Open Space Property Value Premium Analysis

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House price amenity premium analysis

Undeveloped lands, often collectively referred to as open space, have the potential to provide a wide range of private and public benefits. These benefits accrue from the direct use of open space for recreational activities or the aesthetic appreciation of scenic views and landscapes. Open space also provides benefits in the form of ecosystem services such as clean water and air, or habitat for plant and animal species valuable to humans. Finally, particularly scenic lands may also provide substantial passive use benefits because of the existence, stewardship, or bequest motives people may have for these lands (Krutilla, 1967). All of these benefits carry associated economic values.

In some cases, open space may be valued not for providing particular amenities, but for providing an absence of the disamenities associated with development, such as traffic congestion, noise, and air pollution (Irwin, 2002; Irwin and Bockstael, 2001). For example, Heimlich and Anderson (2001) summarize a number of studies that examine households' willingness to pay to prevent the development of farmland. They find that willingness to pay to preserve farmland from development increases with the intensity of the hypothesized development. This suggests that in some cases at least, open space may not primarily be valued for what it is, but rather, for what it is not – namely, development (Irwin, 2002).

Regardless of whether it is valued for providing amenities or for preventing disamenities, open space clearly is valuable to people. The value of open space to nearby residents to some degree is reflected in private property and real estate markets, because the prices of residential properties surrounding open space often reflect the value property owners assign to the amenities provided by open space in the vicinity, such as recreation opportunities, aesthetics, and air quality.[1]

Of course, open space is not just valued by nearby residents, but by the community at large. After all, the aesthetic benefits of open space may accrue not just to people residing in the vicinity of the open space, but also to passers-by or to visitors. The same is true for the benefits associated with the recreational use of open space. This is evidenced by the success of open space preservation ballot initiatives at the local, county, and state levels. As Banzhaf et al. (2006) point out, between 1997 and 2004, over 75 percent of the more than 1,100 referenda on open space conservation that appeared on ballots across the U.S. passed, most by a wide margin. The focus of this section, however, is exclusively on the value open space contributes to residential properties.

1. Literature review: Factors determining the presence and size of open space amenity premiums

The incremental value a property receives from its proximity to open space is variously referred to as the open space property value premium, the property enhancement value, or the amenity premium. This premium is the result of what Crompton (2001) calls the proximate principle, namely, the general observation that the value of an amenity is at least partially captured in the value of

[1] However, due to imperfections in real estate markets, the value of open space for a particular property is not always fully reflected in property prices. This point will be discussed in more detail below.

properties in proximity to that amenity. The idea underlying the proximate principle is that a property, like any good, may be thought of as a bundle of attributes (Lancaster, 1966). The price of the good therefore reflects the value consumers assign to that bundle of attributes. In the case of a property, these attributes include the physical characteristics of the property itself and of any structures, such as property size, relative scarcity of land, size and quality or age of structures, as well as neighborhood characteristics such as schools, public safety, and environmental amenities provided by surrounding lands, such as scenic views, clean air, or recreation opportunities. If people value open space and the amenities associated with it, then these values to some extent should be reflected in property prices.

The evidence in the published literature for the existence of the property enhancement value of open space is certainly strong. There are over 60 published articles in the economics literature that examine the property enhancement value of open space (McConnell and Walls, 2005). A number of recent literature reviews have been conducted on the topic. Some of these cover various types of open space, including forest lands, parks, coastal and inland wetlands, grasslands, and agricultural lands (e.g. Fausold and Lillieholm, 1999; Banzhaf and Jawahar, 2005; McConnell and Walls, 2005 – by far the most comprehensive review), while others are specific to particular types of open space such as parks (Crompton, 2001), wetlands (Brander et al., 2006; Boyer and Polasky, 2004; Heimlich et al., 1998), or agricultural lands (Heimlich and Anderson, 2001).

Factors influencing the magnitude of open space property value premiums

The published literature also shows that the value of open space tends to vary across the landscape. This, of course, is not surprising, because open space is not a homogenous good. As a result, its enhancement value for a property should be expected to vary with its physical attributes, such as size and type of vegetation cover (forest, park, wetland, prairie, grassland, cropland, barren land), its general attractiveness, and its distance from the property. In general, the closer the proximity of open space to a property, the higher the open space amenity premium captured by the property.[2] Another important driver of open space values appears to be the certainty (or lack thereof) about the permanence of the open space, which is a function of its ownership and protection status. Intuitively, one would expect permanent open space to be valued higher than developable, unprotected open space. This a priori assumption generally is borne out by the few studies that explicitly compare protected and unprotected open space. For example, Earnhart (2006) finds that the enhancement value of a permanently protected prairie for property owners in Lawrence, Kansas is more than twice that of a prairie with a 50 percent chance of development during the time of the residents' ownership. Similarly, Geoghegan (2002) shows that the property enhancement value of permanently protected open space in suburban Howard County in Maryland is over three times as high as that of developable open space. Irwin's (2002) analysis of open space in several suburban and exurban counties in central Maryland generates similar results, finding that protected open space increases residential property values by between 0.6 percent and 1.9 percent more in absolute terms than developable open space.

[2] An exception to this general rule can occur in cases of heavily used public open spaces such as some urban parks. Adjacency to such areas may lead to a loss in privacy for some properties and to an associated negative open space premium on properties adjacent to the park (see for example Weicher and Zerbst [1973] or Shultz and King [2001]).

The magnitude of open space property premiums would also be expected to be influenced by the attributes of the surrounding developed space (low- vs. high-density residential, commercial or industrial), something confirmed in the literature (Ready and Abdalla, 2005). In addition, open space value premiums are a positive function of the potential alternative uses of the open space. For example, conversion of farmland open space to large-lot residential use may not decrease property values, while conversion to high-density residential use would be expected to reduce open space premiums (Ready and Abdalla, 2005). This is confirmed by Heimlich and Anderson's (2001) findings of a positive relationship between households' willingness to pay for farmland preservation and the intensity of the hypothesized development, and seems to confirm Irwin's (2002) hypothesis of open space being valued at least in part for what it is not.

Not surprisingly, the absolute size of the value of the amenities provided by undeveloped lands also is a positive function of income levels in an area (McConnell and Walls, 2005). For example, Brander et al. (2006) find this to be the case for wetlands. This would be expected because the monetary value people attach to a good or service (as revealed by their purchasing decisions or stated in surveys) necessarily is linked to their ability to pay. The more interesting question is whether or not open space also becomes *relatively* more valuable at higher income levels, that is, whether it is perceived as what economists refer to as a luxury good – a good for which demand arises only once a certain income threshold has been surpassed or increases with income. This question has not been satisfyingly resolved by the open space literature. Certainly, there is evidence from studies on local environmental pollution that seems to suggest that this might be the case.[3] For example, Netusil et al. (2000) report that in their study of open space amenity premiums in the city of Portland, Oregon (see also Bolitzer and Netusil, 2000; Lutzenhiser and Netusil, 2001), they found no amenity premiums in neighborhoods with primarily low and medium-value homes, while positive and significant premiums were detected in high-income neighborhoods. However, the authors hypothesize that the negative externalities of living in low and mid-value neighborhoods may mask the amenity effects of open space. Earnhart (2006) finds that in explaining the open space premium associated with decreasing the likelihood of development for a piece of prairie in the city of Lawrence, Kansas, from 50 percent to zero, the coefficient on the income variable is comparably-sized, small, and insignificant for low and medium income households, while it is high and significant for high-income households. Investigating the effect of mature trees on residential housing values in Quebec City, Theriault et al. (2002) found that in households with children, the effect of trees on sale price changes with the economic status of the neighborhood. Trees are estimated to have a negative impact on sale price in poorer neighborhoods while in high-income neighborhoods, they are estimated to increase sale price. On the other hand, in households without

[3] This hypothesis is commonly referred to as the Environmental Kuznets Curve. It stipulates that during the process of economic development of a country, pollution initially rises as a result of increased output. Proponents of this hypothesis take this to indicate that at this stage of low per-capita incomes, output is valued more highly than environmental quality. At some point however, according to the hypothesis, once individuals are sufficiently wealthy to satisfy the material needs of life, they begin to value a cleaner environment relatively more highly and begin to devote more resources to the clean-up of pollution at the expense of increases in production and income. Although evidence in the literature seems to reject the general applicability of the hypothesis that there exists a strong link between pollution and per-capita income levels, there is some evidence that the relationship might hold for some ambient urban air pollutants (Stern, 2004). This would suggest that it might also apply to open space, which also is a local environmental amenity. For an excellent review of the history and a detailed critique of the Environmental Kuznets Curve hypothesis, see Stern (2004).

children, the estimated effect of trees on sale price is positive and consistent regardless of neighborhood economic status. Bates and Santerre (2001) find that in Connecticut communities, the demand for *locally owned* open space is highly responsive to income, with an estimated elasticity of 1.0. This would imply that income and demand for open space increase proportionately - a 10 percent increase in income would be associated with a 10 percent increase in the demand for (locally owned) open space. Based on the balance of the evidence, it is impossible to judge whether open space amenity values have an income elasticity of larger than one or whether in lower and medium income neighborhoods these values simply are masked by disamenities of open spaces more pronounced in those neighborhoods.

Furthermore, the open space amenity premium would be expected to be a function of the relative scarcity of open space in an area, that is, the degree of urbanization or the population density in a region (McConnell and Walls, 2005; Brander et al., 2006). For example, Brown and Connelly (1983), in their analysis of the open space property value impacts of six New York State parks, find that the four parks located in sparsely settled areas showed no effect on property values, while those located near towns did. Similarly, Geoghegan et al. (1997) in their analysis of open space premiums in seven Maryland counties, find a variation in preferences for diversity and fragmentation of land uses between urban, suburban, and rural settings. They interpret this as suggesting that preferences for these characteristics vary, among other things, with their relative scarcity, and that where rural land predominates and conveniences such as shopping areas are scarcer, landscape diversity and fragmentation again become valued. This finding is mirrored by the results of Anderson and West (2006), whose analysis of home sales prices in the Minneapolis-St. Paul metropolitan area shows that the value of proximity to open space is higher in neighborhoods that are dense. Confirming this, Acharya and Bennett (2001), who examine the property value impacts of open space in new Haven, Connecticut, find that the percentage of open space exhibits decreasing returns. Walsh's (2004) results of open space values in Wake County, North Carolina, support this view. Walsh creates an "index of local amenities" that includes the percentage of open space. This index is increasing in open space percentage over an initial range of values, but beyond some critical point a negative relationship holds, where open space ceases to be perceived as a relatively high-value amenity. In the five different models Walsh employs, the critical threshold of percentage of open space at which the negative turn occurs is estimated at around one third of total area, indicating that more open space is desirable in more urban areas, but less desirable or undesirable in exurban areas. Bin and Polasky (2005) examine the property enhancement value of wetlands in a rural county in North Carolina in which wetlands account for about 45 percent of total land cover, and find that wetlands appear to lower property values, a finding that contrasts sharply with the findings of positive wetland impacts on house prices in urban areas (e.g., Mahan et al., 2000; Doss and Taff, 1996). Seemingly confirming this, Lupi et al. (1991) find that wetlands were relatively more valuable in areas where they were relatively scarce. These findings suggest that in general, there appears to be an inverse relationship between the scarcity of open space and its property enhancement value, suggesting that open space is relatively more valuable where it is in relatively short supply (McConnell and Walls, 2005).

This of course does not mean that property premiums do not exist in rural areas. As Ready and Abdalla (2005) note in response to a reviewer's comments, it is theoretically plausible that individuals' WTP for open space could also be higher in suburban or rural areas, because at least a part of the residents in those areas locate there specifically because of their high preferences for open space. There are a number of studies in rural areas that do show that open space does indeed increase property values considerably also in those areas (Phillips, 2000; Vrooman, 1978; Brown and Connelly, 1983; Thorsnes, 2002). However, these studies involve public open spaces that generally are comparatively large and enjoy a high level of protection from development, including state parks, forest preserves, and wilderness areas.

Table 1 summarizes the findings reported in the literature on how particular study area characteristics influence open space premiums.

Table 1: Variables that influence the property enhancement value of open space

Variable	*Direction of influence*
Scarcity of open space	+
Protected status/permanence	+
Size of open space	+
Distance to open space	- *
Type of open space	+/-
Opportunity costs / value of competing land uses	+
Income	+

Notes: * Exception: In cases of heavily used public open spaces such as some urban parks, adjacency to such areas may lead to a loss in privacy for some properties and to an associated negative open space premium on properties adjacent to the park.

The impact of study methodology

Finally, estimates of the magnitude of open space property value premiums also tend to vary depending on the study methodology. The choice of study method defines what types of economic values are captured in the resulting value estimates. The majority of studies analyzing the property enhancement value of open space employ revealed preference approaches, which use observed prices (specifically, market transactions of properties) and observable attributes of properties to infer people's implicit value for open space amenities. Revealed preference methods comprise several different approaches, namely, hedonic pricing methods, discrete choice hedonic methods, and equilibrium sorting models. Of these, hedonic methods are the most widely employed in the estimation of open space property value impacts.

Hedonic value estimates

Building on Lancaster's (1966) idea that the value of a good is a function of the value of its characteristics or attributes, Rosen (1974) developed a model that uses "observed product prices and the specific amounts of characteristics associated with each good [to] define a set of implicit or 'hedonic' prices" (p. 34). This "hedonic" analysis uses people's observed purchasing behavior for a good (say, a house) to infer the value they assign to particular attributes of the good (say, scenic views and access to recreational opportunities). Simply put, hedonic analysis is premised on the idea that people should have the same willingness to pay (WTP) for two goods that are identical with respect to the attributes important to consumers. If two goods differ from each other only in one attribute, such as the size of open space surrounding them or the distance to the nearest open space, but are otherwise identical, and if their prices differ, then, so the argument goes, the price difference must be caused by the difference in that one attribute. By comparing the prices of large numbers of houses transacted in a particular geographical area and systematically accounting for differences in all attributes that are expected to influence house prices, one can estimate the value of the natural amenity attributes, for example, an additional acre of a particular type of open space within a given radius, or a decrease in distance between open space and a property.[4]

This estimation approach reveals the marginal implicit price, that is, the value the average resident assigns to an incremental change (for example, a one-foot decrease in distance to the nearest open space, or an additional acre of open space within a certain radius) in a particular type of open space characteristic in that location. When the open space effect of interest is not marginal, however, it is not appropriate to use marginal implicit prices for estimating the residential value of the open space. Rather, to estimate the value of non-marginal open space impacts, a second-stage estimation needs to be added to derive the demand (that is, willingness to pay) function of all residents for that open space. Once this function is determined, the total economic value that residents place on open spaces in the neighborhood can be estimated. Implementing this second-stage analysis, however, has proven to be rather challenging because of the associated identification problem (Mahan et al., 2000), which is why most hedonic studies do not attempt it.[5] Rather, instead of deriving a demand function that would allow taking into account the variation in WTP across individuals and thus would allow the estimation of the total economic value of the open space to area residents, most studies simply derive estimates of open space value by using the estimated implicit price of open space at mean house values.

Irwin and Bockstael (2001) show that hedonic models may not always be able to empirically detect the positive amenity value of open space due to identification problems. These problems arise in a hedonic residential property price model when the open space is privately held and developable. They can be distinguished into an *endogeneity problem* and a *spatial autocorrelation problem*. The endogeneity problem arises from the fact that the residential value of a parcel x is affected by whether neighboring parcels are developed. The likelihood of development of neighboring parcels is a function of their respective values in residential use, which themselves in turn are partly a function of whether parcel x is developed. The spatial autocorrelation problem arises when some of the factors that determine the value of parcels in residential use are omitted from the model and are spatially correlated, either because they are difficult to observe or to measure. If any of the variables

[4] The standard hedonic pricing model assumes that a continuous function relates the price of a house to the attributes of the house and that people select a house by equating the marginal utility of each house attribute to its price (Earnhart, 2001). By contrast, the discrete-choice hedonic model views the individual as choosing the house that provides the highest utility from all the houses in its feasible choice set, with utility as a function of house attributes (McFadden, 1978). The advantage of the discrete-choice hedonic model is that it easily can be combined with stated preference approaches such as contingent valuation or choice-based conjoint analysis, which may be superior to standard hedonic approaches because they allow a better isolation of the impact of particular variables on individuals' willingness to pay (Earnhart, 2001).

[5] Specifically, the first-stage analysis yields a hedonic price function that represents the marginal willingness to pay for open space at different points over a range of prices. However, the observations at different prices are from different individuals. For each of these individuals, willingness to pay functions need to be estimated. This requires a number of assumptions. As Freeman (2003) suggests, the identification issue can be overcome by using for example segmented markets from within a city or by using observations from different cities, but implementing this approach in practice has proven difficult (see for example Mahan et al., 2000).

that lead to spatial variation in property prices are omitted from the analysis, the variables measuring surrounding open space will be correlated with the error term. Both the endogeneity problem and the spatial autocorrelation problem lead to biased coefficient estimates, that is, they lead to inaccurate estimates of the value of open space premiums. Failure to address the endogeneity problem leads to underestimation of the amenity impacts (see for example Irwin and Bockstael, 2001). Several more recent hedonic studies use an instrumental variable (IV) approach to address the endogeneity problem, in which physical and hence exogenous features of properties that are expected to influence their value for residential purposes (such as slope, drainage potential of the soil, suitability for septic tanks, soil suitability for construction) are substituted for the variables prone to endogeneity (see for example Irwin and Bockstael, 2001; Ready and Abdalla, 2005). The spatial autocorrelation problem can be addressed by eliminating observations from the analysis until no two observations are "close" to each other (Irwin, 2002).

A further problem with hedonic estimates of the property enhancement value is that these estimates may be biased and time sensitive if the housing market is not in equilibrium, as is assumed in the hedonic model. If a market for a good is not in equilibrium, prices for the good do not reflect its real value for consumers, and by extension do not reflect the real value of its attributes such as open space characteristics. As Riddel (2001) shows in the case of Boulder, Colorado, because of real estate market imperfections and the associated time lags with which changes in environmental amenities are incorporated into housing prices, the size of the estimated amenity value premium may depend on the time the study is conducted. Riddel's study suggests that in the case of Boulder it took over a decade for changes in open space amenities to fully become reflected in housing prices. It is hard to tell whether or not the findings of her case study are generalizable, but they suggests that hedonic studies may underestimate open space premiums if they are conducted before the effects of changes in the open space characteristics of the particular area are fully incorporated into local real estate markets.

Stated preference methods

In addition to revealed preference methods, a number of studies have employed stated preference approaches to estimate the amenity premiums associated with open space.[6] Stated preference methods rely on individuals to state directly how much they would be willing to pay for an environmental good or service, or for a change in that good or service.[7] They either take the form of a contingent valuation survey, in which a hypothetical scenario is constructed and respondents are then asked to indicate explicitly the amount they would be willing to pay for (a given change in) the amenity described in the scenario. Or they employ contingent choice or conjoint analysis, in which individuals are asked to choose between or to rank different options, usually combinations of bundles of amenities and associated costs. The responses can then be used to infer preferences or estimate values.

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[6] See Heimlich and Anderson (2001) for stated preference studies on the open space amenity impact of farmlands, Nicholls and Crompton (2005) for studies of the effect of greenways, and McConnell and Walls (2005) for studies on the value of urban open spaces, agricultural lands, and wetlands.

[7] In some cases when dealing with reductions in environmental goods or services, the question is framed in terms of respondents' willingness to accept such a change rather then their willingness to pay to prevent it. The appropriate concept in a given situation depends on the sense of endowment individuals might have or the property rights situations with respect to the good or service in question.

Value estimates based on state preference methods frequently have been considered less reliable than those based on observed (market-based) behavior, because their accuracy depends crucially on the quality of the survey design and its implementation (Diamond and Hausmann, 1994). Specifically, for responses to be an accurate reflection of individuals' values for the resource in question, respondents must understand exactly what it is they are being asked to value. This includes the specific good in question, its characteristics (quantity and quality), and the valuation context (how the good compares to similar goods). However, if best-practice guidelines (Arrow et al., 1993) are followed, contingent valuation will yield estimates that are no less valid than those based on revealed preferences and generally are comparable to the latter (Hanemann, 1994). Carson et al. (1996) analyzed 83 studies of comparisons of contingent valuation and revealed preference estimates for quasi-public goods (goods for which an implicit private market exists), and found that the mean ratio of the two estimates was 0.89, indicating that well-executed contingent valuation and revealed preference studies should yield similar estimates of WTP for goods for which implicit private markets exist.[8] Specifically regarding open space values, Ready et al. (1997) in their investigation of the value of the amenity benefits of farmland found that stated and revealed preference methods yielded results within 20 percent of each other.

However, in the case of goods with attributes that exhibit pure public good aspects, contingent valuation-based WTP estimates would be expected to be higher than estimates based on revealed preferences, because the latter do not capture passive use values which in some cases can be a sizeable component of the total value of a resource (Kramer et al., 2002; Krutilla, 1967; Walsh et al., 1984). Stated preference approaches thus may yield higher value estimates than revealed preference approaches if the resource in question has important passive use values and is non-excludable. As Carson et al. (2001) point out, the reason for this is that

> "Revealed preference techniques are usually only capable of capturing the quasi-public value, that is the direct use portion of total value, because they rely on the availability of an implicit private market for a characteristic of the good in question. The availability of this market allows for potential excludability based on price. In contrast, passive use value can be seen as simply a special case of a *pure* public good" (p. 176).

By contrast, stated preference methods capture the total WTP of the resource. Hence, the results of the two approaches may not be directly comparable for open spaces that have important associated passive use values.

To summarize, evidence from both studies based on revealed preference approaches and those using stated preference approaches shows that preserving open space generally creates economic value. Nevertheless, these values tend to be case specific, varying considerably with the factors discussed above and shown in Table 1.

[8] A pure public good is a resource that is both nonrival and nonexclusive. A good is rival if its enjoyment by one individual impacts the possibility for others to enjoy it. A good is exclusive if the owner can prevent others from enjoying it. Pure private goods such as a meal are both rival and exclusive, while quasi-public goods either are not perfectly nonrival (rivalry occurs beyond a certain threshold of users is surpassed) or not perfectly exclusive (exclusion is theoretically possible but impractical).

In the next section, we develop a statistical model that allows us to pool the observations in the open space literature, with the objective of estimating a function that relates the size of the open space value premium to a range of variables. The goal is to develop a function that can be used to estimate the property enhancement value of a particular open space in a particular location. Based on this function, we develop am easy-to-use open space property value Estimator Tool (Excel-based, provided in the Appendix) that allows the user to generate open space property value premium estimates for a particular area of their interest. A user manual featuring a step-by-step explanation of the Tool and examples of its application are provided in the appendix. The appendix also provides brief descriptions of the studies we reviewed for this report.

In this study, we do not include studies that focus exclusively on agricultural lands or heavily used urban parks, because often such lands do not provide high-quality habitat for sensitive wildlife, that is, wildlife identified as priority targets for conservation in State Wildlife Action Plans or Wildlife Conservation Strategies. We do, however, include several studies that examine agricultural (mostly pasture) land as one of several forms of open space considered jointly.

2. Statistical analysis of the contribution of different determinants of open space property value premiums to premium size

The size of open space property value premiums in a given location depends on a variety of factors. The most important of these were discussed in Section 1 of this chapter. Because several different factors determine premium size and because all of these vary across space, the presence and especially the size of open space premiums is case specific. Consequentially, it generally is difficult to develop estimates of open space premiums for residential properties in a given location on the basis of comparisons with existing studies, because each study in the literature is characterized by a unique combination of the relevant characteristics. In this section, we systematically analyze the literature findings on open space premiums in order to estimate a statistical function that relates the individual study characteristics to the size of the open space property enhancement value. Our objective is to estimate a meta-analysis function that incorporates the variables shown to influence open space premiums. This function then can be adjusted to a particular location by setting the values of the independent variables to reflect local conditions, and used to estimate the size of open space premiums for properties in that location.

