
DES Score 29	0	0	6	6
DES Score 28	1	0	1	11
DES Score 27	0	0	0	1
DES Score 26	0	0	0	0
DES Score 25	0	0	0	0
DES Score 24	0	0	1	0
DES Score 23	0	0	0	0
DES Score 22	0	0	0	0
DES Score 21	0	0	0	0

Table 6.2b: **Charles County** Targeting Package for GreenPrint – **Benefits**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	5	7	16	29
Total Acres	615	822	3014	5146
Total Cost	$1,314,493	$ 1,659,442	$ 5,328,575	$ 8,310,206
Mean Predicted Parcel Market Value	$ 262,899	$ 237,063	$ 333,036	$ 286,559
Mean Parcel Market Value per Acre	$ 2,139	$ 2,019	$ 1,768	$ 1,615
Mean % of Parcel with Highly Erodible Soils	56.3%	54.9%	57.5%	45.2%
DES Score 32	2	2	2	2
DES Score 30	3	4	7	7
DES Score 29	0	0	7	8
DES Score 28	0	1	0	12
DES Score 27	0	0	0	0
DES Score 26	0	0	0	0
DES Score 25	0	0	0	0
DES Score 24	0	0	0	0
DES Score 23	0	0	0	0
DES Score 22	0	0	0	0
DES Score 21	0	0	0	0

Table 6.2c: **St. Mary's County** Targeting Package for GreenPrint – **Benefits**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	6	8	16	28
Total Acres	625	761	2869	4325
Total Cost	$1,302,225	$ 1,658,968	$ 5,256,917	$ 8,274,354
Mean Predicted Parcel Market Value	$ 217,038	$ 207,371	$ 328,557	$ 295,513
Mean Parcel Market Value per Acre	$ 2,083	$ 2,181	$ 1,832	$ 1,913
Mean % of Parcel with Highly Erodible Soils	22.3%	16.7%	21.4%	28.4%
DES Score 32	0	0	0	0
DES Score 30	6	7	10	10
DES Score 29	0	0	3	3
DES Score 28	0	0	3	14
DES Score 27	0	0	0	1
DES Score 26	0	0	0	0
DES Score 25	0	1	0	0
DES Score 24	0	0	0	0
DES Score 23	0	0	0	0
DES Score 22	0	0	0	0
DES Score 21	0	0	0	0

These packages reveal that St. Mary's County has no parcels with DES score 32, the highest possible DES ranking. Under the budget scenarios, the three counties would target comparable numbers of parcels and comparable total acreage. The mean predicted parcel market value is higher in Calvert County than in the other two counties, suggesting that fewer parcels could be targeted for a given budget scenario. The county level targeting packages, when combined across the three counties, target fewer parcels in the top DES scores than the overall targeting packages would target under the various budget scenarios.

Tables 6.3a – 6.3c present the Acreage targeting packages for each of the three Southern Maryland counties separately. These targeting packages target comparable numbers of parcels, though the greatest amount of acreage is targeted in Charles

County and the least amount of acreage is targeted in Calvert County. This suggests that a targeting package with greater funding for Charles County would increase the acreage targeted over what is available under these equal budgets for each county. Also, the sum of the three county targeting packages would preserve less acreage than the overall Acreage targeting packages would preserve. This is true for each of the four projected budget scenarios. This indicates again that the county targeting packages are less optimal than the overall targeting packages.

Table 6.3a: **Calvert County** Targeting Package for GreenPrint – **Acreage**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	3	3	11	20
Total Acres	1148	1565	4286	6116
Total Cost	$1,292,968	$ 1,665,359	$ 5,302,232	$ 8,250,250
Mean Predicted Parcel Market Value	$ 430,989	$ 555,120	$ 482,021	$ 412,513
Mean Parcel Market Value per Acre	$ 1,126	$ 1,064	$ 1,237	$ 1,349
Mean % of Parcel with Highly Erodible Soils	0.0%	0.0%	1.5%	1.7%
DES Score 32	0	0	0	2
DES Score 30	1	1	3	3
DES Score 29	0	0	0	3
DES Score 28	1	0	1	2
DES Score 27	0	1	2	2
DES Score 26	0	0	2	4
DES Score 25	0	0	0	0
DES Score 24	0	0	0	0
DES Score 23	1	1	1	1
DES Score 22	0	0	0	0
DES Score 21	0	0	2	3

Table 6.3b: **Charles County** Targeting Package for GreenPrint – **Acreage**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	3	3	12	17
Total Acres	2020	2547	6232	9043
Total Cost	$1,311,761	$ 1,579,652	$ 5,276,607	$ 8,320,075
Mean Predicted Parcel Market Value	$ 437,254	$ 526,551	$ 439,717	$ 489,416
Mean Parcel Market Value per Acre	$ 650	$ 620	$ 847	$ 920
Mean % of Parcel with Highly Erodible Soils	42.6%	42.6%	41.2%	47.5%
DES Score 32	0	0	0	0
DES Score 30	0	0	0	0
DES Score 29	0	1	2	3
DES Score 28	2	1	3	3
DES Score 27	0	0	0	0
DES Score 26	0	0	3	4
DES Score 25	0	0	2	2
DES Score 24	0	0	1	2
DES Score 23	1	1	1	2
DES Score 22	0	0	0	1
DES Score 21	0	0	0	0

