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Neighborhood Scale Quantification of Ecosystem Goods and Services

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Neighborhood scale quantification of ecosystem goods and services.

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TABLE OF CONTENTS

INTRODUCTION

Humans both alter and benefit from ecosystems in many ways. In many places human presence dominates the landscape, especially in urban and agricultural settings. Every place on Earth is directly or indirectly affected in some way by humans. As a result, many now feel that humans should be included in the definition of ecosystems, while others still think of human activity as an extrinsic source of stress on ecosystems. Human actions often feed back through multiple and often complex interacting pathways to change the ecosystem goods and services that benefit humans. This feedback becomes part of natural, highly complex, cyclic processes. The concept of ecosystem goods and services (EGS) provides a view of ecosystems that is human-centric; and thus, makes it easier to consider human stress on ecosystems as intrinsic. Ecosystem goods and services close the feedback loops that link human actions to human costs and benefits from ecosystems. Mapping of ecosystem goods and services is useful for making this information available to the general public, their representatives, and scientists. Here, we present mapped inventories of ecosystem goods and services production at a neighborhood scale within the Tampa Bay, FL region. Comparisons of the inventory between two alternative neighborhood designs are presented as an example of how one might apply EGS concepts to land use decisions at this scale.

Ecosystem goods and services for an area of land/seascape are dependent on ecosystem type, the presence of human made complementary resources, such as a means of transportation or the presence of residential buildings, and the impact of human and natural stressors on that area. Changes in EGS can be estimated using a strictly supply side view or can take into account human demand functions. The supply side method can estimate changes in ecological structure and function due to replacement of an ecosystem by another ecosystem type at the landscape scale; e.g., forest change to agricultural land causes a net change in the landscape's ecological functions that then may change the supply of EGS and derived benefits. These EGS supplies only become realized and valuable when one accounts for the connections between source areas and human beneficiaries. These landscape replacement related changes in EGS supply tend to track linearly with the amount of ecosystem replacement; the rate of change being wholly dependent on the specific types of ecosystem replacement and not on their interaction with beneficiaries. A more complete and meaningful assessment needs to account for changes in the spatial arrangement of complementary factors, such as location of human residences, water flow paths, and transportation networks that are paramount to turning these potential EGS into realized EGS with actual benefits to identifiable human beneficiaries.

Ecosystem goods and services are those ecological structures and functions that humans can directly relate to their state of well-being. Ecosystem goods and services include, but are not limited to, a sufficient fresh water supply, fertile lands to produce agricultural products, shading, air and water of sufficient quality for designated uses, flood water retention, and places to recreate. The US Environmental Protection Agency (USEPA) Office of Research and Development's Tampa Bay Ecosystem Services Demonstration Project (TBESDP) modeling efforts organized existing literature values for biophysical attributes and processes related to EGS. The goal was to develop a database for informing mapped-based EGS assessments for current and future land cover/use scenarios at multiple scales. This report serves as a demonstration of applying an EGS assessment approach at the large neighborhood scale (~1,000 acres of residential parcels plus common areas).

Land cover/land use replacement based assessment of EGS has to be linked to specific spatially explicit landscape units that are monitored or modeled through time. The National Land Cover Dataset (NLCD) is a good national scale example of the type of required geospatial data available for use in EGS production assessments but it limits temporal assessments due to its decadal update schedule and spatial assessments due to its restricted number of resolved land cover types (Homer et al. 2007). A dataset that alleviates these two problems, at least for assessments in Florida, is the Florida Land Use/Cover Classification System (FLUCCS) (SWFWMD 2012) dataset that is updated much more often and classifies almost twice as many specific land use/cover types as the NLCD (Figure 1). Combinations of the FLUCCS dataset with supplementary information housed in the NLCD's percent canopy cover database, county residential parcel boundaries, state transportation networks, and digital elevation models allowed us to identify where most of the ecosystems responsible for the production of EGS are located on the landscape at a neighborhood scale.

METHODS AND RESULTS

We estimated EGS production for two alternative neighborhood scale development scenarios. Scenario A was based on the FishHawk Ranch development in the Alafia River basin of Tampa Bay (Figure 2). Scenario A represents an example of a relatively extensive "green" development that occurred over a period of almost 20 years. Ranched scrub-shrub land was converted to areas of light, medium, and dense residential housing with associated roads, schools, parks, and other infrastructure. Scenario B uses the exact spatial boundary as Scenario A, but relocated over an area in East Tampa that we use as a proxy for a traditional blocked neighborhood layout. Our comparison between scenarios is only meant to illustrate how one can complete a neighborhood scale assessment of EGS differences and should in no way be considered as an endorsement of either development approach by USEPA. These types of comparisons could be considered alongside other benefit cost analysis factors during neighborhood planning.