Specification of meta-analysis equation

The open space value meta-analysis equation expresses the size of the open space property value premium (the dependent variable) as a function of open space quantity and quality (open space type) characteristics, valuation method, and study area context (Table 2).

The studies we reviewed operationalize the open space variable in four different ways. The majority of studies define this variable as an increase in the percentage of open space within a certain radius of a property, or as an additional acre of open space within a given radius.[9] The next largest group of studies measure open space as a reduction in the distance of a property to the nearest open space. The remaining studies measure open space impacts using a dummy variable, as the result of either proximity of a property to open space, or adjacency to open space.[10] Some studies measure open space impacts in more than one way.

Table 2: Variables included in meta-analysis function

Study characteristic	*Corresponding variable in meta-analysis model*	*Variable name*	*Variable type*
Percent increase in property value (dependent variable)		%INCR_PV	Continuous
Open space quantity			
- if study measures impact of an increase of the percentage of open space of all land in a given radius:	Percent open space	%OS	Continuous
	Radius (miles)	RAD	Continuous
	Radius squared (miles)	RAD_SQ	Continuous
- if study measures impact of a reduction in distance to nearest open space:	Reduction in distance (miles)	%R_DIST	Continuous
	Mean distance squared (miles)	M_DIS_SQ	Continuous
- if study measures impact of proximity or adjacency to open space through dummy variable:	Mean distance* (miles)	M_DIST	Continuous
	Mean distance squared (miles)	M_DIS_SQ	Continuous
Open space quality			
Type of land cover	Forest	FOR	Dummy
	Park	PARK	Dummy
	Wetland – base case		
	Prairie	PRAI	Dummy
	Agricultural (primarily pasture)	AG	Dummy
Protection status/permanence	Protected	PROT	Dummy
Ownership	Private**	PRIV	Dummy
	Public**	PUB	Dummy
Valuation method	Hedonic	HED	Dummy
Study area context			
Level of development of area	Population density	POPDENS	Continuous
	OR: Urban, Rural	URB, RUR	Dummy
Mean property value	Mean property value	PROPVAL	Continuous

Notes: *Adjacency is quantified as a 1 meter distance to open space; proximity is quantified as mean distance of open space in the study. ** Both private and public ownership are included as dummy variables because in some studies, the open space premiums associated with mixed ownership lands are assessed. In those cases, both dummies are set to 1 to indicate that both ownership types are present.

[9] The two measures are interconvertible. For example, one acre represents 0.8 percent of all land within a 400 m (1,312.4 ft) radius of a property (measured from the center of the property), or 0.05 percent of all lands within a 1 mile (1,609 m) radius.

[10] Studies using an open space proximity dummy distinguish properties as being either located within a certain radius, say 1,500 feet, of open space, or as not being located within that radius. Hence, they are distinguished from studies measuring distance to the nearest open space by not using a continuous distance measure.

Measures of distance to nearest open space, percentage of open space within a given radius, and adjacency or proximity to open space are not readily interconvertible, because most of the studies do not provide the information needed to convert their particular open space measure into any of the other measures. As a result, we grouped the observations from the studies into three sets that we analyzed separately. The first contains observations that measure open space impacts on property value as a result of a reduction in distance to the nearest open space; the second, observations that measure open space impacts as a result of an increase in the percentage of open space in a given radius; the third combines observations from studies that use proximity or adjacency dummy variables to measure open space impacts. These latter two can be combined by assigning to properties adjacent to open space a distance of zero, and assigning to properties in proximity to open space a distance equivalent to the mean distance to open space of the properties included in the respective studies. However, because studies in this third group measure open space premiums associated with being within a certain range of open space, they cannot be combined in our analysis with studies in the first group, which estimate changes in open space premiums that result from a change in the distance of a property to the nearest open space. We include radius squared and distance squared terms, respectively, because the literature suggests that the relation between property premium and distance to open space does not appear to be constant (see for example Walsh, 2004).

To account for differences in the quality of open space, we include indicator variables that identify the general type of land cover (forest, park, agricultural lands, and prairie) characterizing an open space, and the protection status and ownership of an open space.[11,12] We distinguish between parks and forests by defining parks as being smaller in size and located in more developed urban or suburban areas. Thus, state parks that are primarily in forest, national forests, as well as forest tracts and large forested greenbelts are coded as forests, while urban parks are coded as parks. In the park category, we only include observations on "special" parks characterized by natural vegetation and expressly intended as wildlife habitat.

The protection status is a proxy for the permanence of an open space, that is, the absence of the risk of future development that generally is associated with private, developable urban land. Protected lands include private lands covered by conservation easements and public lands, as well as lands held by land trusts or conservation organizations. We include a separate indicator for public ownership in our analysis because some of the studies we include analyze open space premiums associated with lands that include both private and public lands. Thus, a dummy variable for private ownership would not be sufficient to correctly code those studies for our estimation. By setting both private and public dummy variables to 1, we can appropriately code such mixed ownership of lands.[13]

Most studies included in our review use hedonic analysis, two use contingent valuation or contingent

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[11] We do not include a wetland variable in our estimation function because wetlands serve as our base, or reference, land cover.

[12] An indicator or dummy variable is a binary variable that takes on the value of one if the condition it describes is present in the case at hand, or zero if it is not. For example, observations from a study that analyzes property value premiums generated by proximity to a forest would be coded with the forest indicator variable set to 1, and all the other land cover variables set to 0.

[13] Obviously, the *public* and *protected* variables are likely to be highly correlated.

valuation combined with conjoint analysis, and three studies use other types of analysis methods.[14] As discussed in Section 1, approaches that infer the value of open space on the basis of market transactions capture only the use portion of the total economic value of open space to residents. In some cases, the resulting value estimates may only capture part of residents' total willingness to pay for living close to natural areas. Value estimates based on stated preferences (contingent valuation, and analyses using conjoint analysis and contingent choice approaches) that attempt to capture total economic value may in many cases give a more complete estimate of the real value to people of residing close to natural areas. In addition, hedonic studies estimate only the marginal value of open space because they tease out the increment in open space value among properties located at different distances from open space (or between properties characterized by different amounts of open space within a given radius from the property), while studies based on stated preference approaches generally estimate the total value respondents assign to open space. For these reasons, estimates of the value of open space from studies that use stated preference approaches can be expected often to yield higher value estimates than those based on expressed preferences. We therefore include a dummy variable for the type of valuation approach used in a given study.

Ideally, one would also include the type of amenities provided by an open space in a particular study (that is, context), such as recreational access, aesthetic views, or particular wildlife habitat. Open spaces providing all or several of these amenities would be expected to be valued higher than those providing only one of these, or none at all, all else equal. Unfortunately, only a few studies provide this information, which makes it impossible to include these open space amenity attributes in our analysis.

We use two alternative approaches to account for the relative scarcity of open space in an area. Ideally, the source studies would contain information of the total amount of open space as a percentage of the area studied. Only very few studies provide this information, thus preventing the inclusion in our analysis of a continuous measure of open space scarcity. Instead, we design two alternative specifications of our estimated model that use proxies that capture the overall level of development in an area. One proxy is a pair of dummy variables that broadly categorize an area as either urban or rural (with both variables set at zero indicating a suburban area). Alternatively, we use the population density of an area as a second, finer-scale proxy for open space scarcity.

Finally, we do not include household income, a hypothesized determinant of willingness to pay for open space amenities, in our analysis but rather use property values as a proxy for income. The reason for this is that property values are likely to be highly correlated with household income, and that the studies reviewed overall contain more observations that have information on property value than ones that provide information on household income.[15] Since we measure open space property value premiums as percent increase in property value and not in absolute terms, we already account for differences in property values and, by proxy, incomes. Including property value as an

[14] These are vector error correction modeling (Riddel, 2001), discrete choice hedonic analysis combined with conjoint analysis (Earnhart, 2001), and structural equilibrium modeling (Walsh, 2004).

[15] Census income data could potentially be used to fill data gaps in the studies, but would be inappropriate in the many cases where the study areas do not overlap with census geography or where only properties with particular characteristics were included in studies.

independent variable allows us to detect whether the income elasticity (as a proxy for property price elasticity) of open space is different from one.

Our literature review identified the value of competing land uses (that is, opportunity costs) as a variable influencing open space values (see Table 1). However, this value depends on the expectations of individuals, which in turn are influenced by land use regulations like zoning. Such expectations are difficult to capture. In many cases, where residential use is an alternative use of open space, the value of competing land uses would already be captured by our property value variable.

The meta-analysis function we estimate takes the following basic linear form in matrix notation:

$$P_{OS} = a + b_{\mathrm{os}}X_{\mathrm{os}} + b_{\mathrm{a}}X_{\mathrm{a}} + bHED + u \;,$$

where
P_{OS} = open space property value premium in % of "base" property price,
a = intercept,
X_{os} = matrix of open space quantity and quality characteristics (open space size/distance/proximity, land cover type, protection status, and ownership),
X_a = matrix of study area characteristics (rural/urban or population density, mean property value),
HED = hedonic valuation method,
the *b*'s are vectors of the estimated coefficients,
and *u* is the vector of residual errors.

The particular open space quantity characteristics included in the regression analysis vary among the three data sets as shown in Table 2.

We ran regressions on the urban-rural and population density model specifications, in both linear and semi-log form, and with and without interaction terms. Because property value impacts in our analysis already are measured in percent, and because both the *reduction in distance* (*%R_DIST*) and *increase in percent open space* (*%OSChange*) variables are already measured in percent as well, we did not run regressions on double-log forms of models using the latter two open space variables as interpretation of the estimated coefficients would be less straightforward.

Results of model estimation for the three individual open space datasets

The general observations of our regression analysis that run across all model specifications are that there are very few significant variables, and that the regression models themselves do not show any level of overall statistical significance. The open space quantity variable in some cases has the expected sign, but in no case is it statistically significant. In other cases, it has a counterintuitive sign. The same is true for many of the open space type variables. All models have low predictive power, with adjusted R^2 substantially lower than the R^2 of the models, indicating that some explanatory variables may be missing.

There are several likely explanations for these findings. First, although we use a number of open space indicator variables for land cover, protection and ownership in an attempt to capture differences in the "quality" of different open spaces, these indicators cannot fully capture the amenity attributes of the areas, such as visual attractiveness or crowding. The studies do not provide sufficient information to adequately characterize these attributes for the development of finer-grained quality measures. Hence, we are not able to fully characterize the quality of open space and, as a result, our open space variable likely exhibits substantial variation within each of the categories (for example, forest or park), which reduces significance of the estimated coefficients. In a few cases, where studies did not include all of the relevant information needed for our analysis, we filled in data gaps from other sources. For example, two studies measuring open space premiums as a function of distance to open space (Brown and Connelly, 1983; Shultz and King, 2001) did not provide mean distance measures. We developed estimates based on visual analysis of current maps, which in one case (Shultz and King, 2001) may introduce a sizeable error, thus potentially increasing data variability. In general, some studies do not provide information on the spatial scale at which some of the variables they include are measured. This appears to be the case especially for population density figures. While we devoted considerable efforts to compile population density data for the study areas using Census block group or even block-level data for studies that did not provide that information, population density estimates in studies that reported them may in fact not always be that accurate. Some studies appear to report county-level or city-level density estimates as opposed to estimates for their study area.[16]

The problem of high variability in the data is exacerbated by the low number of observations in each of the samples and the large number of explanatory variables. The total of 73 observations we obtained from the literature are distributed into three distinct open space measures (percent open space within a radius of a property, distance to nearest open space, and adjacency/proximity to open space), making the number of observations in each of the samples small – 29, 22, and 22, respectively. This, together with the large number of variables included in the models (12-16, depending on whether or not interaction variables are included) contributes to the general lack of statistical significance of the findings.

Conversion of "reduction in distance to nearest OS" and "proximity/adjacency to OS" data sets to "increase in percentage of OS within a given radius" specification

The problem caused by the relatively small number of observations in each of the three types of open space measures could potentially be addressed by pooling the three samples. This can be done either by converting the three open space measurements into some other open space measure, by converting two of the measures into the open space measure employed by the third, or, at a minimum, by identifying an open space measure that would allow a combined ranking of the observations in the three datasets. As already pointed out, the integration of the four open space measures is far from straightforward.

[16] The effort involved in compiling accurate population density data for all studies, even those that provide this information, is prohibitive given the scope of our analysis.

If original GIS datasets were available for all studies from which the observations were taken or if information on all relevant open space characteristics were reported in the studies, all three open space measures would be interconvertible. Neither is the case, however. As a result, we identified a methodology that allows us to convert two of the three open space measures, namely, *reduction in distance to nearest open space* and *adjacency to open space*, into the corresponding value of the third open space measure, *increase in the percentage of open space within a given radius*. This methodology, presented below, allows us to identify for 26 out of the 44 observations in the two datasets the equivalent increase in the percent within a given radius that is occupied by open space. For the remaining 18 observations, one or several pieces of information were missing that prevented conversion of the open space measure to percent open space. However, seven of these observations stem from studies that also report open space impacts as a result of increased percentage of open space within a radius or as a reduction in distance to open space. As a result, only four of the 16 studies that quantify open space property value impacts as a function of reduced distance or of proximity or adjacency to open space are excluded from our pooled sample.

As a result of pooling the three groups of studies, the number of observations in our pooled sample increased to 55, compared to 29 (percent open space), 22 (distance), and 22 (adjacency/proximity), respectively, in the three individual samples.

1) Converting *reduced distance to nearest open space* into the equivalent *increase in percentage of open space within a given radius*

Reducing the distance of a property to the nearest open space (or to a particular open space considered in a study) is equivalent to moving that open space into a circle around the property with a radius equal to the original distance between the property and the open space (where beforehand it lay just outside of that radius). The "movement" of the open space towards the property results in an increase in the amount of open space within the circle. The size of that increase depends, in addition to the reduction in distance, on the size and shape of the open space. If the open space is sized such that the reduction in distance brings it completely into the circle defined by the radius, the increase in open space within the circle is given by the total area of the open space. If the shape of the open space is such that a given reduction in distance does not bring it completely into the circle of the property, the increase of the percent of open space in the circle depends on the shape of the open space.

Consider the two examples shown in Figure 1. In panels a) and b), the points of the two open spaces, indicated by the green shapes, that are closest to the centers x of the identical circles, are equidistant from the centers. In other words, the distance of the centers of the circles to the nearest open space is the same in both cases. Nevertheless, the amount of open space within the circles, that is, within radius r is very different in the two panels, being several times as large in panel a) as in panel b).

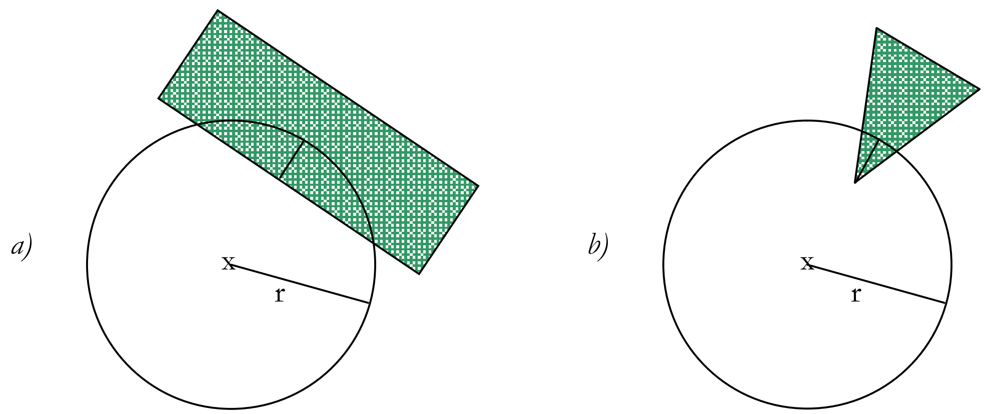

Figure 1: Open spaces of different shapes but with their nearest points equidistant to point *x*

The boundary cases are given by a rectangular open space whose overlap with the circle takes the form of a circular segment (panel *a* in Figure 1), and an open space that is a perpendicular line to the center of the circle (imagine the open space triangle in panel *b* but with an infinitely small base). An intermediate case between these two extremes is a circular open space with a radius approximately 5/8 of that of the circle with which it is overlapping (see Figure 2).

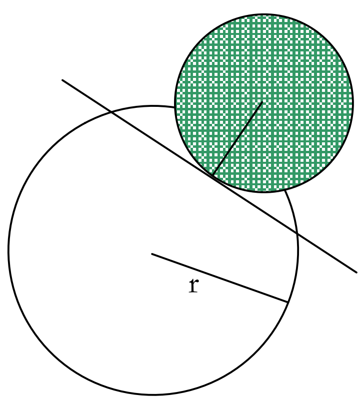

Figure 2: Smaller diameter circular open space overlapping with a circle, resulting in intermediate overlap area compared to parallel and perpendicular open space shapes (see Fig. 1)

Converting a reduction in the distance of a property to the nearest open space into the corresponding increase in the percentage of open space within a given radius of that property therefore requires information on the shape of the open space. The exception to this is the case where the size of the open space is known and where the reduction in distance in question brings the open space fully within the circle around the property.

To convert the distance reduction between a property and an open space into the corresponding change in the percentage of open space in a circle with the property at its center, the radius of the circle is defined by the mean distance of properties to the nearest open space reported in a study.

Correspondingly, the "movement" of the open space into the circle is defined by the reduction in open space distance for the mean property reported in the study results. Since the mean distance of properties to the nearest (or a particular) open space defines the radius used in the conversion, any reduction in open space distance results in an overlap, and hence in an increase of open space in the circle.

In none of the studies was the reduction in distance examined large enough to absorb the open space completely into the circle around the mean property. Therefore, the reduction in distance in all cases resulted in partial overlap between the property circle and the open space. Thus it was necessary to identify the shape of the open space in the studies in order to determine the appropriate shape for calculating the overlap.

Case 1: Large number of open spaces of varied geometry

Because of the diverse shapes of open spaces in the studies that include multiple open spaces, we assume a circular shape for the average open space, except in cases where a study considers only one open space of a particular, non-circular shape (e.g., Kim and Johnson, 2002). A circular open space shape reasonably well approximates the mean overlap area for a study context that features many open spaces of small to intermediate sizes and a sufficiently large number of properties included in the analysis. Some residential properties will be located parallel to the nearest open space, others will be located facing the corner of an open space, while the orientation of the remaining properties in relation to the nearest open space varies between these two extremes.

For a circular open space, the area of overlap A created by a reduction in distance between the mean property and the open space is calculated as

$$A = r^2 \cos^{-1}\left(\frac{d^2 + r^2 - R^2}{2dr}\right) + R^2 \cos^{-1}\left(\frac{d^2 + R^2 - r^2}{2dR}\right) - \tfrac{1}{2}\sqrt{(-d + r + R)(d + r - R)(d - r + R)(d + r + R)} \qquad \text{(eq. 1)}$$

where r is the radius of the (circular) mean open space, R is the radius of the circle around the mean property (the distance between the mean property and the nearest open space), and d is the distance between the center of the property circle and the center of the open space after the reduction in distance.[17]

All of the studies we included in the conversion provided the relevant information, except for Doss and Taff (1996), who did not provide information on the mean size of the open spaces included in their study. We estimated this parameter based on visual examination of the included open spaces (wetlands) in their study area.[18]

[17] See Weisstein (2005).

[18] Ramsey-Washington Metro Watershed District, Wetlands Biological Monitoring Program. Online at http://rwmetrowatershed.govoffice.com/index.asp?Type=B_BASIC&SEC={48C24320-A126-4885-9380-388797A56FA5} Last accessed September 5, 2007.

Case 2: Single large open space

In the cases where a study examined the impact on property values that resulted from a reduction in the distance of properties to one specific open space, based on the study information the relevant open space boundary in all cases could be approximated as a straight line. In this case, the overlap of the open space and the property circle after the reduction in distance between mean property and the open space is represented not by a circle but rather by the circular segment enclosed by a chord (see panel *a* in Figure 1), where the cord is located at a distance from the perimeter of the circle that is equal to the reduction in distance of the mean property to the open space. The area of overlap between the open space and the circle, *A*, is given by

$$A = R^2 \tan^{-1}\left[\sqrt{\left(\frac{R}{r}\right)^2 - 1}\right] - r\sqrt{R^2 - r^2} \qquad \text{(eq. 2)}$$

where *R* is the radius of the circle around the property (with a length equal to the mean distance of the properties to the open space) and *r* is the distance of the chord from the center of the circle.[19]

2) Converting *adjacency to open space* or *proximity to open space* into the equivalent *increase in percent open space within given radius*

In order to convert measures of adjacency and proximity to open space into the equivalent measure of increase in the percent of open space within a given radius of a property, information is needed on the mean distance to open space of properties not adjacent or not proximate to open space.

a. Adjacency

To convert adjacency of a property to open space into the equivalent measure of the percentage of open space within a given distance of a property, we compare the difference in the amounts of open space between properties adjacent to open space and those not adjacent to open space. This difference can be calculated by measuring the mean distance to the nearest open space (or the particular open space in question in a given study) of properties adjacent to open space, and of properties not adjacent to open space. The mean non-adjacent property does not have any open space within a radius equal to its distance to the nearest open space (or the particular open space in question). On the other hand, the mean open space-adjacent property has a distance to open space equal to the distance between the property's center and the open space. Shifting the mean property not adjacent to open space towards the open space such that it overlaps with the mean property adjacent to open space increases the amount of open space within the above-defined radius of the property. The quantity of open space of the mean property adjacent to open space can be calculated as the area of a circular segment defined by a chord at a distance from the center, where the distance is the distance between the center of the property adjacent to open space and the open space, using the formula shown in equation 2.

[19] See Weisstein (2002).

Consider the example shown in Figure 3. The red *x* indicates the mean distance to the open space in question (the green area on the left-hand side of the image) of properties not adjacent to that open space (those located in the white-shaded area). By definition, the associated circle contains no portion of the open space. Shifting this circle such that its center is located at the center of the mean property adjacent to open space (indicated by the blue *x*) increases the percent of open space in the circle. This percentage can be calculated as the ratio of the yellow-shaded area and the total area of the circle, respectively.

Figure 3: Example of shifting mean property location to allow calculation of differences in open space between two locations

Thus we obtain the difference between adjacent and non-adjacent properties, respectively, with respect to the percent of open space in the mean property's vicinity, that is, within a circle of a given radius around the mean property.

Three studies measuring the property value impact of adjacency to open space (Earnhart 2001, 2006; Vrooman 1978) do not provide the needed information on the mean distance to open space of non-adjacent properties. The remaining studies provided this information either in numeric form, or it could be obtained from the maps provided in the studies.

b. Proximity

None of the five studies measuring property value impacts associated with proximity to open space provided the needed information on mean distance to open space of properties not located within the radius within which proximity impacts where measured. Thus, it was not possible to convert these observations to increases in the percent of open space with a given radius of a property. Unlike in the case of studies measuring adjacency impacts, the mean distance of properties not proximate to open space could not be derived from maps provided in those studies.

Results of pooled dataset estimation

In the analysis of the pooled data, we included an additional variable, *%OS_Squared*, in order to capture any non-linear relationship between the percentage of open space and property value premiums.

The statistical analysis of the pooled dataset yields results that are of much higher significance as well as much more in line with prior expectations as to the direction of the influence of open space characteristics on property values than those of the three individual datasets (Tables 3 and 4). Both the *Population Density* and the *Urban/Rural* model show very similar results not only in terms of the signs but also the size of the respective coefficients, and both have a high overall level of significance of p=0.001.[20] Both explain almost 60 percent of the observed variation in real estate premiums reported in the source studies, and both indicate that the variation in the percent of open space in the vicinity of a property is the second-most powerful influencing factor on open space property premiums, after private open space ownership.

