Economic Benefits of Conserving Natural Lands:

Case Study: Collier County Pine and Swamp Lands, Florida

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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

ASR	Aquifer storage and recovery
C	Carbon
CO_2e	Carbon dioxide equivalent
CREW	Corkscrew Regional Ecosystem Watershed
CWCS	Comprehensive Wildlife Conservation Strategy
FWC	Florida Fish and Wildlife Conservation Commission
in	Inches
IAS	Intermediate aquifer system
LWC	Lower West Coast planning region
MGD	Million gallons per day
NWR	National Wildlife Refuge
SAS	Surficial aquifer system
SFWMD	South Florida Water Management District
SHCA	Strategic Habitat Conservation Area
yr	Year

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 an 825 square-mile area in southwestern Florida that is under high development pressure and has been identified as a priority for conservation in Florida's Comprehensive Wildlife Conservation Strategy.

Our analysis includes the value associated with the open space premiums that accrue to residential properties located in the vicinity of undeveloped open spaces; the value associated with outdoor recreation activities practiced in the area by local residents and visitors; and the value of two ecosystem services provided by the undeveloped lands in the area: carbon sequestration and water provision (specifically, recharge of the surficial and intermediate aquifer systems through infiltration and percolation of rainwater).

Our analysis shows that the undeveloped lands in the study area generate substantial economic value. The total estimated annual value of the land uses included in our analysis ranges from $145 million to $315 million, depending on the prices used to value the carbon sequestration and water provision services provided by the lands (Table ES-1). Our results also reveal that the combined value provided by these two ecosystem services far surpasses the value associated with direct uses of the area's undeveloped lands (recreation and residential open space property value premiums).

Table ES-1: Annual value of selected uses of undeveloped lands in study area

	Low estimate	*High estimate*
	million 2004$ per year	
Open space property value premiums	6.5	6.5
Recreation	2.6	2.6
Ecosystem services:		
Carbon sequestration	5.1	21.2
Water provision	130	285
TOTAL	145	315

Due to limitations on available data and the use of generally conservative value estimates throughout our analysis, both our "Low" and "High" value estimates should be considered conservative. The omission from our analysis of several other economically important services provided by the undeveloped lands in the study area, such as pollination of agricultural crops by native pollinators, erosion control, water quality improvements through reduction of nutrient loading of surface waters by runoff from agricultural lands, or provision of habitat for species that carry existence value for people, as well as the downward bias in our per-unit value estimates mean that the actual economic value of the undeveloped lands is likely to be considerably higher than indicated by our estimates. Furthermore, 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 for many services, the value of these outputs is only expected to increase over time.

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 our Florida 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 the new cover type, 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-

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[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 a variety of human uses supported by the undeveloped lands in a specific area in Southwestern Florida that is under high development pressure, 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.

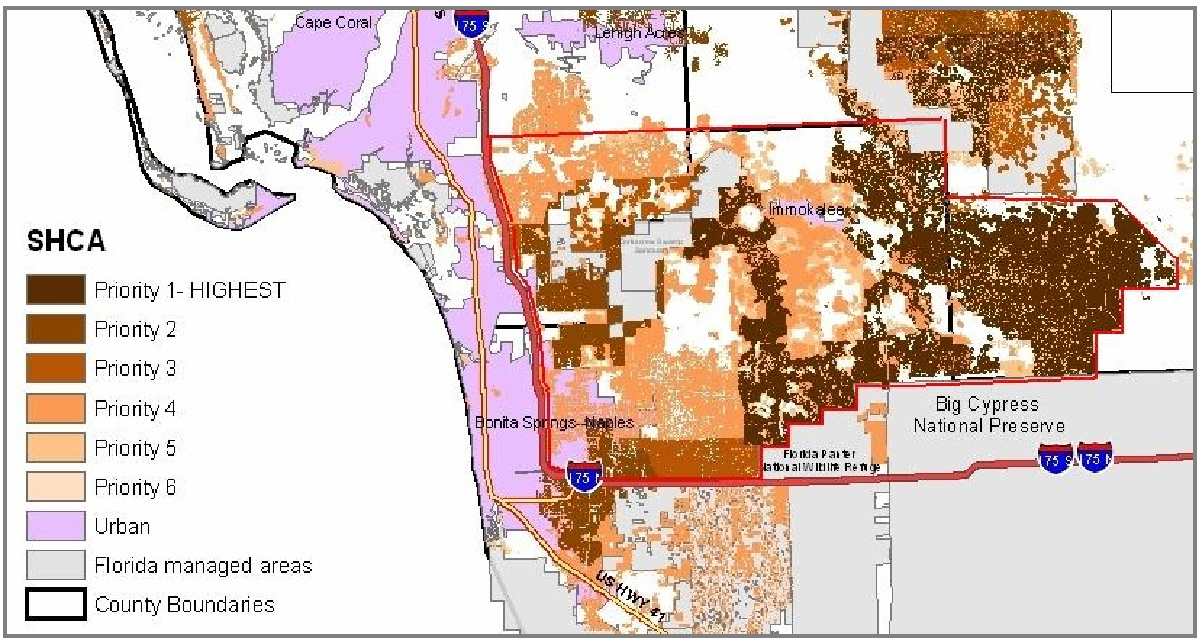
[3] This assumes landowners act as profit-maximizers. In the case of a landowner who has a preference for keeping the land in an undeveloped state for non-financial motives, the payment would not necessarily need to be financially competitive with development. Rather, payment would merely need to be 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 was to achieve a representation of diverse geographic regions, ecosystem types, land use composition and land ownership within the sample.

The Florida case study area is indicated by the red-bounded area in Figure 1. The selection of this area was based on a variety of criteria. The area includes mostly highest and high-priority Strategic Habitat Conservation Areas (SHCAs) as identified in Florida's Conservation Needs Assessment (Florida Natural Areas Inventory, 2006, fig. 1-1). These areas are defined as uplands and wetland areas that are important habitat and are currently not protected (Florida Fish and Wildlife Conservation Commission, 2005, p. 98).



Source: Florida Natural Areas Inventory (2006), figure 1-1

Figure 1: Florida case study area (red boundary) in relation to Florida's Strategic Habitat Conservation Areas

The area also contains several of the highest-priority significant landscapes, linkages and conservation corridors and high and highest-priority rare species habitat conservation lands as identified in the Conservation Needs Assessment (Florida Natural Areas Inventory 2006, figs. 3-1 and 2-4). Furthermore, the area contains a substantial portion of Florida's highest-priority Landscape-Sized Protection Areas (Florida Natural Areas Inventory, 2006, fig. 5-1).

Vegetation in the area is predominantly natural pineland, dry prairie, and freshwater marsh and wet prairie, all characterized as very high threat status in Florida's Comprehensive Wildlife Conservation Strategy (CWCS; Florida Fish and Wildlife Conservation Commission, 2005), as well as cypress swamp and hardwood swamp/mixed wetland forest, both characterized as high priority habitat in the Strategy.

In addition, a large portion of the area is identified as prime recharge lands and unprotected recharge lands in natural condition (The Nature Conservancy, 2005, p. 7, based on data from the Florida Natural Areas Inventory's *Conservation Needs and Assessment*, 2001 and updates).

Finally, the area is largely co-extant with the Collier County Pine and Swamp Lands area listed among the Florida Conservation Priorities and Areas of Conservation Interest by The Nature Conservancy (2005).

In the west, interstate I-75 was chosen both as a convenience boundary and because there are very few areas to the west of this boundary that are identified as priority habitat. The Collier county line was chosen as the northern boundary and extended westward into Lee County because few priority lands are located north of this line, except in the east. In the south, I-75 was chosen as a boundary up to the Florida Panther National Wildlife Refuge (NWR) as much of the high-priority lands are north of this line. The southern border of the study area is drawn along the northern edge of the Florida Panther NWR and Big Cypress National Preserve. In the east, the study area extends beyond the Collier county border to include a large highest-priority SHCA. The total size of the study area is approximately 528 thousand acres, or 825 square miles. The majority of the lands is privately owned, and only nine percent (47 thousand acres) of the total area is protected (Figure 2 and Table 1).