Table 6.3c: **St. Mary's County** Targeting Package for GreenPrint – **Acreage**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	3	3	10	18
Total Acres	1621	1958	5559	7677
Total Cost	$1,230,817	$ 1,560,895	$ 5,329,630	$ 8,285,758
Mean Predicted Parcel Market Value	$ 410,272	$ 520,298	$ 532,963	$ 460,320
Mean Parcel Market Value per Acre	$ 759	$ 797	$ 959	$ 1,079
Mean % of Parcel with Highly Erodible Soils	88.2%	73.8%	40.5%	48.4%
DES Score 32	0	0	0	0
DES Score 30	0	0	0	0
DES Score 29	0	0	1	1
DES Score 28	0	0	1	1
DES Score 27	0	0	1	1
DES Score 26	0	1	1	1
DES Score 25	0	0	0	1
DES Score 24	1	1	3	6
DES Score 23	0	0	0	0
DES Score 22	2	1	3	4
DES Score 21	0	0	0	3

Tables 6.4a – 6.4c present the Erodible Soils targeting packages for each of the three counties. Parcels in Calvert County have lower percentages of highly erodible soils than parcels in the other two counties. Splitting the projected budget evenly between the counties is less efficient than developing a targeting package amongst all counties with one budget amount so that funds could be directed toward parcels in Charles and St. Mary's Counties.

Table 6.4a: **Calvert County** Targeting Package for GreenPrint – **Erodible Soils**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	6	7	17	33
Total Acres	428	577	2221	3843
Total Cost	$1,311,242	$ 1,665,935	$ 5,315,486	$ 8,297,280
Mean Predicted Parcel Market Value	$ 218,540	$ 237,991	$ 312,676	$ 251,433
Mean Parcel Market Value per Acre	$ 3,064	$ 2,887	$ 2,393	$ 2,159
Mean % of Parcel with Highly Erodible Soils	28.5%	28.3%	18.8%	9.9%
DES Score 32	0	0	0	0
DES Score 30	1	2	2	2
DES Score 29	0	0	1	1
DES Score 28	0	0	0	1
DES Score 27	0	0	0	1
DES Score 26	0	0	4	5
DES Score 25	1	1	2	2
DES Score 24	1	1	3	4
DES Score 23	1	2	3	3
DES Score 22	1	0	0	5
DES Score 21	1	1	2	9

Table 6.4b: **Charles County** Targeting Package for GreenPrint – **Erodible Soils**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	7	9	31	42
Total Acres	306	351	1388	2532
Total Cost	$1,302,373	$ 1,570,975	$ 5,282,195	$ 8,175,408
Mean Predicted Parcel Market Value	$ 186,053	$ 174,553	$ 170,393	$ 194,653
Mean Parcel Market Value per Acre	$ 4,258	$ 4,470	$ 3,807	$ 3,229
Mean % of Parcel with Highly Erodible Soils	100.0%	100.0%	100.0%	100.0%
DES Score 32	0	0	0	0
DES Score 30	0	0	0	0
DES Score 29	0	0	0	0
DES Score 28	2	2	6	10
DES Score 27	0	0	0	0
DES Score 26	0	0	2	5
DES Score 25	0	0	0	0
DES Score 24	0	0	4	7
DES Score 23	0	0	0	0
DES Score 22	5	7	14	14
DES Score 21	0	0	5	6

Table 6.4c: **St. Mary's County** Targeting Package for GreenPrint – **Erodible Soils**

Projected Budget	$1.33 million	$1.66 million	$5.33 million	$8.33 million
# of Parcels	9	10	24	33
Total Acres	457	619	2257	3911
Total Cost	$1,319,347	$ 1,647,852	$ 5,321,800	$ 8,272,950
Mean Predicted Parcel Market Value	$ 146,594	$ 164,785	$ 221,742	$ 250,695
Mean Parcel Market Value per Acre	$ 2,889	$ 2,660	$ 2,358	$ 2,115
Mean % of Parcel with Highly Erodible Soils	96.3%	100.0%	99.2%	97.8%
DES Score 32	0	0	0	0
DES Score 30	0	0	1	1
DES Score 29	0	0	0	0
DES Score 28	2	2	3	5
DES Score 27	1	2	2	2
DES Score 26	0	0	0	0
DES Score 25	0	0	1	1
DES Score 24	1	1	6	8
DES Score 23	2	2	2	3
DES Score 22	2	1	5	8
DES Score 21	1	2	4	5

Across the Benefits, Acreage, and Erodible Soils targeting, the combination of the three separate county targeting packages is less optimal than the overall targeting packages. The overall targeting packages can maximize the appropriate optimization metrics across the entire area. By contrast, the three counties have constrained parcel choice sets by which to maximize the optimization metric. Economic theory suggests, and results above support, the overall targeting packages as more effective at reaching the optimal goal than the county-specific constrained packages. This empirical observation supports statewide administration of the GreenPrint program over local administration. More generally, this observation supports large-scale, comprehensive land preservation programs to maximize ecological benefits while most efficiently allocating public funds.

An alternative to dividing the funding equally between the three counties is to give all of the GreenPrint funding to one county for land acquisitions. A potential advantage of this approach is that the targeted lands would be in closer proximity to each other, and targeted parcels are more likely to be contiguous. This would enable GreenPrint to target larger portions of hubs or whole hubs. Tables 6.5a – 6.5c display the targeting packages for St. Mary's County under a scenario in which this county receives all of the GreenPrint budget funding.

