Economic Benefits of Conserving Natural Lands:

Case Study: Mt. Agamenticus Area, Maine

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Defenders of Wildlife

This study, the remaining case studies, and a companion report (Kroeger and Manalo, 2006) outlining the basic theory underlying economic valuation of natural resources and approaches used in valuation can be found online at
http://www.defenders.org/programs_and_policy/science_and_economics/conservation_economics/economic_valuation_of_natural_resources_and_ecosystem_services/conservation_economics_valuation_publications.php

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List of Abbreviations

CO_2	Carbon dioxide
CH_4	Methane
CS	Consumer surplus
Cu. ft.	Cubic feet
NPP	Net primary productivity
ORV	Off-road vehicle
TNC	The Nature Conservancy
WD	Water district
WTP	Willingness to pay

Executive Summary

The ongoing loss of ecologically important natural lands in many parts of the U.S. is well-documented. This loss carries an associated economic cost, because natural lands and the ecosystems they contain support a large variety of human uses that carry economic value.

Documenting the economic value of human activities supported by natural lands in itself is not sufficient to ensure the conservation of those lands and the protection of the values they provide. Nevertheless, assessing the economic value of natural lands can yield information that can inform better land use decisions and conservation policy making.

In this study, which forms part of a set of five case studies that cover natural lands in Florida, Maine, Nebraska, New Mexico and Oregon, we develop estimates of the economic value of several human uses supported by The Mt. Agamenticus area, a 60 square-mile area in southern coastal Maine that has been identified as a conservation focus area in the state's Comprehensive Wildlife Conservation Strategy.

Our analysis develops non-comprehensive quantitative estimates of the economic value associated with recreation and timber harvests in the Mt. Agamenticus area. It also estimates the value of carbon sequestration and water provisioning services provided by the ecosystems in the area, and the value of the open space premiums that accrue to residential properties located in the vicinity of undeveloped open spaces. Due to a lack of the required data, we were unable to quantify the value of other uses supported by the Mt. Agamenticus area, such as small-scale agricultural production, research and education and ecosystem services other than carbon sequestration and water supply. In addition, our value estimates generally are rather conservative because available data on some uses are very incomplete.

Despite these limitations in our study, our results show that the Mt. Agamenticus area generates substantial economic value. The total estimated annual value of the land uses included in our analysis ranged from $5.3 million to $6.4 million (Table ES-1).

Table ES-1: Estimates of the annual value of selected uses supported by the Mt. Agamenticus study area

Area uses	*Value (million 2004$)*	
	Low estimate	*High estimate*
Forestry (Kittery water district only)	0.07 *	
Agriculture	*not quantified*	
Recreation (Consumer surplus only)	0.25 *	
Research and education	*not quantified*	
Open space property value premiums	2.0 †	
Ecosystem services:		
Water supply	2.73 †	
Carbon sequestration	0.24 – 1.33	
Other	*not quantified*	
TOTAL	5.29	6.38

Notes: * incomplete estimate. † Lower bound estimate.

Water provision by the ecosystems in the area generates the single largest value, followed by open space residential property value premiums. Carbon sequestration generates substantial economic value as well, although the current uncertainties surrounding access and credit prices on emerging carbon markets make this estimate somewhat less reliable than those for the other uses of the study area.

The area provides a number of additional uses, such as mostly small-scale agricultural production, support for educational and research activities and habitat provision for rare species. We did not quantify the value of these uses in our analysis for lack of the required data. In addition, our value estimates generally are rather conservative because available data on some uses are very incomplete.

Land use planning and conservation policy making should consider the economic value generated by the conservation of undeveloped lands and the increasing relative scarcity and rising value of the goods and services provided by those lands in order to achieve economically sensible results. With a large share of both ecologically and economically valuable undeveloped lands in private ownership, not just in the Mt. Agamenticus study area but also at state and national levels, existing financial incentive systems that encourage land conservation on private lands will need to be improved and in many cases additional ones will need to be created in order to better align privately and socially desirable outcomes. This is a challenging task whose urgency is increasing in lockstep with the continuing loss and degradation of natural lands.

Introduction

Ecosystems and the habitats and species they contain provide a wide range of economic benefits to society (Hassan et al., 2005; Daily et al., 1997). The type, quantity and quality of services provided vary among different ecosystems. Therefore, the type, quantity and quality of the ecosystem services a particular piece of land provides for onsite and offsite uses generally is affected by changes in the ecosystem. For example, conversion of the land cover from forest to pasture, through its impacts on both ecosystem structure and function, is expected to result in changes in the type, quantity or quality of the services provided by the land. The degree to which service flows change as a consequence of land cover changes depends on a variety of factors, including the original and new cover types, the extent of the loss of the original cover and the spatial arrangement of any remaining original cover, both on the site itself and in relation to off-site land covers.

At the landscape scale, land cover changes on any given plot occur periodically as a result of natural disturbance regimes. Thus, the flow of ecosystem services from a particular piece of land is never static. For example, soil production and erosion control services may be reduced after a disturbance from storms, fires or pest infestations. However, as the ecosystem recovers from the disturbance, the service flows generally gradually return to pre-disturbance levels. In the case of human-induced disturbances, the return of the ecosystem to pre-disturbance conditions often is impeded because of the placement of long-lived or permanent (at least as measured on societal time scales) structures such as paved surfaces or buildings, or because of measures directed at preventing the return of vegetation to pre-disturbance conditions, as in the case of agriculture or lawns.

The modified ecosystems do not necessarily provide an inferior suite of services. [1] In fact, the economic value of the particular suite of services desired by a landowner may be higher for the converted land, judging from her decision to carry out the conversion.

Nevertheless, the particular services that increasingly are of primary public concern, such as biodiversity conservation, water provision or erosion control are usually reduced or lost altogether on the converted lands.[2] Most of these services represent what economists refer to as *public good* ecosystem services. Public good services are characterized among other attributes by the fact that they benefit not just the landowner on whose property they are produced, but also others, whom the landowner is not able to prevent from enjoying these benefits and who therefore receive them for free. Prime examples of public good ecosystem services are biodiversity preservation (except perhaps in the rare cases where the species of concern occurs only on one or a few privately-held properties) or climate regulation. Because the landowner cannot exclude others from the off-site benefits they receive off her lands and charge them for these services, she has no financial incentive to take the value of those third-

[1] Of course, all ecosystems by now are impacted by human activities (Vitousek et al., 1997a, 1997b, 1997c) and thus may be considered modified. However, here we refer to systems purposefully changed by humans through land conversion.

[2] We follow general usage and apply the term “conversion” here to describe a change from “natural” vegetation or land cover to a “developed” use such as residential/commercial or agriculture. Thus, conversion does not describe changes in the opposite direction, which also occur, for example in the case of wetland reclamation or afforestation or natural succession on abandoned farmlands.

party benefits into account in her land use decisions. This divergence between individual and society-wide benefits from public good ecosystem services provided by a property may lead to land use decisions that are suboptimal or inefficient for society as a whole (Kroeger and Casey, 2007). The total value of the services the land provides to society as a whole may be lower following the conversion, but the *private* benefits to the landowner from the conversion exceed the *private* cost for the landowner in the form of the services reduced or foregone by *her*. It is the realization of this conflict between privately and socially desirable land use choices that underlies much of public natural resource conservation policy making.

The recognition of, and the generation of quantitative information about the value of natural lands is an important, though neither a necessary nor a sufficient condition for making intelligent conservation policy decisions. Even if the value of the goods and services provided to society by a particular land or ecosystem, or some approximation thereof, is known, the protection of those values is contingent on two further factors. First, institutional mechanisms must be in place that allow the owner of the land to capture the value of the off-site services her land provides. Such mechanisms can take several possible forms, including government payment programs, ecosystem service markets based on regulation or voluntary action (e.g., carbon sequestration payments), or fiscal incentives (e.g., tax deductions) (Kroeger and Casey, 2007). In addition to the need for a value capture mechanism, the sum of the landowner's private (on-site) benefits and the compensation she receives for the off-site benefits her land provides must exceed the benefits she expects to obtain from land development.[3]

Thus, information on the value of the benefits associated with land conservation by itself cannot guarantee the conservation of undeveloped lands, but it is a first step towards making that outcome more likely.

In this study we identify several human uses supported by the undeveloped lands in a specific area in south-eastern Maine that is under pressure from residential development, quarrying and commercial gravel mining, and develop quantitative estimates of the economic value of those uses for which we have sufficient data.

This study forms part of a set of five case studies that examine the economic benefits provided by diverse natural lands identified as priority conservation areas in the respective states' Comprehensive Wildlife Conservation Strategies or Wildlife Action Plans.

[3] This assumes landowners act as profit-maximizers. In the case of a landowner who has a preference for keeping the land in an undeveloped state for non-financial motives, the payment would not necessarily need to be financially competitive with development. Rather, payment would merely need to be sufficient to make it financially possible for the landowner to avoid selling off the property to developers.

Methodology

Study area selection and characteristics

The main objective in selecting our sample of five case study areas for this research project was to achieve a representation of diverse geographic regions, ecosystem types, and land ownerships within the sample. The Mt. Agamenticus case study area, indicated by the red bounded areas in Figures 1 and 2, represents the only temperate mixed upland forest and wetlands in our sample of conservation opportunity areas and is the only area in our sample that is located in the Northeast. The remaining study areas can be broadly characterized as riparian (south-central Nebraska), mixed forest and swamp (southwestern Florida), low to mid-altitude dry forest (New Mexico) and estuary (Oregon), with a variety of different land use and ownership patterns.