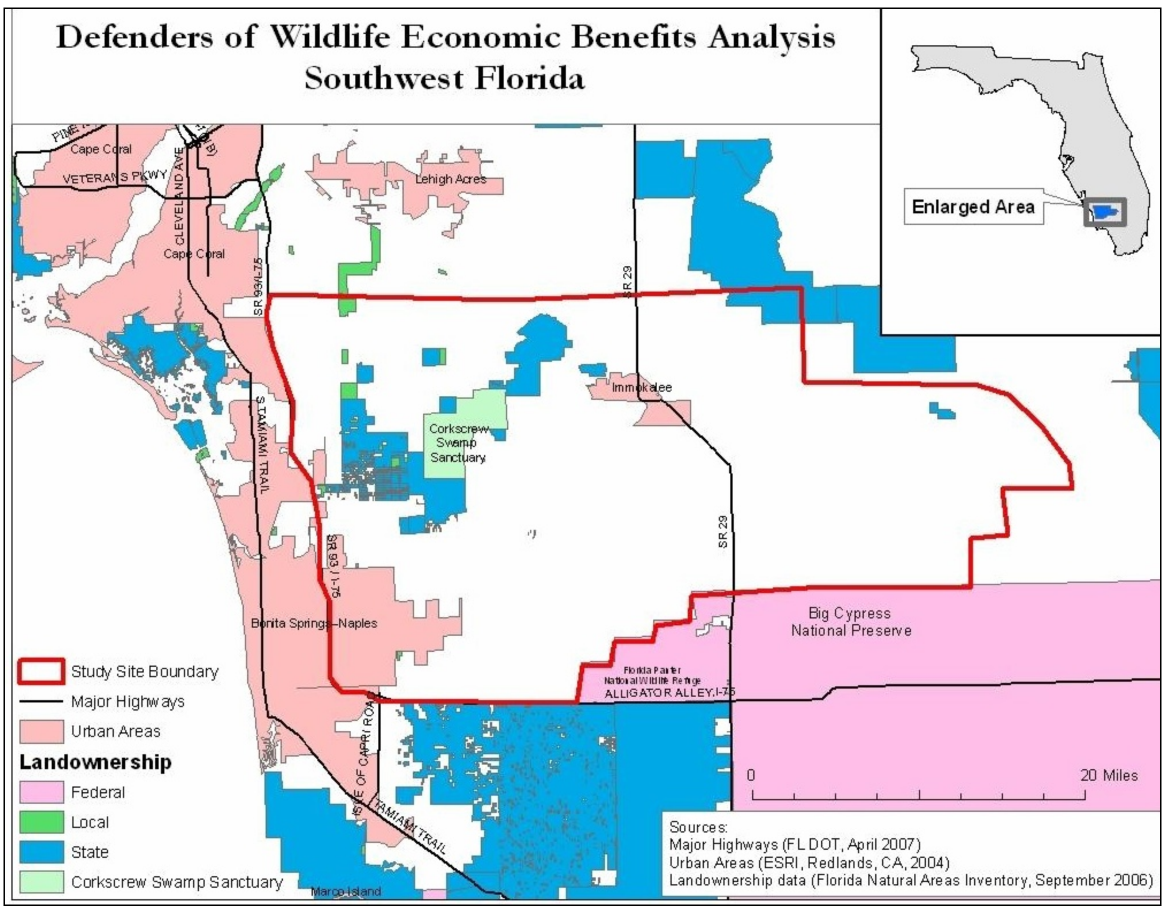


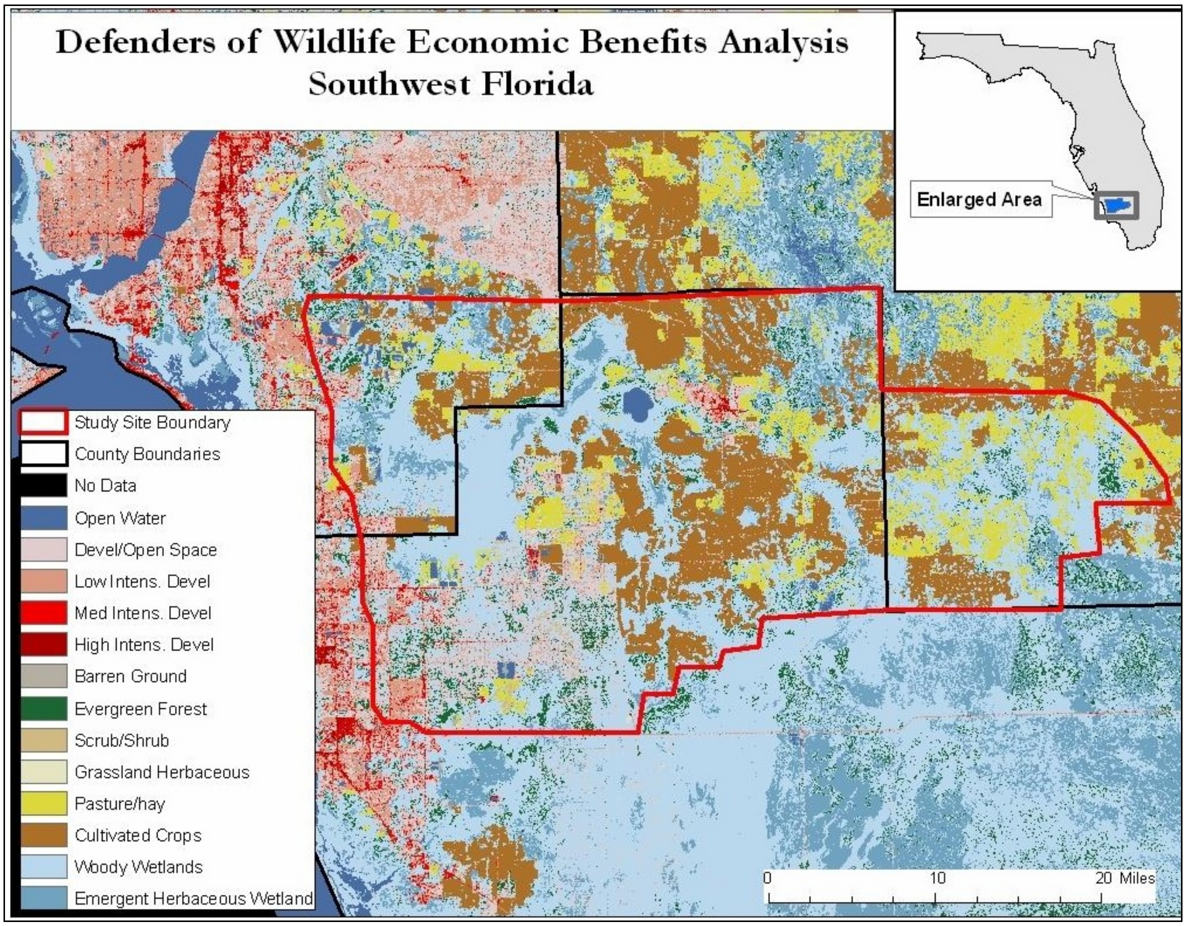
Figure 2: Land ownership in the study area

Table 1: Ownership of protected lands in the study area

Owner	*acres*
Local	1,271
State	32,020
Private	13,885

Source: GIS analysis of map layers from Florida Natural Areas Inventory (2006).

Figure 3 provides an overview of the main land cover types found in the study area. (Note: Figure 3 is based on USGS 2001 land cover data. In our ecosystem service analysis we used the more detailed 2003 Florida Vegetation and Land Cover Data (Stys et al., 2004).



Source: USGS 2001.

Figure 3: Land cover types in the study area

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 most of the needed data are available. In those cases where the data used are from a different year, we indicate this in the text. All values are expressed in 2004 dollars ($2004).

Following common practice, our analysis of the economic values provided by the area is separated into two parts. The first 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. The second is based on an economic impact analysis perspective and attempts to quantify the total contribution the natural lands in the study area make to the local economy, by quantifying the total final output (sales), labor income, and employment in the area derived from activities supported by the natural systems in the study area. The 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, while the impact analysis-based assessment only includes observed market impacts attributable to expenditures associated with the ecosystems.[4]

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 of the ecosystems or their components, as for example in the case of recreation or scenic views from surrounding 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 to the 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 these features. For example, studies have shown that people value the existence of unique landscapes; of particular, "charismatic" species like the Florida panther (*Felis concolor coryii*) or the Florida black bear (*Ursus americanus floridanus*) (FWC, 2000, 2008a); or they may 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 for which we were able to obtain quantitative information and that are compatible with and contingent upon the continued conservation of the area. These are shown in Table 2. The fact that a particular activity is not indicated in Table 2 does not imply that this

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

activity does not occur in the study area. It merely indicates that in our research we have not come across evidence of its occurrence.

Table 2: List of documented uses of the study area's ecosystems

Direct uses	Timber extraction Non-timber products Grazing Recreation - Camping - Backpacking - Picnicking and general relaxation - Fishing - Hunting - Hiking - Wildlife watching Research and education Property value premiums
Indirect uses	Ecosystem services - Water retention and generation (water quantity) - Water quality - Species habitat provision * - Biodiversity maintenance - Temperature modulation - Carbon sequestration - Air quality
Passive uses	Provision of habitat for threatened, endangered, rare or "charismatic" species - Florida panther, Florida black bear

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

Due to our focus on uses that depend on the conservation of the area, we do not quantify directly the economic value associated with uses that are not dependent on or compatible with the conservation of aboveground ecosystems. Examples of such uses are unsustainable timber extraction and agriculture. Nevertheless, to the extent that these non-compatible activities depend on ecosystem services provided by the conserved lands in the area and to the extend that we quantify those services in our analysis, we do capture part of the contribution of conservation lands to the economic value of those activities. Specifically, we quantify the water provisioning services provided by conservation lands in the study area and the value of those services to agriculture. Thus, our analysis is able to capture part of the value of the agricultural production in the area that is attributable to the conservation lands.

Some conservation-compatible uses of the study area have important non-market values, that is, their full economic value cannot be assessed on the basis of observed market transactions alone (Table 3). Whenever possible, we attempt to capture this non-market value component by using appropriate valuation approaches. For example, in the case of many recreation activities, studies have shown that the average participant in these activities derives a value from engaging in them that surpasses his or her expenditures associated with recreation trips. We use published estimates of this additional value for the recreation activities practiced in the area in order to quantify this non-market portion of the economic value of recreation.

Table 3: Uses of the study area and types of associated economic values

Use	*Market value*	*Non-market value*
Recreation	ü	ü
Research and education	ü	ü
Property value premiums	ü	
Ecosystem services	ü	ü

Due to limits in the scope of our analysis, we do not develop estimates of the values of research and education or of most ecosystem services provided by the study area. In addition, information is incomplete on the levels of some of the uses we do include in our analysis. For example, while we do have quantitative information on the numbers of recreation visitors for some of the protected lands in the study area, such information does not exist for the unprotected lands, which make up over nine-tenths of the area. As a result, our value estimates exclude some uses and incompletely capture the true value of others. Thus, they necessarily represent underestimates of the total value of the annual flow of benefits provided by the ecosystems in the area.