Table 6.5a: **All St. Mary's County** Targeting Package for GreenPrint – **Benefits**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	14	15	52	85
Total Acres	1832	2745	8238	12093
Total Cost	$3,969,859	$ 4,992,403	$15,983,117	$ 24,950,626
Mean Predicted Parcel Market Value	$ 283,561	$ 332,827	$ 307,368	$ 293,537
Mean Parcel Market Value per Acre	$ 2,167	$ 1,819	$ 1,940	$ 2,063
Mean % of Parcel with Highly Erodible Soils	17.3%	16.2%	35.5%	39.0%
DES Score 32	0	0	0	0
DES Score 30	10	10	10	10
DES Score 29	2	3	3	3
DES Score 28	2	1	18	18
DES Score 27	0	0	11	11
DES Score 26	0	0	8	10
DES Score 25	0	1	1	19
DES Score 24	0	0	0	13
DES Score 23	0	0	0	1
DES Score 22	0	0	1	0
DES Score 21	0	0	0	0

Table 6.5b: **All St. Mary's County** Targeting Package for GreenPrint – **Acreage**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	8	11	40	76
Total Acres	4411	5252	12431	16814
Total Cost	$3,982,787	$ 4,997,795	$15,995,256	$ 24,992,714
Mean Predicted Parcel Market Value	$ 497,848	$ 454,345	$ 399,881	$ 328,852
Mean Parcel Market Value per Acre	$ 903	$ 952	$ 1,287	$ 1,486
Mean % of Parcel with Highly Erodible Soils	45.1%	35.8%	49.4%	48.1%
DES Score 32	0	0	0	0
DES Score 30	0	0	2	6
DES Score 29	0	1	2	2
DES Score 28	1	1	6	9
DES Score 27	1	1	2	3
DES Score 26	1	1	4	6
DES Score 25	1	0	2	4
DES Score 24	2	2	9	13
DES Score 23	0	0	2	7
DES Score 22	2	3	5	15
DES Score 21	0	2	6	11

Table 6.5c: **All St. Mary's County** Targeting Package for GreenPrint – **Erodible Soils**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	18	23	56	88
Total Acres	1667	2144	8590	12578
Total Cost	$3,968,844	$ 4,994,383	$15,938,539	$ 24,974,219
Mean Predicted Parcel Market Value	$ 220,491	$ 217,147	$ 284,617	$ 283,798
Mean Parcel Market Value per Acre	$ 2,380	$ 2,329	$ 1,856	$ 1,985
Mean % of Parcel with Highly Erodible Soils	99.9%	99.3%	92.1%	82.8%
DES Score 32	0	0	0	0
DES Score 30	1	1	1	1
DES Score 29	0	0	1	1
DES Score 28	2	3	5	7
DES Score 27	2	2	4	5
DES Score 26	0	0	1	5
DES Score 25	1	1	4	10
DES Score 24	4	5	14	18
DES Score 23	2	2	5	8
DES Score 22	3	5	13	23
DES Score 21	3	4	8	10

The Benefits packages for St. Mary's County target fewer parcels with the highest DES Scores than the overall Benefits packages target. The Acreage packages for St. Mary's County also target less acreage than the overall Acreage packages target, and a similar result is found for the Percent of Highly Erodible Soils benefit. Thus, again, it is clear than more optimal results are gained from an unconstrained choice set. Comparing the targeting packages for St. Mary's County to the sum of the separate targeting packages for the three counties, the St. Mary's County packages target more parcels, in general, at a lower mean predicted parcel market value. The St. Mary's County targeting packages are less optimal with respect to DES Scores and acreage than the sum of the three county targeting packages. However, due to the lower proportion of highly erodible soils on Calvert County parcels, the St. Mary's County targeting packages are more optimal than the sum of the three county packages with respect to the mean percent of highly erodible soils.

Unimproved Parcel Targeting Packages

While improved land is currently included in the GreenPrint rankings, program managers may choose to target only unimproved land to meet the program's goals. Targeting packages are presented in Tables 6.6a – 6.6c for unimproved lands across the three counties. As with the overall targeting packages, the Erodible Soils packages target the greatest number of parcels at the lowest mean predicted parcel market value. The Benefits packages target the greatest proportion of parcels with the highest DES Scores, and the Acreage packages target the greatest amount of acreage.

Table 6.6a: Unimproved Parcels Targeting Package for GreenPrint – Benefits

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	15	20	66	99
Total Acres	2036	2581	8721	13844
Total Cost	$3,965,780	$ 4,998,255	$15,969,276	$ 24,962,960
Mean Predicted Parcel Market Value	$ 264,385	$ 249,913	$ 241,959	$ 252,151
Mean Parcel Market Value per Acre	$ 1,948	$ 1,937	$ 1,831	$ 1,803
Mean % of Parcel with Highly Erodible Soils	29.4%	33.4%	40.6%	38.2%
DES Score 32	2	2	2	2
DES Score 30	11	11	11	11
DES Score 29	2	5	6	6
DES Score 28	0	1	46	54
DES Score 27	0	0	1	12
DES Score 26	0	0	0	14
DES Score 25	0	1	0	0
DES Score 24	0	0	0	0
DES Score 23	0	0	0	0
DES Score 22	0	0	0	0
DES Score 21	0	0	0	0

Table 6.6b: Unimproved Parcels Targeting Package for GreenPrint – Acreage

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	8	11	48	88
Total Acres	4890	5774	14265	19758
Total Cost	$3,999,501	$ 4,988,507	$15,967,503	$ 24,928,063
Mean Predicted Parcel Market Value	$ 499,938	$ 453,501	$ 332,656	$ 283,273
Mean Parcel Market Value per Acre	$ 818	$ 864	$ 1,119	$ 1,262
Mean % of Parcel with Highly Erodible Soils	48.0%	47.2%	39.1%	35.3%
DES Score 32	0	0	0	1
DES Score 30	0	0	2	3
DES Score 29	1	1	1	2
DES Score 28	1	2	13	22
DES Score 27	0	0	2	4
DES Score 26	2	2	6	11
DES Score 25	0	1	5	13
DES Score 24	3	3	10	14
DES Score 23	0	0	1	3
DES Score 22	1	2	6	11
DES Score 21	0	0	2	4