Table 3: Estimation results for the Urban-Rural model specification-pooled dataset

Variable	*Unstandardized Coefficients*	*Std. Error*	*Standardized Coefficients*	*t-statistic*	*p-value*
(Constant)	-3.0111	3.8598		-0.7801	0.4399
%OSChange	0.4005	0.1519	1.2685	2.6371	0.0118
%OSChangeSq.	-0.0063	0.0036	-0.8124	-1.7692	0.0845
Radius	-0.1160	0.8842	-0.0493	-0.1311	0.8963
RadiusSquare	0.0267	0.0992	0.0959	0.2690	0.7893
OS-Forest	2.0472	1.4782	0.2292	1.3849	0.1738
OS-Park	1.7143	2.2833	0.1097	0.7508	0.4572
OS-Agland	-3.2226	1.7705	-0.3460	-1.8201	0.0762
Protected	2.8134	1.5875	0.3150	1.7722	0.0840
Private	5.4093	1.4924	0.6639	3.6246	0.0008
Public	0.4472	1.6784	0.0501	0.2664	0.7913
Hedonic	-1.4688	2.1422	-0.1041	-0.6857	0.4969
MeanPropVal	0.0000	0.0000	-0.0374	-0.2174	0.8290
Urban	-1.8876	1.4519	-0.2308	-1.3001	0.2010
Rural	-0.9628	1.5727	-0.0915	-0.6122	0.5439
R^2		0.5655	N=55	F-statistic	3.7193
Adjusted R^2		0.4135		Prob.(F)	0.0005
Std. Error of the Estimate		3.1356			

Notes: OLS estimation. Dependent variable: %INCR_PV.

The *%Open Space* variable is significant at or around the one percent level in both the *Population Density* and the *Urban/Rural* model specifications (p=0.004 and 0.012, respectively). Of the land cover variables, the signs on both *Forest* and *Park* are positive (though not significant at the p=0.1 level), while the sign on *Agricultural Land* is negative (significant at the ten percent level). The

[20] All regressions were performed using SPSS v.9.0.

coefficients on the land cover indicator variables indicate the direction and size of the impact of these land covers compared to wetlands, which represent the reference point. Thus, the results indicate that forest and parks have larger positive impacts on property values than wetlands, while agricultural lands (specifically, pasture lands, since we did not include any observations on open space benefits/costs of row crops) have a smaller impact. Both the *Protected* and the *Private* landownership variables are positive as well (significant at the ten and 0.1 percent levels, respectively). The results suggest that the size of the open space premium is not dependent on the value of a property. The negative signs on the coefficients of the *Urban* and *Population Density* variables are counterintuitive, as the prior expectation is that open space premiums increase in urban areas with higher population density where such space is scarcer. However, given the uncertainty of the data regarding population density measures reported in the studies, this finding is not all too surprising. In any case, the coefficients on these variables were not significant.[21]

Table 4: Estimation results for the Population Density model specification-pooled dataset

Variable	*Unstandardized Coefficients*	*Std. Error*	*Standardized Coefficients*	*t-statistic*	*p-value*
(Constant)	-3.1594	3.8293		-0.8251	0.4141
%OSChange	0.4479	0.1452	1.4184	3.0854	0.0036
%OSChangeSq.	-0.0073	0.0035	-0.9339	-2.0988	0.0420
Radius	-0.4393	0.8579	-0.1868	-0.5120	0.6114
RadiusSquare	0.0589	0.0959	0.2116	0.6139	0.5426
OS-Forest	1.9806	1.4341	0.2217	1.3810	0.1748
OS-Park	1.5340	2.2244	0.0982	0.6896	0.4943
OS-Agland	-2.8971	1.6521	-0.3111	-1.7535	0.0870
Protected	2.9799	1.5544	0.3336	1.9170	0.0622
Private	5.5531	1.4389	0.6816	3.8592	0.0004
Public	0.5228	1.6638	0.0585	0.3143	0.7549
Hedonic	-1.9958	2.2277	-0.1414	-0.8959	0.3756
MeanPropVal	0.0000	0.0000	-0.0069	-0.0447	0.9645
PopDensity	-0.0006	0.0005	-0.1812	-1.1739	0.2472
R^2		0.5613	N=55	F-statistic	4.0355
Adjusted R^2		0.4222		Prob.(F)	0.0003
Std. Error of the Estimate		3.1122			

Notes: OLS estimation. Dependent variable: %INCR_PV.

Finally, in both models, the coefficients on the squared open space percentage variable are negative and significant (p=0.05 and 0.01, respectively). Thus, open space premiums decrease in size for successively larger increases in the percentage of an area occupied by open space. This finding mirrors those by Walsh (2004) and Acharya and Bennett (2001), who found that open space acreage exhibits decreasing returns.

[21] Recall that suburban areas were coded with both *Urban* and *Rural* variables set to zero. Thus, the results of our estimation of the Urban-Rural model specification suggest that open space premiums in suburban areas are higher than in either urban or rural areas.

We also tested models with interaction terms that interacted protection status with land cover (FORPROT, AGPROT) and private ownership (PRIVPROT). The signs on the estimated coefficients of the interaction variables all were the same as on the noninteracted variables of the base models (FOR, AG, PRIV, PROT) (see Tables A1-1 and A1-2 in the appendix). We decided to retain the original models, however, because *F*-tests indicated that there was no significant difference between the original and the interaction models (see Table A1-3 in the appendix).

Both the *Population Density* and the *Urban/Rural* models contain several variables that our analysis does not identify as being significant for our sample.[22] These include the *Radius* and *Radius Squared* of a property in which the quantity of open space is measured, *Forest* (which with a *p* value of 0.17 is close to the commonly-used significance level of 0.1), *Park*, *Public* ownership, *Hedonic* study method, *Urban* and *Rural* (or *Population Density* in the alternative model specification), and *Mean Property Value*. We used the backward elimination procedure to exclude the least significant variables, with the exception of the *PARK* variable.[23] We retained the *PARK* variable because it is one of our land cover indicator variables, and because its statistical insignificance likely is due to a large extent to the very small number of observations (four). By eliminating the statistically insignificant variables, the reduced versions of both models contain the same variables, and thus are identical (Table 5).

Table 5: Estimation results for the reduced form model - pooled dataset

Variable	*Unstandardized Coefficients*	*Std. Error*	*Standardized Coefficients*	*t-statistic*	*p-value*
(Constant)	-6.5903	1.6353		-4.0299	0.0002
%OSChange	0.4221	0.1290	1.3370	3.2714	0.0020
%OSChangeSq.	-0.0068	0.0032	-0.8801	-2.1432	0.0373
OS-Forest	2.7619	1.1329	0.3092	2.4379	0.0186
OS-Park	1.6768	1.9629	0.1073	0.8543	0.3973
OS-Agland	-2.7367	1.1696	-0.2938	-2.3399	0.0236
Protected	3.5067	1.1039	0.3926	3.1767	0.0026
Private	5.3409	1.2818	0.6555	4.1667	0.0001
R^2		0.5433	N=55	F-statistic	7.9878
Adjusted R^2		0.4753		Prob.(F)	0.0000
Std. Error of the Estimate		2.9658			

Notes: OLS estimation. Dependent variable: %INCR_PV.

The reduced model is statistically even more significant than the full models, both at the level of the model and at the level of the individual variables.

The estimated coefficients of the variables in the reduced model are very similar to those of the full models. For example, the elasticity of property value premiums with respect to the percentage of open space in the vicinity of a property is 0.42, the average of the two values in the full models (0.45 and 0.40), while the coefficient on the open space percentage squared is -0.0068, again the average

[22] This of course does not indicate that these variables are not influencing real estate open space premiums. It merely indicates that they do not do so in our sample.

[23] We used a probability of *F* to remove of >0.1.

of that of the full models. Thus, an increase in the percentage of open space in an area from zero to ten percent will increase property values on average by 3.5 percent.[24] For forested, private, or protected open space or for parks, this value is higher, while for agricultural open space it is lower. Because of the increasing power of the negative squared term for successively larger increases in open space, the marginal open space property premiums become negative once open space accounts for approximately 1/3 (32 percent) of the total area. This closely matches Walsh's results who found that in Wake county, North Carolina, marginal open space premiums turned negative for percentages of open space that exceed roughly 1/3 of the total area.

It must be noted, however, that our model likely overestimates the attenuation of the size of marginal open space premiums that results from large open spaces. The reason for this is that when estimating our model, part of the premium estimates in our pooled dataset (those based on the transformation of property value premium estimates from studies that measure premiums as a function of reductions in distance to nearest open space or of adjacency to open space) were "interpreted" by the regression analysis to be associated only with the sizes of the particular open spaces in question, while in fact the premiums also were affected by the other open spaces present in the respective source study contexts. With few exceptions, the source studies do not provide information on the total open space in the respective areas that would have allowed us to incorporate this factor in the analysis. Any analysis of open space premiums based on these transformed observations will attribute observed decreases in the returns to open space fully to the particular open spaces whose impacts are analyzed, as opposed to to the total open spaces in the study areas. Consider for example a case in which the results reported in a study indicate that a 200m reduction in the distance of the mean property to the nearest open space increases property values by five percent. Assume that given the shape and size of the open space considered in that study and given the initial distance of the mean property from the open space, the reduction in distance results in a 20 percent increase in the percentage of open space within a ¼ mile radius of the property. The premium reported in the original study was a function, in addition to the reduction in distance to the open space, also of the total open space (and its distribution) in the area. After transforming the observation from "reduction in distance" to "increase in the percentage of open within a ¼ mile radius" in order to be able to include it in our pooled dataset, however, the premium is treated as being the result only of the 20 percent increase in open space. Our regression thus will associate the "20 percent" value of the open space variable with the "five percent" property value variable. This would be correct if the open space in question were the only open space in the original study. However, in most studies, this was not the case. Thus, the "20 percent" increase in open space might in fact represent an increase in total open space in the area of analysis from, say, 30 percent to 50 percent. Consequently, the five percent premium reported in the study reflects the premium of moving from 30 percent to 50 percent open space, not from zero to 20 percent. If, as the literature suggests[25], marginal open space premiums decline beyond a certain point, a 20 percent increase in open space from a basis of 30 percent would be expected to result in lower property value premiums than a 20 percent increase from a base of zero. Our model therefore will underestimate the premium that is associated with an increase from zero to 20 percent.

[24] $0.4221*10 - 0.0068*(10^2) = 3.5$.

[25] See Acharya and Bennett (2001), Bin and Polasky (2005), and Walsh (2004).

Since almost half (47 percent) of the observations included in our analysis are of this "transformed" type, our estimated model likely suffers from this overattenuation of open space premiums. This overattenuation manifests itself in a downward bias in the coefficient on the *%OS* variable and an upward bias in the coefficient on the *%OS squared* term. The combined effect of these two factors is a downward and leftward shift of our estimated premium curves (see Figure 4) compared to the actual curves. Thus, our model is likely to overestimate the attenuation of the property value benefits of additional open space increments, and to underestimate open space premiums.

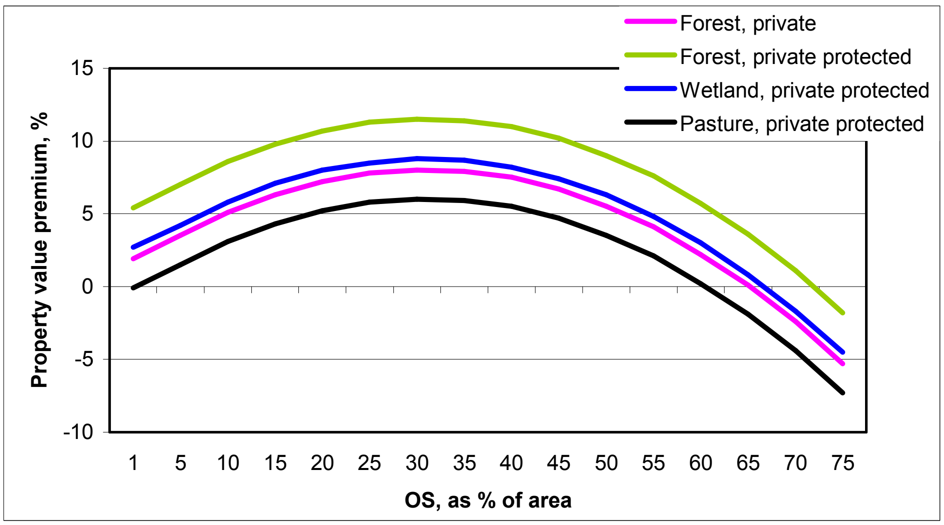

Figure 4: Open space property value premiums for some open space types as estimated by the model

The reduced model serves as the basis for the property premium estimator we develop in this project. The estimated equation for the models is as follows:

$$P_{OS} = -6.5903 + 0.4221 * \%OSChange - 0.0068 * \%OSChangeSquared + 2.7619 * FOR + 1.677 * PARK - 2.7367 * AG + 3.5067 * PROT + 5.3409 * PRIV. \quad \text{(eq.3)}$$

where P_{OS} is the open space property premium in percent.

A note on appropriate uses of the model

Our property premium estimator model considers the particular value premiums associated with a given open space. The model was estimated on the basis of observations that link *increases in OS* in an area to increases in residential property values. Therefore, it is most appropriately used to estimate the premiums associated with a particular open space, existing or proposed, irrespective of the other open spaces in the area. The impact of those other open spaces on the size of the premiums associated with the particular opens pace in question are already implicitly accounted for in the premium estimates, because the observations in the source studies express the marginal or incremental impact of an *additional* unit of open space on property values, *given the total quantities of open space in the study area.*

Our model was estimated over observations of open space premiums for increases in open space that ranged from 1% to 46% of the study area. Therefore, the model should only be applied to the evaluation of property premiums of individual open spaces that roughly fall within this size range.

Open space premiums and their impact on property tax revenues

The publicly financed preservation or creation of open spaces competes with other projects for scarce public funds. From a fiscal perspective, the conservation or creation of open spaces in many cases may constitute a viable investment. A number of studies have shown that the portion of property values that is associated with open space premiums may account for a sizeable share of the total property tax revenue in an area. This is not surprising, as open space-related property value premiums become capitalized into assessed values of nearby properties, and thus directly increase property tax revenues (Crompton, 2001). In the case of newly created open spaces, the positive impact on property tax revenues may be delayed until the next reassessment and may be slowed down due to limits on permissible increases in assessment values. However, the premiums eventually are fully incorporated into assessed property values.

For example, Brown and Connelly (1983) found that Keewaydin State park in New York enhanced the average assessed property values in the three nearby communities of Alexandria Bay (town), Orleans and Alexandria Bay (village) by 3.8%, 15.6%, and 16.4%, respectively. Similarly, Moscovitch (2004), in his study of property values in Alachua and Leon counties in Florida found that the increased tax revenues attributable to open space premiums amounted to an estimated $3.5 million per year in each of the two counties.

In another case, Geoghegan et al. (2003) analyzed the open space premiums associated with agricultural land under easement in two suburban Maryland counties. The authors found that a one-percent increase in open space under easement in these counties (equivalent to 181 and 148 acres, respectively) would generate an increase in aggregate housing values for properties located within one mile of the protected lands of an estimated $56 million and $28 million, respectively, resulting in increased annual property tax revenues of $580 thousand and $252 thousand, respectively.

The impact of open spaces on property tax revenues depends on a variety of factors, like the shape of the open space and its attractiveness (Crompton, 2001), and the number and assessed value of impacted properties. Evidence from studies suggests that natural areas containing woods, hills, ponds or marshes are preferred over open spaces used primarily for athletic activities (Kaplan and Kaplan, 1989). Thus, the preservation or restoration of natural areas may be self-financing through the resulting increases in property values and tax revenues. In fact, investments in open space often are likely to be fiscally superior to increased residential development, because the cost of community services associated with the latter exceed residential tax revenues by, on average, 15 percent (Crompton, 2001b).

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Appendix 1

Table A1-1: Estimation results for the Urban-rural model specification with interaction terms

Variable	*Unstandardized Coefficients*	*Std. Error*	*Standardized Coefficients*	*t-statistic*	*p-value*
(Constant)	2.6030	3.6812		0.7071	0.4838
%OSChange	0.3565	0.1613	1.1292	2.2100	0.0332
%OSChangeSq.	-0.0054	0.0037	-0.6923	-1.4405	0.1579
Radius	-0.3092	0.9008	-0.1315	-0.3433	0.7333
RadiusSquare	0.0401	0.0999	0.1441	0.4016	0.6902
OS-Forest	0.2641	2.5911	0.0296	0.1019	0.9193
OS-Park	1.4236	2.4787	0.0911	0.5743	0.5691
OS-Agland	-0.1742	2.8590	-0.0187	-0.0609	0.9517
Protected	-2.5483	2.8115	-0.2853	-0.9064	0.3704
Public	0.6781	1.8001	0.0759	0.3767	0.7085
Hedonic	-1.4619	2.1416	-0.1036	-0.6826	0.4990
MeanPropVal	0.0000	0.0000	-0.0727	-0.4182	0.6782
Urban	-1.5245	1.4727	-0.1864	-1.0351	0.3071
Rural	-0.8686	1.5793	-0.0826	-0.5500	0.5856
For-Prot	1.9618	3.1410	0.2408	0.6246	0.5360
Ag-Prot	-4.0626	2.8409	-0.3531	-1.4300	0.1609
Priv-Prot	5.8980	1.5305	0.6333	3.8536	0.0004
R^2		0.5879	N=55	F-statistic	3.3885
Adjusted R^2		0.4144		Prob.(F)	0.0010
Std. Error of the Estimate		3.1331			

Notes: *Private ownership* variable excluded due to collinearity. Dependent variable: %INCR_PV

Table A1-2: Estimation results for the Population Density model specification with interaction terms

Variable	*Unstandardized Coefficients*	*Std. Error*	*Standardized Coefficients*	*t-statistic*	*p-value*
(Constant)	2.7336	3.7232		0.7342	0.4672
%OSChange	0.3977	0.1537	1.2594	2.5865	0.0135
%OSChangeSq.	-0.0062	0.0036	-0.7983	-1.7218	0.0930
Radius	-0.6064	0.8707	-0.2579	-0.6964	0.4903
RadiusSquare	0.0707	0.0963	0.2539	0.7339	0.4674
OS-Forest	0.0815	2.5737	0.0091	0.0317	0.9749
OS-Park	1.2593	2.4201	0.0806	0.5204	0.6058
OS-Agland	0.1757	2.6759	0.0189	0.0656	0.9480
Protected	-2.5159	2.7706	-0.2817	-0.9081	0.3694
Public	0.7700	1.7827	0.0862	0.4319	0.6682
Hedonic	-1.9932	2.2169	-0.1412	-0.8991	0.3741
MeanPropVal	0.0000	0.0000	-0.0416	-0.2673	0.7906
PopDensity	-0.0005	0.0005	-0.1595	-1.0339	0.3075
For-Prot	1.9772	3.0854	0.2427	0.6408	0.5254
Ag-Prot	-4.2887	2.7773	-0.3727	-1.5442	0.1306
Priv-Prot	6.0706	1.4729	0.6518	4.1214	0.0002
R^2		0.5869	N=55	F-statistic	3.6942
Adjusted R^2		0.4280		Prob.(F)	0.0005
Std. Error of the Estimate		3.0965			

Notes: *Private ownership* variable excluded due to collinearity. Dependent variable: %INCR_PV

Table A1-3: Results of *F* tests of no significant difference between base and interaction models (H_0)

Model	*F-statistic*	*F-test critical value*	
Urban-rural specification with interaction terms	1.0316	F(0.05; 2; 38) = 3.23 F(0.10; 2; 38) = 2.44	H_0 not rejected H_0 not rejected
Population Density specification with interaction terms	1.2087	F(0.05; 2; 39) = 3.23 F(0.10; 2; 39) = 2.44	H_0 not rejected H_0 not rejected

Notes: Numbers in parentheses of F-test critical value indicate level of significance, degrees of freedom of numerator, and degrees of freedom of denominator, respectively. H_0 = no difference between base and interaction model.

Appendix 2

Manual for

Open Space Property Premium Estimator Model

This section contains supporting information and instructions for use of the Property Premium Estimator. The estimator itself is available as a separate Excel file.

The Property Premium Estimator was developed to allow users to generate estimates of the increase in the value of local properties as a result of an increase of a particular type of open space in a location of interest.

A note on appropriate uses of the model

Our property premium estimator model considers the particular value premiums associated with a given open space. The model was estimated on the basis of observations that link *increases in OS* in an area to increases in residential property values. Therefore, it is most appropriately used to estimate the premiums associated with a particular open space, existing or proposed, irrespective of the other open spaces in the area. The impact of those other open spaces on the size of the premiums associated with the particular opens pace in question are already implicitly accounted for in the premium estimates, because the observations in the source studies express the marginal or incremental impact of an *additional* unit of open space on property values, *given the total quantities of open space in the study area*.

Our model was estimated over observations of open space premiums for increases in open space that ranged from 1% to 46% of the study area. Therefore, the model should only be applied to the evaluation of property premiums of individual open spaces that fall within this size range. To prevent application of the model to cases where the open space in question accounts for a substantially larger share of the area in which property premiums are analyzed, the Estimator Model does not accept open space percentages of over 50 percent. If an open space exceeds this value, the model returns an "Out of Range" notice.

It is important to bear in mind that the property value premiums generated by the Estimator only constitute estimates of the actual premiums. The reason for this is that open space premiums always are location-dependent. The Estimator is based on a regression function that was estimated over 55 observations of open space property value premiums taken from 22 published studies. Given the relatively small number of observations and the limited number of explanatory variables included in the original studies and in the estimation of the function underlying the Estimator, the Estimator has been derived on the basis of a relatively small subset of the universe of location-specific contexts found across the U.S. In contexts that are very different from those of the studies from which the function underlying the Estimator was derived, the Estimator may not yield reliable estimates of the property value impacts of open space. Thus, the Estimator may generate reasonable accurate premium estimates in many instances, while in others it may not.

In cases where a particular location of interest to the user is geographically closer or otherwise very similar to one of the locations analyzed in the literature, the open space premium estimates derived in the relevant study(ies) might serve as good indicators of the magnitude of open space premiums in the location of interest. We encourage the user to consult the spreadsheet that contains the studies we reviewed in order to identify whether or not one of them might be an appropriate candidate for a single-value benefits transfer to his or her own study context. In general, the closer the study characteristics match the characteristics of the site for which open space property premium estimates are desired, the higher the applicability of the study estimates. The spreadsheet listing the studies provides information on many study characteristics identified as important in the literature.

If there is no existing study that represents a suitable source for a benefits transfer to the site for which estimates are desired, or if a second estimate is desired for a site that closely matches one of the study sites listed in the spreadsheet, our Estimator provides a straightforward tool for generating such estimates.

Using the Estimator Tool

The Estimator tool can be used to generate estimates of the property enhancement value of increases in open space in a particular area. The tool is based on the reduced model estimated in the main part of this report, and takes the following form:

$$P_{OS} = -9.327 + 0.4221 * \%OSChange - 0.0068 * \%OSChangeSquared + 5.4986 * FOR$$
$$+ 4.4135 * PARK + 2.7367 * WET + 3.5067 * PROT + 5.3409 * PRIV \qquad \text{(eq.4)}$$

where P_{OS} is the open space property value premium, expressed in percent;

%OSChange is the increase in open space - measured as percent of the area in which impacts are analyzed - for which the corresponding property value premium is sought;
%OSChangeSquared is the square of the increase in open space;
FOR is an indicator (binary) variable that takes the value 1 if the open space in question is a forest and a value of zero otherwise;
PARK is an indicator variable that takes the value 1 if the open space in question is a park and a value of zero otherwise;
WET is an indicator variable that takes the value 1 if the open space in question is a wetland and a value of zero otherwise;
PROT is an indicator variable that takes the value 1 if the open space in question is protected and a value of zero otherwise; and
PRIV is an indicator variable that takes the value 1 if the open space in question is privately owned and a value of zero otherwise.