Estimates of the Economic Value of Land Uses

In this section, we develop estimates of the value of some of the uses supported by the natural lands in the study area shown in Table 2. We limit our analysis to the value of those uses that are compatible with or contingent upon natural lands in the study area and for which we were able to obtain data.

Agriculture and forestry

Substantial portions of our study area are devoted to agricultural uses, and some others are used for timber production. Approximately eleven percent of the area are used for pasture (both improved and unimproved), and 16 percent are planted to crops, mostly citrus and field crops (Table 4). Because agricultural lands generally displace native vegetation and do not represent high-quality habitat for native species, we do not include the value associated with agricultural crops in our analysis of the benefits generated by natural lands.

Table 4: Agricultural uses in study area

Crop type	*Acres*
Improved Pasture	42,694
Unimproved Pasture	14,593
Citrus	46,026
Row/Field Crops	35,404
Other Agriculture	2,517

Source: Calculated from 2003 Florida Vegetation and Land Cover Data (Stys et al., 2004).

A moderate amount of timber harvesting also occurs in the study area. However, sustainable forestry harvesting is minimal, and overall it is not a significant economic factor in the area. The main species harvested are south Florida slash pine and sabal palms (for landscaping).[5]

Recreation

The study area contains important wildlife resources that attract large numbers of recreation visitors each year. Corkscrew Swamp Sanctuary, the Corkscrew Regional Ecosystem Watershed (CREW) and Lake Trafford account for the majority of recorded recreation visits Table 5).

Audubon's Corkscrew Swamp Sanctuary, located in Collier county (Figure 2), comprises over 10,500 acres of pine flatwoods, wet prairie, pond cypress, bald cypress forest, and marsh and slough ecosystems. The sanctuary attract between 80,000 and 100,000 visitors annually, most of whom engage in wildlife viewing from the 2.25-mile raised boardwalk. The length of the average visit is about two hours.[6]

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5 Pers. comm., Kevin Podkowka, Forestry Resource Administrator, Caloosahatchee Forestry Center, Ft. Myers, Florida, Nov. 16, 2007.

6 Pers. comm. with Lori Piper, administrator of the Sanctuary's Blair Audubon Center, May 5, 2007

Table 5: Estimates of annual recreation visitation in the study area

Site	*Primary visitation purpose*	*Estimated visitation, persons/yr*
Corkscrew Swamp Sanctuary	Wildlife viewing, Environmental education	80,000-100,000
CREW	Hiking	>2,000
	Camping	>50
	Environmental education	1,000
	Hunting	318
Lake Trafford	Wildlife viewing	10,000
	Angling	10,000
	Alligator hunting	64

Sources: See text.

The CREW offers hiking, camping, and hunting opportunities. No comprehensive visitor counts are maintained. In 2006, 1,093 hikers filled out voluntary comment cards, and an additional 1,011 participated in guided hikes. The area also received 991 education visitors ranging from elementary school to college age, as well as over 50 camping visits.[7] The CREW is designated by the Florida Fish and Wildlife Conservation Commission (FWC) as a Wildlife and Environmental Area and supported a total of 318 hunting visitor days in 2006. [8]

Lake Trafford historically was a prized location for freshwater fishing in Florida. However, as a result of hydrilla invasions and associated management actions, the oxygen content and depth of the shallow lake drastically declined, resulting in several fish kills. It is hoped that a recently-completed major dredging project will improve the quality of the lake as fish habitat and bring fishing back to pre-invasion levels. Lake Trafford also is a popular destination for airboat rides because of its wildlife resources, especially water birds and alligators. Visitation of the lake by anglers and others is not recorded, but in an average year, the lake is estimated to draw upward of 10,000 angling visits and airboat rides.[9] The lake also supports alligator hunting, with a total harvest of 64 animals projected for 2007 (FWC, 2007).

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 needed for quantification. 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, they 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 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). 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

[7] Pers. comm. with Brenda Brooks, CREW Land and Water Trust, May 8, 2007.
[8] Pers. comm. with Page Martin, FWC, Jan. 9, 2008.
[9] Pers. comm. with Ed Olesky, owner of Lake Trafford Marina, Nov. 15, 2007.

fishing, hunting, or engaging in some other activity of interest.[10] We can construct an estimate of the total value visitors attach to nature recreation 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.

Based on Loomis' (2005) work, we identified six studies in Florida that estimate the consumer surplus or net benefits received by recreationists engaging in activities practiced in our study area – camping, fishing, hiking, hunting and wildlife viewing. Excluding Bowker and Leeworthy's (1998) estimates for recreation on Florida keys, an environment very different from that found in our study area, the consumer surplus estimates range from $15 per person per day for fishing to $65 per day for a camping and fishing day. The studies listed in Table 6 do not provide estimates of the consumer surplus associated with hiking or general recreation on the mainland.

Table 6: Literature estimates of average consumer surplus per activity day for selected outdoor recreation activities in Florida

WTP, 2004$/ person/day	*Valuation method*	*Habitat type*	*Primary activity*	*Respondents*	*Study*
$65.02	TCM	River	Camping, fishing	R	Gibbs (1974)
$15.13	CVM	Other	Fishing	n.a.	Brown and Hay (1987)
$30.28 [1]	TCM	Florida keys	General recreation	R&NR	Bowker and Leeworthy (1998)
$189.46 [2]	TCM	Florida keys	General recreation	R&NR	Bowker and Leeworthy (1998)
$55.61	CVM	Other	Hunting	R&NR	Waddington et al. (1991)
$26.89	CVM	Other	Hunting	n.a.	Brown and Hay (1987)
$18.49	CVM	Other	Hunting	n.a.	Brown and Hay (1987)
$52.90	CVM	Other	Wildlife viewing	R&NR	Waddington et al. (1991)
$26.89	CVM	Other	Wildlife viewing	R&NR	Hay (1985)
$33.36	CVM	Other	Wildlife viewing	n.a.	Connelly and Brown (1988)

Notes: [1] Hispanic respondents. [2] White respondents. R – residents only; R&NR – residents and non-residents. n.a. – not available.
Source: Extracted from online spreadsheet database in Loomis (2005).

Although the consumer surplus estimates shown in Table 6 stem from studies carried out in Florida, it is difficult to assess the extent to which their particular study contexts, especially the site characteristics, are similar to those found in the prime recreation sites in our study area. In order to assess how the values from the Florida studies compare to regional values, and to obtain consumer surplus estimates for hiking, we present a second set of estimates from studies that examined consumer surplus values of recreationists throughout the southeastern U.S. (Table 7). In general, these values are not necessarily inferior indicators of the values recreationists receive in our study area, since they represent averages from in most cases much larger numbers of observations than are provided by the Florida studies. In any case, a comparison of Tables 6 and 7 shows that the means of the consumer surplus

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

estimates of particular recreation activities in the Florida studies and the Southeast studies are fairly similar.

Table 7: Average consumer surplus per person of selected recreation activities - studies for southeastern U.S., 1967-2003

	Consumer surplus per activity day			*N*
	Minimum	*Mean* *2004$*	*Maximum*	
Camping	3.3	25.79	65.02	11
Fishing	3.6	79.21	556.82	27
General recreation	5.02	42.77	189.46	9
Hiking	1.87	60.38	262.04	7
Hunting	5.69	35.36	82.8	44
Wildlife viewing	2.86	40.10	134.34	54

Notes: Southeast includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia. N – number of observations.
Source: Loomis (2005)

For our analysis, we use the lower one of the estimates shown in Tables 6 and 7, after averaging the values for hunting, fishing and wildlife viewing, activities for which multiple estimates exist from Florida studies (see Table 6). We exclude environmental education from the consumer surplus analysis because most participants in this activity are not adults and are not necessarily engaging in the activity of their own volition. Exclusion of environmental education visitors will result in a downward bias in our value estimate as undoubtedly some participants do value that activity. We assume that a total of 90,000 visitors engage primarily in wildlife viewing (Table 5) and that the average length of time these individuals spend on-site is two hours (pers. comm, Lori Piper, Corkscrew Swamp Sanctuary). We assume that the average length of fishing and hunting trips in our area is the same as for the state as a whole (1.4 days; U.S. Fish and Wildlife Service and U.S. Census Bureau, 2002) and that the average length of hiking and camping trips is one activity day.

Multiplying the average consumer surplus per activity day by the number of total activity days yields an estimate of the total consumer surplus, or net economic benefit, associated with each activity (Table 8). Total annual consumer surplus of the included recreational activities in the study area is estimated at $1.3 million (2004$).

Spending on recreation activities commonly is distinguished into equipment and trip expenditures. Since equipment may be used for a variety of activities other than a particular recreation activity such as hunting, including equipment purchases in estimates of the spending on a particular recreation activity may lead to overestimates of spending attributable only to that activity. Thus, in the interest of generating conservative estimates, we only include trip expenditures in our analysis of spending associated with recreation in our study area. These include spending on food, lodging, transportation and other items such as gifts or entrance fees.

Table 8: Consumer surplus values used in our analysis

Activities in study area	*CS per activity day, 2004$*	*Est. number of participants per year*	*Total est. activity days per year*	*Total CS, 2004$*
Wildlife viewing	37.72	90,000	15,000	565,765
Hiking	60.38	2,000	2,000	120,760
Camping	25.79	50	50	1,290
Environmental ed.	- excluded from analysis -			
Hunting	33.66	382	535	18,022
Angling	40.07	10,000	13,931	558,288

Notes: Conversion of visitation numbers into visitor days assumes average length of wildlife viewing trip on site is two hours (pers. comm., Lori Piper, Corkscrew Swamp Sanctuary). Average trip length is estimated to be 1.4 days for hunting and fishing (U.S. Fish and Wildlife Service and U.S. Census Bureau, 2002) and a full activity day (12 hours) for camping and hiking.
Sources: Tables 6 and 7.