We selected Maine's Mt. Agamenticus area, which is one of the species at-risk focus areas discussed in the state's State Wildlife Comprehensive Strategy (Maine Department of Inland Fisheries and Wildlife, 2005). This landscape scale area covers approximately 38,600 acres and was identified by biologists from the state's Department of Conservation (Maine Natural Areas Program) and Department of Inland Fisheries and Wildlife as a "focus" area, that is, an area that merits special conservation attention. Focus area designation is based on documented locations of "rare plants, animals and natural communities, high quality common natural communities, important wildlife habitats, and their intersections with large blocks of undeveloped habitat" (Beginning with Habitat, 2003).

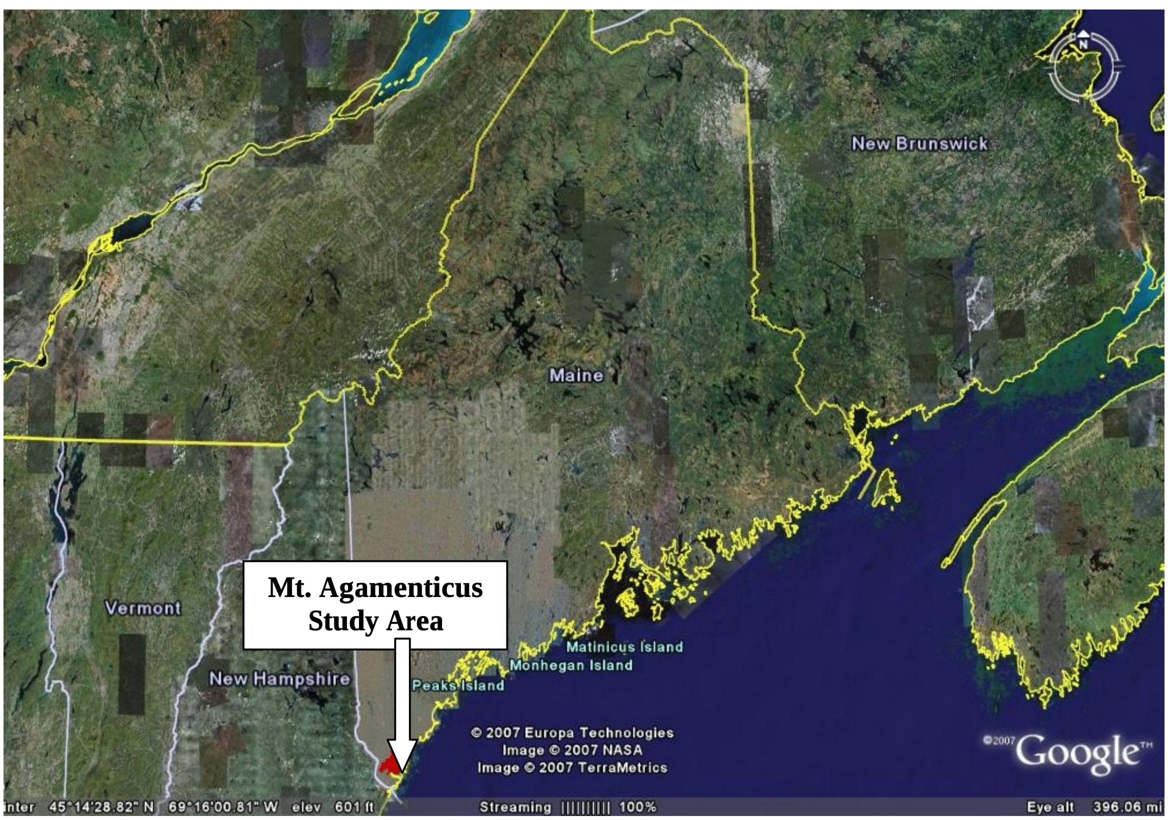

Figure 1: Location of the Mt. Agamenticus Study Area (red-shaded area)

Figure 2: Mt. Agamenticus study area boundaries (indicated in red)

The Mt. Agamenticus area comprises the largest contiguous, intact area of scarcely developed land in southern York County (Maine Department of Conservation, 2004). The upland and wetland complexes are home to plant and animal collections not found farther north in the state (Maine Department of Conservation, 2004) (Table 1). In addition, the study area is home to several rare and exemplary natural communities (Table 2). Residential development, quarrying and commercial gravel mining already threaten the area's habitats (Maine Department of Conservation, 2004).

The primary land cover types found in our Mt. Agamenticus study area are forest, wetland, and grassland (Figure 3). The remaining six percent of the area are in lakes/ponds (2%), upland shrub/scrub (2%), developed land (2%), bare ground (0.26%), estuarine sand/mud shore (0.09%), estuarine open water (0.06%), cultivated land (0.04%) and perennial streams (0.01%). Forest ecosystems in the study area include upland mixed, upland deciduous, and coniferous forest. Wetlands include deciduous and coniferous swamps, deciduous and coniferous shrub swamps and estuarine and fresh marshes.

Table 1: Rare species in the Mt. Agamenticus focus area

Common Name	*Scientific Name*
	Rare Plants
Wild Leek	*Allium tricoccum*
White wood aster	*Aster divaricatus*
Upright bindweed	*Calystegia spithamaea*
Atlantic White-Cedar	*Chamaecyparis thyoides*
Spotted Wintergreen	*Chimaphila maculata*
Sweet pepperbush	*Clethra alnifolia*
Flowering dogwood	*Cornus florida*
Eastern joe-pye weed	*Eupatorium dubium*
Featherfoil	*Hottonia inflate*
Smooth winterberry holly	*Ilex laevigata*
Slender blue flag	*Iris prismatica*
Mountain Laurel	*Kalmia latifolia*
Spicebush	*Lindera benzoin*
Broadbeech fern	*Phegopteris hexagonoptera*
Pale green orchis	*Platanthera flava*
Alga-like pondweed	*Potamogeton confervoides*
Chestnut oak	*Quercus Montana*
Tall beak-rush	*Rhynchospara macrostachya*
Sassafras	*Sassafras albidum*
Swamp Saxifrage	*Saxifrage pensylvanica*
Columbia Water-Meal	*Wolffia Columbiana*
	Rare Animals
Spotted Turtle	*Clemmys guttata*
Wood Turtle	*Clemmys insculpta*
Blanding's Turtle	*Emydoidea blandingii*
Northern black racer	*Coluber constrictor*
Ribbon snake	*Thamnophis sauritus*
Swamp darter	*Etheostoma fusiforme*
Brown snake	*Storeria dekayi*
New England cottontail	*Sylvilagus transitionalis*
Spring salamander	*Gyrinophilus porphyriticus*
Scarlet Bluet	*Enallagma pictum*
New England Bluet	*Enallagma laterale*
Ringed Boghaunter Dragonfly	*Williamsonia lintneri*

Source: Maine Department of Conservation, 2004.

More than 7,000 acres of the Mt. Agamenticus study area are in public or quasi-public ownership, including the Maine Department of Inland Fisheries and Wildlife, the towns of York, South Berwick and Eliot, and the York and Kittery Water Districts. The Nature Conservancy, Great Works Regional Land Trust and York Land Trust also own land (Table 3).

Table 2: Rare and Exemplary Natural Communities in the Mt. Agamenticus study area

Atlantic White Cedar Swamp
Chestnut Oak Woodland
Pocket Swamp/Hemlock - Hardwood Pocket Swamp
Leatherleaf Bog/Boggy Fen
Grassy/Mixed Graminoid Shrub Marsh
Sandy lake bottom/ Pipewort – Water lobelia Aquatic-Bed
Pitch Pine Bog
Red maple/Red maple - Sensitive fern Swamp
White Oak – Red Oak Forest

Source: Maine Department of Conservation, 2004.

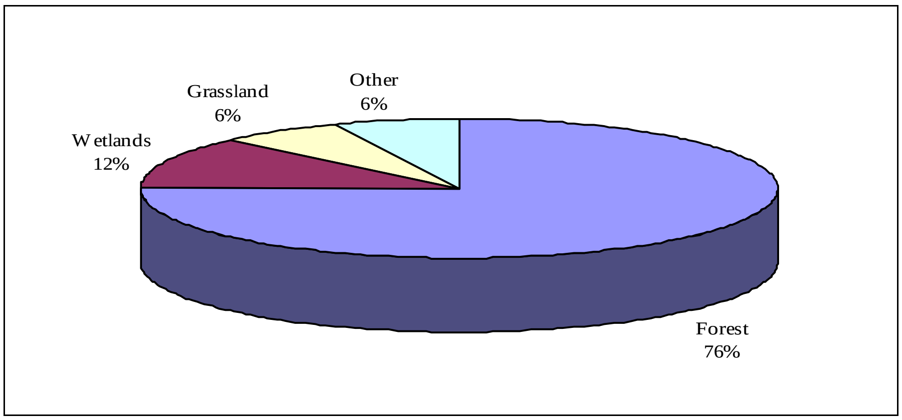

Figure 3: Mt. Agamenticus land cover
Source: GIS analysis of map layers from the Beginning with Habitat Program