Table 6.6c: Unimproved Parcels Targeting Package for GreenPrint – Erodible Soils

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	26	31	74	108
Total Acres	1027	1458	7495	13207
Total Cost	$3,951,555	$ 4,990,865	$15,985,834	$ 24,891,963
Mean Predicted Parcel Market Value	$ 151,983	$ 160,996	$ 216,025	$ 230,481
Mean Parcel Market Value per Acre	$ 3,847	$ 3,423	$ 2,133	$ 1,885
Mean % of Parcel with Highly Erodible Soils	100.0%	100.0%	98.7%	94.1%
DES Score 32	0	0	0	0
DES Score 30	0	0	1	1
DES Score 29	0	0	2	3
DES Score 28	2	6	15	21
DES Score 27	0	1	2	2
DES Score 26	1	1	5	8
DES Score 25	0	0	0	4
DES Score 24	4	5	14	20
DES Score 23	2	2	3	6
DES Score 22	11	10	19	26
DES Score 21	6	6	13	17

Comparing the targeting packages in Tables 6.6a – 6.6c to those in Tables 6.1a – 6.1c, it is evident that the mean predicted parcel market value is lower in the targeting packages limited to unimproved parcels as expected. With cheaper parcel market values, the unimproved parcel targeting packages can target more parcels. However, each optimization metric has lower target results in the packages constrained to unimproved parcels. The Benefits packages for unimproved parcels target fewer parcels with the highest DES scores than the unconstrained Benefits packages in Table 6.1a. The Acreage packages for unimproved parcels target less total acreage than the packages in Table 6.1b. Similarly, the Erodible Soils packages for unimproved parcels target parcels with slightly lower percentages of highly erodible soils than the unconstrained packages in Table 6.1c.

100+ Acre Targeting Packages

The GreenPrint program is designed to preserve large land parcels for the protection of ecosystem services and habitat. Preservation of large land parcels can be accomplished by targeting only large land parcels. Tables 6.7a – 6.7c target parcels at least 100 acres in area. Comparisons between the 100+ Acre Parcel Targeting Packages reveal that the Benefits and Erodible Soils packages target the greatest number of parcels and have similar mean predicted parcel market values. The Acreage packages target the most acreage and the Benefits packages target the greatest number of parcels with the top DES Scores.

Table 6.7a: 100+ Acre Parcels Targeting Package for GreenPrint – **Benefits**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	13	16	44	75
Total Acres	2033	2714	10026	15428
Total Cost	$3,924,661	$ 4,971,035	$15,952,422	$ 24,957,275
Mean Predicted Parcel Market Value	$ 301,897	$ 310,690	$ 362,555	$ 332,764
Mean Parcel Market Value per Acre	$ 1,930	$ 1,832	$ 1,591	$ 1,618
Mean % of Parcel with Highly Erodible Soils	28.1%	28.1%	27.0%	30.1%
DES Score 32	4	4	4	4
DES Score 30	8	11	15	15
DES Score 29	1	0	16	16
DES Score 28	0	1	9	39
DES Score 27	0	0	0	1
DES Score 26	0	0	0	0
DES Score 25	0	0	0	0
DES Score 24	0	0	0	0
DES Score 23	0	0	0	0
DES Score 22	0	0	0	0
DES Score 21	0	0	0	0

Table 6.7b: 100+ Acre Parcels Targeting Package for GreenPrint – **Acreage**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	7	9	30	54
Total Acres	5417	6579	16697	23850
Total Cost	$3,897,505	$ 4,990,285	$15,919,732	$ 24,923,564
Mean Predicted Parcel Market Value	$ 556,786	$ 554,476	$ 530,658	$ 461,547
Mean Parcel Market Value per Acre	$ 719	$ 758	$ 953	$ 1,045
Mean % of Parcel with Highly Erodible Soils	48.6%	51.0%	39.8%	39.2%
DES Score 32	0	0	0	0
DES Score 30	0	0	2	3
DES Score 29	1	1	4	4
DES Score 28	0	1	4	12
DES Score 27	0	0	2	3
DES Score 26	0	1	6	8
DES Score 25	0	1	2	5
DES Score 24	3	3	4	7
DES Score 23	1	1	3	3
DES Score 22	2	1	3	6
DES Score 21	0	0	0	3

Table 6.7c: 100+ Acre Parcels Targeting Package for GreenPrint – **Erodible Soils**

Projected Budget	$4 million	$5 million	$16 million	$25 million
# of Parcels	13	15	46	68
Total Acres	1980	2448	9000	14983
Total Cost	$3,978,550	$ 4,964,502	$15,897,629	$ 24,989,726
Mean Predicted Parcel Market Value	$ 306,042	$ 330,967	$ 345,601	$ 367,496
Mean Parcel Market Value per Acre	$ 2,009	$ 2,028	$ 1,766	$ 1,668
Mean % of Parcel with Highly Erodible Soils	97.6%	97.9%	97.9%	95.2%
DES Score 32	0	0	1	1
DES Score 30	1	1	1	1
DES Score 29	0	0	2	3
DES Score 28	0	0	7	8
DES Score 27	0	0	0	1
DES Score 26	3	3	5	5
DES Score 25	2	2	5	9
DES Score 24	4	5	10	15
DES Score 23	0	0	2	6
DES Score 22	3	3	7	12
DES Score 21	0	1	6	7