The most recent information on trip expenditures for wildlife-associated recreation in Florida is from the Fish and Wildlife Service's and the Census Bureau's (2002) *2001 National Survey of Fishing, Hunting and Wildlife-Associated Recreation*.[11] This information indicates that residents and nonresidents on average spent different amounts on wildlife-associated trips (Table 9). It is thus necessary to distinguish recreation visitors in our analysis into state residents and out-of-state participants. Because information on the breakdown of total days by recreation activity into these two groups is not available for our study area, we use information for the state as a whole (Table 10).

Table 9: Average trip expenditure of recreationists in Florida per activity day

Avg. trip expenditure per activity day	*Residents*	*Nonresidents*
	2004$	
Wildlife viewing [1]	6	113
Freshwater fishing	41	110
Hunting	24	112

Notes: [1] Away from home.
Source: U.S. Fish and Wildlife Service and U.S. Census Bureau (2002)

We were unable to obtain information on average trip expenditures per hiking day and resident vs. out-of-state composition of hikers. We assume instead that hikers on average spend as much per activity day as resident wildlife viewers, that is, $6. Total annual trip expenditures by recreation visitors to our study area are estimated at $1.3 million per year (Table 11).

[11] The 2006 update of the *National Survey of Fishing, Hunting and Wildlife-Associated Recreation: Florida* will be published in early 2008 and will provide updated data. However, as of the time of our study, the 2001 data are the most recent available. The 2006 *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: State Overview* (U.S. Fish and Wildlife Service's and U.S. Census Bureau, 2007) published in November 2007 does not provide state-level data needed to calculate expenditure-per-activity day estimates.

Table 10: Share of Florida residents and out-of-state participants in wildlife-associated recreation activities in Florida in 2001

	Residents	*Nonresidents*
Wildlife viewing [1]	65%	35%
Hunting	98%	2%
Freshwater fishing	90%	10%

Notes: [1] Away from home.
Source: U.S. Fish and Wildlife Service and U.S. Census Bureau (2002)

Table 11: Estimated annual trip spending by recreationists in study area

<table>
<tr><th></th><th>Residents</th><th>Nonresidents</th><th>Total</th></tr>
<tr><td></td><td colspan="3">2004$</td></tr>
<tr><td>Wildlife viewing [1]</td><td>61,776</td><td>593,675</td><td>655,451</td></tr>
<tr><td>Hunting</td><td>513,207</td><td>153,358</td><td>666,565</td></tr>
<tr><td>Freshwater fishing</td><td>12,427</td><td>1,196</td><td>13,623</td></tr>
<tr><td>Hiking</td><td colspan="2">12,672</td><td>12,672</td></tr>
<tr><td>Total</td><td></td><td></td><td>1,348,312</td></tr>
</table>

Finally, summing consumer surplus and expenditures, we can obtain the total economic value, measured as willingness-to-pay, recreation visitors assign to recreation activities in the area. This value is an estimated $2.6 million ($2004) per year. Roughly half of this is spent on engaging in the various activities, while the remainder constitutes a net benefit for recreation visitors.

Property value premiums

The open spaces in our study area include over 47,000 acres of protected state, local and private lands (Table 12), as well as unprotected private lands that currently are still undeveloped. Evidence from a large volume 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 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 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.

Table 12: Ownership of protected lands in the study area

Owner	*Acres*
Collier County	
McIntosh	7
School Board Property - Section 24	66
Winchester Head	5
Red Maple Swamp Preserve	61
Lee County	
Gator Hole Preserve	177
Wild Turkey Strand Preserve	591
Pine Lake Preserve	129
Imperial Marsh Preserve	236
South Florida Water Management District	
Lake Trafford Impoundment	635
Critical Flowway	34
Corkscrew Regional Mitigation Bank	644
Corkscrew Regional Ecosystem Watershed	26,054
Okaloacoochee Slough State Forest	4,654
Private	
Panther Island Mitigation Bank	2,778
Corkscrew Swamp Sanctuary	10,545
Bar Ranch Conservation Easement	562

Source: GIS analysis of map layers from Florida Natural Areas Inventory (2006).

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.

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

Table 13: 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.[12] They included only those studies that examined predominantly "natural" open spaces, excluding crop lands and heavily-developed urban recreational areas. Their estimated meta-analysis-based regression function has the following form[13]:

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

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.[14] 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 14.

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

[13] 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.

[14] $0.4221*10 - 0.0068*(10^2) = 3.5$.

Table 14: 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.
Source: Kroeger et al. (2008)

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 our study area. We conducted separate analyses for the protected private, unprotected private, and public lands in the study area, by setting the values of all variables in the function such that they reflect the particular local context of the different open spaces in our study area. We defined open space as undeveloped, relatively undisturbed natural lands. As a result, we did not include agricultural lands and golf courses in our analysis. We also generally did not include open spaces in low density residential areas. However, in certain locations, particularly in the eastern outskirts of Naples where the density of residential structures is very low, we used our qualitative judgment to decide whether or not an undeveloped area constituted primarily natural open space.

We used U.S. Census Bureau (2002) data and maps to partition our study area into subsections and to identify the number of those properties in the Census tracts, block groups, or individual blocks contained in these subsections that were located within one mile of open spaces in our study area (Table 15). In all cases, the properties in these subsections are located within a roughly one-mile radius of the natural open spaces.

Utilizing Google Earth satellite imagery, we identified large individual open spaces in the different subsections of the study area and estimated for each of the subsections the percentage that open space accounts for within a one-mile radius of the average property (Table 15). 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. Nevertheless, this truncation will tend to decrease the aggregate open space premium estimate for the areas because the additional benefits of protected open space at larger distances are unlikely to be zero.

Table 15: Location and number of housing units in study area located within one mile of natural open space

Location of residences by county and Census subdivision		*Number of housing units*	*Open space as % of area within one mile of average property*
Collier Co.	CT 104.07	875	20%
	CT 104.11	1,993	15%
	CT 104.12	1,716	30%
	CT 104.13	741	50%
	CT 104.14	821	20%
	CT 105.03	31	20%
	CT 112.01	1,206	50%
	CT 112.02	627	60% *
	CT 112.04	1,162	50%
	CT 112.05	989	30%
	CT 113	2,318	25%
	CT 114	846	25%
Lee Co.	CT 401.05	174	40%
	CT 502.02	513	15%
	CT 502.03	242	10%
	CT 503.06	231	40%
	CT 503.08	58	30%
	CT 503.09	2,399	40%
	CT 503.10	1,163	25%
Hendry Co.	CT 5	8	30%
		18,113	

Notes: The number of housing units shown refers only to those units that lie within 1 mile of an open space within our study area. CT – Census tract. * This value exceeds the upper limit (50%) of the range of values over which our model was estimated. We adjusted this value to 50% before applying our model.
Source: U.S. Census Bureau (2002). Percentage of open space within a one-mile radius of the average property estimated based on satellite imagery.

With the open space percentage (*%OSChange* in eq.1) identified for each subsection of our study area, we set the indicator variables in the function at their appropriate values. Depending on whether a particular open space was a wetland or forested, the *FOR* variable was set to zero or one (1), respectively. The *PRIV* variable was set to one (1) if the space in question was privately owned, and to zero if it was publicly owned. For open spaces that are privately-owned and protected by easements (as in the case of Audubon's Corkscrew Swamp Sanctuary and the Bar Ranch Conservation Easement), both the *PROT* and *PRIV* variables were set to one. All other variables were set to zero.

Our analysis indicates that the average open space premium received by residential properties is estimated to range from about three percent to about eight percent for the different communities (Table 16), 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 16).

Table 16: 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$)*	*Avg. property premium*	
				% of property value	*Total value (million 2004$)*
Collier Co.	CT 104.07	875	220,469	7.22%	13,928,107
	CT 104.11	1,993	107,405	6.31%	13,507,016
	CT 104.12	1,716	148,694	8.03%	20,489,273
	CT 104.13	741	153,111	5.54%	6,285,417
	CT 104.14	821	141,929	7.22%	8,413,025
	CT 105.03	31	90,502	7.22%	202,562
	CT 112.01	1,206	267,433	3.70%	11,933,391
	CT 112.02	627	124,052	6.28%	4,884,635
	CT 112.04	1,162	81,254	2.77%	2,615,349
	CT 112.05	989	65,289	8.03%	5,185,061
	CT 113	2,318	46,582	5.96%	6,435,419
	CT 114	846	69,390	5.96%	3,498,732
Lee Co.	CT 401.05	174	95,748	5.63%	937,970
	CT 502.02	513	121,550	6.31%	3,934,623
	CT 502.03	242	222,292	5.05%	2,716,629
	CT 503.06	231	94,136	5.63%	1,224,260
	CT 503.08	58	159,205	8.03%	741,480
	CT 503.09	2,399	72,005	7.46%	12,886,475
	CT 503.10	1,163	124,193	6.88%	9,929,991
Hendry Co.	CT 5	8	495,450	8.03%	318,277
					130,067,691

Notes: Column one summarizes properties by census tract only, not by the finer-scale block group level used in the analysis. 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: Number of housing units and median home values from U.S. Census Bureau (2002).

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 $130 million (2004$). Although this value is quite large, it is likely to be an underestimate of the actual total premium received by homeowners in the study area, because both the number and especially the average value of housing units in the area have increased substantially since 2000.