This model is a rescaled version of the reduced Model II described in Section 2 of this report (see eq. 3). The model was rescaled such that agricultural land (specifically, pasture) now constitutes the base land cover. The original Model II uses wetland as the (arbitrarily chosen) base land cover. The rescaling was carried out in response to requests by participants in a workshop that evaluated the benefits toolkit. Participants argued that pasture generally constitutes the least valuable wildlife habitat for uncommon species or species of conservation concern. Therefore, it would be helpful if the toolkit would use that least valuable land cover as the base case against which to evaluate the property premium impacts of the other, more desirable land (wetland, natural area parks and forests). The rescaling of the model achieves just that. Note that the rescaling does not impact the property value premium estimates generated by the model. The original Model II (eq. 3) and the rescaled model built into the Estimator Tool (eq. 4) generate the same outputs.

Incidentally, our regression results indicate that this ranking also appears to reflect the view of home owners. As revealed by the coefficients on the land cover indicator variables, pasture is the land cover that generates the lowest premiums, followed by wetland, natural area park, and forest. These coefficients indicate the additional, land cover-specific premiums associated with the different open space land covers.

The Estimator Tool generates estimates of the property value premiums associated with open space. **These premiums indicate the increase in property values compared to the alternative to open space, namely, development**. Specifically, the premiums indicate house price increases compared to single-family detached housing, which is the predominant housing type in the study areas in the source studies we used to estimate our model and the housing stock for which the source studies estimated open space premiums.

To generate open space premium estimates for an area, all the user needs to do is set the boundaries for the area of analysis, calculate the percentage of this area that would be devoted to additional open space, and identify the appropriate settings for the indicator variables.

The Estimator Tool equation will generate an estimate of the premium received by an average property as a result of an increase in the amount of open space of a particular type in a property's vicinity. Thus, it indicates the percent by which the value of a property is increased as a result of increased open space. The total property premium resulting from an increase in open space in a given area however is the sum of all premiums received by individual properties. Thus, the premium estimated by the Estimator must be multiplied by the number of properties contained in the area of analysis. The size of the total property value premium generated by an open space thus will increase with the size of the area around the open space that is being considered, as long as the increase in size of the area is accompanied by an increase in the number of properties contained in the area.

Open space premiums are a function of the sum of open space-related benefits received by a given property. These benefits include visual amenities, access for recreational purposes and environmental health benefits such as cleaner air (as a result of trees intercepting airborne particulate matter and thus reducing ambient concentration of pollutants (Escobedo et al., 2007; Novak et al., 1998, 2006). These benefits generally are attenuated by distance, with the level of attenuation likely to vary for different benefits. However, visual amenities will depend on the geography of the area, with a line of sight between property and the open space generally being a precondition for their accrual to a property. The benefits accrue to residents, irrespective of whether or not they own the properties on which they reside. Open space benefits increase the attractiveness of a given property and thus get factored into rents and property prices alike. Thus, when estimating the aggregate value of open space property premiums for a given area, there is no need to distinguish between owner-occupied and rented properties.

The Estimator tool implicitly takes into account the attenuation of open space benefits with increasing distance from the open space, by estimating property premiums as a function of an increase in the percentage of an area occupied by open space. As the size of the area analyzed is increased, the open space in question will account for a smaller share of this area. Thus, the Estimator avoids the potential fallacy of generating unrealistically large aggregate open space premium estimates for a given open space, which would result if one were to simply apply a fixed open space premium to a large number of properties located in a large area, many of which are far removed from the open space in question.

Generating open space property value estimates using the Estimator tool

1. *Select the area of analysis*

The first step in generating estimates of the property value increases generated by an open space is the selection of the area of analysis. The area of analysis chosen should have a circular shape (a square is acceptable) with the open space in question at its center. The reason for this is that the studies on which the estimation is based analyzed open space impacts as a function of the percentage of open space within a radius of a property, that is, in a circular area with the property at its center and at a given distance from the open space. Furthermore, we used the same distance-based radius measure to convert the results of studies that measured impacts of open space using distance or adjacency measures into open space percentages within a given radius of a property (see section 2 of this report for details). As a result, the dataset over which we estimated our model measured open space impacts at given distances (i.e., within given radii of properties). Thus, even though we operationalized open space as percent within a given area, our estimated model is implicitly based on the particular spatial arrangement of open spaces and properties shown by the green area and point *A* in Figure A2-1. The impact of the green space on the value of property *A* is (in part) a function of the distance of the open space. That impact therefore likely will not be the same as that experienced by property *B*, which is located at a greater distance from the open space.

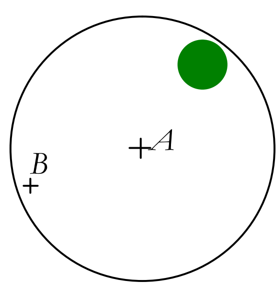


Figure A2-1: Properties located at different distances from open space (green area)

Since open space impacts are distance-dependent, the average and total property value impacts of a given open space located in the far corner of an analysis area would be expected to be smaller than those of an open space located at the center of the area, because the average distance of a property would be larger in the former case. However, the Estimator would yield the same estimates in both cases because it measures open space as percent of land cover in the area analyzed.

Consider for example the circular and rectangular areas shown in Figure A2-2. Assume that both areas are of equal size and have the same number of residential properties distributed evenly throughout them. In the circular area, the average property will be located at a distance approximately equal to the length of line *l* from the open space, indicated by the green area. By comparison, in the rectangular area, the average property will be located at a distance from the open space equal to the length of the line *L*, which is several times the length of line *l*. Thus, the average distance of properties from the open space is much larger in the rectangular area than in the circular area.

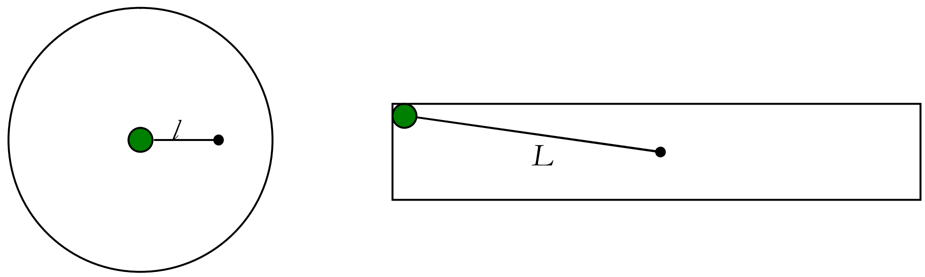


Figure A2-2: Average distance of properties from open space in circular and rectangular areas of identical size

As a result, the aggregate open space premium for the rectangular area likely would be overestimated. The same would be true for an open space located outside of the center in a circular area of analysis.

a. Calculate the size of the area

In order to calculate the percent of the area of interest *A* that is occupied by the open space in question, the size of the area must first be determined. This is done most easily for circular and rectangular areas, by using the formulas shown below.

> <u>Circular area</u>: $A = \pi \cdot r^2$, where π is a constant with the approximate value of 3.1416 and r is the radius of the circle.
>
> <u>Rectangular area</u>: $A = l \cdot w$, where l and w are the length and width of the rectangular, respectively. NOTE: Recall that if using a rectangular area of analysis, both sides of the rectangular should be of equal or at least similar length.

For areas with shapes other than circular or rectangular, area estimation is less straightforward and usually will require application of GIS tools.

b. Calculate the percentage of the area that is/would be occupied by the open space under analysis

The percentage of the area of interest that is occupied by the open space whose property value impacts are being estimated is derived by dividing the area of the open space by the area of analysis.

2. *Set the indicator variables to their appropriate values*

The indicator variables describe particular characteristics of an open space that our meta-analysis has identified as being of importance in determining open space property value premiums. An indicator variable can take a value of either "1", indicating that the open space has the particular characteristic, or "0", indicating that the characteristics is not present. In many cases, an open space may not be homogenous and may exhibit different characteristics in different portions of its area. In this case, the predominant characteristic (in terms of area) should be chosen as the characteristics for purposes of the analysis.

The land cover (*FOR*, *PARK*, *WET*) indicator variables must be set to match the characteristics of the open space. The dominant land cover type should be chosen as the land cover type for the estimation, and only one land cover type can be chosen. All other cover types must be set to "0". NOTE: Agricultural land (pasture) is the base case land cover type. Thus, if the land cover of the open space in question is a agricultural land, all other land cover indicator variables must be set to zero.

Table A2-1 shows the coding that was employed to assign the land covers in the source studies to the different land covers employed in the model. Use this coding as a general guideline for selecting the land cover type that best matches the area for which you want to generate property value premium estimates.

Table A2-1: Land cover type coding

Land cover type variables used in Property Value Premium Model	*Land cover in sources studies coded as that variable*
Agricultural	Includes pasture and mixed pasture and cropland; croplands do not include large monocultures
Wetland	Covering the full continuum from forested wetlands, scrub-shrub wetlands, emergent wetlands, and open-water wetlands, and from urban to rural locations; also includes seasonal wetlands (e.g., washes)
Park	Urban or suburban natural area parks, not including heavily developed parks, generally intended and used for dispersed recreation and wildlife habitat; exhibiting a high proportion of tree cover, alternating with interspersed grasslands or shrub lands; publicly or privately owned; more heavily frequented than forest
Forest	Large tracts characterized generally by contiguous tree cover; may contain interspersed, generally very low density single-family residential units on large lots dominated by tree cover, or individual multi-unit structures visually isolated by vegetation from neighboring developments; includes state, national and private forests, state forest preserves, wilderness areas, arboretums, wildlife refuges and large greenbelts/greenways; located generally in rural, exurban, or suburban areas

There are some land covers that cannot be matched to any of our land cover types. Examples of these are beach, dunes or desert. We were unable to find studies that estimated open space premiums for residential properties near those land cover types. In addition, we did not include aquatic land covers in our analysis, with the notable exception of wetlands. The rationale for not quantifying the open space premiums associated with lakes or rivers is that our model is intended to assess the increase of property values that stems from the conservation of wildlife habitat in an area, thus making it possible to quantify the value that would be lost in case of the conversion or development of that open space. Since lakes or rivers generally are not at risk of being converted to other land cover types, we did not include these land covers in our analysis. Our analysis can still be applied to habitat along rivers or lakes, as long as that habitat falls into the forest, wetland, agricultural or park categories.

The protection (*PROT*) variable must be set to "0" if the open space in question is not protected, and to "1" if it is. An open green space is considered protected if it is publicly owned or if it is privately owned and covered by a conservation easement.

The land ownership variable (*PRIV*) must be set to "1" if the open space is privately owned, and to "0" otherwise.

With the values for all variables entered, the Estimator tool indicates the estimated percent of property value increase for the mean property in the area that is attributable to the open space. The Estimator can also be used to assess how the premium would change if the nature of the open space is changed. For example, the Estimator could be used to analyze the change in the open space premium that would result if a forested area that currently is privately owned and unprotected were to be protected. To do this, the Estimator first is run to estimate the current premium, with the values of the indicator variables *FOR* and *PRIV* set to 1 and *PARK*, *WET* and *PROT* set to zero. It is then rerun with the value of the *PROT* variable set to 1. The difference between the two estimates is attributable to the change in the protection status.

3. *Multiply the estimated premium by the number of properties located in the analysis area*

Finally, the estimated premium must be multiplied with the number of properties in the analysis area. The equation underlying the estimator was generated for single-family homes only. Thus, the number of properties used in this step should be the number of single-family residences in the area. Obviously, open space premiums also accrue to multi-unit dwellings such as duplexes, condominiums or apartment buildings. If many of these structures are present in the area of analysis, the estimated aggregate open space premium calculated on the basis of single-family homes only will tend to be substantially underestimated.

Explanation of the individual steps involved in generating estimates using the Estimator tool

STEP 1: Select the shape of the area in which property value premiums are analyzed

Enter the shape of the area of analysis in the first box. Use "C" for a circular area, "R" for a rectangular area. NOTE: Recall that if using a rectangular area of analysis, both sides of the rectangular should be of equal or at least similar length.

STEP 2: Enter the radius (in case of a circular area) or length and width (in case of a rectangular area) of the area of analysis.

Depending on whether "C" or "R" was entered as the shape of the area in STEP 1, the user is prompted to enter either the radius or the length and width of the study area, **expressed in feet**. The Estimator then calculates the size of the study area, expressed in acres.

STEP 3: Enter the size of the open space

In this box, the user enters the size of the open space **in acres**. The model then calculates the corresponding percentage the open space represents as a portion of the study area.

STEP 4: Enter the appropriate values for the indicator variables

Here, the user is prompted to set the values of the five indicator variables as either "1" or "0", depending on whether the open space characteristic indicated by the variable is present or not.

After entering the required information, the model generates the estimated property value premium for the open space (P_{OS}).

STEP 5: Enter the number of properties located in the study area and their average value

In order for the model to generate a dollar estimate of the aggregate property premium attributable to the open space of interest, the user must specify the number of properties and their average value. This information may be collected from public appraisers' offices or Census data.

Examples (NOTE: see also the more elaborate examples in Appendix 3)

Example 1: Property impact estimate of a 85-acre privately owned forest on properties within a radius of one half of a mile from the center of the open space.

Figure A2-3 shows the screen with the Estimator model for this example.

STEP 1: Since the open space premium is estimated for a circular area, enter "C" in the blue-bordered box.

STEP 2: Enter "2640" in the blue-bordered box showing the radius of the area in feet (NOTE: 2640 ft is ½ mile, the analysis radius used in this example). The *OUTPUT* field indicates the acreage of the area of analysis, 503 acres in this case. This is the area within which the property value impacts of the 85-acre open space are analyzed.

Property value premium estimator model

Instructions: Fill in all cells marked "ENTER >". (See accompanying user manual for detailed instructions and documentation.)

STEP 1: Select shape of area of analysis in which property value premiums are analyzed

ENTER >	C	Enter "C" for circular and "R" for rectangular shape of area

STEP 2: Enter the radius (circular area) or length and width (rectangular area) of the area of analysis

ENTER >	2640	Radius of area in feet
OUTPUT:	503	Size of study area (acres)

STEP 3: Enter the size of the open space

ENTER >	85	Size in acres of the open space whose property value impact is to be estimated
OUTPUT:	16.9	**%OSChange.** Percentage of the study area occupied by the open space of interest. Example: A 20 percent share of open space in the area of interest is indicated as "20".

STEP 4: Enter the appropriate values for the indicator variables

ENTER >	1	**FOR**. Enter "1" if the open space is a forest. Otherwise, enter "0".
ENTER >	0	**PARK**. Enter "1" if the open space is a park. Otherwise, enter "0".
ENTER >	0	**WET**. Enter "1" if the open space is a wetland. Otherwise, enter "0".
ENTER >	0	**PROT**. Enter "1" if the open space is protected. Otherwise, enter "0". Protection is defined as the absence of the possibility of development (i.e., easement, public ownership).
ENTER >	1	**PRIV**. Enter "1" if the open space is privately owned. Otherwise, enter "0".
P_{OS} =	6.7	**% increase in average residential property value from open space of interest**

STEP 5: Enter the number of residential properties located in the area

ENTER >	150	Number of properties located in study area. NOTE: Include only single-family homes.
ENTER >	$250,000	Average value of properties ($)
OUTPUT:	$2,511,138	**Estimated total property premium in study area attributable to open space of interest**

Figure A2-3: Screen of Estimator model for Example 1

STEP 3: Enter "85", the size of the open space in acres, in the blue-bordered box. The *OUTPUT* field indicates the percentage of the study area (503 acres) taken up by the open space under analysis (85 acres) – 16.9%.

STEP 4: Set the values of the indicator variables as follows: "1" for *FOR* "0" for both *PARK* and *WET*, since the open space is a forest; "0" for *PROT*, since the forest is not publicly owned and is not under an easement; "1" for *PRIV*, since the forest is privately owned. The property value premium field P_{OS} shows the estimated open space value premium for the average property that is attributable to the open space in question in the area of analysis – 6.7% in this example.

STEP 5: Enter the number of single-family homes in the study area and their average value in the blue-bordered boxes. In this example, let us assume there are 150 such properties with an average value of $250,000. In the *OUTPUT* box, the Estimator displays the estimated aggregate property value in the study area that is attributable to the 85-acre privately-owned forested area. In this example, the total value premium is an estimated $2.5 million.

Example 2: Same as Example 1, but with the open space under easement.

As a result, in STEP 4, the value of the *PROT* variable is now set to "1". Because the protected status of the open space increases the associated property premium, the aggregate premium for the area as a whole increases to an estimated $3.8 million.

Figure A2-4 shows the screen for this example.

Property value premium estimator model

Instructions: Fill in all cells marked "ENTER >". (See accompanying user manual for detailed instructions and documentation.)

STEP 1:	**Select shape of area of analysis in which property value premiums are analyzed**		
	ENTER >	**C**	Enter "C" for circular and "R" for rectangular shape of area
STEP 2:	**Enter the radius (circular area) or length and width (rectangular area) of the area of analysis**		
	ENTER >	**2640**	Radius of area in feet
	OUTPUT:	**503**	Size of study area (acres)
STEP 3:	**Enter the size of the open space**		
	ENTER >	**85**	Size in acres of the open space whose property value impact is to be estimated
	OUTPUT:	**16.9**	**%OSChange.** Percentage of the study area occupied by the open space of interest. Example: A 20 percent share of open space in the area of interest is indicated as "20".
STEP 4:	**Enter the appropriate values for the indicator variables**		
	ENTER >	**1**	**FOR**. Enter "1" if the open space is a forest. Otherwise, enter "0".
	ENTER >	**0**	**PARK**. Enter "1" if the open space is a park. Otherwise, enter "0".
	ENTER >	**0**	**WET**. Enter "1" if the open space is a wetland. Otherwise, enter "0".
	ENTER >	**1**	**PROT**. Enter "1" if the open space is protected. Otherwise, enter "0". Protection is defined as the absence of the possibility of development (i.e., easement, public ownership).
	ENTER >	**1**	**PRIV**. Enter "1" if the open space is privately owned. Otherwise, enter "0".
	P_{OS} =	**10.2**	**% increase in average residential property value from open space of interest**
STEP 5:	**Enter the number of residential properties located in the area**		
	ENTER >	**150**	Number of properties located in study area. NOTE: Include only single-family homes.
	ENTER >	**$250,000**	Average value of properties ($)
	OUTPUT:	**$3,826,151**	**Estimated total property premium in study area attributable to open space of interest**

Figure A2-4: Screen of Estimator model for Example 2

Example 3: Property value impact of a 28-acre public park in a square area ½ mile long and wide that contains 98 single-family homes with an average value of $200,000.

Figure A2-5 shows the screen for this example.

STEP 1: Since the open space premium is estimated for a rectangular area, enter "R" in the blue-bordered box.

STEP 2: Enter "2640" in the blue-bordered box showing the length of the area in feet (NOTE: 2640 ft is ½ mile). Upon entering "R" in STEP 1, a second box labeled "width of area in feet" appears below the length box. Enter "2640" in this box as well, since the impact area analyzed in this example is square. The *OUTPUT* field indicates the acreage of the impact area of analysis, 160 acres in this case. This is the area within which the property value impacts of the 28-acre open space are analyzed.

Property value premium estimator model

Instructions: Fill in all cells marked "ENTER >". (See accompanying user manual for detailed instructions and documentation.)

STEP 1:	**Select shape of area of analysis in which property value premiums are analyzed**		
	ENTER >	**R**	Enter "C" for circular and "R" for rectangular shape of area
STEP 2:	**Enter the radius (circular area) or length and width (rectangular area) of the area of analysis**		
	ENTER >	**2640**	Length of area in feet
	ENTER >	**2640**	Width of area in feet
			NOTE: If area is rectangular, make sure that sides of area are of similar length!
	OUTPUT:	**160**	Size of study area (acres)
STEP 3:	**Enter the size of the open space**		
	ENTER >	**28**	Size in acres of the open space whose property value impact is to be estimated
	OUTPUT:	**17.5**	**%OSChange.** Percentage of the study area occupied by the open space of interest. Example: A 20 percent share of open space in the area of interest is indicated as "20".
STEP 4:	**Enter the appropriate values for the indicator variables**		
	ENTER >	**0**	**FOR**. Enter "1" if the open space is a forest. Otherwise, enter "0".
	ENTER >	**1**	**PARK**. Enter "1" if the open space is a park. Otherwise, enter "0".
	ENTER >	**0**	**WET**. Enter "1" if the open space is a wetland. Otherwise, enter "0".
	ENTER >	**1**	**PROT**. Enter "1" if the open space is protected. Otherwise, enter "0". Protection is defined as the absence of the possibility of development (i.e., easement, public ownership).
	ENTER >	**0**	**PRIV**. Enter "1" if the open space is privately owned. Otherwise, enter "0".
	P_{OS} =	**3.9**	**% increase in average residential property value from open space of interest**
STEP 5:	**Enter the number of residential properties located in the area**		
	ENTER >	**98**	Number of properties located in study area. NOTE: Include only single-family homes.
	ENTER >	**$250,000**	Average value of properties ($)
	OUTPUT:	**$952,399**	**Estimated total property premium in study area attributable to open space of interest**

Figure A2-5: Screen of Estimator model for Example 3

STEP 3: Enter "28", the size of the open space in acres, in the blue-bordered box. The *OUTPUT* field indicates the percentage of the study area (160 acres) taken up by the open space under analysis (28 acres) – 17.5%.

STEP 4: Set the values of the indicator variables as follows: "0" for *FOR*, "1" for *PARK*, and "0" for *WET*, since the open space is a park; "1" for *PROT* and "0" for *PRIV*, since the park is publicly owned and thus protected from development. The property value premium field P_{OS} shows the estimated open space value premium for the average property in the area of analysis that is attributable to the open space in question – 3.9% in this example.