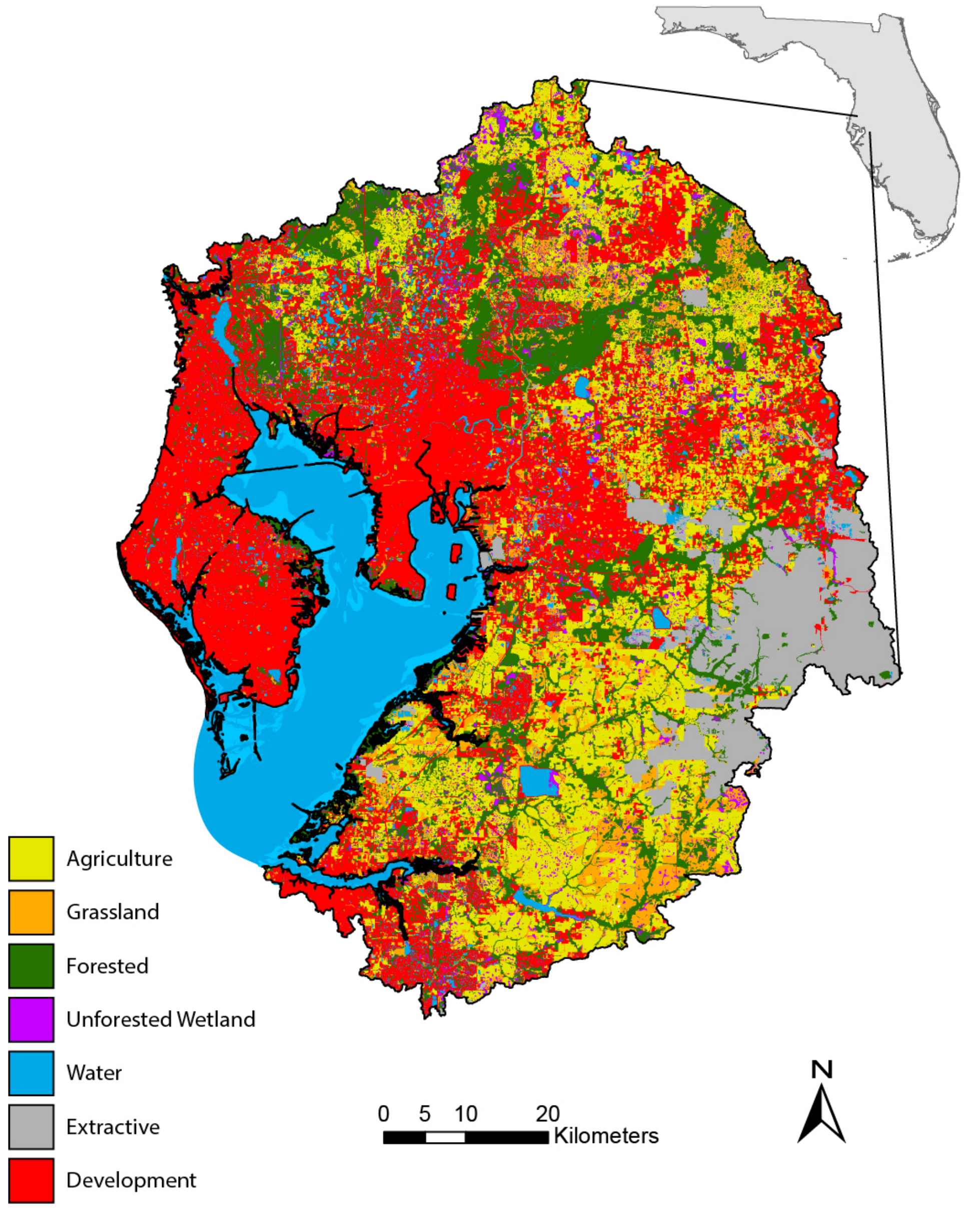

Figure 1. Simplified Florida Land Use/Cover Classification System map for the Tampa Bay region, 2006.