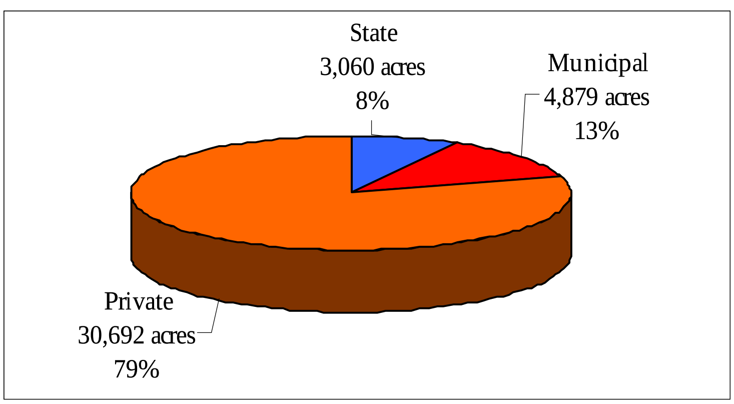

Figure 4: Mt. Agamenticus land ownership
Source: GIS analysis of map layers from the Beginning with Habitat Program

Table 3: Protected and public lands in the Mount Agamenticus area

Land Owner	*Acreage*
Maine Department of Inland Fisheries & Wildlife	3,060
Kittery Water District	2,578
York Water District	1,604
Great Works Regional Land Trust	1,217
York Land Trust	1,104
Town of South Berwick	356
The Nature Conservancy	256
Town of York	182
Town of Eliot	160
TOTAL	10,516

Source: GIS analysis of map layers from the Beginning with Habitat Program

Economic analysis framework

The economic theory underlying the valuation of natural resources and the general approaches used in valuation applications are discussed in a companion report (Kroeger and Manalo, 2006). In this study, we develop quantitative estimates of the economic value of the annual flows of benefits generated by the study area. Our estimates therefore represent the values of benefit flows in a given year, not the total present value of the natural resource stocks found in the area. In other words, we do not estimate the total economic net present value of the natural assets in the area (e.g., the forest and woodlands, animal and plant species, etc.), but rather the value of the benefits flowing from these stocks that accrue to humans in a given year (e.g., timber harvests, recreation, carbon sequestration, scenic views). The base year for our analysis is 2004, the most recent year for which many of the needed data for our five study areas are available. In those cases where the most recent available data are for a different year, we indicate this in the text. All values are expressed in 2004 dollars ($2004).

Our analysis of the economic values provided by the area uses a welfare analysis-based perspective and attempts to quantify the total economic value of the benefits examined for all individuals who directly or indirectly use the area. This welfare analysis-based assessment includes market as well as non-market economic values and use as well as passive-use and ecosystem service values associated with the benefits provided by the ecosystems in the area.[4] Due to information constraints, however, we are able to quantify only a portion of the value of the human uses the area supports. Likewise due to the lack of the required recreation expenditure data, and in contrast to our other four case studies, this analysis does not include an economic impact analysis.

Uses included in analysis and associated economic values

The native ecosystems in the study area provide a wide variety of benefits to local and regional human populations. Part of these benefits result from the direct use humans make

[4] For a more detailed discussion of the different types of values, see Kroeger and Manalo (2006).

of the ecosystems or their components, as for example in the case of recreation or scenic views from nearby properties. In addition to these direct uses, the ecosystems in the area provide a number of services that benefit local or regional residents. Examples of such services are the clean water the area supplies for several local drinking water reservoirs or to underlying aquifers through infiltration of precipitation, the maintenance of a diverse fauna and flora, or the sequestration of atmospheric carbon by perennial plants. Finally, some aspects or components of the study area may hold passive use values, to the extent that some people appreciate their existence independently of any direct use of or interaction with these features. For example, studies have shown that many people value the existence of unique landscapes and particular "charismatic" species, and that they value the thought of preserving particular areas intact and largely unaffected by human development (see studies cited in Kroeger and Manalo, 2006).

Of the full range of benefits potentially provided by the natural systems in an area (see table 1 in Kroeger and Manalo, 2006), in this study we focus only on the benefits associated with those uses that are compatible with and contingent upon the continued conservation of the area. These are shown in Table 4. The fact that a particular activity is not indicated in Table 4 does not necessarily imply that this activity does not occur in the study area. It merely indicates that in our research we have not come across any evidence of its occurrence.

Table 4: List of documented uses of the study area's ecosystems

Direct uses	Timber extraction Non-timber products Agriculture Recreation - Biking - Skiing - Picnicking and general relaxation - Fishing - Hunting - Hiking - Wildlife watching - Off Road Vehicle Use Research and education Property value premiums
Indirect uses	Ecosystem services - Water retention and generation (water quantity) - Water quality - Species habitat provision * - Biodiversity maintenance - Carbon sequestration
Passive uses	Provision of habitat for threatened, endangered, rare or "charismatic" species

Notes: * Part of the associated value is captured in fishing and wildlife viewing uses.

Some conservation-compatible uses of the study area have important non-market values (Table 5), that is, their full economic value cannot be assessed on the basis of observed market transactions alone. Because we lacked comprehensive quantitative data on most of the study area's uses (e.g., recreation, research and education, etc.), however, we were not able to capture the non-market value components.

Table 5: Uses of the study area and types of associated economic values

Use	*Market value*	*Non-market value*
Recreation	ü	ü
Commercial/subsistence uses (forestry, livestock production)	ü	-
Research and education	ü	ü
Property value premiums	ü	-
Ecosystem services (water provision, carbon sequestration)	(ü)	ü

Estimates of the Economic Value of Land Uses

In this section, we quantify the value of some of the uses supported by the natural lands in the Mt. Agamenticus area (Table 4). We limit our analysis to those uses that are compatible with or contingent upon natural lands in the study area and for which we were able to obtain data.

Recreation

A variety of outdoor recreation activities are practiced throughout the study area, including hiking, mountain biking, wildlife watching, cross-country skiing, off-road vehicle (ORV) use, and hunting (The Nature Conservancy [TNC], 2004). According to Robin Stanley, the TNC's Mt. Agamenticus Conservation Coordinator, there are an estimated 30,000 visitors to the mountain itself each year, based on visitor surveys and the number of brochures taken. This, however, probably represents an underestimate since some people visit multiple times and may not pick up a brochure every time.[5] Also, in 2001 about 3,600 cars drove to the summit of Mt. Agamenticus, and about 40 percent of the mountain's visitors stated that they were there for the first time (The Nature Conservancy, 2004).

Unfortunately, no quantitative information was available on the activities these visitors engaged in or on the average length of their visit. Nevertheless, the variety of recreational opportunities and the visitation estimates strongly suggest that this area provides recreational benefits to local residents as well as to visitors from outside of the area. Despite the lack of detailed quantitative information, we can construct a rough estimate of the total net benefit participants receive from recreation in the area.

The economic value associated with recreation activities in the study area is measured as the total willingness-to-pay (WTP) of participants for the activities they engage in. The total value individuals assign to a particular recreation activity can be distinguished into two components, on the basis of the different approaches applied to quantify these value components. The first is the actual expenditures individuals incur in the process of engaging in a particular activity such as wildlife watching. The second is the consumer surplus (CS), or net benefit, participants receive from the activity, which measures how much the individuals would have been willing to spend on the activity above and beyond what they actually spent. Information on trip and equipment expenditures is reflected in market transactions, and for wildlife-associated activities is collected in comprehensive statewide expenditure surveys conducted every five years by the U.S. Fish and Wildlife Service and the U.S. Census Bureau (2008; and earlier issues). Information on consumer surplus is obtained through revealed preference approaches such as contingent valuation surveys, and is commonly reported in terms of consumer surplus per activity day, that is, per day spent fishing, hunting, or engaging in some other activity of interest.[6] Based on these data, one can construct an estimate of the total value recreationists attach to activities in our study area by combining estimates of total activity days per year with information on average consumer surplus and spending per activity day.

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5 Pers. comm. with Robin Stanley, The Nature Conservancy, April 23, 2007.

6 For a more detailed description of the different valuation methods, see Kroeger and Manalo (2006).

Unfortunately, we lack estimates for Maine of the average expenditures per activity day for activities other than hunting. Thus, we limit our analysis to the consumer surplus (CS) of the Mt. Agamenticus recreation activities. As a result, our estimate excludes a substantial portion - likely around 50 percent - of the total economic value associated with the recreation activities practiced in the area.[7]

Assuming conservatively that the average recreation visitor spends only two hours in the area, the lower-bound estimate of 30,000 visitors annually is equivalent to 6,000 full activity days per year.[8] Multiplying the number of annual activity days by the average consumer surplus per activity day for the main recreation activities practiced in the area (Table 6) yields an estimated total net benefit of approximately one quarter of a million dollars per year from recreation activities practiced in the study area.

Table 6: Average consumer surplus for main recreation activities practiced in the Mt. Agamenticus area

Activity	*Avg. WTP per activity day 2004$*
Hiking	75.18
Mountain biking	40.93
Cross-country skiing	34.60
Wildlife watching	31.30
OHV use	23.93
Hunting	47.45
AVERAGE	42.23

Notes: Average CS estimates are from Loomis (2005) and represent averages for the Northeastern U.S., except for ORV driving, which represents the average value reported in studies that analyzed multiple regions of the U.S.

The actual economic value of these activities likely is substantially higher, due to the fact that our estimate does not include the expenditure portion of the total recreation values and because our estimated visitation level of 6,000 activity days per year likely is an underestimate.

The local spending by of out-of-area recreation visitors generates output, employment, income in the area and produces local, state and federal tax revenues. Due to the lack of expenditure estimates for recreationists, however, we are unable to quantify these economic impacts for the Mt. Agamenticus area.

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7 For example, Kroeger et al.'s (2008) analysis showed that in the case of wildlife-associated activities, CS only accounts for between one third (wildlife viewing) to one half (big game hunting; freshwater fishing) of the total economic value of these activities.