A comparison of the targeting packages in Tables 6.7a – 6.7c to those in Tables 6.1a – 6.1c highlights the differences between the 100+ acre packages and the overall targeting packages. Due to the restriction on parcel size, and the positive marginal value of acres on market value, the 100+ acre targeting packages contain parcels with a greater mean predicted market value and, thus, fewer parcels. The Benefits packages under the 100+ acre constraint target fewer parcels with the very top DES Scores than the overall Benefits packages target. The Erodible Soils packages under the 100+ acre constraint are also less optimal than the unconstrained Erodible Soils packages. Specifically, the mean % of parcel with highly erodible soils is lower in the constrained packages. The Acreage packages target the same parcels, save for one parcel with 93 acres, with and without the 100+ acre constraint.

The unimproved parcel and 100+ acre parcel constraints confirm the findings with the three county targeting packages that these constrained parcel choice sets lead to less optimal results with respect to the optimization metrics of Benefits, Acreage, and Erodible Soils than with an unconstrained parcel choice set. That this is true across all optimization metrics suggests that it is important for the GreenPrint program to review and rank as many Maryland land parcels as possible when developing the targeting packages.

Targeting Suggestions based on Hedonic Model Estimation Results

The hedonic model estimation results for both the improved and unimproved parcels offer insight on the relative costs of targeting various land characteristics for acquisition. The insignificance of waterfront location on market value for an unimproved parcel suggests that GreenPrint should target lands with shoreline on unimproved parcels. Since waterfront location has a positive effect on market value for improved parcels, the GreenPrint program can more efficiently target waterfront acreage through unimproved parcels.[21] Among improved parcels, those parcels with pasture land have lower market values than identical parcels without pasture land. Among improved parcels, GreenPrint should target parcels with pasture before targeting parcels with cropland, which adds to the parcel's market value. Pasture land is more highly valued ecologically by the GreenPrint program as well, as this land is less intensively developed than cropland.

[21] Unimproved parcels with waterfront location may have significant barriers to development, such as floodplain soils or wetlands, that keep these parcels unimproved.

The negative parameters on the soil characteristics for both the improved and unimproved parcels (S_SLOPE_M_H, S_ERODEHIGH, S_ERODEM, and S_FLOOD) suggest that GreenPrint should continue to target land parcels with highly erodible soils, wetlands, and greater topographic relief.[22] These ecologically valuable characteristics have negative marginal market values, so parcels with these characteristics would have lower acquisition costs than identical parcels without these characteristics.

Conclusions

The overall targeting packages results show that each of the three sets of targeting packages has a unique advantage over the others. The Benefits packages clearly target the parcels with the greatest ordinal DES scores. The Acreage packages target the greatest amount of acreage for preservation under the budget constraints. The Erodible Soils packages target the greatest number of parcels at the lowest mean predicted parcel market value and provide the highest mean % of parcel with highly erodible soils. The GreenPrint program can weigh the relative advantages of each of these targeting packages when determining how to spend the scarce program funding to preserve land parcels.

The findings from this study are immediately actionable with the targeting packages using the geographically referenced data set compiled across the entire state of Maryland for this study. The GreenPrint ordinal DES calculation heavily weights

[22] The GreenPrint ecological scores include area of highly erodible soils and area of wetlands as well

Green Infrastructure acreage in the rankings. The results of the targeting packages suggest that GreenPrint program managers may utilize the Acreage targeting packages among the "excellent" DES rankings to maximize the acreage targeted and preserved under the budget constraints. This allows GreenPrint to target the greatest amount of land with the highest ecological benefits value, as measured by the DES Score.

The study's three county, unimproved parcel, and 100+ acre parcel constraints highlight the benefits of developing targeting packages from an unconstrained parcel choice set. The optimal targeting packages should be developed across larger regions, even across the entire state, rather than in smaller isolated pockets.

The next step for direct implementation across Maryland is development of hedonic models for the remaining private land markets in the state. With those hedonic model algorithms, the predicted land market values combine with the benefits and acreage measures for all land parcels to develop targeting packages across the state given any budget.

Future work for direct implementation of this preservation targeting technique across the state of Maryland can include improvement of the hedonic model. The inclusion of additional data, especially more ecological characteristics of the land parcels, would strengthen the hedonic model. The addition of commercial and industrial lands to the targeting packages would enable Maryland to encompass all potential GreenPrint target parcels in the targeting packages. The ability to predict parcel

---

as topographic relief.

market values for commercial and industrial land parcels hinges on the availability of improved data, such as structural characteristics and whether a parcel has been improved, for those lands.

Partial parcel acquisition must be addressed to maximize the benefits from the Benefits targeting packages. Currently, the DES rankings assume full parcel acquisition. Parsing the DES for partial parcels would help in targeting parts of large parcels, where there may not be sufficient funds to target the entire parcel. Finally, calculation of the cardinal fine-scale ecological scores would enable researchers to develop benefit/cost ratios utilizing the ecological scores for the benefits and the predicted parcel market values for the costs.

Appendix

GreenPrint Composite Ecological and Development Risk Rankings

The composite ecological ranking relies on the rankings of the hubs in each physiographic province by 27 different parameters. The rankings are not state-wide, but are made within the six physiographic regions. Maryland's geologic diversity leads to tremendous habitat diversity so, by ranking hubs within physiographic regions, the State hopes to emphasize a variety of habitat types. The physiographic provinces are Appalachian Plateau, Ridge and Valley, Blue Ridge, Piedmont, Coastal Plain West, and Coastal Plain East.