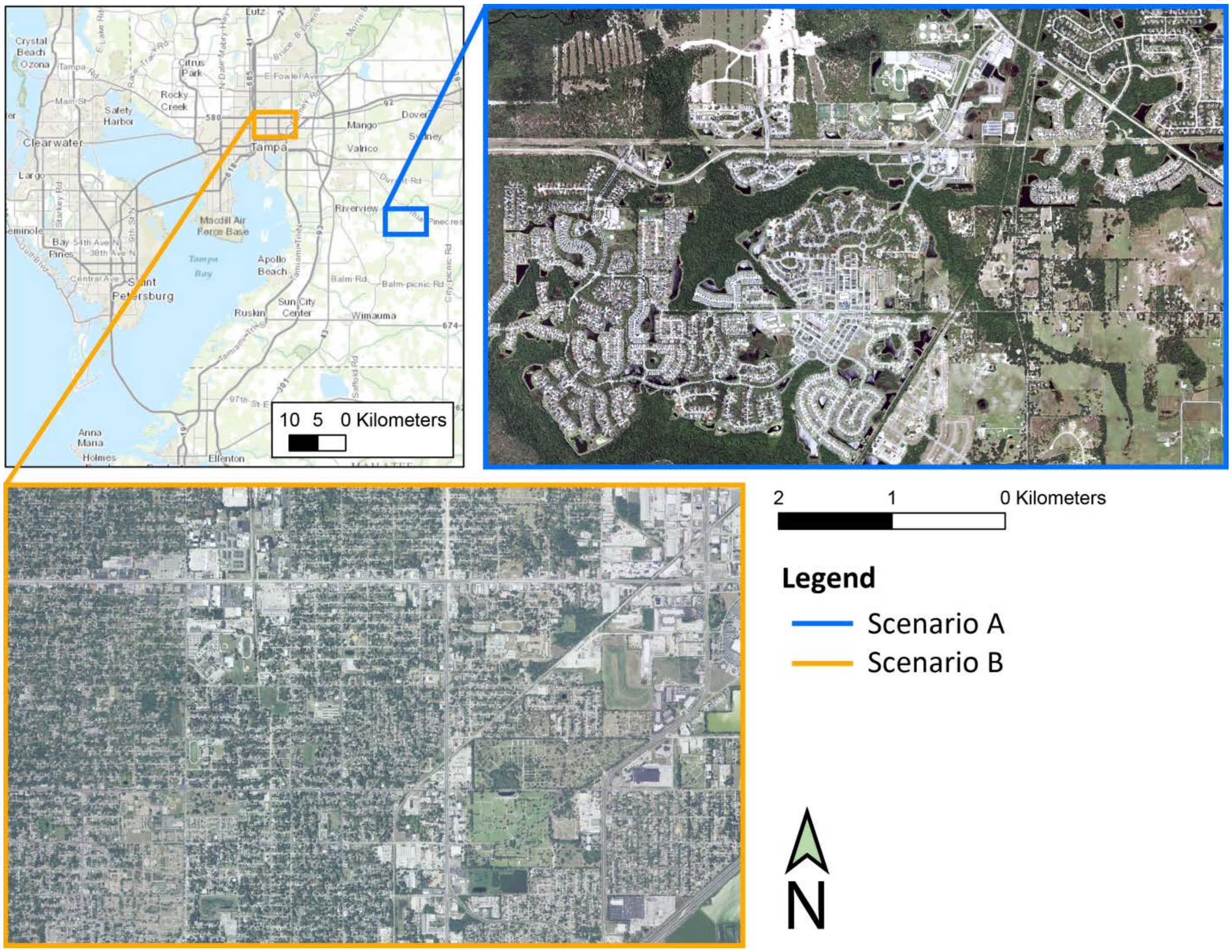

Figure 2. Location and aerial photograph of Scenario A and B developments.

We applied ecosystem service process rates and ecosystem goods stock estimates obtained from an extensive literature review to biophysical features on the landscape using various spatial datasets. Biophysical attributes, considered here as direct measurements or secondary indicators of final ecosystem goods and services, include carbon sequestration for mitigation of climate change, nitrogen removal for maintaining downstream water quality, atmospheric pollution removal for maintaining higher quality air, shading for maintaining lower heating and cooling energy costs, and water viewscapes and presence of accessible green spaces for maintaining physical and mental well-being. It should be noted that while ecosystem goods and services seem to overlap, the majority of ecosystem services (ES) are valued on a per year basis since they continue to function or produce as long as they are not significantly disturbed while ecosystem goods (EG) are valued as a stock at a specific point in time and are generally a result of ecological processes in the past. For ES that generate regional-scale benefits (e.g., nitrogen removal and carbon sequestration) we present potential value, while those that are more locally enjoyed (shading and air pollution removal) are weighted by estimated use and are closer to a realized value of benefits. Realized valuation of ES most often requires a further assessment of how they deliver benefits to specific beneficiaries through time so the calculation of realized value for regional and global scale ES requires connecting sources of production to beneficiaries in spatial and temporal scales that are beyond the scope of this report. Ecosystem goods do not generate further value unless human demand increases, and or stocks are increased by continued ecological production.

Final ecosystem goods and services (FEGS) are biophysical features that human beneficiaries can directly relate to and would, theoretically, be willing to pay to maintain even in the absence of any other biophysical change (Johnston and Russell 2011; Landers and Nahlik 2013). Biophysical attributes, and the processes producing them, relevant for assessing final ecosystem goods and services at the neighborhood scale are summarized in Table 1. These FEGS are then translated into derived human benefits using various valuation methods (Table 1). In most cases the beneficiaries are local residents, however for the larger-scale processes of nitrogen removal and carbon sequestration the beneficiary groups, such as downstream water users or those affected by climate change, are associated with both local, but also watershed and global scale boundaries. We also present the spatial arrangement of biodiversity at the neighborhood scale since it is difficult to fully translate this biophysical measure into an EGS that directly benefits human well-being using a common currency such as US dollars.