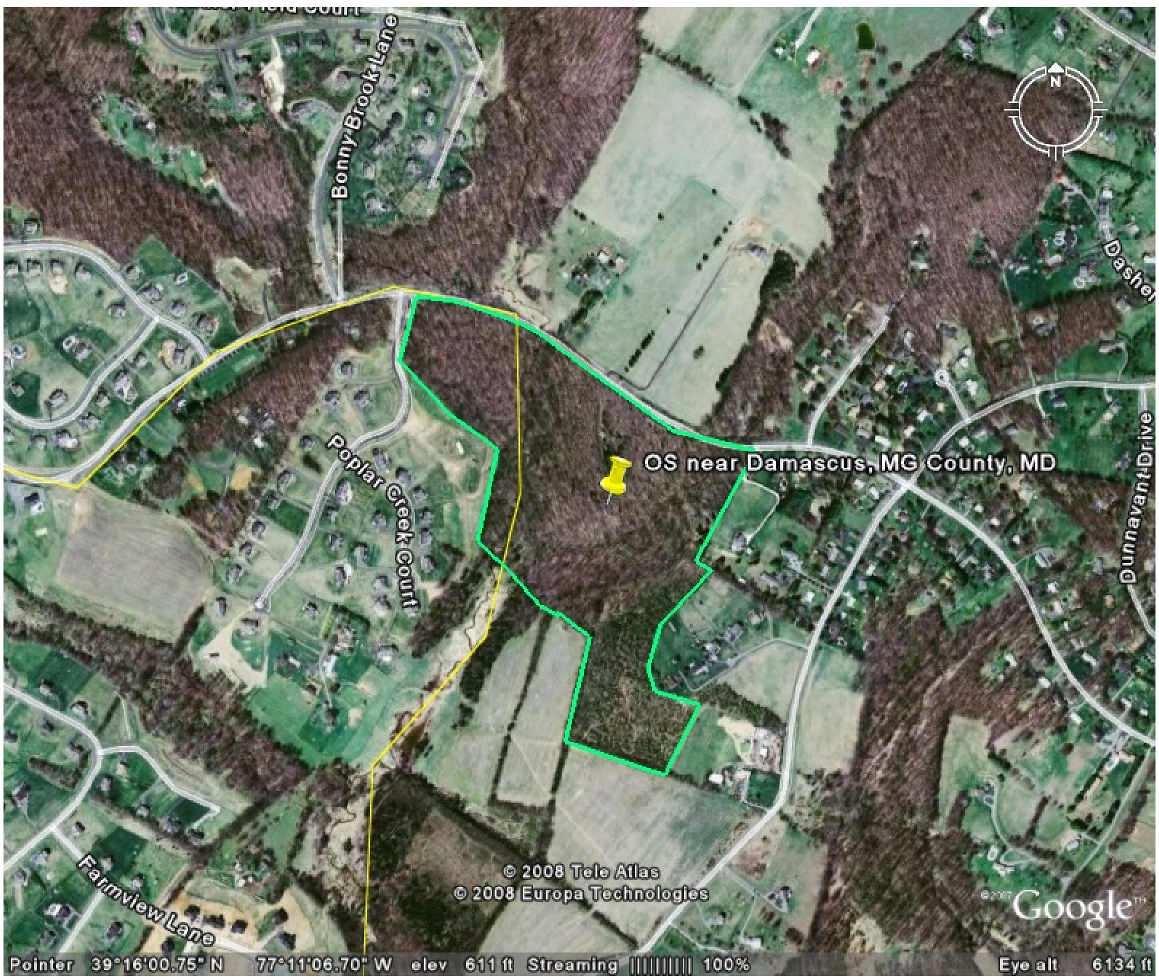
STEP 5: Enter the number of single-family homes in the study area (98) and their average value ($200,000) in the blue-bordered boxes. In the *OUTPUT* box, the Estimator displays the estimated aggregate property value in the study area that is attributable to the 28-acre park. In this example, the total value premium is estimated at around $950,000.

Appendix 3

Application of the Property Value Premium Estimator Model to concrete cases

Example 1: Benefits provided by existing open space

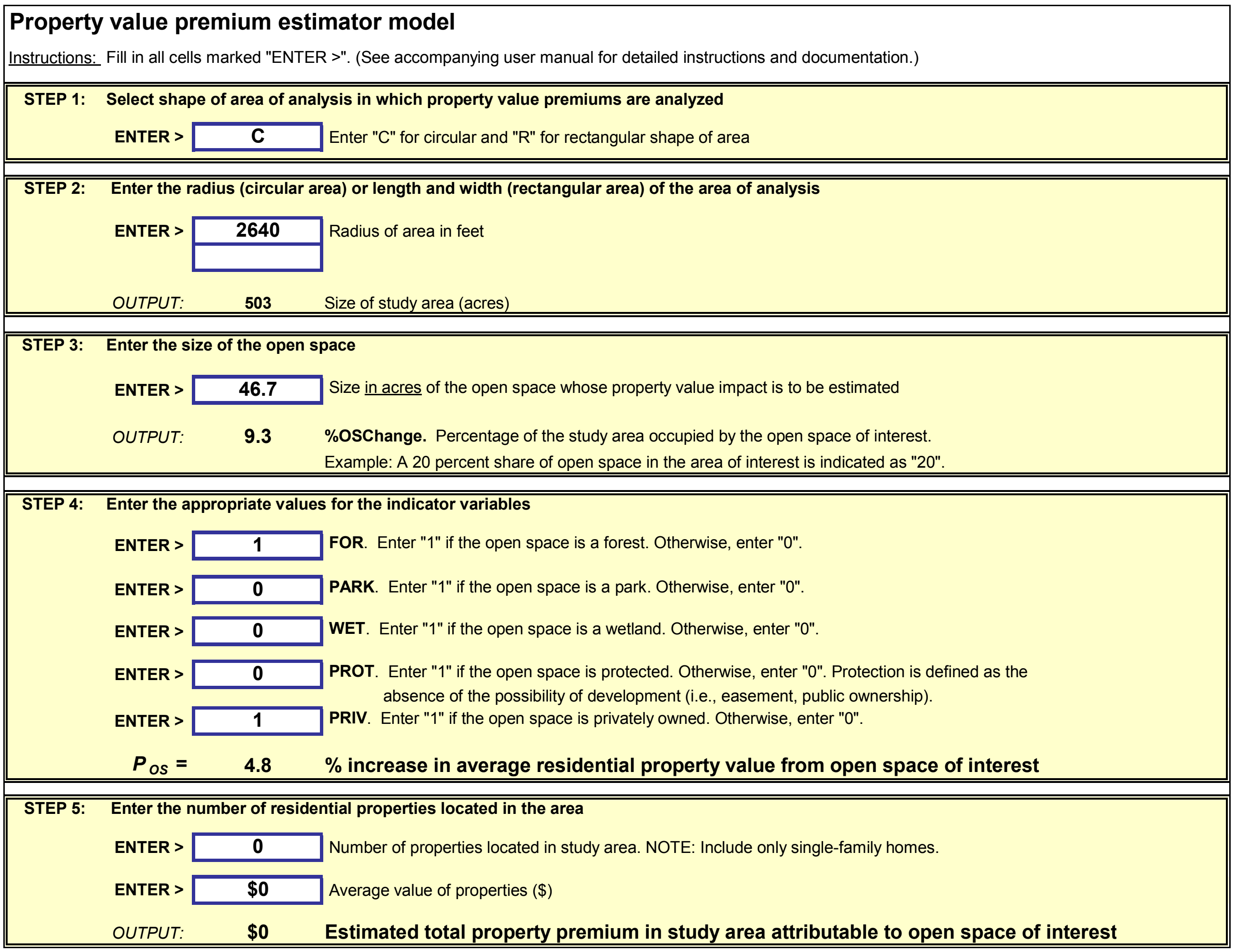
Picture 1 shows a Google Earth satellite image of an area in the town of Damascus in Montgomery county, MD. We are interested in the open space premiums received by residential properties located within a ½ mile radius of the center of the open space. The open space of concern is indicated by the light green boundary (Picture A3-1). This 46.7-acre area is in forest, is privately owned and is not covered by an easement.



Picture A3-1: Forested open space in Damascus, Montgomery County, MD (39°16'00.57" N; 77°11' 04.9" W)

To estimate the price premium the average residential property within ½ mile receives from the open space, we apply the Property Value Premium Estimator Model (the "model"; see Figure A3-1).

- In STEP 1 of the model, enter "C" for a circular are of impact analysis (the ½ -mile radius for which property value impacts are estimated).
- In STEP 2, enter the radius of the area of analysis **in feet** (1/2 mile = 2,640 ft)
- In STEP 3, enter the size of the open space of interest **in acres** (46.7 acres)
- In STEP 4, set the variables such that they reflect the open space characteristics: enter "1" for forested space (FOR) and "0" for all other land covers (PARK, WET). Set the value for the protection variable (PROT) to "0" as the open space is not publicly owned or under easement. Set the private ownership variable (PRIV) to "1".



Property value premium estimator model

Instructions: Fill in all cells marked "ENTER >". (See accompanying user manual for detailed instructions and documentation.)

STEP 1: Select shape of area of analysis in which property value premiums are analyzed

ENTER > **C** Enter "C" for circular and "R" for rectangular shape of area

STEP 2: Enter the radius (circular area) or length and width (rectangular area) of the area of analysis

ENTER > **2640** Radius of area in feet

OUTPUT: **503** Size of study area (acres)

STEP 3: Enter the size of the open space

ENTER > **46.7** Size in acres of the open space whose property value impact is to be estimated

OUTPUT: **9.3** **%OSChange.** Percentage of the study area occupied by the open space of interest.
Example: A 20 percent share of open space in the area of interest is indicated as "20".

STEP 4: Enter the appropriate values for the indicator variables

ENTER > **1** **FOR**. Enter "1" if the open space is a forest. Otherwise, enter "0".

ENTER > **0** **PARK**. Enter "1" if the open space is a park. Otherwise, enter "0".

ENTER > **0** **WET**. Enter "1" if the open space is a wetland. Otherwise, enter "0".

ENTER > **0** **PROT**. Enter "1" if the open space is protected. Otherwise, enter "0". Protection is defined as the absence of the possibility of development (i.e., easement, public ownership).

ENTER > **1** **PRIV**. Enter "1" if the open space is privately owned. Otherwise, enter "0".

P_{OS} = **4.8** **% increase in average residential property value from open space of interest**

STEP 5: Enter the number of residential properties located in the area

ENTER > **0** Number of properties located in study area. NOTE: Include only single-family homes.

ENTER > **$0** Average value of properties ($)

OUTPUT: **$0** **Estimated total property premium in study area attributable to open space of interest**

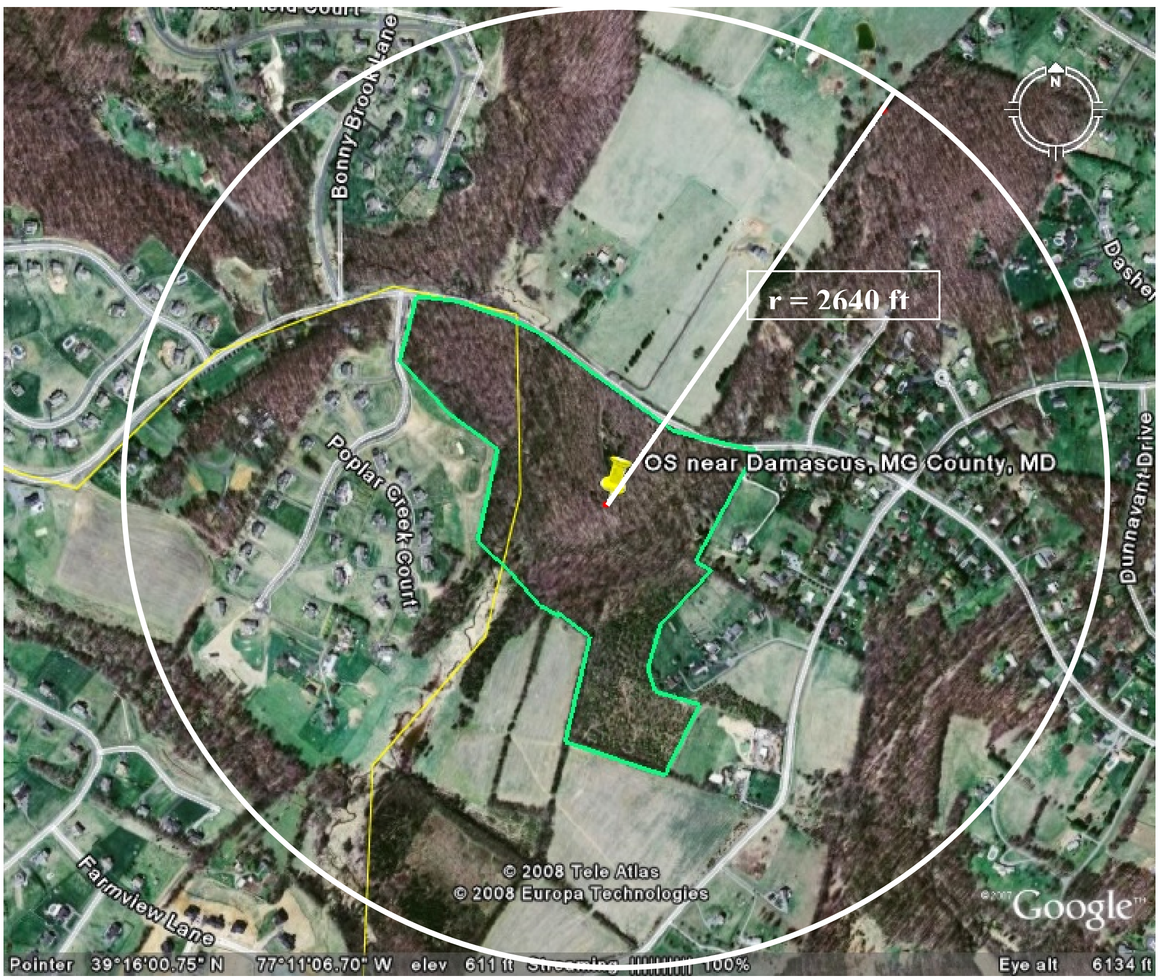
Figure A3-1: Screen shot of the Property Value Premium Estimator Model with all variables set at their appropriate values for the open space of interest

Result: The value premium received by developed residential properties located within ½ mile of the forested open space is estimated to be 4.8% on average. Thus, on average, 4.8% of the value of the average property in the area analyzed is attributable to that open space.

Developing estimates of the actual dollar value of the individual and total open space premiums for the area

In order to develop estimates of the actual dollar values of the open space premiums attributable to the open space, one needs to obtain information on the mean home (property plus structures) values and the number of homes in the area of analysis. This information is then entered in STEP 5 of the model to obtain an estimate of the total dollar value of the open space premium for the impact area analyzed. Ideally, information on mean home value and number of homes is obtained from the public assessor's office or from private real estate appraisers. Alternatively, if for whatever reason this information cannot be obtained from these sources, it can be approximated using Census information. In the following we will illustrate how Google Earth and Census information can be used to generate dollar estimates of open space premiums.

Picture A3-2 shows a circle with a radius of ½ of a mile overlaid over the center of the open space (use the circle tool of Google Earth Pro to draw the circle; alternatively, export the Google Earth image to another program and draw the circle over the image – this is made easier if before exporting the image the desired radius is first drawn into the image using Google Earth's ruler tool).



Picture A3-2: Same as Picture 1, but with a circle with ½ mile radius drawn around the center of the OS.

Visual examination of the Google Earth image allows the user to identify the number of properties located within the circle (this may require some zooming-in and panning across the area of interest, but should be fairly straightforward in most cases, given that the distance over which open space premiums should be estimated with the model generally should not exceed 1 mile).[26] In the example at hand, that number is 137. All of these are detached single-family homes. The number of homes is entered in the first box in STEP 5 of the estimator.

The final piece of information needed to estimate the aggregate dollar value of the open space premiums captured by homes located in the circle is the mean home value of the houses. The Census data do not provide information on mean home values for Census geographic areas. They do however, provide information on median home values, which may serve as a reasonable approximation of mean values. This information is available down to the block group level from Summary File 3.

To identify the block group(s) in which the area of interest is located, we use the American FactFinder Census Reference Maps.[27] The Reference Map for our area is shown in Figure A3-2.

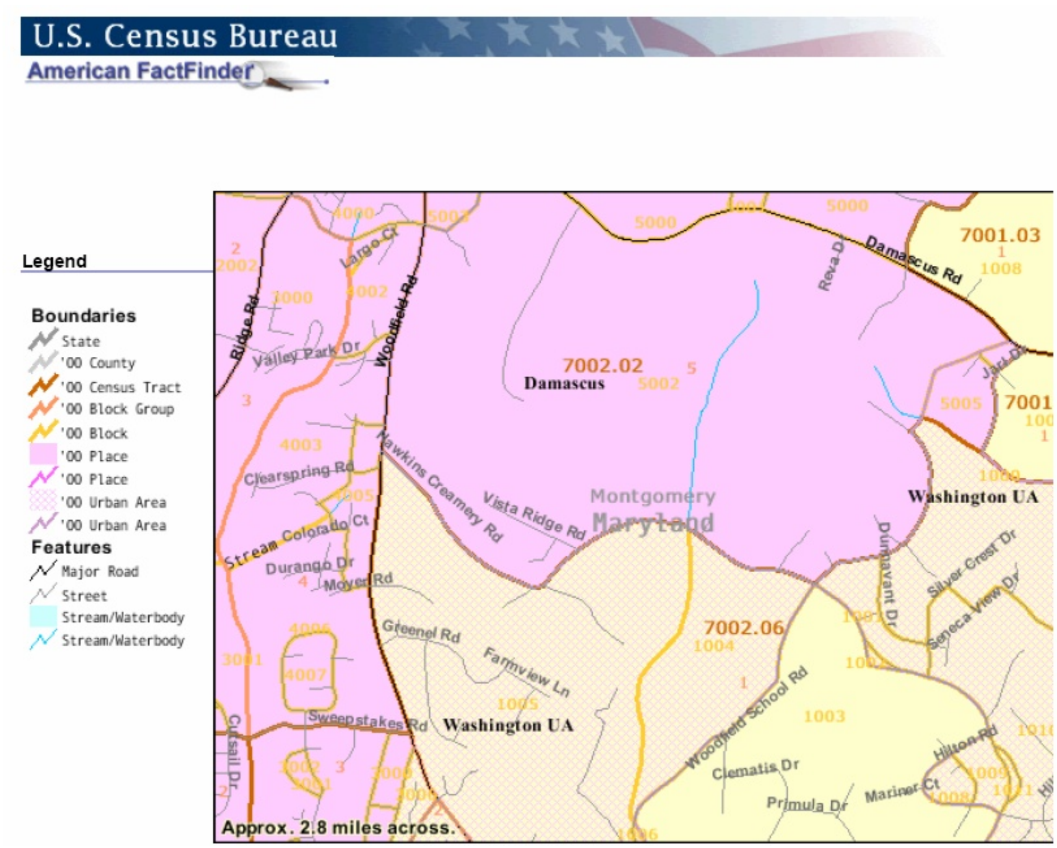


Figure A3-2: Census Reference Map of the study area

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[26] Most studies included in the meta-analysis on which the model is based estimated property value impacts within a distance of one-mile or less, with only a handful of observations exceeding that distance. Thus, the validity of the premium estimates generated by the model is uncertain for distances greater than 1 mile.

[27] http://factfinder.census.gov/servlet/ReferenceMapFramesetServlet?_bm=y&-ds_name=DEC_2000_SF3_U&-tree_id=420&-bucket_id=50&-_caller=dataset&-_lang=en#?520,278 (last accessed March 12, 2008).

Through comparison of roads on the Census map and Google Earth images we can identify the Census block groups in which our area of interest (circle) is located. The two maps can also be overlaid to further ease visual analysis (see Figure A3-3).[28]

The maps show that our study area is located in census tract (CT) 7002.02, block group (BG) 5, Block 5002, and in CT 7002.06, BG 1, Blocks 1001, 1003, 1004, 1005. Thus, we need to obtain information on median home values for CT 7002.02, BG 5 and CT 7002.06, BG 1 (recall that Census median home values are available only down to the block group level).

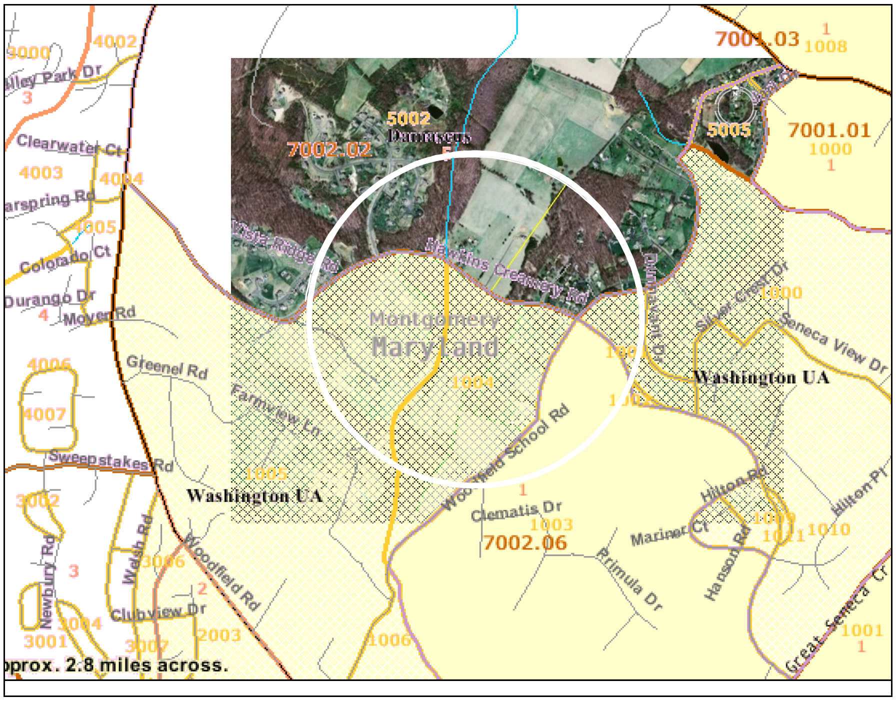


Figure A3-3: Census Reference Map overlaid over Google Earth image with ½-mile radius circle.

NOTE: The Census block groups are larger than our 1-mile diameter area of interest. Using census data thus may introduce an error into our home value estimates, because only a fraction of the block groups are contained in our study area. Specifically, in our case, the area of interest is about 1/9 of the total combined area of the two BGs. Thus, if home value vary substantially among different areas contained in a block group, using block group-level home value information may introduce errors into the analysis.

Median home values for the block groups of interest can be obtained from the Census Bureau's American FactFinder Summary File 3 as follows:[29, 30]

Click on Detailed tables

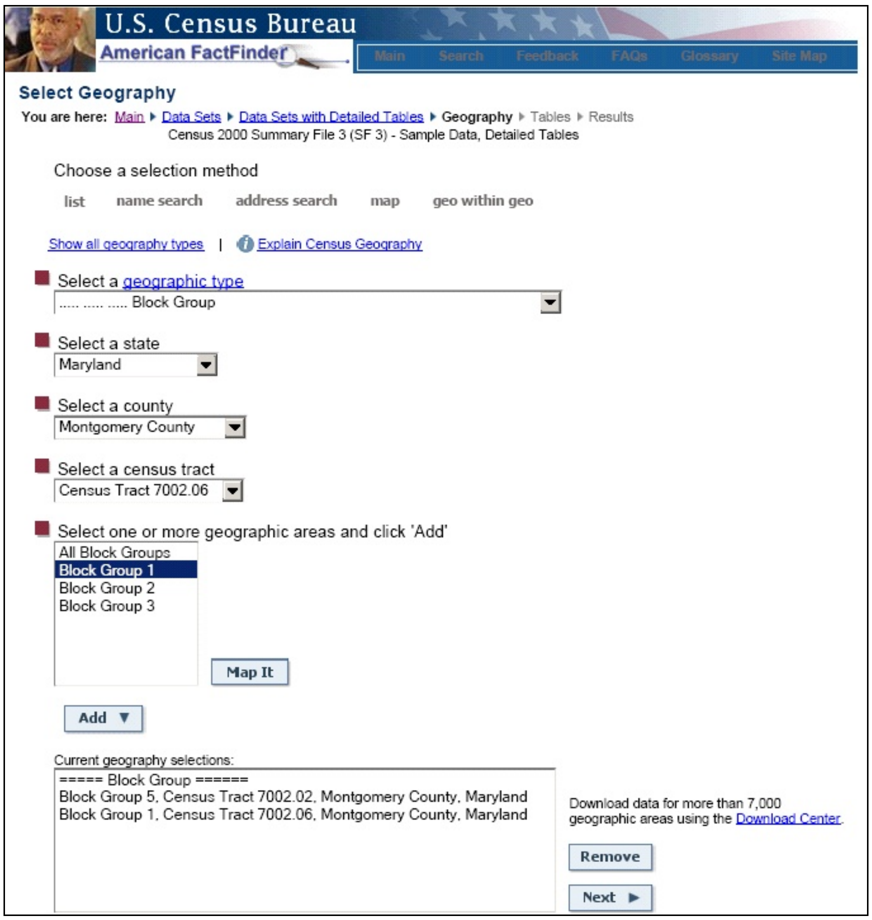
On the new page that opens, select the following options from the dropdown menus:

[28] Note that in order to do this, resizing of the maps may be needed to match their scales. In Figure A3-3, the pink area in the Census map was set to transparent to allow the underlying image to become visible.