8 Except for mountain bikers, for the majority of out-of-area recreation visitors to the Mt. Agamenticus area, recreation in the area generally does not constitute the prime trip purpose. Rather, for these visitors, a visit to the Mt. Agamenticus area is ancillary to other activities in the region (pers. comm., Keith Fletcher, The Nature Conservancy, Maine, April 30, 2007).

Agriculture and Forestry

The majority of the agricultural operations in the Mt. Agamenticus study area are small-scale subsistence farms, ranging in size from 20 to 50 acres. These farms include mostly small market gardens, beef operations of ten or less animals and mixed livestock. The local farmers' markets absorb much of the output of these farms. [9]

Forestry is also a commonly practiced land use in the study area, although no quantitative information was available for the entire study area. According to Keith Fletcher at the Nature Conservancy in Maine, the Kittery Water District and the York Water District practice more forestry than any other entity in the study area. [10] The Kittery Water District, which owns roughly 2,600 acres of land in the study area, netted $68,000 from their timber harvest in 2004.[11] The York Water District also conducts regular timber harvests, but we were unable to obtain corresponding revenue information. [12] Certain private lands within the study area also have timber management plans (The Nature Conservancy, 2004), but again, no quantitative information on timber production levels on these lands was available.

Research and Education

The study area is home to many educational and research opportunities. While no comprehensive quantitative data exists on the number of people partaking in these opportunities, activities range from school field trips to university research to adult nature classes (The Nature Conservancy, 2004). The activities offered through the White Pine Programs, a nonprofit educational organization, illustrate the variety of opportunities available in the study area. The programs offer year-round children, family and adult programs on subjects like vernal pools, campfire cooking, birding, natural history, wildlife tracking and ecology.[13]

Property value premiums

Our study contains over 38,600 acres of undeveloped lands. This total includes unprotected private lands as well as protected state, local and private open spaces. Evidence from a large number of studies suggests that proximity to open space increases the values of nearby properties. Thus, the open space property value premiums attributable to the natural lands in the Mt. Agamenticus area constitute one of the benefits produced by these lands. In this study, we focus on those natural lands located within one mile of residential properties.

The increment in value a property receives due to 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

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9 Pers. comm. with Jeannie Demetracopoulos, Great Works Regional Land Trust, May 1, 2007 and May 4, 2007.
10 Pers. comm. with Keith Fletcher, The Nature Conservancy, April 30, 2007.
11 Pers. comm. with Mike Rogers, Kittery Water District, May 14, 2007.
12 Pers. comm. with Gary Stevens, York Water District. December 27, 2006.
13 Pers. comm. with Dan Gardoqui, co-founder and director, White Pine Programs, April 30, 2007.

partially captured in the value of 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).

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). These studies generally involve public open spaces that often are comparatively large and enjoy a high level of protection from development, including state parks, forest preserves, and wilderness areas. The large open spaces in the Mt. Agamenticus area, although currently to almost three quarters unprotected and under threat from fragmentation along the edges (Maine Department of Inland Fisheries and Wildlife, 2005), appear not to be under general and immediate pressure from land conversion. Thus, many of the open spaces in the area are comparable to the large protected open spaces studied in the literature with respect to their expected permanence. Since the literature suggests that it is this permanence of an open space rather than the protected status itself that people value (Earnhart, 2001, 2006), we expect that the open spaces in the study area generally are not intrinsically less attractive to nearby residents than if they were officially protected.

Open space is not a homogenous good, and the particular attributes of a given open space can be expected to influence the size of the associated premiums received by nearby properties. This is confirmed by the large range in open space premiums (measured as a share of the total value of a property) found in the literature. Table 7 summarizes the findings reported in the literature on how particular study area characteristics influence open space premiums.

Table 7: 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.
Source: Kroeger et al. (2008)

No study on the open space premiums of property values exists for our study area. In situations where no original studies are available on the value of the benefits produced by environmental amenities like open space, benefits transfer is a possible tool for inferring the value people assign to these benefits. Benefits transfer is a technique in which researchers estimate the value of particular benefits for a site of interest by using the results of existing studies of similar sites (Loomis, 2005). The validity of the resulting transfer-based estimate depends on the similarity of the sites and user groups. The context-dependence of open space premiums calls into question the validity of using a particular open space premium reported in the literature as an indicator of the premiums received by properties in a different area. Because no original study exists for the study area or an area that would appear to be similar in terms of its physical characteristics and ownership, application of either point or average value based benefits transfer approaches to estimate the property value premiums would possess questionable validity. This leaves meta-analysis-based benefits transfer as a possible approach. Meta-analysis is a statistical technique that uses regression analysis of the findings of several empirical studies to systematically explore study characteristics as possible explanations for the variation of results observed across primary studies (Brouwer, 2000; U.S. Environmental Protection Agency, 2000). The values of key variables from the policy case then are inserted into the estimated benefit function to develop policy-site-specific value estimates. One such meta-analysis of open space property value premiums is available in the literature (Kroeger et al., 2008).

Kroeger et al. (2008) conducted a meta-analysis of 21 original quantitative studies in the U.S. containing a total of 55 observations of open space impacts of conserved lands on property values.[14] They included only those studies that examined predominantly "natural" open

[14] The remainder of the reviewed studies did not provide the required information for their inclusion in the analysis.

spaces, excluding crop lands and heavily-developed urban recreational areas. Their estimated meta-analysis-based regression function has the following form[15]:

$$P_{OS} = -6.5903 + 0.4221 * \%OSChange - 0.0068 * \%OSChangeSquared + 2.7619 * FOR + 1.677 * PARK - 2.7367 * AG + 3.5067 * PROT + 5.3409 * PRIV, \quad \text{(eq.1)}$$

where P_{OS} is the open space property premium in percent, $\%OSChange$ is the percentage of the area within a given radius of a property that is occupied by the open space in question, FOR is an indicator (dummy) variable set at 1 if the open space is forested and at zero otherwise, $PARK$ is an indicator variable set at 1 if the open space is an urban park whose prime purpose is provision of wildlife habitat or dispersed recreation and that is characterized by predominantly native vegetation, and at zero otherwise, and AG, $PROT$ and $PRIV$ are indicator variables set at 1 if the open space is natural agricultural land (pasture, or pasture with some cropland), is protected, or is privately owned, respectively, and at zero otherwise.

Kroeger et al. found that the share of open space in the vicinity of a property ($\%OSChange$) was highly significant. The elasticity of property value premiums with respect to the percentage of open space in the vicinity of a property is 0.42 while the coefficient on the open space percentage squared is -0.0068. 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.[16] For forested, private, or protected open space or for natural area 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 (i.e., additional) 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.

Kroeger et al.'s model explains almost 50 percent of the variation observed in the data and as a whole is highly significant (p=0.0000). Their detailed results are shown in Table 8.

It should be noted that this model likely overestimates the attenuation of the size of marginal open space premiums that results from large open spaces, for reasons explained in detail in Kroeger et al. (2008). As a result, the model is likely to underestimate premiums in areas with large amounts of open space.

We applied Kroeger et al.'s property value premium function (eq. 1) to estimate the property premiums for properties located in the vicinity of the open spaces in the Mt. Agamenticus study area. We defined open space as undeveloped, relatively undisturbed natural land, consistent with the definition used by Kroeger et al. (2008). Utilizing Google Earth imagery, we located large individual open spaces in the Mt. Agamenticus study area. Since the vast

[15] The full model estimated by Kroeger et al. included a number of additional variables hypothesized to impact open space premiums. However, these were not found to be statistically significant and were excluded from the model.

[16] $0.4221*10 - 0.0068*(10^2) = 3.5$.

majority of the study area is undeveloped or has low density development, we included almost the entire study area as open space.

Table 8: Estimation results for the open space property premium model

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. Results shown are for the reduced model.
Source: Kroeger et al. (2008)

In order to identify the number of properties that receive open space premiums, we used Google Earth to identify and manually count the number of single family homes that fell within a one-mile radius of open space. [17] Our decision to truncate the open space included in the analysis at a one-mile distance from the outer edges of a developed place is based on two factors. First, the empirical evidence suggests that open space benefits decrease with increasing distance. Second, most studies underlying our property value estimation function analyzed open space impacts within a one-mile radius of a property.

We then visually estimated for each residential area in the study area the approximate percentage of the lands within a one-mile radius of that area that was occupied by open space. We excluded from the analysis those residential properties that had 50 percent or more open space within a one-mile radius, since the open space premium model was not estimated for such situations. The reason for excluding these properties from the analysis is that the model overestimates the attenuation of the size of marginal open space premiums for larger open spaces.[18] The excluded properties amount to approximately one-third (1,779) of all properties within a one-mile radius of the M. Agamenticus area.

We used U.S. Census Bureau (2002) data and maps to partition residential areas located within one mile of study area open space into subsections, specifically, block groups. We

[17] We limited our analysis to single-family detached homes because almost all of the studies based on which our open space premium model was estimated used this home type in their analysis. Thus, the premium estimates generated by our model should be considered most reliable for single-family detached homes, though open space premiums certainly also apply to townhouses, apartments, condominiums or other home styles. We tried to differentiate single family homes from mobile homes, apartment buildings and other home types using factors like the size or shape of the structure or the presence of multi-car parking lots.

[18] This overattenuation can be countered by reducing the coefficient on the squared term in the estimation model, as we did in the New Mexico case study that forms part of our group of five case studies.

then averaged the open space percentages across residential units to obtain the overall percentage of open space within a mile of each block group (Table 9).