All hubs in a province are ranked from highest to lowest according to a parameter such as area of upland interior forest. Each hub's rank is transformed into a rank percentile by multiplying the hub's rank by 100 and then dividing by the maximum rank in that physiographic region. A parameter weight is assigned to each parameter, which indicates the relative importance of the parameter in determining the overall ecological value of land. The composite ecological ranking is a combination of all 27 parameters. Each parameter percentile rank is multiplied by its importance weight. The composite ecological ranking is the summation across the hub's 27 weighted parameter percentile ranks. Table X.A lists the parameters and their relative importance weights.

Table X.A: Parameters and weights used to rank overall ecological significance of each hub within its physiographic region.

Parameter	Weight
Heritage and MBSS element occurrence (occurrences of rare, threatened and endangered plants and animals; rated according to their global or range-wide rarity status; state-specific rarity status; and population size, quality, or viability)	12
Area of Delmarva fox squirrel habitat	3
Fraction in mature and natural vegetation communities	6
Area of Natural Heritage Areas	6
Mean fish IBI score	1
Mean benthic invertebrate IBI score	1
Presence of brook trout	2
Anadromous fish index	1
Proportion of interior natural area in hub	6
Area of upland interior forest	3
Area of wetland interior forest	3
Area of other unmodified wetlands	2
Length of streams within interior forest	4
Number of stream sources and junctions	1
Number of GAP vegetation types	3
Topographic relief (standard deviation of elevation)	1
Number of wetland types	2
Number of soil types	1
Number of physiographic regions in hub	1
Area of highly erodible soils	2
Remoteness from major roads	2
Area of proximity zone outside hub	2
Nearest neighboring hub distance	2
Patch shape	1
Surrounding buffer suitability	1
Interior forest within 10 km of hub periphery	1
Marsh within 10 km of hub periphery	1

(Source: Weber, 2003)

The hubs in each physiographic region are divided into three equal groups according to their composite ecological rankings. Tier 1 comprises the 33 percent of hubs with highest composite ecological rankings. Tier 2 includes the middle 33 percent of hubs, and Tier 3 contains the hubs with the lowest rankings.

Corridors are also ranked by ecological parameters. Due to the importance of maintaining pathways between hubs, the corridors connecting hubs in Tier 1 are evaluated separately from the corridors linking Tier 2 and Tier 3 hubs. Corridors are further divided by length, with corridors less than 0.85 miles in one group and corridors greater than 0.85 miles in a second group. Twenty two parameters were used to rank the corridors. Similar to the hub composite ecological rank, the corridor parameters were transformed to percentiles, weighted, and summed to calculate the composite ecological rank for corridors. Table X.B lists the parameters and importance weights for the corridor composite ecological ranking.

Table X.B: Parameters and weights used to rank overall ecological significance of each corridor segment within its physiographic region.

Parameter	**Weight**
Does corridor link hubs in top ecological tier?	8
Top ecological ranking of hubs connected by corridor	4
Mean upland impedance	4
Mean wetland impedance	4
Mean aquatic impedance	4
Total area	1
Number of corridor breaks	4
Road crossings, weighted by road type	8
Percent of gap area	2
Sum of rare species scores	2
Area of Delmarva fox squirrel habitat	1
Fraction in mature and natural vegetation communities	2
Fish IBI	1
Benthic invertebrate IBI	1
Presence of brook trout	1
Area of upland interior forest	1
Area of wetland interior forest	1
Area of other unmodified wetlands	1
Length of streams within interior forest	1
Area of highly erodible soils	1
Mean distance to the nearest primary or secondary road	1
Surrounding buffer suitability (within 300' of hub)	2

(Source: Weber, 2003)

The Green Infrastructure lands are mostly undisturbed, natural lands. The current state of such land is at least only recoverable at a high cost once development – residential, commercial, industrial, or institutional – occurs on it. Therefore, in addition to the ecological rankings, the hubs and corridors are evaluated with respect to risk of development. As with the composite ecological ranking, the hubs and corridors are ranked on each of 11 parameters within the lands' physiographic regions. The rankings are transformed to percentile ranks, each percentile rank is multiplied by its importance weight, and the 11 weighted parameter ranks are summed together to obtain the overall risk of development ranking. Table X.C lists these development risk parameters and their importance weights.

Table X.C: Parameters and weights used to rank overall development risk of each hub within its physiographic region.

Parameter	**Weight**
Mean level of protection from development	5
Percent of hub in inside designated Priority Funding Areas	3
Percent of hub with existing or planned sewer service	3
Population growth or loss 1990-2000	2
Number of parcel centroids in the hub, divided by hub area	1
Commuting time to urban centers	1
Land demand from proximity to Washington DC and Baltimore	2
Mean market land value	2
Mean distance to nearest major road	2
Area of waterfront property	2
Mean proximity to preserved open space	2

(Source: Weber, 2003)

GreenPrint Fine Scale Ecological and Development Risk Rankings

The local feature score is created by summing across the weighted parameters shown in Table X.D. The local feature scores are scaled from 0 to 100 statewide, where 100 is the most ecologically valuable.