Table 1. Summary of neighborhood scale metrics used to estimate ecosystem goods and services and valuation method used to estimate global, regional, and locally derived benefits.

Metric	**Ecosystem Service (FEGS)**	**Benefit**	**Valuation Method**
Tree canopy coverage	Atmospheric pollution removal (Clean air)	Increased respiratory health	Avoided medical costs
Tree canopy coverage (South side of residential property)	Shading (Shade)	Decreased energy use	Avoided energy costs
Rate of carbon sequestration	Atmospheric regulation (Stabilized climate)	More predictable climatic patterns	Avoided social costs
Rate of denitrification	Nutrient removal (Clean water)	Water of sufficient quality is available to meet designated uses	Replacement costs
Walking distance to open green spaces, trails, and parks	(Accessible green spaces)	Increased opportunity to recreate	Hedonic pricing
Number of viewable mature trees	(Viewable, aesthetically pleasing trees)	Increased mental health and well-being	Hedonic pricing
Number of viewable water features	(Viewable water)	Increased mental health and well-being	Hedonic pricing

Biophysical and value maps were produced for two alternative development scenarios, one based on the 2009 FishHawk Ranch development and the other using an identically shaped and sized area from East Tampa as an example of what this area could have been developed into if a more traditional block neighborhood layout had been used.

The following sections present spatial estimates of biophysical attributes and resulting benefit valuation estimates for EGS in 2009 for Scenario A (Figure 3) and an alternative development pattern Scenario B (Figure 4) taken from East Tampa and representative of a more traditional blocked development pattern. These two neighborhoods were chosen to represent maximal differences between traditional and “green” oriented development patterns. Comparisons between scenario EGS production and values serve to illuminate the tradeoffs society can consider as areas are developed or redeveloped to meet growing housing needs. Differences in EGS can be positive or negative depending on how the landscape is modified during development and how humans interact with remaining or newly constructed neighborhood biophysical features.

SECTION 1. ECOSYSTEM SERVICES

AIR POLLUTION REMOVAL

Air pollutants are removed when tree canopy intercepts pollutants in the atmosphere. Air pollution removal service through time yields cleaner air, which is important for maintaining human respiratory health. The rates of pollutant removal are a function of the downward flux of the pollutant and the resistance of the canopy vegetation (Nowak et al. 2006). The canopy coverage of our scenarios were determined by spectral analysis of remotely sensed images, which identified pixels that reflect light in a pattern indicative of tree canopy vegetation. The 1 m^2 resolution coverage of tree canopy was combined with established pollutant attenuation rates for carbon monoxide, ozone, particles, sulfur dioxide, and nitrous oxide to calculate the total air pollutant removal (Nowak et al. 2006).