Table 9: Location and number of housing units within one mile of natural open space in Mt. Agamenticus study area

Location of residences by Census subdivision	*Number of housing units*	*Open space as % of area within one mile of average property in block group*
Census Tract 330, Block Group 2	130	9%
Census Tract 340.01, Block Group 6	286	6%
Census Tract 340.01, Block Group 7	508	12%
Census Tract 340.02, Block Group 3	143	36%
Census Tract 350, Block Group 1	170	25%
Census Tract 350, Block Group 2	446	22%
Census Tract 350, Block Group 4	158	10%
Census Tract 360.01, Block Group 2	816	12%
Census Tract 360.01, Block Group 6	5	6%
Census Tract 360.02, BG 1	62	24%
Census Tract 360.02, BG 2	153	32%
Census Tract 360.02, BG 3	300	28%
Census Tract 360.02, BG 4	16	44%
Census Tract 370, BG 2	124	11%
Census Tract 370, BG 3	472	17%
Census Tract 380.02, BG 4	60	5%
	3,849	

Note: BG – block group

With the open space percentage (*%OSChange* in eq.1) identified for each subsection, we set the indicator variables in the function at their appropriate values. The predominant land cover type in the Mt. Agamenticus area was forest; therefore, for most subsections, the *FOR* variable was set to 1. There were, however, also wetlands and agriculture/field land cover types, generally interspersed with forestlands, within one mile from residential locations. When this was the case, we ran the premium model for each land cover type separately and took a weighted (by land cover share) average of the resulting open space premium percentages. For example, if half of the open space in the subsection was forest and the other half was wetlands, we averaged the results of the two models to obtain the estimate of the size of the open space premium for the subsection.

While a substantial portion of the study area is in public ownership or otherwise protected, most of the open space within a mile of the populated subsections was privately owned and unprotected (Figure 5). As a result, the *PRIV* variable was set to 1 for all subsections but one. In that one subsection, about half of the open space was publicly protected and half was privately protected. Thus, we ran the open space premium model twice, once with both the $PRIV$ and the PROT variables set to 1, and once with the $PRIV$ variable set to zero and the $PROT$ variable set to 1, and then took the average of the two estimates as the premium estimate for the subsection.

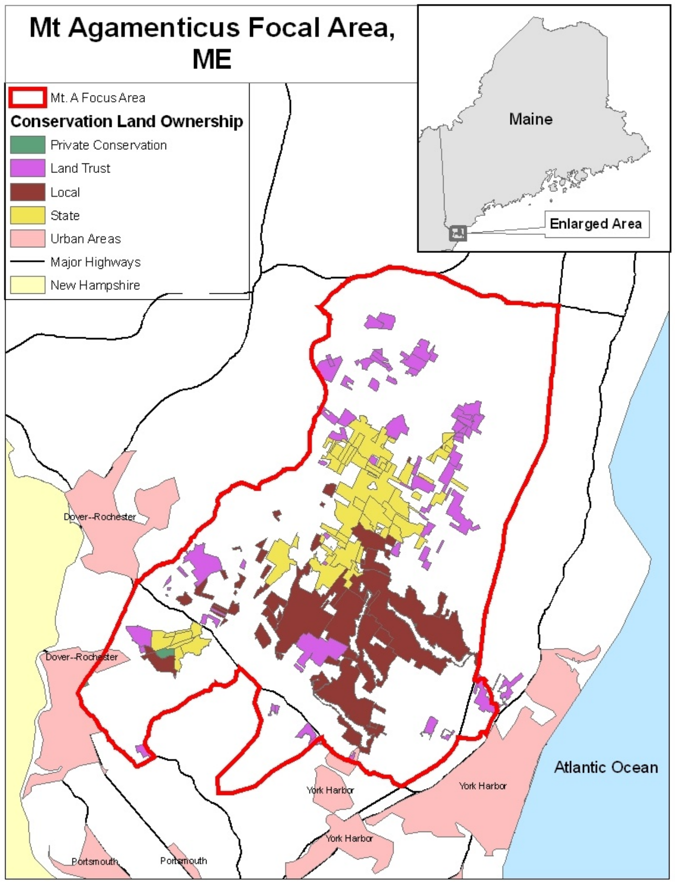

Figure 5: Conservation lands in the Mt. Agamenticus study area

Our analysis indicates that the average open space premium received by residential properties is estimated to range from about 3.5 percent to about 8 percent (Table 10), as a result of the different amounts of natural lands found in the vicinity of the residential areas. Combining these estimates with information on the number of houses and the median home value in each locale allows us to generate an estimate of the total open space premium received by home owners in the area (Table 10).

These results show that in 2000, the latest year for which comprehensive Census data on housing numbers and median home values are available, the total property value premium received by residences located within one mile of the natural open spaces in our study area was an estimated $40 million (2004$). This value is likely to be a very conservative estimate of the actual total premium received by homeowners in the study area, because it does not account for the premiums received by roughly one-third of all properties excluded from the analysis because the amounts of open space in their surroundings where so large that they exceeded the range over which our model was estimated. In addition, the number and the average value of housing units in the area have increased since 2000, both of which will increase the value of open space premiums.

Table 10: Estimated open space premiums for residential homes located in or adjacent to study area within one mile of natural lands

Census location	*Number of housing units*	*Median home value in 2000 (2004$)*	*Avg. property premium*	
			% of property value	*Total value (million 2004$)*
CT 330, BG 2	130	108,999	4.76%	674,192
CT 340.01, BG 6	286	197,079	3.80%	2,141,354
CT 340.01, BG 7	508	158,874	5.59%	4,514,610
CT 340.02, BG 3	143	149,186	6.47%	1,380,617
CT 350, BG 1	170	152,158	7.79%	2,016,163
CT 350, BG 2	446	142,580	7.49%	4,763,897
CT 350, BG 4	158	168,563	5.05%	1,345,018
CT 360.01, BG 2	816	225,375	5.59%	10,287,225
CT 360.01, BG 6	5	250,367	3.80%	47,559
CT 360.02, BG 1	62	213,374	7.71%	1,019,585
CT 360.02, BG 2	153	189,152	8.02%	2,321,790
CT 360.02, BG 3	300	165,370	5.22%	2,590,059
CT 360.02, BG 4	16	197,519	5.94%	187,694
CT 370, BG 2	124	182,876	5.33%	1,208,394
CT 370, BG 3	472	164,379	6.71%	5,208,777
CT 380.02, BG 4	60	129,257	3.45%	267,731
				39,974,664

Notes: Number of housing units indicates only units located within one mile of natural area in study area. Median home values shown are weighted values of the block groups contained in the listed census tracts.
Source: Median home values from U.S. Census Bureau (2002).

The estimated open space premium of around $40 million in 2000 does not represent an annual benefit flow. Rather, it is the total value of the open space premiums captured by residential properties that existed in that year, that is, the value incorporated in the existing residential housing stock. In order to make this benefit comparable to the other benefits generated by natural lands in the study area that are assessed in this report, we convert this stock value into its equivalent annual flow. The common approach to doing this is to regard the stock value ($40 million) as a principal that could be invested at market rates. The principal could generate a perpetual stream of annual payments equivalent to the interest earned. At a five percent annual interest rate, which is slightly less than the average annual return on certificates of deposit during the last 20 years (1987-2006), would be $2 million. [19]

These results show that the open space-based property value benefits the natural lands in the study area produce for area residents rank among the most important economic benefits generated by these lands. The relative importance of the property value premium benefits is even larger than suggested by our analysis because the open space benefit estimates are

[19] The annual payout is derived using the following perpetuity formula: $PV = A/i$, where PV is the present value (in our case, the principal of $40 million) of the perpetual annuity A, and i is the annual interest rate.

constructed using house price data. These data, like all observed willingness-to-pay data, are an indicator only of the *minimum* value home owners assign to the amenity benefits generated by proximity to natural lands. The actual value is likely to be higher. Its estimation, however, requires the construction of an aggregate housing demand curve that incorporates natural amenities, something that to date has not been done.

Ecosystem services

The natural systems in the study area provide a wide variety of ecosystem services. The benefits associated with some of these services accrue primarily to local residents and visitors (water provision, recreation opportunities and scenic views) or producers (crop pollination from native pollinators[20]). Other services generate benefits also on a regional or even larger scales (water provision, species habitat provision, biodiversity maintenance, carbon sequestration). In some cases, the value of some of these services is already captured in our analysis of other human uses of the study area. For example, the use value of species and habitats enjoyed by humans for recreational purposes is already partially accounted for in our (incomplete) analysis of the recreational value of the study area. Likewise, the value of the scenic views provided by the land is already captured in our estimate of the property enhancement value generated by the open lands in the area. In this section, due to the limited scope of the study, we only develop estimates of the value of water provisioning and carbon sequestration services provided by the ecosystems in the area.

Water supply by the study area

The water supply for the towns of York and Kittery, with a combined population of over 25,000, is provided by a number of rain-fed surficial reservoirs, including Chase's Pond, Welch's Pond, Boulter Pond, Middle Pond, Folly Pond and Bell Marsh Reservoir (Kittery Water District, 2007). All of these reservoirs are located within the study area boundaries and receive most of their water from the run-off from land within the study area. In addition, the study area provides groundwater recharge for aquifers that are a main source of water in many rural portions of the area (The Nature Conservancy, 2004). Thus, water supply for human uses is one of the ecosystem services provided by the natural lands in the study area. The integrity of these natural lands is crucial for maintaining a high-quality public water supply in the communities that depend on these resources. The York and Kittery Water Districts together own nearly 4,200 acres of land in the study area and actively manage these lands for the protection of reservoir water quality.