Table X.D: Fine Scale ecological parameters and weighting

Parameter	**Weight**	**Weighted score range**
Rare plant and animal element occurrences	4	0-200
Delmarva fox squirrel habitat	6	0 or 60
Proximity to Natural Heritage Areas or other heritage areas	3 - 5	0-100
Land cover	4	0-40
Proximity to development	4	0-40
Distance to nearest road, weighted by road type	2 - 4	0-40
Highly erodible soils	2	0-20
Proximity to unmodified wetlands	4	0-40
Interior forest	4	0-40
Proximity to streams	2 - 6	0-60
Proximity to stream nodes	1	0-10

(Source: Weber, 2003)

Table X.E lists the fine scale development risk parameters and importance weights.

Table X.E: Parameter importance weights for fine scale development risk models

Parameter	**Weights**
Level of protection from development	6
Inside Priority Funding Areas, or with existing or planned sewer service	4
Population growth or loss 1990-2000	1
Parcel size, interpolated from MdProperty View centroids	1
Commuting time to town centers	1
Land demand from proximity to Washington DC and Baltimore	2
Market land value per acre, interpolated from MdProperty View centroids	2
Distance from primary roads	2
Distance from secondary roads	1
Waterfront property	2
Proximity to preserved open space	2

(Source: Weber, 2003)

References

Anselin, Luc. 2002. "Under the Hood: Issues in the Specification and Interpretation of Spatial Regression Models." Agricultural Economics 27: 247-267.

Anselin, Luc and Daniel Griffith. 1988. "Do Spatial Effects Really Matter in Regression Analysis?" Papers of the Regional Science Association 65: 11-34.

Babcock, Bruce, P.G. Lakshminarayan, JunJie Wu, and David Zilberman. 1996. "The Economics of a Public Fund for Environmental Amenities: A Study of CRP Contracts." American Journal of Agricultural Economics 78: 961-971.

Babcock, Bruce, P.G. Lakshminarayan, JunJie Wu, and David Zilberman. 1997. "Targeting Tools for the Purchase of Environmental Amenities." Land Economics 73(3): 325-39.

Bastian, Chris, Donald McLeod, Matthew Germino, William Reiners, and Benedict Blasko. 2002. "Environmental Amenities and Agricultural Land Values: a Hedonic Model Using Geographic Information Systems Data." Ecological Economics 40(3): 337-349.

Bell, Kathleen and Nancy Bockstael. 2000. "Applying the Generalized-Moments Estimation Approach to Spatial Problems Involving Microlevel Data." The Review of Economics and Statistics 82(1): 72-82.

Bockstael, Nancy. 1996. "Modeling Economics and Ecology: The Importance of a Spatial Perspective." American Journal of Agricultural Economics 78: 1168-1180.

Breffle, William, Edward Morey, and Tymon Lodder. 1998. "Using Contingent Valuation to Estimate a Neighborhood's Willingness to Pay to Preserve Undeveloped Urban Land." Urban Studies 35(4): 715-727.

Bucholtz, Shawn. 2004. "Generalized Moments Estimation for Flexible Spatial Error Models: A Library for Matlab." www.spatial-econometrics.com.

Bureau of Labor Statistics. 2003. Consumer Price Index – All Urban Consumers. U.S. Department of Labor. http://data.bls.gov.

Costanza et al. 1997. "The Value of the World's Ecosystem Services and Natural Capital." Nature 387: 253-260.

Cropper, Maureen, Leland Deck, and Kenneth McConnell. 1988. "On the Choice of Functional Form for Hedonic Price Functions." The Review of Economics and Statistics, 70(4): 668-675.

Faux, John and Gregory Perry. 1999. "Estimating Irrigation Water Value Using Hedonic Price Analysis: A Case Study in Malheur County, Oregon." Land Economics, 75(3): 440-452.

Geoghegan, Jacqueline, Lori Lynch, and Shawn Bucholtz. 2003. "Capitalization of Open Spaces into Housing Values and the Residential Property Tax Revenue Impacts of Agricultural Easement Programs." Agricultural and Resource Economics Review 32(1): 33-45.

Geoghegan, Jacqueline, Lisa Wainger, and Nancy Bockstael. 1997. "Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS." Ecological Economics 23: 251-264.

Greene, William. 2000. Econometric Analysis. New Jersey: Prentice-Hall.\

Griffith, Daniel. 1996. "Chapter 4: Some Guidelines for Specifying the Geographic Weights Matrix Contained in Spatial Statistical Models." In Practical Handbook of Spatial Statistics, Sandra Arlinghaus, ed. CRC Press: 65-82.

Holway, James and Raymond Burby. 1990. "The Effects of Floodplain Development Controls on Residential Land Values." Land Economics 66(3):259-271.

Irwin, Elena. 2002. "The Effects of Open Space on Residential Property Values." Land Economics 78(4): 465-480.

Irwin, Elena and Nancy Bockstael. 2001. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values." American Journal of Agricultural Economics 83(3): 698-704.

Kelejian, Harry and Ingmar Prucha. 1999. "A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model." International Economic Review 40(2): 509-533.

Khanna, Madhu, Wanhong Yang, Richard Farnsworth, and Hayri Nal. 2003. "Cost-effective Targeting of Land Retirement to Improve Water Quality with Endogenous Sediment Deposition Coefficients." American Journal of Agricultural Economics 85(3): 538-553.

Leggett, Christopher and Nancy Bockstael. 2000. "Evidence of the Effects of Water Quality on Residential Land Prices." Journal of Environmental Economics and Management 39: 121-144.

LeSage, James. 1998. "Spatial Econometrics." www.spatial-econometrics.com.

Loomis, John, Paula Kent, Liz Strange, Kurt Fausch, and Alan Covich. 2000. "Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results from a Contingent Valuation Survey." Ecological Economics 33: 103-117.