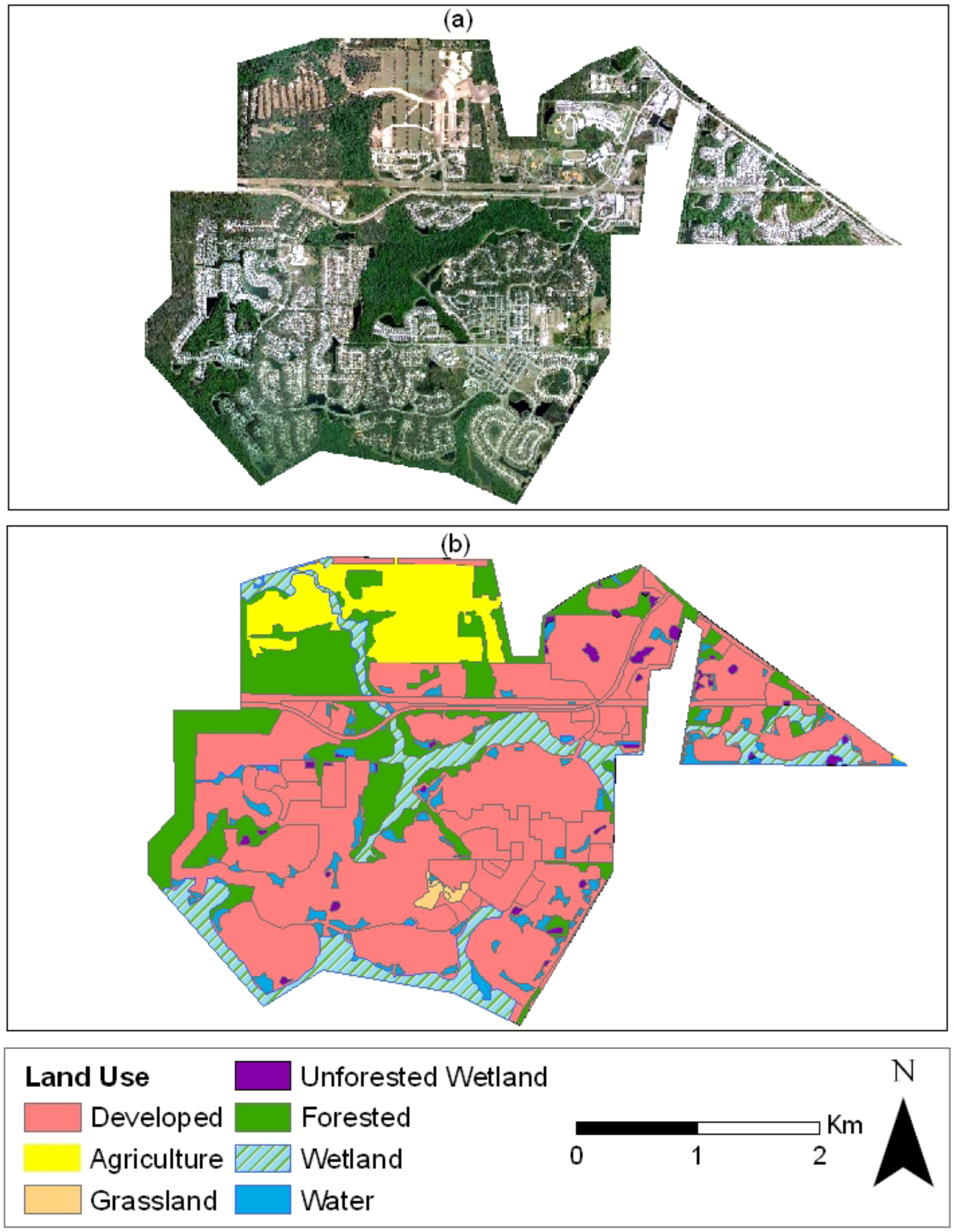

Figure 3. Aerial photo (a) and simplified Florida Land Use Cover Classification System (b) map for Scenario A in 2009.