Total annual metered residential water use in the Kittery and York Water districts is an estimated 78 million cubic feet (Table 11). Including non-residential metered withdrawals in the Kittery district alone brings this number to over 104 million cubic feet. Actual withdrawals are far higher as the numbers in Table 11 do not include water provision to the local Navy base, which in 2007 accounted for 65.5 million cubic feet, equivalent to one-half of all consumption in the Kittery water district (Kittery Water District, 2008).

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[20] Losey and Vaughan (2006) estimate the total value of crop pollination, dung burial and pest control services provided by native insects at over $8 billion per year for the U.S. as a whole.

Table 11: Water withdrawals from study area reservoirs, 2008

	Water withdrawal, million cu. ft./year		
	Residential	*Other*	*Total*
Kittery WD	42.9	31.1	74.0
York WD	35.1	n.a.	n.a.

Notes: Cu. ft. – cubic feet; n.a. – not available; WD – water district. KWD estimates are based on consumption during July-Sep. 2008 prorated over the whole year. "Other" includes commercial, industrial and municipal users. The listed *Total* and *Other* volumes exclude unmetered services provided to the local Navy base, which account for an estimated one-half of total water consumption in the Kittery water district (Kittery Water District, 2008). York estimates are based on avg. per-capita water consumption in the district and York town population of 12,854 (U.S. Census Bureau, 2000).
Sources: Pers. comm.., Linda Johnson, office manager, Kittery Water District, Sep. 26, 2008; pers. comm., Ryan Lynch, treatment plant manager, York water district, Oct. 10, 2008; U.S. Census Bureau, 2000.

It is difficult to estimate what share this represents of the total available fresh water the area provides for human use. With an average annual precipitation in Maine of 42 inches (NOAA, 2002), total annual precipitation input in the area is an estimated 5.9 billion cubic feet. However, a substantial portion of this input drives evapotranspiration in the area's ecosystem and thus is not available for human use. Evapotranspiration, that is, the return of water from the ecosystem to the atmosphere as a result of evaporation and of transpiration by plants, is a function of climate and land cover, and is generally higher in warmer climates and in systems with higher biomass. Studies found that in the southeastern U.S., evapotranspiration returns between 50 (southern Appalachian mountains) and 85 percent (coastal Florida flatwoods) of precipitation to the atmosphere (Lu et al., 2003). In Maine, this ratio is estimated to be between 30 and 40 percent (Maine Geological Survey, 2005). Of the remaining precipitation input that potentially is available for human use, part percolates into the groundwater table. In Maine, this portion represents about ten to 20 percent of precipitation (ibid.). Thus, only approximately 40-60 percent of precipitation in the Mt. Agamenticus area is available as runoff that flows into streams and rivers. However, only a portion of this ends up in the surface reservoirs that provide the public water supply in the Kittery and York water districts; the remainder leaves the area due to topographic factors. Assuming that this runoff not ending up in water reservoirs accounts for between ten and 20 percent of total precipitation inputs, the portion of total precipitation input in the area that is captured in the reservoirs is likely to be only 20-50 percent of total precipitation inputs in the area. As a result, total surface water withdrawals in the Kittery and York water districts in 2007 accounted for an estimated six to 15 percent of total reservoir recharge or of the potentially available renewable surface water supply in the area.

The value of water supply services

Estimating the economic value of the water the study area provides for human uses is a challenging undertaking. Although water, unlike many other ecosystem goods, often is traded in markets, the prices paid by most users generally do not reflect the real scarcity value of water (Hanemann, 2006).[21] Water prices thus are a poor indicator of the value of the

[21] The underpricing of water is the result of a variety of factors (see Hanemann, 2006). Those of particular

water, and valuing water based on user prices or provisioning costs generally will underestimate the true economic value of a given quantity of water .

Rather than being reflected in water prices, the value of the water withdrawn from the study area reservoirs and ponds is the sum of all marginal net benefits the water generates in the uses it is put to. Those marginal benefits however are not readily discernable because, as is true for all goods or services, the value of water is not constant but varies with the scarcity of water, with the value of additional units usually decreasing. Therefore, in order to determine the total value to society of the water withdrawn from the reservoirs and ponds, one would need to know the marginal value of this water in its various applications, which is equivalent to the marginal net benefits produced by the water in the different uses it is put to (Hanemann, 2006). These marginal net benefits are the marginal net utility or net profits the water generates in the many uses to which it is put by households, industrial, commercial, military and municipal users. Knowledge of these marginal water values would allow one to construct the aggregate water demand function for each of these user groups, and thus to estimate the total value of the water by integrating each of these functions. Unfortunately, information on the net marginal benefits produced by the water withdrawn from the study area is not available.

Lacking information on marginal values, the second-best approach to valuing the surface water withdrawals would utilize the opportunity cost of providing that water, that is, the cost of alternative water provisioning approaches that would be required to substitute the surface withdrawals from the study area. This cost would need to be calculated based on the cost of new provisioning schemes, because the existing supply infrastructure may be old and thus its historic cost does not reflect the real scarcity cost of additional supplies (Hanemann, 2006). Unfortunately, we were not able to locate this information for the study area either.

Thus, we relied on the third-best approach to valuing the water provision services by the study area, based on the prices paid by consumers. For reasons mentioned in the previous paragraphs, water prices generally do not reflect the true economic value of water and their use for valuing water will generally result in an underestimate of that value.

Our estimate of the value of the water provided by the study area is limited to residential water use by water district customers in the Kittery and York water districts, since this was the only user type for which we were able to obtain the required information on both water use and charges. Thus, our estimate excludes the value of surface and groundwater use by commercial, industrial, agricultural, military and municipal uses, as well as the value of groundwater water extracted by private wells for residential uses.

The total water charges paid by residential customers in the Kittery and York water districts are an estimated $2.73 million (2004$) per year in 2008 (Table 12). This value thus represents the lower-bound estimate of the annual value of the water provision services rendered by the study area.

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importance include the fact that users generally are charged only for the water supply costs but not for the water itself; that in some cases not even the supply costs are fully covered by user prices; and that user prices generally are based on the historical cost of the supply infrastructure, not on replacement costs, which would be the economically correct approach.

Table 12: Average annual water charges for residential customers in Kittery and York water districts, 2008

	Charge per customer (2004$)	*Number of residential customers**	*Total charges (million 2004$)*
Kittery WD	$177	4,857	$0.86
York WD	$352	5,312	$1.87

Notes and *sources*: * Includes year-round and seasonal hookups. Numbers for Kittery water district (WD) based on June-August 2008 average residential customer consumption and average charge provided by Linda Johnson, Kittery Water District office manager (pers. comm.., Sep. 26, 2008); water charges for York water district based on York WD rate schedule (York Water District, 2008) and average consumption per customer (pers. comm., Ryan Lynch, York WD treatment plant manager, Oct. 10, 2008); York WD customer estimate based on district population and average household size (U.S. Census Bureau, 2000). See the Appendix for the data used in these estimates.

Because of the nature of the applied valuation approach and because of the exclusion from the analysis of non-residential water uses as well as of residential groundwater use – which in the Kittery water district together account for almost two-thirds of total water use Kittery Water District, 2008) – our value estimate of approximately $2.7 million per year is likely to be a substantial underestimate of the actual value of water provided by the Mt. Agamenticus area.

Carbon sequestration in the study area

The quantity of carbon taken up by a given plant varies with the species, the age of the particular specimen, and environmental conditions such as nutrient and water availability, ambient atmospheric carbon dioxide concentration, temperature (and its fluctuation), and the amount of available sunlight. As a result, rates of carbon uptake vary among species and locations. In addition to the species and growing location, forest management practices are an important variable in carbon sequestration (Richards et al., 2006).

Of the lands in the 38,600-acre study area, approximately 96 percent are in non-agricultural terrestrial vegetation (Table 13). These include lands with woody vegetation that are characterized by long-term above- (woody biomass) and belowground (in roots and soil or-

Table 13: Mt. Agamenticus study area land cover composition

Land cover	*Acres*	*Land cover*	*Acres*
Upland mixed forest	16,277	Freshwater marsh	117
Upland deciduous forest	10,701	Perennial stream	5
Upland coniferous forest	2,064	Lake/pond open water	784
Grassland	2,450	Cultivated	15
Upland scrub/shrub	763	Bare ground	100
Deciduous swamp	2,726	Developed	753
Coniferous swamp	849	Estuarine open water	22
Coniferous shrub swamp	15	Estuarine marsh	368
Deciduous shrub swamp	589	Estuarine sand/mud shore	34
		TOTAL	38,632

ganic matter) carbon storage pools as well as prairies where long-term carbon storage occurs in the soil.

These lands absorb atmospheric carbon dioxide during the process of photosynthesis, part of which becomes stored in an increase of perennial plant or soil biomass. An extensive literature search yielded estimates of the annual net carbon fluxes for all types of non-agricultural ecosystems or vegetation communities found in the study area (Table 14). From the studies not carried out in our study area, we selected those estimates that seemed most suitable for our area. For upland deciduous forests, we use Barr et al.'s (2002) net carbon sequestration estimate for temperate deciduous forests in southern Canada as a low estimate and Goulden et al.'s (1996) estimate for temperate deciduous hardwood forest in central Massachusetts as a high estimate. We use the average of Barr et al.'s (2002) and Golden et al.'s (1996) sequestration rates for temperate deciduous forests and Scott et al.'s (2004) estimate for central Maine coniferous forests as our low and high sequestration rates, respectively, for upland mixed forests. The assumed sequestration rate for upland coniferous forests is the one reported by Scott et al. (2004) for a central Maine spruce-hemlock forest.