[29] http://factfinder.census.gov/home/saff/main.html?_lang=en&_ts=

[30] Summary File 1 contains finer-scale (block level) data. However, it does not contain data on home values.

- Select a geographic type: Block group
- Select a state: Maryland
- Select a county: Montgomery County
- Select a census tract: 7002.02
- Select one or more geographic areas and click 'Add': Block Group 5
  Press the Add ▼ button to add the selection to the "Current geography selections" window.
- Repeat the last two steps to select Block Group 1 in census tract 7002.06 to the "Current geography selections" window. Your screen should now look as shown in Picture A3-3.



Picture A3-3: Screen shot of American FactFinder query (SF 3)

- Click the Next ▶ button. In the new screen that opens, under "Select one or more tables and click 'Add'", scroll down in the window and select table H85. Median home value for all owner-occupied housing units. Click the Add ▼ button to add this selection to the field "Current table selections".
- Click the Show Result ▶ button

The new screen that opens lists the median home value for all owner-occupied housing units for the two block groups: $194,500 (CT 7002.02, BG5) and $258,300 (CT 7002.06, BG1).

NOTE: these values are current prices at the time of the 2000 census. Thus, they represent median home prices in the year 2000. Because of both general inflation and particularly the dramatic changes in the real estate market in the years since the census, the year 2000 data are outdated. In our case, suburban Montgomery County, median home sales prices of existing (vs. new) single-family homes doubled from 2000 to 2007.[31] It is therefore essential that the Census median home value data be adjusted to current prices. Doubling the Census values increases median home values to $393,600 (CT 7002.02, BG 5) and $516,600 (CT 7002.06, BG 1). Inspection of Picture A3-2 and the block group boundaries (see Figure 2) reveals that of the 137 homes in our area of analysis, 60 are located in CT 7002.02, BG 5, with the remaining 77 located in CT 7002.06, BG 1. Thus, the weighted median value of the homes in our area of interest was $462,731 in September 2007. Upon entering this value in the second box in STEP 5 of our property value estimator model, the model yields the estimated total value (as of September 2007) captured by residential properties located within ½ mile of the center of the open space of interest: $3.07 million (see Figure A3-4).

Property value premium estimator model

Instructions: Fill in all cells marked "ENTER >". (See accompanying user manual for detailed instructions and documentation.)

STEP 1: Select shape of area of analysis in which property value premiums are analyzed

ENTER >	**C**	Enter "C" for circular and "R" for rectangular shape of area

STEP 2: Enter the radius (circular area) or length and width (rectangular area) of the area of analysis

ENTER >	**2640**	Radius of area in feet
OUTPUT:	**503**	Size of study area (acres)

STEP 3: Enter the size of the open space

ENTER >	**46.7**	Size in acres of the open space whose property value impact is to be estimated
OUTPUT:	**9.3**	**%OSChange.** Percentage of the study area occupied by the open space of interest. Example: A 20 percent share of open space in the area of interest is indicated as "20".

STEP 4: Enter the appropriate values for the indicator variables

ENTER >	**1**	**FOR**. Enter "1" if the open space is a forest. Otherwise, enter "0".
ENTER >	**0**	**PARK**. Enter "1" if the open space is a park. Otherwise, enter "0".
ENTER >	**0**	**WET**. Enter "1" if the open space is a wetland. Otherwise, enter "0".
ENTER >	**0**	**PROT**. Enter "1" if the open space is protected. Otherwise, enter "0". Protection is defined as the absence of the possibility of development (i.e., easement, public ownership).
ENTER >	**1**	**PRIV**. Enter "1" if the open space is privately owned. Otherwise, enter "0".
P_{OS} =	**4.8**	**% increase in average residential property value from open space of interest**

STEP 5: Enter the number of residential properties located in the area

ENTER >	**137**	Number of properties located in study area. NOTE: Include only single-family homes.
ENTER >	**$462,731**	Average value of properties ($)
OUTPUT:	**$3,070,997**	**Estimated total property premium in study area attributable to open space of interest**

Figure A3-4: Screen shot of the Property Value Premium Estimator Model for Example 1

[31] (Montgomery County Planning Department, *Housing Market Update*, September 25, 2007; http://www.mc-mncppc.org/research/documents/HousingBulletin091907_003.pdf last accessed March 13, 2008).

[NOTE: This value also can be expressed as an annual benefit flow (where the annual benefit value represents interest payment that would generated from an investment equal to the total property value premium) using the formula: $A = PV \cdot i$, where A is the perpetual annuity, PV is the present value (in our case, the principal of the $2.450 million) and i is the annual interest rate. Using a 5% interest rate, A = ~$123,000 (The average annual rate of return on certificates of deposit during the last 20 years [1987-2006] was 5.1%.)].

Example 2: Benefits provided by "improvement" of existing open space (protection status)

A land trust is considering placing a permanent easement on the forested open space described in Example 1. The terms of the easement would not permit the development of any part of the open space or the conversion of the forest to a different land cover. The open space will remain privately owned.

Q.: By how much would the easement affect the open space premiums received by surrounding properties? Use the same area of impact analysis as in Example 1.

The placement of the permanent easement on the open space in Example 1 will result in the protection of the space from development. To estimate the resulting impact on property values, set the value for the protection variable (PROT) in STEP 4 of the property value premium estimator model to "1". All other variables remain with their values set as in Example 1. The "protected" status increases the estimated average residential property value premium to 8.35%.

The increase in the open space premium increases the total premium captured by the 137 homes in the study area to an estimated $5.29 million (as of September 2007). Placing the easement on the open space thus is estimated to increase property values in the area of interest by a total of $2.22 million (from $3.07 million to $5.29 million).

Example 3: Benefits provided through increase in size of open space

Assume the Maryland Department of Natural Resources is considering purchasing an easement from the private owner of the area just south of the open space described in Examples 1 and 2 and converting the parcel into a forest tract. This area, highlighted in light green in Picture A3-4, is 23.7 acres in size. It is currently in agricultural use as a pasture and for hay production.

Q.: By how much would surrounding residential property values increase as a result of the conversion?

The open space in question currently is in agricultural use. To identify the change in property values that would be associated with the easement and change in land cover to forest, we estimate the open space property value premiums for the present land cover (pasture) and subtract them from the premiums that would result from the easement (forest).

To estimate the premium associated with the open space in its current state (pasture, unprotected), enter the acreage of the open space (23.7) and set the values of the *PRIV* variable to "1" and those of all others to "0". This yields a property premium value estimate of -2.1%. The negative value indicates that on average, agricultural areas reduce home values compared to single-family detached housing, which constitutes the base case, as it represents the predominant type of development in the studies on the basis of which the property premium model was estimated. (Note: To estimate the open space residential property premium generated by agricultural land, set the values of the *FOR*, *PARK* and *WET* variables to "0". See Open Space Property Premium Estimator Model Appendix 2, p. 9.)

To estimate the residential property value premium that would result if the agricultural open space were converted to a forested open space under easement, the value of the *FOR* variables needs to be set to "1", thus changing the land cover from agricultural land to forest. In addition, since the space will be protected from development through an easement, the *PROT* variable needs to be set to "1". The premium associated with the protected space is estimated at 6.9%.

The increase in the open space premium that would be brought about through the conversion of the open space from pasture to forest under easement thus is estimated to equal 6.9% -(-2.1%), or 9.0%. The aggregate increase in property values due to the easement and conversion to forest that would be captured by homes in the ½-mile radius is an estimated $5.7 million.

Picture A3-4: Agricultural open space (area highlighted in light green)

Appendix 4

Brief description of open space studies reviewed for this report

NOTE: All observations on open space premiums along with the relevant characteristics of each study are listed in the accompanying Excel file that also contains the Estimator tool.

Open space amenity premiums: Findings of selected studies

This section provides a brief summary of the findings of the open space studies reviewed for our analysis. We provide the abstracts or summaries of the original articles. In cases where an abstracts or summary does not contain information on the study that is particularly relevant for our analysis, we provide this information in paragraph following the abstract or summary. For a listing of study characteristics and findings, see also the *Literature data* tab on the Excel file *Property Premium Model* that forms part of the Toolkit.

Acharya, Gayatri, and Lynne Lewis Bennett. 2001. Valuing open space and land-use patterns in urban watersheds. *Journal of Real Estate Finance and Economics* 22:221-237.

ABSTRACT. This article presents the results of a hedonic property value analysis for an urban watershed in New Haven County, Connecticut. We use spatially referenced housing and land-use data to capture the effect of environmental variables around the house location. We calculate and incorporate data on open space, land-use diversity, and other environmental variables to capture spatial variation in environmental quality around each house location. We are ultimately interested in determining whether variables that are reflective of spatial diversity do a better job of describing human preferences for housing choice than broad categories of rural versus urban areas. Using a rich data set of over 4,000 houses, we study these effects within a watershed that includes areas of high environmental quality and low environmental quality as well as varying patterns of socioeconomic conditions. Our results suggest that, in addition to structural characteristics, variables describing neighborhood socioeconomic characteristics and variables describing land use and environmental quality are influential in determining human values. We also find that the scale at which we measure these spatially defined environmental variables is important.

Acharya and Bennett examine over 4,000 house transactions in a watershed of 600 sq. km (610,000 inhabitants) in Connecticut that includes the larger urban areas of New Haven and Hartford. The authors model house price impacts within two zones: a visual zone that extends ¼ mile from a property, and a neighborhood zone that extends 1 mile. They find that percentage of open space and diversity of land use are both significant in determining property values, and that the percentage of open space exhibits decreasing returns. They also find that the magnitude of the coefficients on percentage of open space at ¼ mile and 1 mile are not significantly different, suggesting that open space is an important feature of a neighborhood, not just of an individual property. Their results show that for the average house, the willingness to pay for a one percent increase in open space within the 1-mile radius is $75. The authors also find that within the watershed analyzed, explicit distance variables are very important and much more informative than the commonly employed urban/rural classifications for determining the marginal value of open space.

Anderson, Soren T., and Sarah E. West. 2006. Open space, residential property values, and spatial context. *Regional Science and Urban Economics* 36:773-789.

ABSTRACT. We use hedonic analysis of home transaction data from the Minneapolis–St. Paul metropolitan area to estimate the effects of proximity to open space on sales price. We allow the effects of proximity to vary with demographic and location-specific characteristics and include fixed effects to control for observed and unobserved neighborhood characteristics. We find that the value of proximity to open space is higher in neighborhoods that are dense, near the central business district, high-income, high-crime, or home to many children. Using the metropolitan area's average value may substantially overestimate or underestimate the value of open space in particular neighborhoods.

This study estimates the house price impacts of proximity to open space. The open space included in the analysis are neighborhood parks, regional, state and federal parks and natural areas including arboretums and wildlife refuges (collectively defined as "special parks"), golf courses and cemeteries. The authors include amenity size, population density, income, and other covariates believed to influence the value of open space, as well as home structural attributes and local fixed effects to control for neighborhood characteristics, geographic location, and omitted spatial variables. The estimation results indicate that the value of proximity to open space a) falls with increasing distance to open space; b) increases with decreasing distance to the central business district; and c) increases with neighborhood density. For the average home, a ten percent decrease in distance to the nearest neighborhood park increases house price by 0.035%, and by 0.25% for the nearest special park. As intuitively expected, the study also finds that the amenity value of proximity to natural areas rises with amenity size, indicating that larger natural areas increase benefits. The authors find that the size of the amenity value varies widely across the metropolitan area and is highest near the central business district. The elasticity of the house price variable for distance to the nearest special park, which has a mean value of -0.0260 for the metropolitan area (indicating a 0.26% increase in home value for a 10% decrease in distance to the nearest natural area) is -0.050 for house in the 10^{th} distance percentile and -0.038 for houses in the 25^{th} percentile. These results indicate that the property value amenity premiums associated with special parks decline with distance.

Bates, L.J., and R.E., Santerre. 2001. The public demand for open space: The case of Connecticut communities. *Journal of Urban Economics* 50(1):97–111.

ABSTRACT. At both the state and national levels, public policies are being designed to stimulate the demand for locally owned open space. Yet very little is known about the factors that influence the demand for open space and the sensitivity of demand to price and income. To fill the void, this study uses data for Connecticut cities and towns to estimate the public demand for open space. The empirical results suggest that the demand for open space is relatively insensitive to changes in price but highly responsive to changes in income. The findings also show that federal and state open space may tend to crowd out locally owned open space and that locally owned open space represents a highly congestible good. Finally, the analysis indicates that privately owned open space is not a good substitute for locally owned public open space.

This study does not estimate any property value premiums associated with open space.

Bin, Okmyung, and Stephen Polasky. 2005. Evidence on the amenity value of wetlands in a rural setting. *Journal of Agricultural and Applied Economics* 37(3):589-602.

ABSTRACT. This study uses a hedonic property price method to estimate how wetlands affect residential property values in a rural area. The study utilizes wetland inventory data coupled with extensive property sales records between January 2000 and September 2004 from Carteret

County, NC. Our results indicate that i) a higher wetland percentage within a quarter mile of a property, ii) closer proximity to the nearest wetland, and iii) larger size of the nearest wetland are associated with lower residential property values. These results contrast with previous hedonic studies that use data from urban areas, which found positive associations between wetlands and property values. The amenity value of wetlands appears to depend at least as much on the characteristics of the area being considered as it does on the characteristics of the wetlands.

Bin and Polasky use a hedonic pricing approach to examine the impact of wetlands on property values in a rural area of coastal North Carolina. Their results indicate that a higher percentage in wetland area within 400 meters (~ ¼ mile) of a property lowers property value (coefficient of -0.004, at 0.0000 level of significance), with a 25% increase in wetland percentage (from 10% to 12.5%) resulting in a 0.9% reduction in property value for a house with an average property value. It should be noted that wetlands make up almost half (approximately 45 percent) of the total study area analyzed by Bin and Polasky, and that they made up about 10 percent of the area within 400m of each house in Bin and Polasky's sample. The authors suggest that their results, which contrast markedly with the studies on the enhancement value of wetlands in urban areas, might be due to the fact that in their study area, there is no shortage of either open space or wetlands, and there are plenty of other water resources for recreational purposes. Hence, potential negative effects of wetlands, such as disease potential (mosquitoes carrying West Nile virus) and limits on mobility, may dominate people's attitudes towards wetlands and people may see wetlands as more of a nuisance than a scarce attractive resource.

Bolitzer, B., and N.R. Netusil. 2000. The impact of open spaces on property values in Portland, Oregon. *Journal of Environmental Management* 59(3):185-193.

ABSTRACT. Open spaces such as public parks, natural areas and golf courses may have an influence on the sale price of homes in close proximity to those resources. The net effect of open-space proximity is theoretically uncertain because the positive externalities associated with proximity such as a view or nearby recreation facility might be outweighed by negative externalities, for example, traffic congestion and noise. The impact of open-space proximity and type is examined empirically using a data set that includes the sales price for homes in Portland, Oregon, a major metropolitan area in the United States, geographic information system derived data on each home's proximity to an open-space and open-space type, and neighborhood and home characteristics. Results show that proximity to an open-space and open-space type can have a statistically significant effect on a home's sale price. These estimates provide an important step in quantifying the overall benefit from preserving open spaces in an urban environment.

The authors' results show that they 193 public parks analyzed on average had a significant positive effect on nearby property values. The existence of such a park within 1,500 feet of a residence increased house sale prices by an average of $845/1.3 percent (semi-log model) or $2,262/3.4 percent (linear regression model), respectively.

Boyer, Tracy, and Stephen Polasky. 2004. Valuing urban wetlands: A review of non-market valuation studies. *Wetlands* 24(4):744-755.

Abstract: Wetlands provide a range of valuable ecosystem services from water purification and nutrient retention to recreation and aesthetics. The value of these services is often difficult to quantify and document to policy makers and the general public. Economists have developed non-market approaches to address difficult issues related to valuation of the environment. This paper reviews recent literature on non-market valuation as applied to wetlands, with a particular focus on the value of urban wetlands. Wetland valuation studies have generated a wide range of values, in part due to differences in what is valued and in part due to differences in methodology. Several studies have shown that property owners value proximity to wetlands in urban areas. In addition, studies have found positive values for recreation (fishing and hunting), commercial fishing, water purification, and other ecosystem services provided by wetlands, although little of this work has been done on urban wetlands. Valuation studies can provide useful information about relative rankings of value, showing, for example, that certain types of wetlands or certain services are more highly valued than others. Whether the absolute magnitude of valuation estimates is correct is less clear.

This is a literature review of the ecosystem services and associated values provided by wetlands. The authors discuss commonly used valuation methods and review the wetlands valuation studies literature.

Breffle, William S., Edward R. Morey and Tymon S. Lodder. 1998. Using contingent valuation to estimate a neighborhood's willingness to pay to preserve undeveloped land. *Urban Studies* 35(4):715-727.

SUMMARY. Contingent valuation (CV) is used to estimate a neighborhood's willingness to pay (WTP) to preserve a 5.5-acre parcel of undeveloped land in Boulder, Colorado, that provides views, open space and wildlife habitat. Households were surveyed to determine bounds on their WTP for preservation. An interval model is developed to estimate sample WTP as a function of distance, income and other characteristics. The model accommodates individuals who might be made better off by development and addresses the accumulation of WTP responses at zero. Weighted sample WTP estimates are aggregated to obtain the neighborhood's WTP. This application demonstrates that contingent valuation is a flexible policy tool for land managers and community groups wanting to estimate WTP to preserve undeveloped urban land.

This study uses in-person interviews to elicit a neighborhood's WTP for preserving a parcel of undeveloped land through acquisition. The study focuses on residents living within one mile of the property in question (total number of residences: 2,561). The estimated mean WTP of households within 0.1 of a mile is $1,197, for households within 0.5 miles it is $709, and for households within 0.9-1.0 mile it is $47. The estimated sample mean WTP is $294, or 0.2 percent of the value of the average home within a mile of the property. The authors argue that their estimated WTP function does not overestimate the maximum WTP, as is demonstrated through a comparison of their estimated maximum WTP with actual pledges (which are an order of magnitude higher) made to a coalition whose aim it is to acquire the property. In total, residents had made 130 pledges to the coalition, with a mean pledge level of $760.

Brown, Tommy L., and Nancy A. Connelly. 1983. State parks and residential property values in New York. Unpublished manuscript, Cornell University, Department of Natural Resources, Ithaca, NY. (cited in Crompton, 2001).

This study analyzes the impact of six New York State parks on surrounding property values. In four cases, the authors found no impact. They suggest two reasons for this. First, the areas involved lacked intense development and were characterized by predominantly mixed rural land uses. Hence, proximate open space probably had little additional appeal. Second, in areas that were developed around these four parks, lots were large, incorporating backyard pools and other amenities which effectively discounted or nullified the importance of recreational opportunities offered by a nearby state park when the houses were sold. At the other two parks, proximity to the parks did increase property values. Specifically, at Watkins Glen State park, the selling price of a residence increased by an average of $50 (0.1 percent of the house price) for each 100 feet located closer to the park, while at Keewaydin State park, it increased by $72 (0.17 percent of the house price; all in 1983 dollars). At Keewaydin State park, the average enhanced assessed property value in three communities were 3.8% in the town of Alexandria Bay, 15.6% in the town of Orleans, and 16.4% in the village of Alexandria Bay.

Cheshire, Paul and Stephen Sheppard. 1995. On the price of land and the value of amenities. *Economica* 62(246):247-267.

ABSTRACT. A house represents not only a bundle of structural characteristics but also a set of location specific characteristics. Adding locational coordinates and site area to other house characteristics makes it possible to estimate a land rent surface as well as the hedonic prices attached to local patterns of land use and other neighborhood characteristics. One can then estimate how the value of such location-specific characteristics are capitalized into land prices. This analysis, illustrated with estimates based on data from two British towns, has a number of wider implications. It generates a more parsimonious method of estimating amenity values. It also reveals likely systematic biases produced by conventional hedonic studies which exclude land and location. Finally, it clarifies the conceptual definition of land and suggests that monocentric models can perform well despite recent criticism.

The authors examine the impact of open space on the sale price of housing properties in two British towns, Reading and Darlington. The two communities differ markedly in the percentage of publicly-accessible open space and private open space. The authors find that the value of open land is systematically incorporated into land prices. They also find that an increase in publicly accessible open land is inversely related to the available open land: the community with less open land showed higher marginal prices for open land.

We did not include this study in the estimation of our meta-analysis model, because of the potential differences in open space preferences and hence property premiums between England and the Unites States.

Crompton, John L. 2001. The impact of parks on property values: A review of the empirical literature. *Journal of Leisure Research* 33(1):1-31.

ABSTRACT. The real estate market consistently demonstrates that many people are willing to pay a larger amount for a property located close to a park than for a house that does not offer this amenity. The higher value of these residences means that their owners pay higher property taxes. In many instances, if the incremental amount of taxes paid by eahc property which is

> attributable to the presence of a nearby park is aggregated, it is sufficient to pay the annual debt charges required to retire the bonds used to acquire and develop the park. This process of capitalization of park land into the value of nearby proeprties is termed the "proximate principle."
>
> Results of approximately 30 studies which have empirically investigated the extent and legitimacy of the proximate principle are reported, starting with Frederick Law Olmsted's study of the impact of New York City's Central Park. Only five studies were not supportive of the proximate principle and analysis of them suggested these atypical results may be attributable to methodological deficiencies.
>
> As a point of departure, the studies' results suggets thta a positive impact of 20% on property values abutting or fronting a pasisve park area is a reasonable starting point. If it is a heavily used park catering to large numbers of active recreation users, then the proximate value increment may be minimal an abutting properties, but may reach 10% on properties two or three blocks away.

Crompton also reports findings from studies that tested the "proximate principle" (the capitalization of park land into the value of nearby properties) in non-urban areas. Specifically, he reports the findings of Vrooman's (1978) analysis of private land values in the Adirondack Park (then Forest Preserve), Brown and Connelly's (1983) study of the impact of six New York State parks on surrounding property values, and Curtis' (1993) study of the impact of the preservation of a "significant tract of forest land" on house values within one mile of Baltimore, Carroll, and Howard Counties in Maryland.

Curtis, R.E. 1993. Valuing open space in Maryland: An hedonic analysis. Master's thesis, University of Maryland, College Park. (cited in Crompton, 2001).

This study analyzed the impact of preserving a "significant" tract of forest land on house values in three Maryland counties. Results indicated that the forest land accounted for at least 10%, 8%, and 4%, respectively, of house values within one mile in Baltimore, Carroll and Howard Counties.

Doss, Cheryl R. and Steven J. Taff. 1996. The influence of wetland type and wetland proximity on residential property values. *Journal of Agricultural and Resource Economics* 21(1):120-29.

Doss and Taff examine how distance to four wetland types –forested wetlands, scrub-shrub wetlands, emergent wetlands, and open-water wetlands– influences property values in Ramsey County, Minnesota (suburban St. Paul). Forested wetlands (wooded swamps and bogs) show the least open water of the wetland types analyzed in this study. Scrub-shrub wetlands are usually waterlogged during the growing season and are somewhat more open than forested wetlands, with a varied visual pattern due to different heights of vegetation, which includes trees. Emergent vegetation wetlands include seasonally flooded basins and flats, inland fresh meadows, and inland fresh marshes. They are fairly open, with most of the vegetation of the same height. Open-water wetlands include shallow ponds and reservoirs, are the most open of the four wetland types, and provide habitat for the most waterfowl. The authors examine the impact of wetland within a 100m radius of a property.