The estimated open space premium of around $130 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 property 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 ($130 million) as a principal that could be invested at market rates. The principal could generate a perpetual stream of annual payouts 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), the value of the annual payout would be $6.5 million (2004$).[15]

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 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 the 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 retention and generation, air quality, temperature modulation, scenic views) or producers (crop pollination from native pollinators[16]). Other services generate benefits also on a regional or even larger scales (water quality, water generation, 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 enjoyed by humans for recreational purposes is already partially accounted for in our analysis of the recreational value of the study area, in the form of fishing, hunting, and wildlife viewing values. 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 an estimate of the value of carbon sequestration and water provisioning services provided by the ecosystems in the 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

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[15] 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 $130 million) of the perpetual annuity A, and i is the annual interest rate.

[16] 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. Several of the crops grown on the agricultural lands in the study area - including melons, citrus and cucumbers - are partially dependent on native insects (in addition to domesticated honey bees) for their pollination (ibid.). Therefore, part of the value of those crops, estimated at over $372 million in 2000 (based on crop acreages in our study area and average per-acre revenues by crop from Townsend et al., 2004) is attributable to the undeveloped lands that provide the habitat for native pollinators.

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 approximately 528,000 acres of lands that make up the study area (Table 17), 55 percent (291,000 acres) are in non-agricultural lands featuring woody biomass.

Table 17: Land cover types and associated acreages in the study area

Class	*Acres*	*Class*	*Acres*
Sand/Beach	1	Open Water	10,451
Dry Prairie	24,975	Shrub and Brushland	1,131
Mixed Pine-Hardwood Forest	2,105	Bare Soil/Clearcut	44,729
Hardwood Hammocks and Forest	12,013	Improved Pasture	42,694
Pinelands	64,968	Unimproved Pasture	14,593
Cabbage Palm-Live Oak Hammock	694	Citrus	46,026
Freshwater Marsh and Wet Prairie	41,466	Row/Field Crops	35,404
Shrub Swamp	18,140	Other Agriculture	2,517
Cypress Swamp	56,353	Australian Pine	4
Cypress/Pine/Cabbage Palm	8,612	Brazilian Pepper	65
Mixed Wetland Forest	37,984	High Impact Urban	30,838
Hardwood Swamp	22,404	Low Impact Urban	8,497
Mangrove Swamp	1	Extractive	1,189
		Total acreage:	527,854

Source: Calculated from 2003 Florida Vegetation and Land Cover Data (Stys et al., 2004).

These lands absorb atmospheric carbon dioxide during the process of photosynthesis, part of which becomes stored in an increase of plant or soil biomass. The literature provides estimates of the annual net carbon fluxes for many of the non-agricultural ecosystems or vegetation communities that predominate in the study area, with the notable exception of dry prairie lands (Table 18).

Table 18: Net annual carbon sequestration rates by ecosystem type

Ecosystem type	*Location*	*kg C/ha/yr*	*C stocks included in analysis*	*Source*
Slash pine	South-central Florida	6,750	Total aboveground biomass and coarse roots	Clark et al., 1999
Cypress	South-central Florida	605	Total aboveground biomass and coarse roots	Clark et al., 1999
Southern hardwoods	Tennessee	5,250	Total aboveground biomass and coarse roots	Greco and Baldocchi, 1996
Pine-spruce wetland	Florida	4,260	Total aboveground and soil organic carbon	Li et al., 2004

Estimates of the annual net carbon flux estimates for the remaining major ecosystem types in the area can be based on actual net sequestration measurements of non-urban tree plots in the Tampa area carried out by the University of Florida's IFAS-School of Forest Resources and Conservation as part of a larger study.[17] The IFAS study measures sequestration in aboveground woody tree biomass for individual 0.04 hectare plots. The study data also document the tree species composition of all analyzed plots. Comparing the tree species in all plots with the dominant species in each of the particular habitats found in the study area allowed us to identify plots that contain ecosystem types found in our study area.[18] The annual net C sequestration estimates for the matching plots from the IFAS study are shown in Table 19.

Table 19: Net C sequestration in aboveground woody tree biomass in selected vegetation types in the Tampa area

Vegetation type	*Main species*	*IFAS plots No.*	*Avg. C sequestration, kg/ha/yr*
Shrub swamp	Willow, wax myrtle, primrose willow, buttonbush, red maple, and saplings of red maple, sweetbay, black gum and other hydric species	650, 683	1,417
Hardwood swamp	Black gum, water tupelo, bald cypress, dahoon holly, red maple, swamp ash	697, 875	5,263
Cypress swamp	Bald cypress, pond cypress	877	4,220
Hardwood hammock forest	Laurel oak, hop hornbeam, blue beech, sweetgum, cabbage palm, American holly, and southern magnolia	892	163
Mixed hardwood-pine forest	Longleaf pine, slash pine, and loblolly pine in mixed company with live oak, laurel oak, and water oak, together with other hardwood species	651, 682, 793, 874	2,871
Mixed wetland forest	Hardwoods mixed with pine or cypress	797	1,704
Cabbage palm/live oak hammock		313, 69	407
Cypress-Pine-Cabbage palm		746	127
Dry Prairie	<10-15 % palmetto and pine trees	69	58
Mangrove swamp	Red, back, and white mangrove	22	7,796

Source: Dr. Francisco Escobedo, IFAS - School of Forest Resources and Conservation, University of Florida at Gainesville.

In the case of six out of the ten vegetation types in our study for which we were able to identify matching plots in the IFAS study, there was only a single matching plot. Furthermore, some plots have only very low total tree biomass resulting in very low sequestration estimates for the plot. As a result, the C sequestration estimates of these plots

[17] Data provided by Dr. Francisco Escobedo, IFAS-School of Forest Resources and Conservation, University of Florida at Gainesville.

[18] Identification of the primary species of the habitats present in the study area was based on the habitat descriptions in the state's Comprehensive Wildlife Conservation Strategy (FWC, 2005).

may or may not be representative of the average sequestration rate of those vegetation types in the study area.

Importantly, the IFAS estimates measure only net C accumulation in aboveground woody tree biomass, that is, they do not include the C accumulated in soil and root biomass or in non-woody vegetation. Use of these estimates thus results in an underestimation of the total C sequestered by non-agricultural ecosystems in the study area, particularly in the dry prairie ecosystem in which trees generally account for less than 10-15 percent of total vegetation by area (FWC, 2005).

In estimating total net C sequestration in our study area we use the data from the published literature (Table 18) where possible because these estimates capture total (above and belowground) net C sequestration in the whole ecosystem while the IFAS data only capture above-ground woody tree biomass (Table 20). We use the IFAS values for the remaining vegetation types. Note that no estimates of sequestration rates are available for freshwater marsh and wet prairie or shrub and brush lands.

Table 20: Net sequestration estimates for vegetation types in the study area

Vegetation type	*Presence in study area*	*Avg. C sequestration*	
	ha	*kg/ha/yr**	*tons/yr*
Dry Prairie	10,107	58	586
Mixed Pine-Hardwood Forest	852	6,000**	5,111
Hardwood Hammocks and Forest	4,862	5,250**	25,523
Pinelands	26,292	6,750**	177,468
Cabbage Palm-Live Oak Hammock	281	407	114
Freshwater Marsh and Wet Prairie	16,781	n/a	n/a
Shrub Swamp	7,341	1,417	10,401
Cypress Swamp	22,806	4,220	96,229
Cypress/Pine/Cabbage Palm	3,485	3,677**	12,817
Mixed Wetland Forest	15,372	1,704	26,197
Hardwood Swamp	9,067	5,785	52,447
Mangrove Swamp	<1	7,796	2
Shrub and Brushland	458	n/a	n/a
TOTAL			406,895

Notes: n/a not available. *Unless otherwise indicated, values are based on IFAS data. **Based on data in Table 18.
Sources: Tables 17, 18, 19.

Based on the available data, we estimate that the ecosystems in the study area sequester over 400,000 tons net of C per year, or 1.6 tons per acre for the lands included in the analysis. This estimate does not include any sequestration by soils or vegetation on agricultural lands, and for most non-agricultural vegetation types in the area it excludes sequestration in the form of increases in soil organic matter and root biomass. In addition, the sequestration estimate does not include C storage in freshwater marsh and wet prairies, which make up ten percent of the vegetated lands in our study area. Our estimate therefore is likely to understate actual net C sequestration in the study area.

The value ofcarbon 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 Florida in particular have been documented (Field et al., 2007; Stanton and Ackerman, 2007; Alvarez, 1998), estimating the expected value of damages associated with climate change is impossible due 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.[19] 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 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

[19] 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.

were the result of changes in land management practices or of avoided loss of vegetation that would result under a business-as-usual approach from the expected growth of development in coastal south-central Florida (SFWMD, 2007b). 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).[20, 21] 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.[22]

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, 1.49 million tons of CO_2e, is equivalent to six percent of the total volume of voluntary transactions in 2006. [23] 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 voluntary and mandatory emission reductions, which is likely to raise demand for credits and increase prices.

Applying the low and high prices to the carbon sequestration estimates for our study area (Table 20) yields a total value of the sequestration services estimated at $5.1 million to $21.1 million per year (Table 21). The average estimate of the value of sequestration services, constructed by using the mean of low and high carbon prices, is $13 million per year.

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[20] 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.

[21] 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.

[22] 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.

[23] 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.

Table 21: Estimated annual value of carbon sequestration services provided by study area ecosystems

	LOW scenario	*HIGH scenario*
Quantity of C sequestered (metric tons)	406,895	
Corresponding quantity of CO_2 (metric tons)	1,492,085	
Price per ton of CO_2e (2004$)	3.41	14.21
Value of carbon sequestration (2004$)	5,088,052	21,202,954

Note: Quantities of carbon dioxide are derived by multiplying the volume of sequestered carbon by 3.667, the ratio of the weight of CO_2 to that of C.