Table 14: Carbon sequestration estimates for ecosystem/vegetation types found in the study area

Ecosystem/vegetation type /species and location	*Net C uptake by*	*tC/ha/yr*	*Source*
Deciduous Forests			
Temperate deciduous (mixed wood) forest stand - southern Canada	Ecosystem	1.50	Barr et al. (2002)
North American deciduous forests - MA	Ecosystem	1.75	Curtis et al. (2002)
North American deciduous forests - TN	Ecosystem	2.64	Curtis et al. (2002)
North American deciduous forests - WI	Ecosystem	1.86	Curtis et al. (2002)
North American deciduous forests - IN	Ecosystem	3.20	Curtis et al. (2002)
North American deciduous forests - MI	Ecosystem	2.12	Curtis et al. (2002)
Temperate deciduous forest - central MA	Ecosystem	2.24	Goulden et al. (1996)
Temperate mixed hardwood forest (mid-western US - IN)	Ecosystem	2.40	Schmid et al. (2000)
Coniferous Forests			
Spruce-hemlock forest in central Maine	Ecosystem	1.80	Scott et al. (2004)
Grasslands			
Restored grassland - Great Plains	Top 5 cm of soil	0.57	Follet et al. (2001)
8+ yr-old CRP grasslands - WI	Top 5 cm of soil	0.25	Kucharik et al. (2003)
Previously cultivated 16yr old prairie - WI	Top 5 cm of soil	0.13	Kucharik (2007)
12 Northeastern CO shortgrass steppe sites, 53 yrs after abandonment of cultivation	Top 5 cm of soil	0.04	Burke et al. (1995)
Five northern Great Plains locations	Ecosystem	0.73 [1]	Gilmanov et al. (2005)
Estuarine Marsh			
Avg. of tidal marshes in conterminous U.S.	Landscape-scale sediment net C sequestration	2.2	Bridgham et al (2006)
Avg. of tidal marshes in Canada	Landscape-scale sediment net C sequestration	2.1	Bridgham et al (2006)

Notes: [1] Average of range observed across sites.

Our literature search did not yield any carbon sequestration estimates for northeastern grasslands. Instead, we use Burke et al.'s (1995) and Gilmanov et al.'s (2005) grassland net carbon uptake estimates for the grasslands in our study area. We do not include upland scrub and shrub lands in our carbon uptake analysis because the only data for carbon uptake by shrub/scrub lands we found are for semi-arid southwestern communities (Scott et al., 2006).

Because of the paucity of data and the high uncertainty surrounding available figures, we also do not develop estimates of the net carbon uptake by the approximately 4,300 acres of swamp and freshwater marshes in the study area.

The dominant wetlands types in the Mt. Agamenticus area are coniferous and deciduous swamp (Table 13). Very few estimates exist in the literature on the net carbon uptake by temperate forested wetlands. Trettin and Jurgensen (2003) report literature estimates for net primary productivity (NPP) of such wetlands. However, NPP and carbon accumulation are not the same, unless carbon import, export, and nonbiological oxidation of organic carbon are negligible, which generally they are not (Lovett et al., 2006). One could calculate net carbon sequestration by correcting NPP for organic carbon losses from the soil to the air in the form of CO_2 and CH_4 emissions for losses of dissolved organic carbon from the soil to groundwater, but Trettin and Jurgensen (2003) report such estimates only for temperate bottomland hardwood swamps. However, the reported range in CH_4 emissions from bottomland hardwoods is large enough to make temperate forested swamps either sinks or sources of greenhouse gases, due to the high global warming potential of CH_4.[22] This finding is consistent with Bridgham et al. (2006) assessment that, with the exception of estuarine wetlands, methane emission from wetlands may largely offset benefits from carbon sequestration in soils and plants in terms of climate forcing. Thus, the net contribution of temperate forested wetlands to atmospheric concentrations of greenhouse gases is unclear and we do not include these systems in our net carbon uptake analysis.

Finally, we use Bridgham et al.'s (2006) estimates for the net carbon sequestration rate of Canadian and U.S. estuarine tidal marshes as the low and high sequestration rates, respectively, for the estuarine marshes in our study area.

Based on these sequestration data, we estimate that the natural lands in the study area that are included in the analysis constitute a net sink of between 19 thousand and 26 thousand tons of carbon per year (Table 15), or between 0.5 and 0.7 tons per acre.

The value of carbon sequestration services

Assigning an economic value to the carbon sequestration services provided by the ecosystems in our study area is complicated by several factors. The true value of the carbon uptake consists in the associated incremental reduction in the negative consequences of increased atmospheric carbon concentrations, such as coastal inundation or storm surges. Although the potential future impacts of climate change on the U.S. in general or on the U.S. Northeast in particular have been documented (Field et al., 2007; Frumhoff et al., 2007), estimating the expected value of damages associated with climate change is impossible due

[22] Methane has a 100-year global warming potential of 25, that is, over a period of 100 years, one kilogram of CH_4 has the 25-fold warming impact (radiative forcing) of one kilogram of CO_2 (Forster et al., 2007).

Table 15: Net sequestration estimates for natural lands in the study area for which sequestration rates are available

Land cover	*Net sequestration per ha*		*Total net sequestration*	
	Low est.	*High est.*	*Low est.*	*High est.*
	tC/ha/yr		*tC/yr*	
Upland mixed forest	1.65	2.02	10,869	13,306
Upland deciduous forest	1.50	2.24	6,496	9,700
Upland coniferous forest	1.80	1.80	1,504	1,504
Grassland	0.04	0.73	37	724
Estuarine marsh	2.10	2.20	313	327
TOTAL			19,218	25,561

to the structural uncertainties in the science of climate change and the inability to place a meaningful upper bound on the potential catastrophic losses associated with disastrous temperature changes (Weitzman, 2008). Thus, estimating the reduction in the severity of these impacts that is achieved through the uptake and storage of atmospheric carbon by the ecosystems in our study area is beyond the scope of our study, and probably is not feasible at this point in time.

An alternative approach to valuing the carbon uptake produced by the ecosystems is based on the prices of carbon credits in appropriate markets. However, several different markets exist for carbon credits, and the prices of the credits traded on them vary widely. Some of these markets are regulation-driven, and as such they restrict access on both the buyer and seller side.[23] All of these regulation-driven markets currently are outside of the U.S., and under their current legal frameworks, carbon credits generated in the United States are not eligible for transaction in these markets (Diamant, 2006).

Several regional U.S. emission trading schemes currently are under development. These include the recently created Western Regional Climate Action Initiative, the northeast Regional Greenhouse Gas Initiative (RGGI) and the California Climate Action Registry (CCAR). However, until the reduction targets are set for these markets and the accompanying carbon credit trading begins, it is impossible to predict what credit prices will be on these markets once they begin operation.

Nevertheless, a number of voluntary carbon credit markets already exist in the U.S. whose carbon prices can serve to construct first rough estimates of the value of carbon sequestration provided by the study area. These include the Chicago Climate Exchange, various carbon-offset schemes operated by private suppliers, and a new offset-scheme created by the U.S. Forest Service and the National Forest Foundation.

An accurate valuation of the carbon sequestration services provided by the ecosystems in the study area based on market prices for carbon requires a careful analysis of the access conditions of the various mandatory and voluntary markets. Depending on the market in question, admissible carbon credits must fulfill a number of conditions with respect to

[23] Examples are all Kyoto-based or regionally defined carbon credit markets, such as the EU's, the UK's, and Norway's Emissions Trading Schemes, Australia's NSW Greenhouse Gas Abatement Scheme, the Clean Development Mechanism and Joint Implementation programs, or Canadian, Japanese, and Swiss programs.

verifiability, additionality, permanence and leakage that vary in stringency among the markets. Some of those markets currently would not admit sequestration-based carbon credits from existing, protected forest lands, while others would accept such credits if they were the result of changes in land management practices or of avoided loss of vegetation that would result under a business-as-usual scenario. With respect to our study area, the pressure from residential development and the ongoing habitat fragmentation on all sides of the Mt. Agamenticus area due to residential development, quarrying and commercial gravel mining (Maine Department of Inland Fisheries and Wildlife, 2005) likely would mean that carbon sequestration associated with land conservation projects in the area would pass the additionality requirement.[24] In any case, the protocols of several existing markets and especially of many of the planned markets are in flux. Here we do not conduct a detailed analysis in order to identify with certainty those markets that currently would accept the credits generated by our study area. Rather, we use prices on those markets that already operate and are not off limits to U.S.-based carbon credits.

The average price on the Chicago Climate Exchange (CCX) during January to July of 2007 was \$3.55 per ton of carbon dioxide equivalent (tCO_2e).[25, 26] The average price charged for air travel CO_2 offsets is \$15 per ton (Kollmuss and Bowell, 2007). A recent survey of voluntary carbon markets (Hamilton et al., 2007) found that the average price paid for carbon credits for U.S.-based projects was \$10 per ton of carbon dioxide equivalent (tCO_2e). Finally, the new "Carbon Capital Project" created by the Forest Service and the National Forest Foundation will charge \$6 per ton of verified CO_2 offset.[27]

Because of the range of prices of voluntary carbon credits, we construct a low and a high estimate of the value of the carbon sequestered by the habitats in our study area. The low carbon price is that found on the CCX during January-July 2007 - \$3.55 per metric tCO_2e. The high price is the average price of air travel carbon offsets in 2006/07 - \$14.80 per metric tCO_2e. The estimated annual quantity of CO_2 sequestered in our study area, 182 to 253 thousand tons of CO_2e, is equivalent to approximately one percent of the total volume of voluntary transactions in 2006.[28] A sale of the hypothetical credits produced by the ecosystems in our study area therefore would be unlikely to result in a supply shock that would drive down prices. Furthermore, transaction volumes on voluntary carbon markets have been increasing rapidly in recent years, which would make the quantities of carbon sequestered in our study area relatively smaller as a share of the overall market. Importantly also, carbon constraints are likely to tighten in the future with expected increases in both

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[24] Specifically, conservation projects likely to fulfill the additionality requirement are those that lead to the protection of currently unprotected lands or bring about increases in carbon sequestration on already protected lands as a result of changes in management practices.