They find that property values decrease with increasing proximity to forested wetlands, but increase with increasing proximity to scrub-shrub, emergent vegetation, and open water wetlands.

Earnhart, Dietrich. 2001. Combining revealed and stated preference methods to value environmental amenities at residential locations. *Land Economics* 77(1):12-29.

ABSTRACT. This paper combines an established revealed-preference method, discrete-choice hedonic analysis, and a relatively new stated-preference method, choice-based conjoint analysis, in order to estimate more accurately the aesthetic benefits generated by the presence and quality of environmental amenities associated with residential location. It applies the combined approach to the housing market of Fairfield, Connecticut, which contains several environmental amenities and is experiencing an improvement in the quality of its coastal wetlands due to active restoration efforts.

Earnhart's study focuses on natural amenities in Fairfield, Connecticut. The author compares respondents' preferences for water-based amenities (Long Island Sound, marsh, river/stream, lake/pond), land-based amenities (forest/woods, open field/park), and backyard lawn ("no amenity"). The sample is drawn from homeowners residing in the town who had purchased homes in the 2½ years preceding the survey. The author carries out three estimations, based on revealed, stated, and revealed plus stated data, respectively. The joint estimation of preferences based on revealed and stated data finds that water-based and land-based features generate higher utility than no natural feature (i.e., backyard lawn). Within the broad category of land-based features, forests generate higher utility than open fields. Restored marshes generate higher utility than disturbed marshes, indicating that marsh restoration increases utility. Translating the findings into welfare measures based on the compensating variation criterion results in the following value of environmental amenity features for the average property:

- Based on revealed preferences: Forest, \$10,967 (4.5% of median house price); open field, \$2,208 (0.9% of median house price).
- Based on combined revealed and stated preferences: revealed utility/revealed marginal utility of income: Forest, \$15,080 (6.2%); open field, \$12,894 (5.3%); stated utility/revealed marginal utility of income: Forest, \$18,652 (7.6%); open field, \$8,032 (3.3%).

Earnhart, Dietrich. 2006. Using contingent-pricing analysis to value open space and its duration at residential locations. *Land Economics* 82(1):17-35.

ABSTRACT. To estimate benefits from open space adjacent to residences, this paper blends contingent valuation and conjoint analysis within a housing market context. The resulting framework—"contingent-pricing analysis,"—represents the stated preference counterpart to hedonic pricing analysis by asking individuals to state prices for hypothetical housing locations, which include an environmental amenity. Then, it asks individuals to state their willingness to pay for a better and longer lasting environmental amenity. As an advantage over hedonic-pricing analysis, it directly isolates willingness to pay. Results indicate that potentially short-lasting open space adds no value, while preserved open space adds \$ 5,066 or 5% to housing value.

This analysis employs contingent-pricing (contingent valuation blended with conjoint analysis) to estimate the aesthetic value (excluding recreational values) of prairie adjacent to residential locations in Lawrence, Kansas. Compared to hedonic pricing analysis, the chosen, stated WTP approach has the advantage that it isolates the individuals' marginal WTP for the open space amenity. Moreover, since respondents are queried about their WTP for a well-understood good commonly traded in markets (houses), the contingent pricing study avoids the potential limited information and hypothetical biases to which contingent valuation studies of non-marketed environmental goods are prone.

The study's findings (5% marginal value of being located next to prairie) are adjusted to account for the possibility that respondents' replies were bottom-censured as a result of the survey format which did not permit negative WTP responses. Without this adjustment, mean marginal WTP for potentially short-lasting prairie (50% development likelihood) was approximately $3,000 (3% of baseline house value), while that for a permanently protected prairie was $8,700 (7.4%). Based on the estimation results of a random-effects Tobit model, the shift from a 50/50 development likelihood to open space permanence increases value by $5,564 (4.7% of mean total housing value of baseline house). Thus, the amenity value of the open space increases as the risk of its development falls. As the author notes, the finding that potentially short-lasting open space adds no value to nearby properties does not necessarily indicate that homeowners do not value unprotected open space. It may simply be the case that the possible negative WTP associated with future construction activities and the potential for undesired development mask the positive WTP associated with temporary open space with a 50/50 likelihood of development.

Espey, Molly and Kwame Owusu-Edusei. 2001. Neighborhood parks and residential property values in Greenville, South Carolina. *Journal of Agricultural and Applied Economics* 33(3):487-492.

ABSTRACT. The effect on housing prices of proximity to different types of parks is estimated using a unique data set of single family homes sold between 1990 and 1999 in Greenville, South Carolina. While the value of park proximity is found to vary with respect to park size and amenities, the estimates from this study are larger than previous studies. The greatest impact on housing values was found with proximity to small neighborhood parks, with the positive impact of proximity to both small and medium-size parks extending to homes as far as 1500 feet from the park.

Espey and Owusu-Edusei examine all sales of single family houses in the city of Greenville, South Carolina, between 1990 and 1999. They use a hedonic price analysis that distinguishes between four open space types: "basic" small active use neighborhood parks that are not particularly attractive; other small parks with some active use that are attractive; medium size parks that included active use but also natural areas; and less attractive medium size parks with no natural area. They also control for house age and condition and other house characteristics, lot size, and 28 Census tracts as neighborhood proxies. Examining the impact of all parks without regard to park size or type, the authors found that proximity to parks had a positive impact on house values, with homes located within 1,500 feet of any park selling for 6.5 percent more than those more than 1,500 feet from a park. The results for specific park sizes and types indicate that medium-sized attractive parks raise property values by on average six percent for properties between 200 and 1,500 feet of the park (coefficient value of 0.06, with 0.05 level of significance). Property values increase by as much as thirteen percent (coefficient 0.13, with 0.01 level of significance) for homes within 600 feet of small attractive parks. Small "basic" parks decrease house values by an estimated 15 percent (0.01 level of significance) for houses within 300 feet (other studies found similar results, and attributed this effect on the disamenity effects of noise and reduced privacy associated with close proximity to active use areas), but increased house prices by 13 percent (0.10 level of significance) for houses within300-500 feet, and seven percent (0.01 level of significance) for houses within 500-1500 feet. Less attractive medium sized parks were estimated to reduce the value of houses within 600 feet by about 66 percent (0.66; 0.05 level of significance).

Geoghegan, Jacqueline, Lisa A. Wainger, and Nancy E. Bockstael. 1997. Spatial landscape indices in a hedonic framework: An ecological economics analysis using GIS. *Ecological Economics* 23(3):251-264.

ABSTRACT. This paper develops a spatial hedonic model to explain residential values in a region within a 30-mile radius of Washington DC. Hedonic models of housing or land values are commonplace, but are rarely estimated for non-urban problems and never using the type of spatial data (geographical information system or GIS) available to us. Our approach offers the potential for a richer model, one that allows for spatial heterogeneity in estimation, and one that ties residential land values to features of the landscape. Beyond the traditional variables to explain residential values, such as man-made and ecological features of the parcel and distance to cities and natural amenities, we also hypothesize that the value of a parcel in residential land use is affected by the pattern of surrounding land uses, not just by specific features of point locations. We have also created and added these variables to the hedonic model by choosing an appropriate area around an observation, and calculating measures of percent open space, diversity, and fragmentation of land uses, measured at different scales around that observation. These indices have, for the most part, been significant in the models. By including two of the landscape indices developed by landscape ecologists, we have developed a model that explains land and housing values more completely, by capturing how individuals value the diversity and fragmentation of land uses around their homes.

This study examines the effect of surrounding agricultural and forested land uses on the value of residential sub-urban and rural lands in the central Maryland region around Washington DC. Property value effects of open space are found to depend on the size of the neighborhood considered: within a radius of 1/10 of a kilometer, the proportion of open space has a positive and significant effect on land values, indicating that in the immediate neighborhood of a house, fragmentation and landscape diversity are seen as undesirable. Within a larger, one-kilometer buffer, diversity has a negative and significant effect. In particular, the authors find that the marginal contribution to selling price of increased diversity and fragmentation changes in different landscape settings (urban, suburban, rural). The authors interpret their findings of different preferences for fragmentation and diversity of land uses between urban, suburban, and rural settings as suggesting that preferences for these characteristics vary, among other things, with their relative scarcity. For example, where rural land predominates and conveniences (such as shopping) are scarcer, diversity and fragmentation again become valued. Within the 0.1 km buffer, a 10 percent increase in open space increases house value by 0.1-0.2 percent (depending on model specification). However, within a 1-km buffer, the open space variable was negatively related to house prices. The authors interpret this finding as suggesting that individuals prefer views of open space from their house, but prefer more diverse land uses at the larger scale, perhaps because they prefer to be able to walk to other important land uses such as shopping areas from their house.

Geoghegan, Jacqueline. 2002. The value of open spaces in residential land use. *Land Use Policy* 19(1):91-98.

ABSTRACT. The preservation of open spaces has become an important policy topic in many regions. Policy tools that have been used include: cluster zoning; transferable development rights; proposed land taxes to fund purchases of remaining open spaces; and private organizations that buy land. This paper develops a theoretical model of how different types of open spaces are valued by residential land owners living near these open spaces, and then, using a hedonic pricing model, tests hypotheses concerning the extent to which these different types of open spaces are capitalized into housing prices. The empirical results from Howard County, a rapidly developing county in Maryland, USA, show that "permanent" open space increases near-by residential land values over three times as much as an equivalent amount of "developable" open space. This methodology can be used to help inform policy decisions concerning open space preservation, such as effectively targeting certain areas for preservation, or as a means of creative financing of the purchase of conservation easements, through the increase in property taxes, resulting from the associated increase in property values.

In her analysis of open space on property values in suburban Howard county, Maryland, the author distinguishes between "developable" open space, which comprises agricultural cropland, pasture, and forest, and "permanent" open space, which includes parks and lands with conservation easements. She constructs a hedonic model to examine the impact the two types of open space have on property prices, by including the open space within a 1.6 km (1 mile) radius of a property. The hypothesis to be tested is that both types of open space have positive impacts on property prices, and that the coefficient on the permanent open space variable is larger than that on the developable open space variable. Both open space variables are defined as the percentage of open space in a 1,600m radius of a property, with the sample mean values of 12 percent for permanent open space and 35 percent for developable open space. The estimated coefficients on both open space variables are positive as hypothesized, and the coefficient on protected open space (0.257) is over three times the size of the coefficient on the developable open space (0.074). These results closely match those of Irwin (2002) and Thorsnes (2002). However, only the estimated coefficient on the protected open space variable was statistically significant at the 5 percent level, while that on the developable open space variable was significant at slightly less than the 10 percent level.

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.

ABSTRACT. Using a unique spatial database, a hedonic model is developed to estimate the value to nearby residents of open space purchased through agricultural preservation programs in three Maryland counties. After correcting for endogeneity and spatial autocorrelation, the estimated coefficients are used to calculate the potential changes in housing values for a given change in neighborhood open space following an agricultural easement purchase. Then, using the current residential property tax for each parcel, the expected increase in county tax revenue is computed and this revenue is compared to the cost of preserving the lands.

Geoghegan et al.'s (2003) findings show that the value of open space is highly location-dependent. The three counties analyzed show different open space values for residential properties, and not all of the observed differences can be explained by different levels of development pressure. As McConnell and Walls (2005) suggest, these findings call into question earlier studies of the Maryland housing market that treated several of these (and other) counties as a single market, and they also show that the question of how to define open space buffers around properties is unresolved.

Heimlich, Ralph, Keith D. Wiebe, Roger Classen, Dwight Gadsby and Robert M. House. 1998. Wetlands and agriculture: Private interests and public benefits. USDA Economic Research Service Report 765 (September). Washington, DC. 94 pp.

Report that includes a review of previous wetland valuation studies but does not generate primary estimates.

Irwin, Elena G. 2002. The effects of open space on residential property values. *Land Economics* 78(4):465-480.

ABSTRACT. The marginal values of different open space attributes are tested using a hedonic pricing model with residential sales data from central Maryland. The identification problems that arise due to endogenous land use spillovers and unobserved spatial correlation are addressed using instrumental variables estimation with a randomly drawn subset of the data that omits nearest neighbors. Results show a premium associated with permanently protected open space relative to developable agricultural and forested lands and support the hypothesis that open space is most valued for providing an absence of development, rather than for providing a particular bundle of open space amenities.

Irwin applies a hedonic pricing model to test whether different types of open space generate significantly different spillover effects. She distinguishes open space first by whether the land is preserved or is developable, and second by land ownership (privately vs. publicly held preserved open space) and land use type (cropland, pasture, and forests that are developable). Impacts are analyzed within a 400m radius around each parcel. The relative attractiveness of different open space types is identified by normalizing land use variables to the developable pastureland variable so that spillover effects can be interpreted as the marginal effect of a neighboring land use relative to pasture. The results indicate that both the privately owned conservation lands and public, non-military open space have a positive and significant (0.001 level) effect on the value of neighboring residential properties relative to developable pastureland. The coefficient on the forest variable is also positive and significant (0.05 level). However, Irwin finds that there are problems with endogenous variables and unobserved spatial correlation, which may bias the OLS estimators. She performs an IV (instrumental variable) test using exogenous features of the landscape (a dummy variable that indicates the steepness of a parcel's slope; a dummy variable that indicates the drainage potential of the soils; a dummy variable that indicates the quality of the soils for agriculture; and the distance from the two urban centers, Baltimore and Washington, DC), and performs estimation using a randomly drawn subset of the data, in which nearest neighbor obersvations are dropped, in order to overcome the remaining spatial error correlation. The results of the IV estimation show that the influence of privately owned conserved open space and publicly owned non-military lands remains positive and significant (both at the 0.01 level) and relatively constant, with both found to generate additional benefits to surrounding residential values relatve to developable pasture land. However, the coefficient associated with surrounding forested lands now is negative and significant (0.001 level), indicating that pasture is preferred over forest. Using the IV first stage estimates and the mean values of the explanatory variables, the results can be used to derive estimates of the marginal values of a change in land uses in a parcel's neighborhood (400m radius). Based on the results, conversion of one acre (0.8% of land within the 400m radius) of pastureland to privately owned conservation land increases the residential value of the mean property by $3,307 or 1.87%; conversion to publicly owned, non-military land use increases residential value by $1,530 or 0.89%, while conversion of one acre from pasture to forest is estimated to decrease the value of a residential property by $1,424 or 0.82%.

Irwin, Elena G. and Nancy E. 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.

Irwin and Bockstael (2001) show that hedonic models may not always be able to empirically detect the positive amenity value of open space due to identification problems. These problems arise in a hedonic residential property price model when the open space is privately held and developable. Two identification problems can be distinguished. One is caused by land price endogeneity. This problem arises because the residential value of parcel *i* is affected by whether a neighboring parcel *j* is developed. Likelihood of development of parcel *j* is a function of its value in residential use, which itself is a function of whether parcel *i* is developed. The second identification problem is spatial correlation. This problem arises because factors that determine the value of parcels in residential use are spatially correlated. If any of the spatially correlated explanatory variables are omitted from the analysis, variables measuring surrounding open space will be correlated with the error term. Both identification problems can lead to biased coefficient estimates. The authors test for presence of these two problems in a dataset of residential property prices in central Maryland and find that both are indeed present. They adopt an instrumental variable approach to address the problems. They find that private open space has a positive and significant (0.01 level) effect on land value, that private open space in conservation has a positive and highly significant effect if it is treated as an exogenous variable, and that the proportion of publicly owned open space has a positive and significant effect (0.05 level). Their results show that OLS estimation biases the estimated marginal value of open space downward. Identification strategies that break the correlation between the endogenous land use externality variables and the error term, such as the instrumental variables used in their paper, are necessary to test for the existence of these spillover effects on residential property values.

Findings of the study on the impact of open space in a 400m radius on residential property (i.e., parcel incl. house) value in an Instrumental Variable model, where "%open space" measures the proportion of open space within that radius:

- % private developable open space (endogenous var.) - pasture, cropland, and forest: 0.0633 (0.005 level)
- % private developable open space + private protected (endogenous var.) - pasture, cropland, and forest: 0.0621 (0.005 level)
- % public open space (exogenous var.) - forest: 0.0306 (0.05 level)
- % private protected open space (exogenous var.) – agricultural lands under easement and conservation lands : 0.2106 (0.005 level)

(Coefficients are based on double log IV estimation, so they indicate the % increase in house values associated a 1% increase in open space; e.g., 10 % increase in private developable open space is estimated to lead to a 0.6% increase in house value, and a 10% increase in private protected open space [exogenous var.] to a 2.1% increase in house value).

Kim, Yeon-Su, and Rebecca L. Johnson. 2002. The impact of forests and forestry management on neighboring property values. *Society and Natural Resources* 15:887-901.

The authors examine the impact of proximity of forests and forest condition or management practices on residential property values of properties in proximity to McDonald-Dunn Research Forest during the period 1990-1996 in the Corvallis, Oregon area, by combining GIS techniques and hedonic modeling using both linear and quadratic Box-Cox models. They use data on 752 properties of primarily residential uses within one mile of the forest, and include the usual structural and neighborhood characteristics in their estimation. They also account for different kinds of deeds that might impact house prices. The results indicate that proximity to the forest enhances property values. The strength of this effect increases with decreasing distance to the forest. The authors also find that the scenic aspects of forest lands matter – properties from which clear cuts are visible at the time of purchase command lower sale prices.

Kline, Jeffrey, and D. Wichelns. 1998. Measuring heterogeneous preferences for preserving farmland and open space. *Ecological Economics* 26(2):211-224.

ABSTRACT. Public preferences for environmental policies often vary among individual citizens according to their socio-economic characteristics and attitudes toward environmental programs. Most researchers account for socio-economic characteristics when conducting public preference surveys, but do not account for differences in preferences that transcend socio-economic categories. Identifying the public's attitudes regarding environmental programs and the role they play in shaping individuals' preferences for policy alternatives can assist policy makers in developing programs that are consistent with public expectations. This paper uses factor analysis and a discrete choice model to describe differences in public preferences that result from different attitudes regarding the goals of programs designed to preserve farmland and open space. Results describe policy implications that are not apparent when using models that address socio-economic characteristics alone.

Kline and Wichelns conducted a public opinion survey to estimate heterogeneous public preferences for preserving farmland and open space in Rhode Island. The authors asked respondents to rank the importance of different reasons for farmland and open space protection, and to chose between pairs of parcels to be protected. Based on survey findings, Kline and Wichelns that preference rankings for particular agricultural and protected open spaces depend on an individual's attitudes toward land preservation, with rankings differing among individuals who primarily favor preservation because of "environmental", "aesthetic" or "agrarian" motives. Statistical analysis of the survey findings reveals the following ordinal preference ranking of the choice set of agricultural and natural open spaces among all respondents:

Ordinal preference ranking of agricultural lands and open space for Rhode Island survey respondents (values are for the mean respondent)

Ordinal rank	*Land type*
1.	Fruit/vegetable with public access
2.	Woodland with public access
3.	Fruit/vegetable without public access
4.	Crop/pasture without public access
5.	River with public access
6.	Woodland without public access
7.	Rocky shoreline with public access
8.	Pond with public access
9.	Crop/pasture with public access
10.	River without public access; Beach without public access
12.	Wetland with public access
13.	Beach with public access
14.	Pond without public access
15.	Wetland without public access; Rocky shoreline without public access
17.	Turf with public access
18.	Turf without public access

Source: Kline and Wichelns (1998)

The preference rankings unveiled by Kline and Wichelns are not directly translatable into residential open space amenity benefits associated with the various land covers since Kline and Wichelns' results are based on respondents overall assessment of the importance of preserving these land covers, not on respondents' preferences as to which of the land covers they would prefer around their residences.

Loomis, John, K. Traynor and T. Brown. 1999. Trichotomous choice: A possible solution to dual response objectives in dichotomous choice contingent valuation questions. *Journal of Agricultural and Resource Economics* 24(2):572-83.

ABSTRACT. We investigate the possibility that some respondents to a dichotomous choice question vote YES, even though they would not pay the posted dollar amount in order to register support for the project or policy. A trichotomous choice question format is proposed to determine if allowing respondents the opportunity to vote in favor of a project at an amount less than their bid affects estimated willingness to pay. Using univariate and multivariate tests, we find the trichotomous choice question format reduces the number of YES responses and produces a statistically significant decrease in willingness to pay for an open-space program.

The authors use a contingent valuation (CV) survey to elicit the WTP of residents of Loveland, Colorado for preserving open space via sales tax add-ons (an approach used by other localities in Colorado) that would fund the acquisition of lands "from willing sellers". The open space is to be used either as recreation lands, as natural areas for wildlife protection, or both. Respondents were informed that the total acreage protected by each program individually was 230 acres, or 460 acres total. Respondents in both dichotomous and trichotomous choice formats[32] expressed a positive WTP to fund such a program through annual payments for ten years. Mean willingness to pay of the trichotomous choice format ($42 for recreation lands, $30 for nature lands, and $34 for both land types combined) was statistically significantly lower than that of the dichotomous choice format ($108 for recreation lands, $116 for nature lands, and $106 for both land types combined), indicating that some respondents stated their willingness to support the program at a given cost in the dichotomous format, but indicated their support with a lower willingness to pay than the given amount in the trichotomous choice format. The results imply that question format and "yes" responses are not independent.

Lupi, Frank. Jr., Theodore Graham-Tomasi, and Steven J. Taff. 1991. A hedonic approach to urban wetland valuation. Staff paper P91-8. University of Minnesota, Department of Agricultural and Applied Economics, St. Paul, Minnesota.

The authors examine WTP for wetland acres in urban areas in Minnesota, specifically, in the survey section in which a house is located. The study finds that WTP for additional wetland acreage was positive at lower wetland density, but negative at higher densities. In other words, wetlands were found to be relatively more valuable in areas where they were relatively scarce.

Lutzenhiser, Margot and Noelwah Netusil. 2001. The effect of open spaces on a home's sale price. *Contemporary Economic Policy* 19(3):291-298.

ABSTRACT. The relationship between a home's sale price and its poximity to different open space types is explored using a data set comprised of single-family home sales in the city of Portland, within Multnomah County, between 1990 and 1992. Homes located within 1,500 feet of a natural park area, where more than 50 percent of the park is preserved in native and/or natural vegetation, are found to experience, on average, the largest increase in sale price. The open space size that maximizes a home's sale price is calculated for each open space type. Natural area parks require the largest acreage to maximize sale price, and specialty parks are found to have the largest potential effect on a home's sale price. A zonal approach is used to examine the relationship between a home's sale price and its distance to an open space. Natural area parks and specialty parks are found to have a positive and statistically significant effect on a home's sale price for each zone studied. Home located adjacent to golf courses (within 200 feet)

[32] In the trichotomous choice format, respondents had three options: 1) indicate they would vote against the program even if it did not result in any costs to them; 2) indicate that they would vote for the program at a given annual cost of *x* (this amount was varied across surveys) for ten years; or 3) indicate that they would vote for the program only if it resulted in annual costs to them of *less than x* for ten years.

are estimated to experience the largest increase in sale price due to open space proximity although the effect drops off quickly as distance from the golf course incraeses.

The authors' analysis reveals that living within 1,500 feet of a natural area park was estimated to raise a home's sale price by on average $10,648 (1990 prices; 0.01 level of significance) at the mean open space size in the study area. The authors define natural area parks as lands with more than 50% preserved in native and/or natural vegetation, with pak use balanced between preservation of natural habitat and natural resource-based recreation. This includes parcels managed for habitat protection only, with no public access or improvements. Specialty parks are defined as areas that are dominated by a single use, with everything in the park related to that use (e.g., boat ramp facilities).