These results suggest that carbon sequestration is the second highest value generator in the study area, behind water provision but before open space real estate premiums.

Water provision

The undeveloped lands in the study area also provide water for human and environmental uses (e.g., wetland hydration) that generate benefits for society. Aquifers represent an important source of water for human uses in the study area (Fairbank and Hohner, 1995; South Florida Water Management District [SFWMD], 2007a). The surficial aquifer system (SAS), which consists of the water table and the lower Tamiami aquifer, and the intermediate aquifer system (IAS), which consists of the Mid-Hawthorn and the Sandstone aquifers, together provide most of the freshwater supply for public drinking water, agriculture, commercial and industrial uses and landscape irrigation within the Lower West Coast planning area (Table 22). This area includes Lee county, most of Collier and Hendry counties, and portions of Glades, Charlotte and Monroe counties (SFWMD, 2000, 2007a). As pointed out in the SFWMD's proposed minimum water level criteria (SFWMD, 2000), "[t]he reliable yield of water from this [water table] aquifer provides a significant role in the economy of the region."

Table 22: Utilization of surface and groundwater resources in the South Florida Water Management District

	Utilization by county in 2000, million gal/yr				
	Lee	*Collier*	*Hendry*	*Charlotte*	*Glades*
Surface water	56,235	43,861	37,966	-	14,654
Aquifers					
Water table	36,381	43,182	7,087	792	2,157
Lower Tamiami	5,521	53,505	14,256		
Intermediate Aquifer System	13,473	7,144	3,676	-	2,748
Floridian Aquifer	22,489	7,774	-	718	-

Source: SFWMD, 2000.

The undeveloped lands in the study area allow the recharge of the surficial aquifer system through the infiltration of precipitation, and of the intermediate aquifer system through downward leakage of water from the surficial aquifer. This natural recharge of the surficial and intermediate aquifer systems in the Lower West Coast planning region, which are being drawn down by increasing human water withdrawals, is crucial to counteract saltwater intrusion and comply with wetland drawdown restrictions and other environmental quality considerations (SFWMD, 2000, 2007a, 2007b).

The projected population increase in the Lower West Coast planning area from 908,500 in 2005 to 1.6 million by 2025 as well as increased industrial and agricultural operations and thermoelectric power generation result in an expected increase of water demand by about 243 million gallons per day by 2025 compared to 2005 levels (SFWMD, 2007b; see Table 23). Because of constraints on expanding existing supplies, most of this increased demand will need to be met from alternative sources, such as reclaimed water, surface water captured during wet-weather flows, aquifer storage and recovery and surface reservoirs, and desalinated brackish surface water and groundwater (ibid.).

Table 23: Estimated raw water withdrawals in the Lower West Coast planning area in 2000 and 2005, and projected withdrawals in 2025

Use type	*Volume, (million gal/day)*		
	2000	*2005*	*2025*
Public supply and domestic self supply	138.61	169.69	303.3
Industrial and commercial self-supply	26.6	26.6	28.9
Recreational self supply, gross irrigation demand	50.2	52.6	62.2
Thermoelectric power, self supply	0.2	0.5	66.9
Agricultural self-supply, gross irrigation demand	689.8	698.1	729.2
Total	905.4	947.5	1190.5

Source: SFWMD (2007b), Appendix D.

Based on the South Florida Water Management District's study of the potential precipitation recharge of the surficial aquifer system for the Lower West Coast Planning Region, the estimated average annual precipitation recharge (infiltration minus leakage) for most of the study area is between 43 and 56 inches (Fairbank and Hohner, 1995; see appendix 1).[24]

Because built-up lands reduce infiltration (Fairbanks and Hohner, 1995), we exclude from our recharge land base those lands classified as low-impact or high-impact urban. We also exclude lands classified as extractive and open water (see Table 17). This leaves approximately 476,900 acres of lands in our study area that recharge the surficial aquifer system through infiltration of precipitation. With an estimated average 43-56 inches of recharge per year, the non-urban portion of our study area provides an estimated 1.7-2.2 million acre-feet of precipitation-based recharge into the surficial aquifer system per year (Table 24).

[24] Some lands in the study area have lower (<43 in/yr) recharge rates, as indicated by the light blue areas in plate III in Fairbanks and Hohner (1995), reproduced here in Appendix 1. However, a roughly equal amount of land in the study area is classified as higher (≥56 in/yr) recharge lands. Thus we assume that the average recharge rate for the study area as a whole is 43-56 in/yr.

Table 24: Total estimated volume of annual recharge of surficial aquifer provided by study area

Recharge volume (acre-feet)	
Lower bound	*Upper bound*
1,708,810	2,225,427

Notes: Excludes areas classified as low-impact urban, high-impact urban, and extractive (see Table 17). Lower bound estimate based on average recharge rate of 43 in/yr; upper bound estimate based on average recharge rate of 56 in/yr (Fairbank and Hohner, 1995).

In 2000, the surficial and intermediate aquifer systems supplied 51 percent (189.9 billion gallons) of the total human water use in the Lower West Coast planning area (Table 22). This volume is equivalent to 26-34 percent of the total aquifer recharge provided by the lands in our study area, depending on whether the lower or the higher average recharge rate is used. Our study area accounts for less than 20 percent of the 5,129 square miles (3.28 million acres) covered by the LWC planning area (SFWMD, 2007b). However, the area contains many of the most important recharge lands in the region for the surficial (and thus the intermediate) aquifer system (Fairbank and Hohner, 1995). Thus, it is clear that human withdrawals from the surficial and intermediate aquifer systems represent a substantial demand on the groundwater resources of the region. The fact that the SFWMD plans to rely primarily on non-traditional sources to cover future water demand increases in the LWC planning area suggests that the limits of sustainable withdrawal volumes of fresh groundwater are being reached in the region. In fact, the saltwater intrusion into aquifers in coastal areas suggests that these limits may have been surpassed in some areas.

On the basis of this assessment, the volume of the water provision services rendered by the ecosystems in the study area currently appears to be similar to the human withdrawals from the surficial and intermediate aquifer systems in the Lower West Coast planning region.

Value of fresh groundwater provisioning services

Determining the economic value generated by a given quantity of water is not a trivial undertaking. Although water, unlike many other ecosystem goods, is traded in markets, the prices paid by most users generally do not reflect the real scarcity value of water (Hanemann, 2006).[25] Water prices thus are a poor indicator of the water's value, 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 SAS and IAS is the sum of all marginal net benefits generated in the uses that water is put to.

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

Those marginal values however are not readily discernable because as is true for all goods or services, the value of water is not static. Rather, it 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 SAS and IAS, 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 profits or net utility the water generates in the many uses to which it is put by households, industrial, commercial, agricultural and recreational users. Knowledge of these marginal water values would allow one to construct the demand function for aquifer water for each of these user groups, and thus to estimate the total value of the water by integrating the functions. Unfortunately, information on the net marginal benefits produced by aquifer water in the study area is not available.

Lacking information on marginal values, a second-best approach to valuing the aquifer water withdrawals is to use the opportunity cost of providing that water, that is, the cost of alternative water provisioning approaches that would be required to substitute the groundwater pumped from the SAS and IAS. This cost should 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).

Using the opportunity cost of alternative water sources to estimate the value of groundwater withdrawals could lead to an over- or underestimation of groundwater values. An overestimation could result if the cost of alternative sources is higher than that of current groundwater uses. In that case, using those alternative costs to estimate the value of replacing the groundwater could lead to the overestimation of the groundwater value *if and only if* the water demand is price-elastic, that is, if some users would in fact elect to reduce their water consumption levels at higher prices.[26] As is the case for most goods, demand for water indeed is price-elastic within certain limits and depending on source substitutes (Whitcomb, 2005).

In 2003, single-family home residential water rates in southwestern Florida were $1.39 per 1,000 gallons for the first 3,700 gallons in Tampa and $1.84-$2.66 per 1,000 gallons for the first 4,000 gallons in Sarasota. These prices are similar to the supply costs for the more expensive alternative water sources (see below). Thus, increased development and use of alternative water sources would not be expected to necessarily result in price increases compared to conventional sources, although a more detailed analysis would be needed to answer this question.

In any case, any overestimation bias caused by ignoring the price elasticity of water demand would be counteracted by the fact that, as pointed out above, cost-based estimates of the value of water do not capture the scarcity value of water and thus result in an underestimation of the value of groundwater withdrawals. Thus, the volumes of water that are not "displaced" by the higher alternative prices would still be undervalued in a cost-based analysis.

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[26] This failure to incorporate the price elasticity of demand is the principal reason why use of replacement costs is the least preferred approach in economic valuation exercises.

The South Florida Water Management District has identified several alternative or nontraditional water sources that will supply the majority of future demand growth in the LWC planning region (SFWMD, 2007a, 2007b). These sources, as well as their respective projected additional supply volumes, are shown in Table 25.