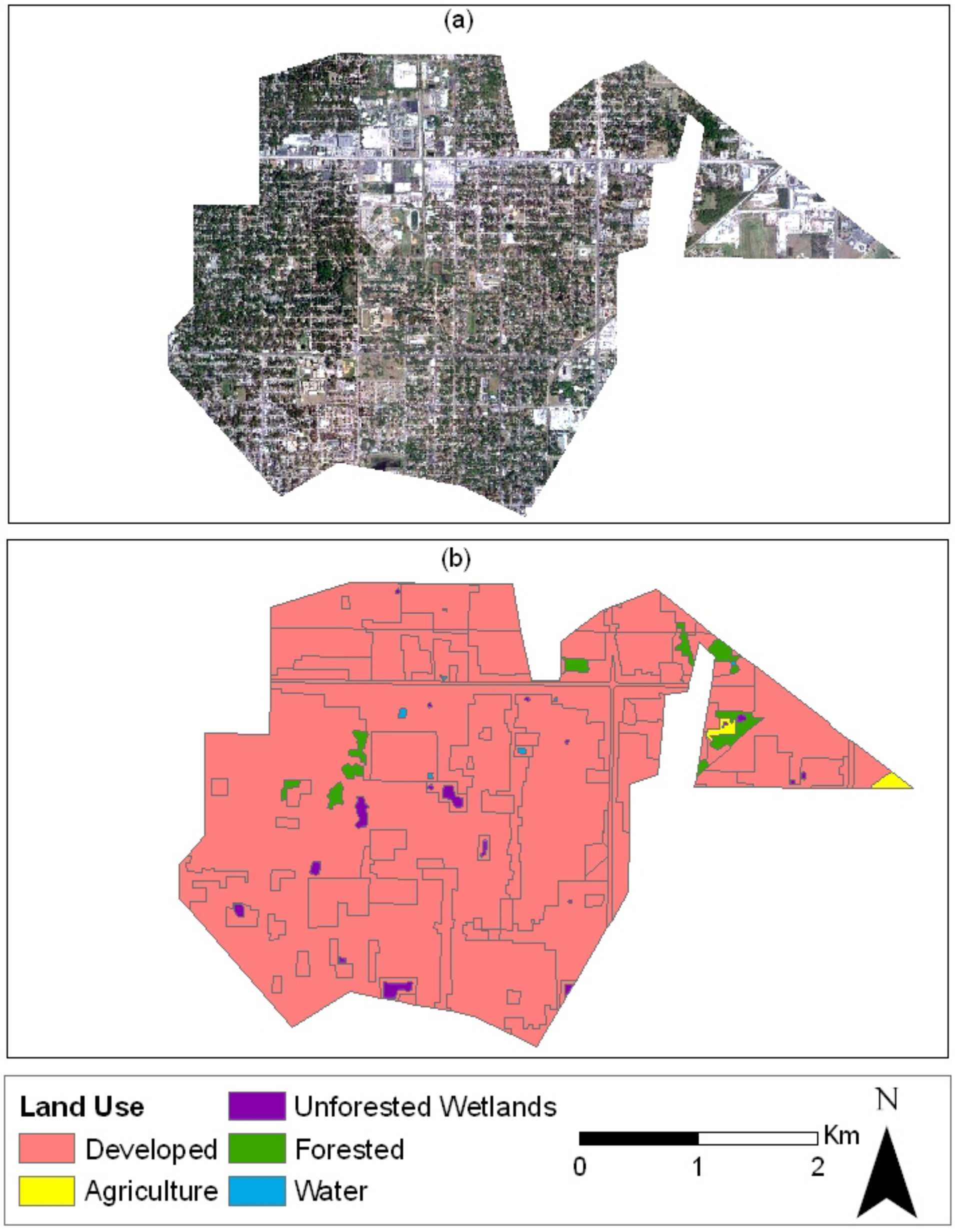

Figure 4. Aerial photo (a) and simplified Florida Land Use Cover Classification System (b) map for Scenario B in 2009.

The rate of air pollutants removal (Figure 5) is the sum of the various pollutants attenuated by tree canopy. The rate of downward pollutant flux for each of the species of interest was calculated by iTree model algorithms (Nowak et al. 2008), and the relative air pollutant costs to human health was used to translate the various pollutant attenuation rates to decreases in human health impact costs (Murray et al. 1994). The estimated value for attenuation of the selected pollutants in 1994 US dollars was $959/ton carbon monoxide, $6,752/ton ozone, $1,653/ton sulfur dioxide, $4,508/ton particulate matter (PM10), and $6,752/ton nitrogen dioxide (Murray et al. 1994). We applied this 1994 estimate to our 2009 scenarios without year-specific corrections for inflation.

The total air pollutant removal was calculated as:

$$Air\ Pollution\ Removed = \sum_i Value_i * FluxRate_i * \%Can * CellSize$$

where *i* represents the individual pollutants, *Value* is the decrease in costs associated with a decrease in pollutant species, *FluxRate* is the removal rate of each pollutant by specific species, *%Can* is the percent canopy cover in each section of the landscape, and *CellSize* is the area of each section in square meters. One meter resolution percent canopy coverage maps were used to calculate the total air pollution removed in 1994 US dollars ($) per year using the raster calculator function in ArcGIS 9.3 (Figure 5). Our Scenario A neighborhood was estimated to have an air pollution removal service of 7,997 kg of pollutants per year while Scenario B had 8,849 kg of pollutants per year. This service is estimated to be worth $0.39 and $0.43 million US per year for Scenario A and B, respectively.

SHADING

The shading service enjoyed by each residential parcel was calculated from the percent canopy cover situated to shade buildings (Figure 6). The production of shade is considered an ecosystem service that continues to provide humans with lower energy needs for cooling. To quantify the amount of shade provided by trees, the center of each parcel was determined and a 25 meter radius semi-circle was drawn on the southern side, representing the area most relevant for shading the south facing section of buildings in the Northern Hemisphere. Then, using a remotely sensed image, the number of 1 m^2 canopy pixels was determined in this shade-providing semi-circle. The number of pixels was then translated into large shade tree equivalents by dividing by the canopy area of a representative large tree within this community (80 m^2). It is important to note that shading service is only provided by the ecosystem when houses or other structures are present, therefore, before development of this area no shading service could be provided even though plenty of shade may have been present.