Mahan, B. L., S. Polasky and R. M. Adams. 2000. Valuing urban wetlands: A property price approach. *Land Economics* 76(1):100-113.

ABSTRACT. This study estimates the value of wetland amenities in the Portland, Oregon metropolitan area using a hedonic property price model. Residential housing and wetland data are used to relate the sales price of a property to structural characteristics, neighborhodd attributes, and amenities of wetlands and other environmental characteristics. Measures of interest are distance to and size of wetlands, including distance to four different wetland types; open water, emergent vegetation, scrub-shrub, and forested. Other environmental variables include proximity to parks, lakes, streams, and rivers. Results indicate that wetlands influence the value of residential property and that wetlands influence property values differently than other amenities. Increasing the size of the nearest wetland to a residence by one acre increased the residence's value by $24. Similarly, reducing the distance to the nearest wetland by 1,000 feet increased the value by $436. Home values were not influenced by wetland type.

Nicholls, Sarah, and John L. Crompton. 2005. The impact of greenways on property values: Evidence from Austin, Texas. *Journal of Leisure Research* 37(3):321-341.

The effect of greenways on surrounding residential property values remains somewhat of an unknown quantity. Though several studies have ascertained that nearby residents tend to view greenways as positive or neutral amenities that increase or have no discernible impact on property values and saleability, these results are mostly based on anecdote rather than actual market data. Using the hedonic pricing method, this study demonstrates that greenways may indeed have significant positive impacts on proximate properties' sales prices. Adjacency to a greenbelt produced significant property value premiums in two of three neighborhoods. Physical access to a greenbelt had a significant, positive impact in one case, but was insignificant in two others. No negative greenway impacts were recorded.

Nicholls and Crompton's study examines the effect on property sale prices of greenways, defined as "linear open spaces established along a natural corridor such as a riverfront or stream valley, an abandoned railroad right-of-way, a canal, a scenic road, or some other linear route" (p. 323, citing Little [1990]).[33] The study includes the following environmental variables 1) location on greenbelt, 2) view of greenbelt, 3) distance to greenbelt entrance, and 4) greenbelt entrance within 1/2 mile (estimated in separate model from continuous distance

[33] Little, C.E. 1990. Greenways for America. Baltimore, MD: Johns Hopkins University Press.

variable). Three areas adjacent to greenways were analyzed. One showed a 12.2% (0.01 significance level) increase in average property values for properties *adjacent* to the greenway; the second showed an increase that was not statistically significant, and the third showed an increase of 5.7% (0.01 significance level). These benefits seemed to come mostly from access to the greenbelt only, as view of the greenbelt did not result in significant impacts.

Phillips, Spencer. 2000. Windfalls for wilderness: Land protection and land value in the Green Mountains. In S.F. McCool, D.N. Cole, W.T. Borrie, J. O'Loughlin, comps. Wilderness Science in a Time of Change Conference – Vol. 2: Wilderness in the context of larger systems; 1999 May 23-27. Missoula, MT. Proceedings RMRS-P-15-VOL-2:258-267. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

ABSTRACT. Land is a composite good, the price of which varies with its characteristics, including proximity to amenities. Using data from sales of land near Green Mountain National Forest wilderness areas in a hedonic price model, a positive relationship between proximity to protected wilderness and market values is revealed. The applications of this result include improved consideration of the positive economic impacts of land conservation and new mechanisms for financing land conservation.

Phillips (2000) examines the "enhancement value" of protected open space in rural areas by analyzing the impact of wilderness areas on parcel prices in towns located in the Green Mountain Wilderness of Vermont. The author examines approximately 6,150 market transactions (excluding land transfers to government agencies and non-profits, and those due to inheritance or divorce) of parcels in proximity to wilderness areas between 1987-1997. Phillips only includes parcels in towns that contain wilderness, towns that are adjacent to towns containing wilderness, and towns adjacent to the second group of towns. Furthermore, he only includes parcels that will primarily be used for residential purposes after the transfer. Using a hedonic pricing analysis that includes a number of variables that control for other property characteristics besides the wilderness variables (town with wilderness; distance to nearest wilderness area), Phillips finds that, all other things being equal, the average parcel price in towns containing wilderness is 13 percent higher (coefficient value 0.1318; 0.002 level of significance) than the average parcel price in towns not containing wilderness. The results also show that the price of parcels decreases by 0.8 percent per acre (coefficient value 0.0000077 per meter; 0.04 level of significance) with each kilometer farther away from the nearest wilderness area.

Ready, R.C., M.C. Berger and G. Blomquist. 1997. Measuring amenity benefits from farmland: Hedonic pricing vs. contingent valuation. *Growth and Change* 28(4):438-458.

ABSTRACT. The amenity value to Kentucky residents from horse farm land was estimated using both the contingent valuation method and the hedonic pricing method. The hedonic pricing model included both the housing and labor markets. A value function estimated from dichotomous choice contingent valuation responses showed that the value of a change in the level of the horse farm amenity was sensitive to the size of the change, with no evidence of value that is independent of the size of the change. The two methods generated estimates of the external benefits from horse farm land that were within 20 percent of each other.

Ready, Richard C. and Charles W. Abdalla. 2005. The amenity and disamenity impacts of agriculture: Estimates from a hedonic pricing model. *American Journal of Agricultural Economics* 87(2):314-326.

ABSTRACT. The positive and negative externalities from farmland are increasingly a focus of public policy discussion about agriculture and land use. A GIS-based hedonic pricing model shows that agricultural open space increases nearby residential property values, but larger-scale animal operations and mushroom production have negative impacts. Animal production facilities with as few as 200 animal equivalent units reduce nearby property values, but larger facilities do not necessarily generate larger impacts. Because they tend to occur together, the negative impacts of animal agriculture and the positive impacts of open space must be simultaneously modeled to avoid omitted variable bias.

This study employs a hedonic model using an instrumental variable approach to simultaneously model amenity and disamenity impacts. Although the goal of the study is the estimation of both the amenity and disamenity impacts of different agricultural uses on residential property values in Berks County, PA, located northwest of Philadelphia, it also includes estimates of value premium associated with a number of non-developed (forested) open space. Specifically, the marginal impact of having one more acre of a given land type as opposed to having it in industrial use. The authors find that within 400m (~1/4 of a mile) of the house, the land use with the largest positive amenity impact is forested, publicly owned open space, with an additional acre increasing residential property value on average by 0.281%. Privately owned forested open space (0.276% increase per additional acre) and privately owned open space in grass, pasture, and crops (0.2373% increase per additional acre) have similarly high amenity values, and the differences between the three are not statistically significant. Eased, privately-owned open space in grass, pasture, or crops increases house price by 0.162% per additional acre. Within 400-1,600m from the house, marginal implicit prices are generally an order of magnitude smaller than in the 400m radius, and of open space land types, only eased (0.011% increase per additional acre) or publicly-owned (0.0123% increase per additional acre) open space have a significantly positive impact on price.

Reynolds, J.E. and A. Regalado. 2002. The effects of wetlands and other factors on rural land values. *Appraisal Journal* 70:182-191.

ABSTRACT. The effect of wetlands and other physical and locational characteristics on the prices of rural land can be estimated. Location, parcel size, capital improvements, proportion of land in intensive uses, and land area in wetlands explained more than 80% of the variation in property sale prices. Although total wetland area has a significant negative impact on rural land prices, when wetlands are divided into different systems and classes, the effect on rural land values varies considerably.

The authors examine the impact of wetlands and different wetland types on real estate values in four counties in rural Florida (DeSoto, Hardee, Highlands, and Manatee) using data on 212 land sales during 1988-1993. Wetlands were present on 187 of the 212 properties, and accounted for 17% of the land area. The authors find that overall, a 10% increase in wetlands is estimated to reduce rural land prices by 0.206%. Riverine wetlands (rivers, channels, and drainage ditches), which the authors point out generally are considered unusable and contribute no productive value, are estimated to reduce land values by 0.066% for a 10% increase (at the mean) in wetland area. Palustrine wetlands (including non-tidal wetlands dominated by trees, shrubs, persistent emergent, emergent mosses or lichens, and all wetlands in tidal areas) accounted for 99% of all wetlands. The authors break these down into scrub-shrub, forested, unconsolidated bottom, and emergent wetlands. They find that scrub-shrub wetlands had a positive effect on property values, with a 10% increase in scrub-shrub wetland acreage increasing rural land prices by 0.12%. (The authors hypothesize that this may be due to the fact that people often do not see these areas as wetlands as they are only occasionally flooded and are at the outer edge of wetland areas). Forested wetlands had a negative effect, with a 10% increase resulting in an estimated 0.185% decrease of land values. A 10% increase in emergent wetlands was estimated to result in a 0.164% decrease in land values. Unconsolidated bottom wetlands and lacustrine wetlands had positive and negative effects, respectively, but these were not significant.

Importantly, this study does not focus on residential parcels, but rather on rural lands in general. As the authors point out, while some individuals may value wetlands for their aesthetic appeal, wetlands make certain activities such as agricultural production more difficult or even unfeasible. By not focusing on residential parcels only, the study effectively captures both of these effects, and therefore it is not appropriate to transfer the results to residential properties.

Riddel, Mary. 2001. A dynamic approach to estimating hedonic prices for environmental goods: An application to open space purchase. *Land Economics* 77(4):494-512.

ABSTRACT. If housing markets exhibit slow adjustment to system shocks, then hedonic estimates of the price impact from environmental amenity trends may be time variant. This paper suggests an alternative to the cross-sectional model for estimating hedonic prices using an error correction approach that allows for endogenous environmental quality. The model is applied to data concerning an open space purchase program in Boulder, Colorado, and shows that the economic impact of an open space purchase takes several years to be fully realized. This observation questions using cross-sectional, hedonic models for evaluating willingness to pay for time-trended environmental amenities.

The author argues that because research has repeatedly shown that housing markets may be endogenous – open space land purchases lead to reduced supply of developable land, pushing land prices up – and inefficient – because of information asymmetry, heterogeneous products, and high transaction costs – and hence not in equilibrium (contrary to the assumption underlying hedonic pricing models), housing price impacts of trended amenities (i.e., sustained increases in amenities) may be time variant. In other words, price effects estimated cross-sectionally may be a function of the time at which the effect is estimated, with different estimated values resulting for environmental amenities at different times. The author uses a dynamic, error-correction approach to estimate the full impact of sustained environmental quality improvements in the face of housing market inefficiency, and compares this impact to that estimated by a conventional hedonic model. The model explicitly incorporates markets impacted by environmental amenities, namely the housing, labor, and rental markets, and analyzes data for the city of Boulder, CO, from 1981-1995. The results indicate a lag between open space purchase (the goal of which it was to curtail the encroachment of Boulder onto the foothills) and the time in which it is capitalized into house prices. The total effect of the increase in open space is a shift of both supply and demand to a higher price with a slightly larger stock of housing. The 15,000 acres of open space purchased between 1981 and 1995 caused prices to rise by 3.75%. A hedonic study performed two years after adding 1,000 acres of open space in Boulder would yield a house price increase of 0.17%, while after six years, it would yield an estimate of 0.25%.

Shultz, Steven D., and David A. King. 2001. The use of Census data for hedonic price estimates of open-space amenities and land use. *Journal of Real Estate Finance and Economics* 22(2/3):239–52.

ABSTRACT. Hedonic price models for determining marginal implicit prices of open space amenities and non-residential land use were estimated using housing data from the census. Alternative model specifications were compared in order to evaluate the effects of aggregating land use data by alternative levels of census geography as well as the use of different sample sizes of census blocks. It was determined that land use is best aggregated at the block group level and that entire populations or very large sample sizes of census blocks should be used with hedonic models.

Shultz and King analyze the impact of distance of residential properties to various types of open space on property values in the Tucson, AZ area. They find that proximity to large protected natural resource areas (Coronado National Forest, Tucson Mountain Park, and Saguaro National Monument) and Class II (river/wash) wildlife habitat, as well as the percentage of vacant lands, increase property values. Proximity to medium-sized and undeveloped natural resource-based parks and Class I (pristine) river/wash wildlife habitat decreases property values. The latter result is surprising, and the authors suggest as a possible explanation that properties in close proximity to these pristine river habitats may have a high potential for flooding.

Smith, V. Kerry, Christine Poulos and Hyun Kim. 2002. Treating open space as an urban amenity. *Resource and Energy Economics* 24(1-2):107-129.

ABSTRACT. In "the welfare economics of city bigness", George Tolley asserts that the virtual price of amenities can be used to judge the efficiency of a urban spatial land use patterns. Expanding this test to open space amenities is not straightforward because those amenities are especially difficult to characterize. Bockstael and Irwin [Economics and the land use—environment link. In: Tietenberg, T., Folmer, H. (Eds.), International Yearbook of Environmental and Resource Economics, 2000/2001. Edward Edgar, Cheltenhan, UK, 2000] suggest that open space amenities and their virtual prices depend on whether surrounding land uses are fixed or adjustable. This paper estimates hedonic price functions over nearly 30 years to evaluate, whether the distinctions between fixed and adjustable land uses help in measuring the value of open space amenities.

Smith et al. examine the impact of open space on residential property values in the Research Triangle Park area of North Carolina between 1980-1998, during the planning and construction of the I-540 loop. The authors build on work by Bockstael and Irwin (2000)[34] and Geoghegan (2002) by distinguishing between fixed and adjustable open space. Adjustable open space comprises lands that can be modified in the future, and includes vacant, agricultural, and forestry lands. Fixed open space includes golf courses, parks, and lands designated as right-of-way for the loop road. The authors note that for most of their sample, they were unable to identify the closest agricultural and forested lands in existence at the time of a property's sale. Hence, most of the regressions they run only include vacant lands in the "adjustable" category. Smith et al. argue that "fixed" open space should affect property values positively, but because "adjustable" open space may be perceived differently by different people, one cannot expect it to "clearly signal undeveloped land's contribution to open space amenities" (p. 112).

The authors find that proximity to golf courses and private vacant land both increase property values; value decreases with increasing distance to these lands, and adjacency to such lands increases value. However, the results of the analysis suggest that public lands have the opposite effect. This result is not consistent with prior expectations, and is not easily explained. The authors point out that this result underlines the inherent difficulty of characterizing homeowners' perceptions of open space indirectly through distance measures, which do not adequately reflect perceptions. McConnell and Walls (2005)[35] point out that the results may be partly attributable to the fact that Smith et al.'s public and vacant land use categories are probably too broadly defined, and that other studies highlight the importance of distinguishing different types of open space in hedonic models (e.g., Anderson and West [2003], Lutzenhiser and Netusil [2001], Shultz and King [2001]).

Thorsnes, P. 2002. The value of a suburban forest preserve: Estimates from sales of vacant residential building lots. *Land Economics* 78(3):426-41.

ABSTRACT. This paper reports estimates of the market value of proximity to forest preserves as capitalized into the sale prices of vacant building lots in residential subdivisions that on one side border a preserve. The results indicate that building lots that border the preserve sell at premia of about $5,800 to $8,400 (19% to 35% of lot price). These proximity premia appear to be highly localized. Estimates obtained from observations on subsequent sales of houses (rather than of vacant building lots) are larger and less precisely estimated, which suggests that omitted house characteristics may bias estimates of amenity value.

Thorsnes examines the impact of protected open space on the property values in three single-family developments in two subdivisions located in rural/suburban areas of the Grand Rapids, MI, metropolitan area. The subdivisions are in townships that provide the full array of urban services, and each borders a tract of permanently protected forested land. All three are surrounded by a variety of different types of open space, ranging from protected forest land to an active use park to privately-owned open space on large residential properties that potentially may develop a higher residential density in the future, to open, still undeveloped

[34] Bockstael, N.E. and E.G. Irwin. 2000. Economics and the land use—environment link. In: Tietenberg, T., Folmer, H. (Eds.), International Yearbook of Environmental and Resource Economics, 2000/2001. Edward Edgar, Cheltenhan, UK.

[35] McConnell, Virginia and Margaret Walls. 2005. The value of open space: Evidence from studies of nonmarket benefits. Washington, DC: Resources for the Future. January, 2005. 78 pp.

parcels in the bordering subdivision. The sample includes 431 lot sales and 486 house sales. The premia for lots bordering the preserve ranges from $5,800 to $8,400 across the three developments, or 19%-35% of the lot prices, and are highly significant. Lots across the street from the preserve have positive amenity values in two out of the three developments, but only one coefficient estimate is weekly significant, while for the third development the estimated coefficient for the "across-the street" variable is negative and significant. (As the author explains, however, further analysis of the geography suggests that the discount [i.e., negative premium] is due to the fact that due to the local topography, many of the houses located behind those that are across the street from the preserve in fact have a view of the preserve but are not accounted for by one of the dummy control variables; hence, the estimates on the various location dummies all represent price premia or discounts relative to these view lots, and the estimated discount on the "across-the-preserve" lots is probably more correctly interpreted as a premium on the view lots, which would increase the estimated premium for that development from $5,800 to $7,800, and hence approximately in between those observed for the other two developments, which are $7,200 and $8,400, respectively.) These results suggest that forest amenity premiums are highly localized, with little if any benefit extending to lots across the street from the preserve. The estimated premium on lots bordering undevelopable (due to topography) private forest land with a creek in one of the developments is $9,500 (33% of lot price), which is slightly larger than the premium for lots bordering the preserve. Lots bordering a park are estimated to have premia of $1,200 to $1,700 (7% in of the respective average lot price in both cases). The author also uses information on the sale prices of house eventually constructed on the lots to estimate the house price premia associated with the forest amenity. These are more than double the value of the estimates from the building lot data, but are significant only in two of the three developments (in the third, it appears that house size variable is picking up the forest effect), with the premia ranging from 7% to 8% of house price (which obviously includes the lot). This analysis confirms the author's hypothesis that the unobserved heterogeneity in house characteristics will generate less accurate (as evidenced by higher standard errors) and possibly biased coefficient estimates.

Tyrväinen, Liisa and Antti Miettinen. 2000. Property prices and urban forest amenities. *Journal of Environmental Economics and Management* 39(2):205-223.

ABSTRACT. Quantitative information on residents' valuations attached to urban forests is needed for assessing urban land-use. The aim of this study is to value implicitly non-priced urban forest amenities by comparing dwelling prices and specific amounts of amenities associated with dwelling units. The empirical study is based on data from the sales of terraced houses in the district of Salo in Finland. According to the estimation results a one kilometer increase in the distance to the nearest forested area leads to an average 5.9 percent decrease in the market price of the dwelling. Dwellings with a view onto forests are on average 4.9 percent more expensive than dwellings with otherwise similar characteristics.

This study finds that distance to the nearest small forest area has a negative and significant effect on residential property values (i.e., a reduction in distance to forest land increases property values) and that the presence of forest view has a positive effect on house prices. Other open space variables are found not to be significant, including the relative amount of forested area within the housing neighborhood and the distance to the nearest large forested area.

NOTE: Results are not from the US and therefore were not included in our meta-analysis estimation due to potentially different welfare functions.

Vrooman, David H. 1978. An empirical analysis of determinants of land values in the Adirondack Park. *American Journal of Economics and Sociology* 37(2):165-177.

ABSTRACT. This study contributes to our knowledge about the determinants of land values in the Adirondack Park in New York State. Sales data for 1971-1973 are used in the multiple regression analysis. The key variables influencing the price per acre for vacant forest land parcels are accessibility by road, location, adjacency to state land, date of sale, land use classification, size of parcel, site type, topography, and nonlocal buyers.

This analysis examines the impact of surrounding protected public lands on adjacent private land values in the Adirondack Park (then Forest Preserve). Sale prices of 284 vacant forested land parcels (no buildings, no waterfront) during a three-year period (1971-73) were analyzed using regression analysis. Adjacency to protected state land was estimated to have a strong and positive impact on price of on average 17.5%, compared to similar parcels that were not adjacent to state land.

Walsh, Randall P. 2004. Endogenous open space amenities in a locational equilibrium. University of Colorado Center for Economic Analysis, Discussion Papers in Economics Working paper No. 04-03. February 2004.

ABSTRACT. Little is known about the equilibrium impact of open space protection and growth control policies on the entire metropolitan landscape. This paper is an initial attempt to evaluate open space policies using an empirical approach that incorporates the endogeneity of both privately held open space and land conversion decisions in a locational equilibrium framework. The analysis yields four striking results. First, when one allows for endogenous adjustments in privately held open space, increasing the quantity of land in public preserves may actually lead to a decrease in the total quantity of open space in a metropolitan area. Second, different strategies for spending the same amount of money to purchase open space have markedly different welfare implications. Third, partial equilibrium welfare calculations are extremely poor predictors of their general equilibrium counterparts. And finally, the analysis suggests that while a growth ring strategy is most effective in reducing total developed acreage in the metropolitan area, this reduction in developed acreage is associated with a large net welfare loss. In addition to its policy relevance, the paper makes two methodological contributions to the locational equilibrium literature. First, the analysis considers a Nash equilibrium with endogenous public goods where these goods arise 'naturally' as a result of land market outcomes. This is in contrast to the work of Epple, Romer, and Sieg (2001) who consider endogenous public goods that are consistent with majority voting. Second, unlike previous work with empirical locational equilibrium models, the analysis incorporates an empirically estimated supply model into the locational equilibrium framework. These methodological contributions are central to the resulting policy analysis.

Walsh develops a household location model to estimate households' demand for "green space," including measures of density, in Wake County, North Carolina (Raleigh area). Interestingly, he finds that green space is valuable for neighboring developments in more urban areas, but that it can have negative values in exurban areas, indicating a desire for more urban infrastructure in relatively undeveloped areas.

These results yield an effective price function of the relation between distance to protected open space and average house values. This function shows that the price impact of protected open space appears to begin at around a 1 mile distance from protected open space, but that this increases sharply for distances of less than 0.5 miles. For example, as the average distance moves from half a mile to one quarter of a mile, the "price augmentation factor" of protected open space increases by 17.5 percent. At the mean of the 50th percentile of lot expenditure ($23,451), this change corresponds roughly to a one-time incremental willingness-to-pay of $4,104.

Wu, JunJie, and Seong-Hoon Cho. 2003. Estimating households' preferences for environmental amenities using equilibrium models of local jurisdictions. *Scottish Journal of Political Economy* 50(2):189–206.

ABSTRACT. Much research has focused on the development of equilibrium models of local jurisdictions to analyze the formation of social structures and community characteristics. These models, however, have been subjected to little empirical testing. In a recent paper, Epple and Sieg (1999) developed a new method for estimating equilibrium models of local jurisdictions, but they did not include environmental amenities in their empirical application. In this paper, we extend and apply this new method to estimate households' preferences for alternative environmental amenities in the Portland Oregon metropolitan area. We show that estimated structural parameters would be biased if environmental amenities are ignored. By including amenities into the structural models of local jurisdictions, households' preferences for alternative environmental amenities and public goods are estimated. Parameter values underlying households' residential choices are uncovered. Many of the empirical regularities observed in the data are replicated.

The authors employ a spatially explicit structural equilibrium model for the Portland, Oregon metropolitan area (which includes 44 cities and 48 townships), which estimates household preferences for public goods based on the way households sort across different communities. They include measures of the percentage of all land in public open space and wetlands in their model, and estimate three different functional forms. Wu and Cho find that the estimated coefficients on both variables are statistically significant and positive, indicating that households' utility increases with increases in the provision of these amenities. In the linear and quadratic models they estimate, parks and other open space are estimated to be somewhat more utility-enhancing than wetlands, while in the inverse semi-log model, the reverse is true. However, the authors do not provide estimates of how increases in these amenities are associated with house values.