Table 25: Nontraditional water sources in the LWC planning area and estimated available additional volumes

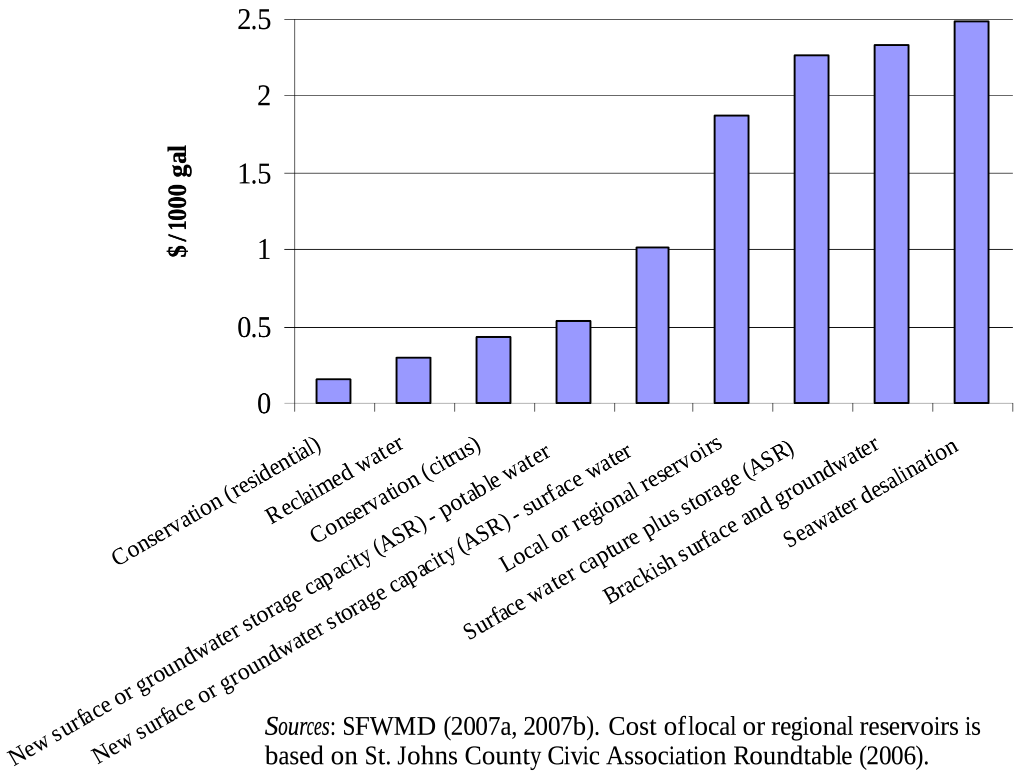
Source	*Estimated additional available volumes Million gallons per day (MGD)*
Residential conservation measures [1]	22
Conversion of remaining flood-irrigated citrus groves to micro-irrigation [2]	36.1
Water reclamation [3]	8.26
New surface or groundwater storage capacity (ASR) - potable water	*
New surface or groundwater storage capacity (ASR) - surface water	*
Local or regional reservoirs	*
Surface water capture plus storage (ASR) [4]	*
Desalination - Brackish surface and groundwater (Floridian aquifer)	Large
Desalination - Seawater	Unlimited for practical purposes

Notes: ASR – Aquifer storage and recovery. * Insufficient data to determine available volumes. [1] The SFWMD (2007a) analysis assumes a 75 percent adoption rate for three measures: showerhead and toilet retrofits for pre-1984 houses, and rain sensors for outdoor irrigation systems. [2] In 2005, 66 percent of the total of 168,118 acres of citrus groves in the LWC already was micro-irrigation irrigated (SFWMD, 2007b). The estimated savings of converting an acre of citrus grove from flood- to micro-irrigation are 230,800 gal/acre/yr (Institute of Food and Agricultural Sciences, 1993). However, several growers in the LWC that use flood irrigation use rain harvesting, recycling water after each use and moving it from one citrus grove to another. Potential savings from switching from flood to micro irrigation therefore will be lower than those projected here, which assume conventional flood irrigation without water recycling. [3] In 2005, 90 percent of treated wastewater in the LWC planning area was already reclaimed. The 8.26 MGD constitute the remaining ten percent of treated wastewater flows. [4] Captured primarily during wet weather events/wet season.
Sources: SFWMD (2007a, 2007b).

As Table 25 indicates, it is impossible to estimate based on available information the potential contribution of several of the alternative water supply sources considered in the LWC planning area. Furthermore, the potential additional supplies from the nontraditional water sources listed in Table 25 are not in all cases mutually compatible. For example, if implementation of residential conservation measures were increased, wastewater flows would be reduced, thus reducing the volume of water available for reclamation. With 90 percent of treated wastewater already reclaimed in the LWC in 2005 (SFWMD, 2007a), the net water gain that would result from the implementation of the top three residential conservation measures would be equivalent to only ten percent of the gross reduction in residential water use. Likewise, precipitation collection and storage systems increase water supply partially at the expense of aquifer recharge and surface water sources, because a portion of the collected flows otherwise would have percolated into the SAS and IAS or would have been absorbed by rivers and lakes currently used as fresh water supplies.

To estimate the minimum cost of alternative water sources providing the 482 MGD supplied by the SAS and IAS in the LWC planning area in 2005, we used source-specific supply cost estimates for the alternatives, based on the Consolidated Water Supply Plan Support Document 2005-2006 (SFWMD, 2007a) and the Lower West Coast Water Supply Plan 2005-2006 Update (SFWMD, 2007b).[27]

As shown in Figure 4, the costs of the various sources vary considerably, with the most expensive (sea water desalination) being about twenty times as costly per unit of water supplied as the least expensive (residential water conservation).



Sources: SFWMD (2007a, 2007b). Cost of local or regional reservoirs is based on St. Johns County Civic Association Roundtable (2006).

Figure 4: Cost of alternative water supply sources in the LWC planning region

Our estimate assumes that residential and citrus grove water conservation together with increased reclamation could supply an additional 46.6 MGD (only ten percent of the 22 MGD estimated achievable water savings from efficiency gains in residential water use would constitute net additional supplies – those ten percent being the currently not reclaimed share of treated wastewater). Since the volumes of potential supplies from the less costly remaining nontraditional sources are uncertain, we construct two scenarios (Table 26).

[27] The costs include facility design, construction, general operation and maintenance, land costs, raw and finished water storage (at the treatment facility site), and concentrate disposal (via deep well injection). No high-service pumping or connection costs for finished water transmission mains were included in the estimates.

In the first, low-cost scenario, the remainder of the volume required for substitution of SAS and IAS water is provided in equal shares by new surface or groundwater storage capacity (ASR) of potable and surface water, respectively. The second, high-cost scenario assumes that the remainder of substituted SAS and IAS water is supplied in equal shares by all sources listed in Table 26.

Table 26: Water supply shares of alternative sources used in cost scenarios

Nontraditional source	*Shares / Volumes of substituted SAS and IAS water supplied by nontraditional sources*	
	Scenario 1	*Scenario 2*
Residential conservation measures	0.5 % (2.20 MGD)	0.5 % (2.20 MGD)
Water reclamation	1.7 % (8.26 MGD)	1.7 % (8.26 MGD)
Conversion of remaining flood-irrigated citrus groves to micro-irrigation	7.5 % (36.1 MGD)	7.5 % (36.1 MGD)
New surface or groundwater storage capacity (ASR) - potable water	45.2 % (217.5 MGD)	16.3 % (72.5 MGD)
New surface or groundwater storage capacity (ASR) - surface water	45.2 % (217.5 MGD)	16.3 % (72.5 MGD)
Local or regional reservoirs	-	16.3 % (72.5 MGD)
Surface water capture plus storage (ASR)	-	16.3 % (72.5 MGD)
Desalination - Brackish surface and groundwater (Floridian aquifer)	-	16.3 % (72.5 MGD)
Desalination - Seawater	-	16.3 % (72.5 MGD)

Notes: See Table 25 for explanations.

It is impossible to assess whether or not these scenarios are feasible, particularly the low-cost Scenario 1 which assumes that new surface or groundwater storage with a total delivery capacity of 435 MGD could be achieved in the LWC planning area. Thus, especially Scenario 1 may be overly optimistic and thus may underestimate the value of the water provided by the SAS and IAS.

Using the two provisioning scenarios (Table 26) and source-specific water costs (Figure 4) to value the water provision services provided by the study area lands results in an estimated annual value of those services of $130 million (Scenario 1) to $285 million (Scenario 2).

Local economic impacts associated with uses of natural lands

In this section we develop estimates of the economic impacts associated with human uses of the natural lands in the study area. Because timber harvesting in our study area is rather limited and likely to be nonsustainable,[28] and because no reliable data on harvest levels was available, we limit our analysis to economic impacts associated with recreational uses.

Economic impacts of trip expenditures by recreation visitors

The estimates of recreation visitors' trip expenditures only represent the first-round of economic impacts associated with that spending. These first-round impacts consist of retail sales in sectors that directly cater to recreationists, such as gas stations, restaurants, hotels and grocery stores, to name a few. The sales impact these sectors receive ripples through the economy because no sector operates independently. The sectors that register the first-round, direct sales impact from recreationists' spending in turn increase their demand for inputs, which results in increased sales in the sectors supplying these inputs, and so forth. These impacts are commonly referred to as indirect impacts. At each turn, some additional output is generated. In addition, the direct and indirect increases in sales lead to increases in jobs and earnings, that is, in salaries, wages, and proprietors' incomes in the sectors directly or indirectly affected by recreation-related spending. Part of this increase in earnings is spent, thus generating further sales, which are referred to as induced impacts.

The ratio of initial, first-round sales impacts and final, total impacts is represented by multipliers. These multipliers are derived from regional economic impact models that combine empirical data on the interrelations between all sectors in the economy.[29]

To estimate the impacts recreation trip expenditures in our study area generate in the Florida economy, we use total output, earnings and job multipliers reported for wildlife watching (Southwick Associates, 2003), freshwater fishing (Southwick Associates, 2007) and hunting (Southwick Associates, 2002) in Florida, shown in Table 27. We use the wildlife viewing multipliers for hiking as we were unable to identify hiking-specific multipliers in the literature.