[25] All prices given here refer to metric tons. The prices given by Kollmuss and Bowell (2007) have been converted from short tons to metric tons.

[26] Average of monthly average closing prices of all vintages. See Chicago Climate Exchange at *http://www.chicagoclimatex.com/* On the CCX, CO_2 is traded in the form of Carbon Financial Instruments (CFI), which each represent 100 tons of CO_2. However, prices are reported in terms of \$/metric tCO_2.

[27] Friends of the Forest, "Forest Service & NFF Combat Climate Change". July 25, 2007. [online] *http://www.carboncapitalfund.org/news/news-59.html* Last accessed August 6, 2007.

[28] The total transaction volume on voluntary carbon markets in 2006 was at least 23.7 million tons of tCO2e (Hamilton et al., 2007). As Hamilton et al. (2007) point out, this estimate may constitute a considerable underestimate of the actual transaction volume of because it was impossible for their survey to capture all over-the-counter transactions.

voluntary and mandatory emission reductions, which is likely to raise demand for credits and increase prices.[29]

Applying the low and high prices to the carbon sequestration estimates for our study area (Table 15) yields a total value of the sequestration services estimated at $240 thousand to $1.3 million per year (Table 16).

Table 16: Estimated annual value of carbon sequestration services provided by study area ecosystems

	LOW scenario	*HIGH scenario*
Quantity of C sequestered (metric tons)	19,218	25,561
Corresponding quantity of CO_2 (metric tons)	70,473	93,733
Price per ton of CO_2e (2004$)	3.41	14.21
Value of carbon sequestration (2004$)	240,000	1,332,000

Note: Quantities of carbon dioxide are derived by multiplying the volume of sequestered carbon by 3.667, which is the ratio of the weights of CO_2 and C, respectively.

[29] For example, several bills considered in the U.S. Congress in February of 2008 are expected to result in carbon prices of between $15 and $40 per metric ton of CO_2e as soon as 2015 (New Carbon Finance, 2008).

Conclusion

Undeveloped lands support a variety of human activities. These activities carry associated economic values because they contribute to individuals' well-being. Some of these values are at least partially reflected in markets, either because the nature-based activity (e.g., wildlife viewing or hunting) requires inputs (e.g., transportation, food and lodging, permits, equipment) that are bought and sold in markets, or because the goods or services provided by undeveloped lands (e.g., water, carbon sequestration) are themselves traded in markets. Thus, to some extent market expenditures associated with human uses of natural lands can serve as a lower-bound indicator of the value individuals place on those uses. However, the value of many goods and services provided by natural lands is not fully reflected in market transactions, either because a good or service is not amenable to being bought and sold in markets (e.g., populations of individual threatened or endangered species or biodiversity more generally); because individuals value these goods or services not for their use alone but also, and in some cases primarily, for their existence per se (e.g., particular "charismatic" species; unique scenic landscapes such as Yellowstone National Park, or untouched, wild places such as wilderness areas); or because market prices do not reflect the consumer or producer surplus or net benefit to individuals or firms that is associated with their consumption of the good or service or with its use as an input to production. Thus, capturing the full value of human activities supported by natural lands requires the use of valuation approaches capable of capturing the portion of the value of natural lands that is not reflected in the market transactions.

This study uses market prices and, to the extent they are available, published estimates of non-market values to develop comprehensive estimates of the economic value of several activities supported by undeveloped lands in the Mt. Agamenticus focus area, a 60 square-mile area in southern coastal Maine that has been identified as important to meeting the state's fish and wildlife conservation goals.

Our analysis develops estimates of the value of the area for outdoor recreation by local residents and visitors. It also quantifies the open space premiums that accrue to residential properties located in the vicinity of undeveloped open spaces in the area and the value of water provision and carbon sequestration services provided by the undeveloped lands in the area. The area provides a number of additional uses, such as mostly small-scale agricultural production, support for educational and research activities and habitat provision for rare species. We did not quantify the value of these uses in our analysis for lack of the required data. In addition, our value estimates generally are rather conservative because available data on some uses are very incomplete. For example, our estimate of the value of outdoor recreation activities in the study area is limited to the consumer surplus (net benefit) associated with these activities and excludes recreation trip expenditures. Similarly, the only data on timber harvests in the area are from the Kittery water district, while most harvests occur on the private lands that account for the majority of lands in the study area.

Despite these important limitations to what we were able to include in our analysis, our results shows that the economic value of the uses of the Mt. Agamenticus area we could quantify is substantial, ranging from an estimated $5.3 million to $6.6 million per year (Table 17).

Table 17: Estimates of the annual value of selected uses supported by the Mt. Agamenticus study area

Area uses	*Value (million 2004$)*	
	Low estimate	*High estimate*
Forestry (Kittery water district only)	0.07 *	
Agriculture	*not quantified*	
Recreation (Consumer surplus only)	0.25 *	
Research and education	*not quantified*	
Open space property value premiums	2.0 †	
Ecosystem services:		
Water supply	2.73 †	
Carbon sequestration	0.24 – 1.33	
Other	*not quantified*	
TOTAL	5.29	6.38

Notes: * incomplete estimate; † Lower bound estimate. Totals may not add up due to rounding. The value of open space property price premiums shown in the table is the annual benefit flow (see p. 21)

Water provision by the ecosystems in the area generates the single largest value, followed by open space residential property value premiums. Carbon sequestration generates substantial economic value as well, although the current uncertainties surrounding access and credit prices on emerging carbon markets make this estimate somewhat less reliable than those for the other uses of the study area.[30]

It bears repeating that our estimates are very incomplete and that the actual total economic value of the area likely far surpasses our estimate.

Given the increasing scarcity of undeveloped lands and of many of the goods and services they provide and given the expected continuation of that trend, the value of these outputs provided by conserved natural areas is only expected to increase over time.[31] Land use planning, in order to achieve economically sensible results, should take into account these economic values that are generated by the conservation of undeveloped lands and the fact that the increasing relative scarcity of these lands will only increase the value generated by land conservation. Since a large share of both ecologically and economically valuable undeveloped lands is in private ownership, not just in the Mt. Agamenticus area but also at the state and national levels, existing financial incentive systems that encourage land conservation will need to be improved and in many cases additional ones will need to be

[30] For example, the price of a carbon credit (called "Carbon Finance Instrument" or CFI) on the Chicago Climate Exchange between February and May 2007 fluctuated between $2.60 and $7.40 per metric ton of CO_2e while the price of CFI futures (maturity date December 2010) fluctuated between $3.25 and $9.75 during the same period. A recent analysis (New Carbon Finance, 2008) suggested that a potential future cap-and-trade system in the U.S. along the lines proposed in several bills considered in the U.S. Congress in February of 2008 might result in carbon prices of between $15 and $40 per metric ton of CO_2e as soon as 2015, depending on whether only domestic or also international trading would be allowed. For comparison, in our calculations we used the average January-July 2007 price of $3.55 per metric ton of CO_2e as a lower bound, and the average price of air travel carbon offsets in 2006/07, $14.80 per metric tCO_2e, as the upper bound.
[31] This already is evident for water provision and carbon sequestration.

created in order to better align privately and socially desirable outcomes. This is a challenging task whose urgency is increasing in lockstep with the continuing loss and degradation of natural lands.

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Appendix: Water cost estimates for residential customers in Kittery and York water districts

The following data were used to compile the estimates shown in Table 12:

Kittery WD:

- Number of residential customers: 4,857 (pers. comm., Linda Johnson, KWD office manager, Sep. 26, 2008)
- Average consumption per customer, June through August 2008: 191 gallons per day (pers. comm., Linda Johnson, KWD office manager, Sep. 26, 2008). Note: According to the Superintendent's Report for 2007 (Kittery Water District, 2008), average consumption during the summer months is below the annual average monthly consumption. We prorated the June-August consumption to the full year to estimate annual consumption.
- The average quarterly (June-August) residential water bill in the district was $47 (2008$) (pers. comm., Linda Johnson, KWD office manager, Sep. 26, 2008).

York water district:

- In 2007, average per-capita water use was 56 gallons per day (pers. comm., Ryan Lynch, York WD treatment plant manager, Oct. 10, 2008).
- The town of York in 2000 had a population of 12,854. Given an average household size in the town of 2.42 (U.S. Census Bureau, 2000), the estimated number of residential water customers in York is 5,312, yielding an estimated average quarterly and annual consumption per residential customer of 12,332 gallons (1,649 cu.ft.) and 49,329 gallons (6,595 cu.ft.), respectively.
- The flat quarterly rate for a 5/8-inch water hookup (the dominant size for residential customers in the district) (pers. comm., Ryan Lynch, York WD treatment plant manager, Oct. 10, 2008) is $58.53 in 2008 (York Water District, 2008). This includes a (quarterly) consumption allowance of 1,000 cu.ft. The rate for additional consumption increments is $5.40 per 100 cu.ft. for the next 2,000 cu.ft. Given the average quarterly consumption of residential customers of 1,649 cu.ft., this rate structure results in an estimated quarterly residential water bill of $93.56 (2008$).