Lynch, Lori and Sabrina Lovell. 2003. "Local Land Markets and Agricultural Preservation Programs," Government Policy and Farmland Markets: The Maintenance of Farmer Wealth, eds. Charles B. Moss and Andrew Schmitz, Iowa State Press, Ames, IA, October 2003.

Lynch, Lori and Sabrina Lovell. 2003. "Combining Spatial and Survey Data to Explain Participation in Agricultural Land Preservation Programs." Land Economics 79(2): 259-276.

Mahan, Brent, Stephen Polasky, and Richard Adams. 2000. "Valuing Urban Wetlands: A Property Price Approach." Land Economics 76(1): 100-113.

Maryland Department of Agriculture. http://www.mda.state.md.us/agland/main.htm. October 15, 2003.

Maryland Department of Business and Economic Development. 2004. www.choosemaryland.org.

Maryland Department of Legislative Services, Library and Information Services. 2004. "KA050 – Department of Natural Resources, GreenPrint Program (Statewide)." http://mlis.state.md.us/2004RS/budget_docs/All/Capital/KA05A_-_DNR_Land_Water_Conservation_GreenPrint_Program.pdf

Maryland Department of Natural Resources. http://www.dnr.state.md.us/greenways/greenprint/. October 1, 2003.

Maryland Department of Natural Resources Chesapeake and Coastal Watershed Services. 2001. "Maryland's GreenPrint Program: Summary of Methods to Identify and Evaluate Maryland's Green Infrastructure DRAFT." Annapolis, Maryland.

Maryland Department of State Planning. 1973. "Natural Soil Groups Technical Report." Baltimore, Maryland: Maryland Department of State Planning, December.

Maryland Department of Planning. 2002. "Median Value of Owner-Occupied Units." May.

Maryland Department of Planning. 2001. "1990 and 2000 Population Density per Square Mile for Maryland's Jurisdictions." Planning Data Services. March.

Maryland Department of Planning. 2000. "Estimated Market Value of Land and Buildings per Acre (Dollar) for Maryland and its Jurisdictions." August.

Maryland Environmental Trust. 2004. www.conservemd.org. February 9, 2004.

Maryland Greenways Commission. 2000. "Maryland Atlas of Greenways, Water Trails, and Green Infrastructure." Department of Natural Resources, Chesapeake Bay and Watershed Programs.

Nickerson, Cynthia and Lori Lynch. 2001. "The Effect of Farmland Preservation Programs on Farmland Prices." American Journal of Agricultural Economics 83(2): 341-351.

Palmquist, Raymond and Leon Danielson. 1989. "A Hedonic Study of the Effects of Erosion Control and Drainage on Farmland Values." American Journal of Agricultural Economics, February.

Palmquist, Raymond, Fritz Roka, and Tomislav Vukina. 1997. "Hog Operations, Environmental Effects, and Residential Property Values." Land Economics 73(1): 114-124.

Pate, Jennifer and John Loomis. 1997. "The Effect of Distance on Willingness to Pay Values: A Case Study of Wetlands and Salmon in California." Ecological Economics 20: 199-207.

Polasky, Stephen, Jeffrey Camm, and Brian Garber-Yonts. 2001. "Selecting Biological Reserves Cost-Effectively: An Application to Terrestrial Vertebrate Conservation in Oregon." Land Economics 77(1): 68-78.

The Resources Agency of California. 2004. "Preserving California's Natural Heritage: State Land Conservation Summary, Selected Funding Sources." http://ceres.ca.gov/planning/conservation_guidebook.

Ridker, Ronald and John Henning. 1967. "The Determinants of Residential Property Values with Special Reference to Air Pollution." The Review of Economics and Statistics 49(2): 246-267.

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." The Journal of Political Economy 82(1): 34-55.

Smith, V. Kerry and Ju-Chin Huang. 1995. "Can Markets Value Air Quality? A Meta-Analysis of Hedonic Property Value Models." The Journal of Political Economy 103(1): 209-227.

St. Mary's County Maryland. 2004. www.co.saint-marys.md.us. Department of Economic and Community Development.

Southern Maryland Association of Realtors. 2004. www.somdrealtors.com

Stumborg, Basil, Kenneth Baerenklau, and Richard Bishop. 2001. "Nonpoint Source Pollution and Present Values: A Contingent Valuation Study of Lake Mendota." Review of Agricultural Economics 23(1): 120-132.

The Trust for Public Land and Land Trust Alliance. 2004. "Land Vote 2003." http://www.tpl.org/content_documents/landvote_2003.pdf.

Tri-County Council for Southern Maryland. 2004. "About the Region." http://www.tccsmd.org/web/region/indexr.html

U.S. Census Bureau. 2003. www.census.gov.

U.S. Census Bureau. 2002. Statistical Abstract of the United States. Washington, D.C.

Weber, Ted. 2003. "Maryland's Green Infrastructure Assessment: A Comprehensive Strategy for Land Conservation and Restoration." Annapolis, Maryland: Maryland Department of Natural Resources, Watershed Services Unit, Landscape and Watershed Analysis Division.

Wu, JunJie, David Zilberman, and Bruce Babcock. 2001. "Environmental and Distributional Impacts of Conservation Targeting Strategies." Journal of Environmental and Ecological Economics 41: 333-350.

Xu, Feng, Ron Mittelhammer, and Paul Barkley. 1993. "Measuring the Contributions of Site Characteristics to the Value of Agricultural Land." Land Economics 69(4): 359-369.