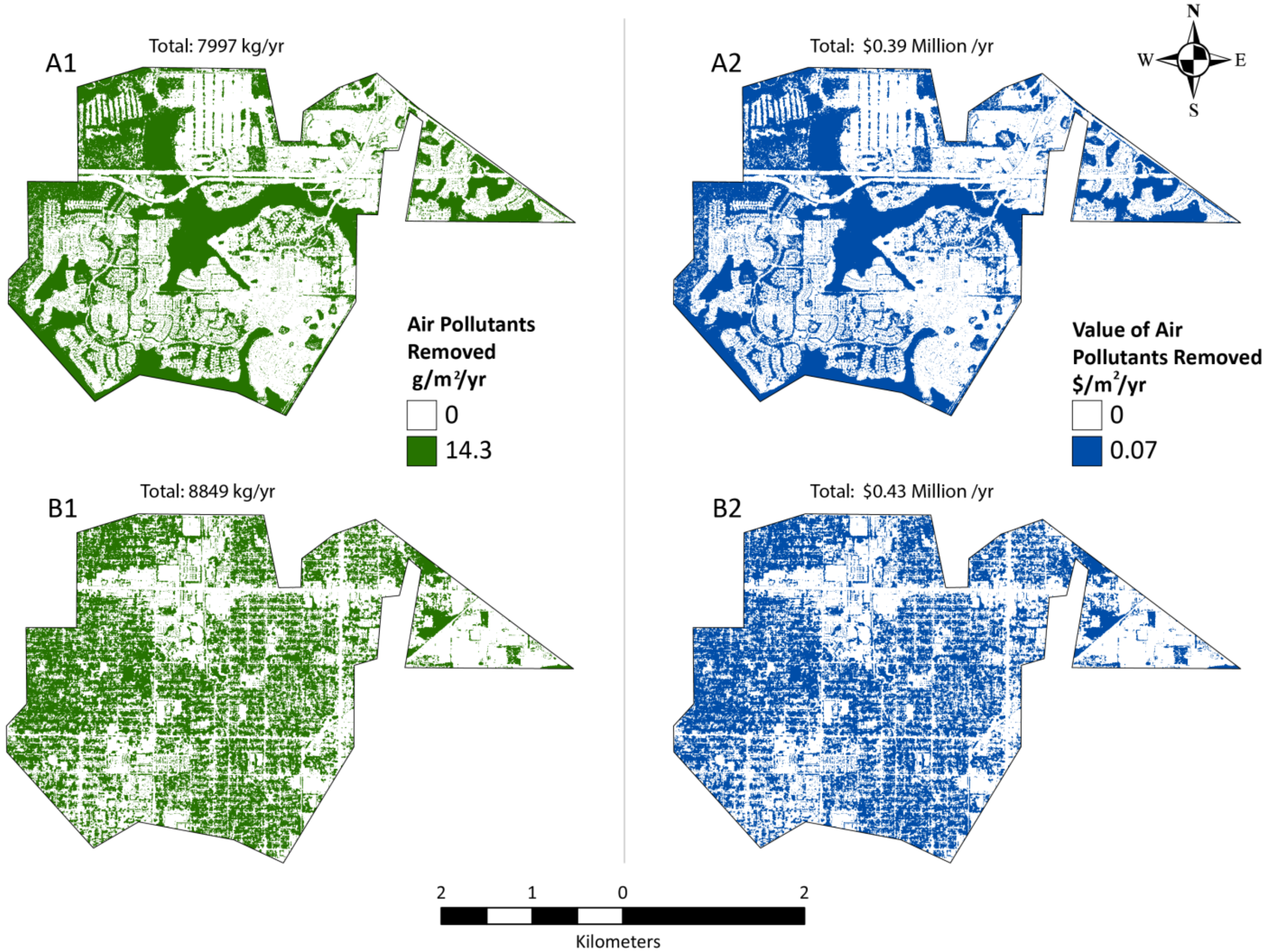

Figure 5. Development scenarios A and B for air pollution attenuation (A1 and B1) corresponding Ecosystem Service Value (A2 and B2).

Figure 6. Example of shade tree coverage estimation from satellite imagery (top panel) summarized for the southern side of a parcel (bottom panel).

The amount of canopy in a semi-circle from southwest to southeast and corresponding cost savings from shading decreasing energy use were estimated (Figure 7). Shading by trees on the southeast and southwest side of a residential house is estimated to reduce energy use by upwards of 350 kWh per year per 80 m^2 of canopy (Simpson and McPherson 1996). Much of this savings takes place in hotter summer months when energy reductions can get as high as 80 kWh per month per 80 m^2 of south side tree canopy cover (Donovan and Butry 2009; Huang et al. 1987). These values, however, were calculated from residential parcels using almost three times as many kWh of energy as the average Tampa Bay region resident's use. Thus, energy savings for

Tampa Bay local residents would be approximately one third of the published value or 116.7 kWh a year per 80 m^2 of south side tree canopy cover. Tampa Electric's 2012 electricity rate was estimated at 9.718 cents per kWh based on an average residential customer using 1,200 kWh per month on a two-tiered fuel and energy cost rate from Tampa Electric (2012). Cost savings per 80 m^2 of tree canopy, assuming a decrease of 26.3 kWh per summer month (Donovan and Butry 2009; Huang et al. 1987) or 116.7 kWh per year (Simpson and McPherson 1996) for the average resident in the Tampa Bay region, would equate to close to $3 per month in summer months and $12 a year. We applied this 2012 estimate to our 2009 scenarios without year specific corrections for inflation. Cost savings will not scale linearly for residents using more than the 1,200 kWh average since per kWh energy costs are higher after the first 1,000 kWh of use. Tampa Electric customers using 1,200 kWh per month with the equivalent of three large 80 m^2 trees to the west-southwest of their residence would be estimated to save up to 80 kWh per month during summer months from afternoon and evening shading (Simpson and McPherson 1996). This is equivalent to 7% of summertime energy costs. Our Scenario A neighborhood was estimated to have a total shading service of 14,724 shade trees while Scenario B had 16,843 shade trees. This service is estimated to be worth $0.18 and $0.20 million US per year for Scenario A and B, respectively.