Table 27: Total output, earnings, and job multipliers of recreationists' trip expenditures in Florida

	Total effect multipliers		
	Output ($/$)	*Earnings ($/$)*	*Jobs (jobs/million $)*
Wildlife viewing	1.882	0.518	20.87
Freshwater fishing	1.712	0.527	16.98
Hunting	1.790	0.452	18.39

Sources: Based on data in Southwick Associates (2002, 2003, 2007).

[28] Pers. comm., Kevin Podkowka, Forestry Resource Administrator, Caloosahatchee Forestry Center, Ft. Myers, Florida, Nov. 16, 2007.
[29] See for example U.S. Department of Commerce (1997).

We now can derive total impact estimates for recreation activities in the study area by multiplying the trip expenditures of recreation visitors to our study area by the respective multipliers. Our analysis indicates that the ecosystems in our study area attract recreation visitors whose spending generates an estimated $2.4 million in total output and $700,000 in earnings year and supports an estimated 26 jobs (Table 28). A portion of these total economic impacts occurs in the study area region, with the balance occurring elsewhere in the state.

Table 28: Total output, earnings, and jobs generated in Florida by recreationists' trip spending in the study area

	Output (2004$)	*Earnings (2004$)*	*Jobs*
Wildlife watching	1,233,559	339,524	14
Freshwater fishing	1,141,160	351,280	11
Hunting	24,392	6,155	<1
Hiking	23,849	6,564	<1
Total	2,422,959	703,523	26

Not all of this economic activity and the jobs it supports would necessarily disappear if the natural habitats in our area did not exist. However, some of this money would be spent on recreation activities or substitute goods elsewhere and generate economic impacts there, either in other regions of Florida or in other states. The regional and state economies thus clearly benefit from the recreation opportunities provided by the ecosystems in the study area.

The actual economic impact of the natural lands in the study area is likely larger than indicated by our estimates because these estimates consider only trip-related expenditures and thus omit the impacts associated with spending on wildlife-related equipment such as cameras, binoculars, or fishing and hunting equipment. Annual spending on equipment surpasses trip-related spending (FWS and CB, 2007). Thus, the economic impacts associated with the study area are likely to be twice as large as our estimates suggest. By comparison, for the state as a whole, in 2006 retail sales from spending on wildlife-associated recreation activities in the state were an estimated $6.8 billion, generating $706 million in state and local taxes and a total statewide economic impact of $11.6 billion and supporting almost 120,000 jobs (Florida Fish and Wildlife Conservation Commission, 2008b).

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., 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 provision or carbon sequestration services) 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 individual 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 value estimates for several activities supported by undeveloped lands in an 825 square-mile area in southwestern Florida. This area is largely composed of land identified as being of high or very high ecological value. Our analysis includes the value associated with open space premiums that accrue to residential properties located in the vicinity of undeveloped open spaces; the value associated with outdoor recreation activities practiced in the area by local residents and visitors; and the value of two ecosystem services provided by the undeveloped lands in the area: carbon sequestration and water provision. The lands in question provide a number of additional uses, such as support for educational and research activities, habitat provision for threatened, endangered, rare or "charismatic" species like the Florida panther or Florida black bear or for native pollinator insects that support agricultural crops, among others. We did not include these uses in our analysis for lack of the required data. In addition, our value estimates for the activities we do include generally are rather conservative, for two reasons. First, in many cases our unit-value estimates are likely to be conservative, since in cases where more than one estimate was available we generally chose the lower one. Second, available data for several of the activities included in our analysis are almost certain to be underestimates because, as in the case of outdoor recreation activities, these data were available only for portions of the study area.

Despite the resulting unavoidable downward biases in most of our value estimates, our analysis shows that the undeveloped lands in the study area generate substantial economic value. The total estimated annual value of the land uses included in our analysis ranges from $145 million to $315 million, depending on the prices used to value carbon sequestration and water provision services provided by the lands (Table 29). It should be noted that the higher estimate is very far from being an upper bound on the values generated by the lands, because even this higher estimate is based on carbon credit and water provisioning prices that do not represent the high end of the respective price ranges. Also, due to frequent changes in some of the prices we used to value these ecosystem services, our estimates should be seen as approximations to the actual values, not as accurate measurements of those values.[30] Nevertheless, our analysis shows that the value of the two ecosystem services included in our study – water provision and carbon sequestration – far exceeds the value generated by direct uses of the study area – recreation and residential open space property value premiums. The uncertainties surrounding an accurate pricing of these services are not expected to affect this result, as our service prices are likely to be conservative.

Table 29: Annual value of selected uses of undeveloped lands in study area

	Low estimate	*High estimate*
	million 2004$ per year	
Open space property value premiums	6.5	6.5
Recreation	2.6	2.6
Ecosystem services:		
Carbon sequestration	5.1	21.2
Water provision	130	285
TOTAL	145	315

Note: The value of open space property price premiums shown in the table is the annual benefit flow (see p. 23)

Considering the omission from our analysis of several other economically important services provided by the undeveloped lands in the study area, such as pollination of agricultural crops by native pollinators, erosion control, water quality improvements through reduction of nutrient loading of surface waters from agricultural lands, or provision of habitat for species that carry existence value for people, and due to the downward bias in our value estimates, the actual economic value of the undeveloped lands is likely to be considerably higher than indicated by our estimates.

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 is only expected to increase over time.[31] Land use planning, in order to achieve economically sensible results, should take into account the economic value generated by the conservation of undeveloped lands and the fact that the increasing relative scarcity of these lands will only

[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.

increase conservation values. Since a large share of both ecologically and economically valuable undeveloped lands is in private ownership, not just in our Florida study area but also at 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 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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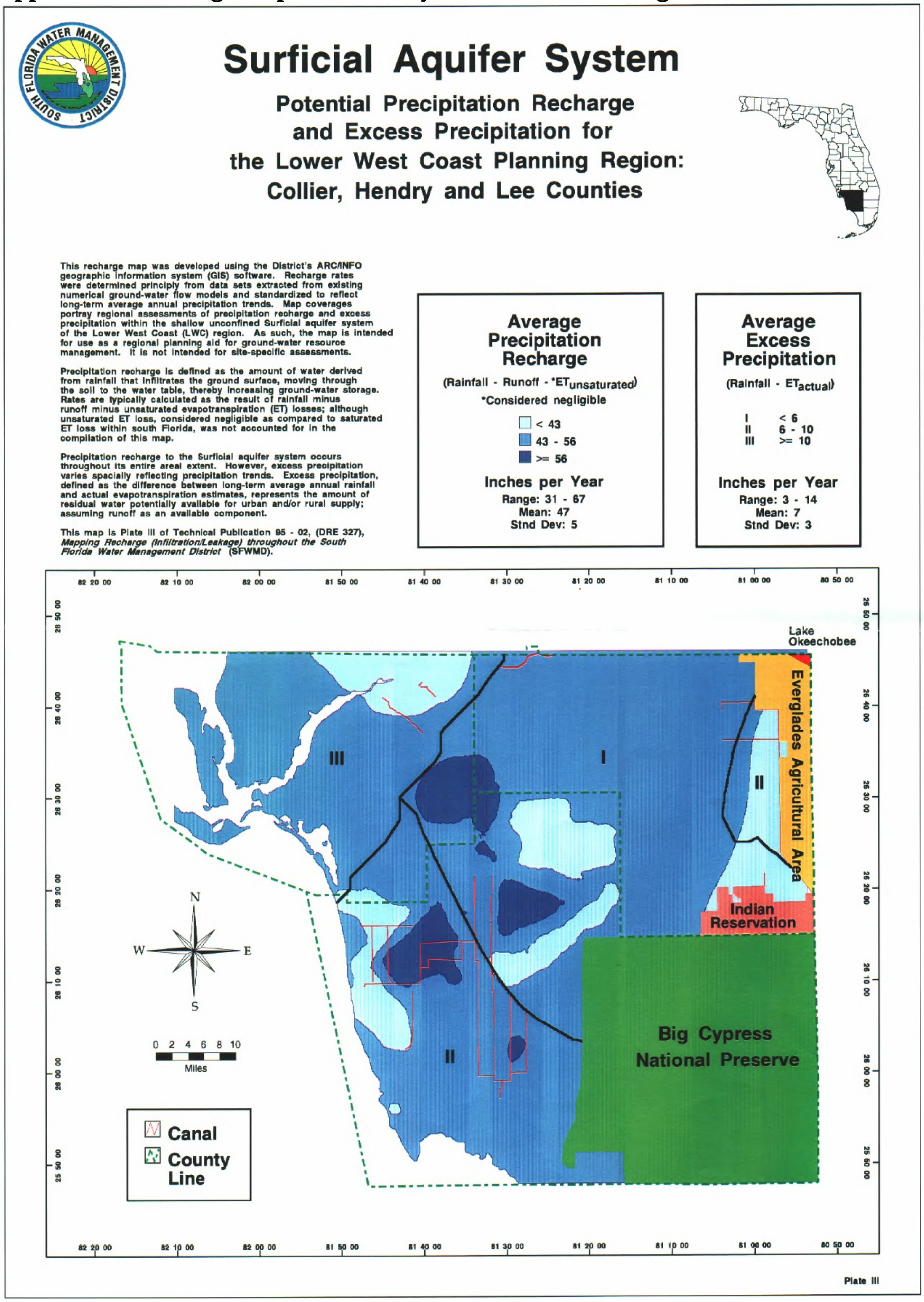
Appendix 1: Recharge map for the study area and surrounding lands



Source: Fairbank and Hohner (1995)