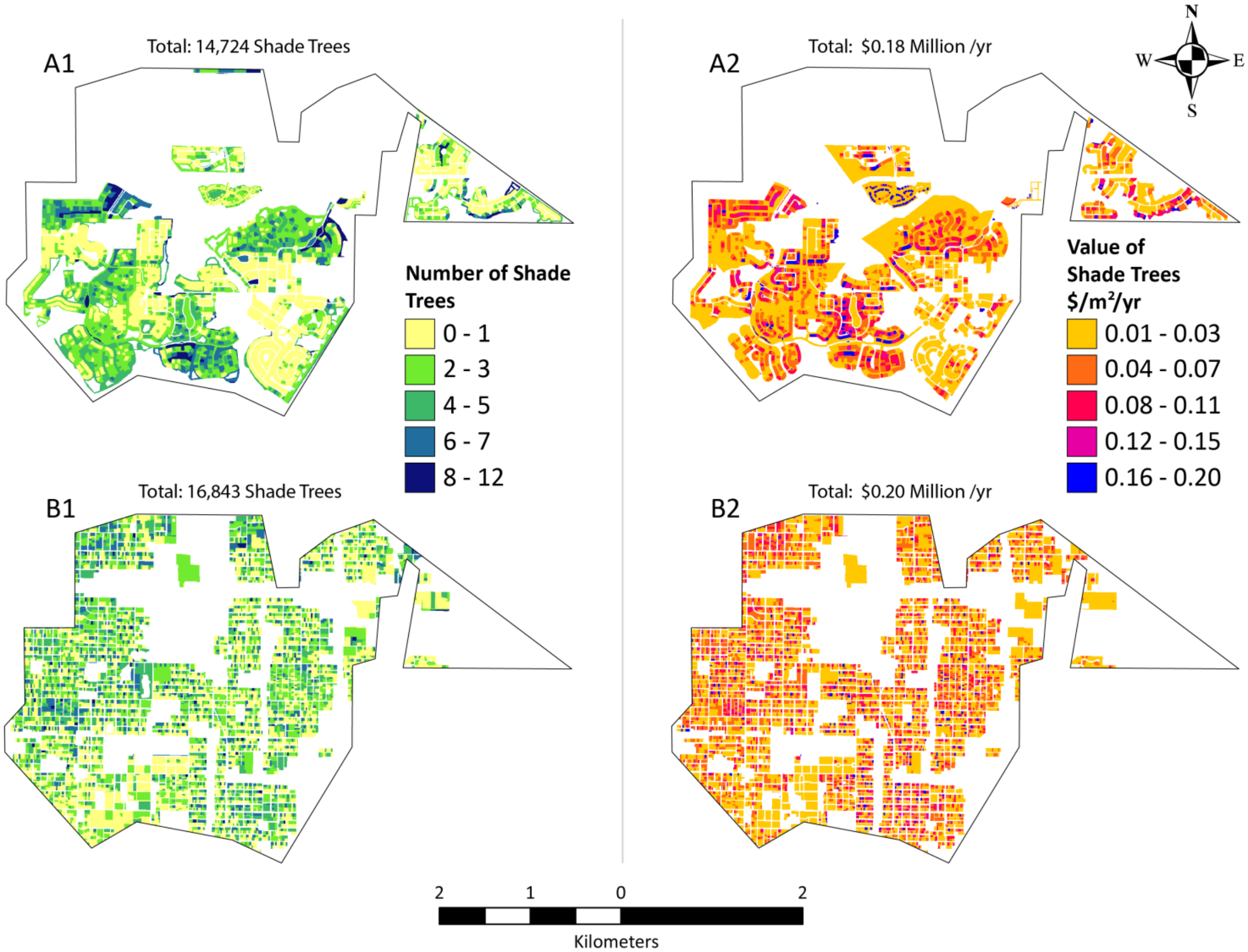

Figure 7. Development scenarios A and B for number of shade trees per parcel (A1 and B1) and corresponding Ecosystem Service value (A2 and B2).

CARBON SEQUESTRATION

Carbon sequestration was estimated by assigning the average rate published in peer-reviewed literature to specific land use types (Table 2). Literature values were used from studies conducted in similar climates and landscapes. However, there is a scarcity of literature reporting carbon sequestration rates for developed areas, including residential, institutional, commercial, transportation, utility, and communication areas. Therefore, the rate of carbon sequestration for the urban land use classes was estimated in the canopy and lawn areas for these land use areas by the following equation:

$$Urban\ Carbon\ Sequestration = \left((1 - \%Imp) * LawnRate + \%Canopy * UrbanTreeRate\right)$$

where *%Imp* is the average percent impervious surface and *%Canopy* is the average percent canopy coverage for the land use category, *LawnRate* is the average published rate of carbon sequestration for lawns in g C m^{-2} yr^{-1} (Bandaranayake et al. 2003; Gebhart et al. 1994; Qian and Follett 2002), and *UrbanTreeRate* is the published rate for typical Florida urban trees in g C m^{-2} yr^{-1} (Nowak and Greenfield 2009). Each scenario was reclassified into the carbon sequestration flux rates in ArcGIS 9.3, and then multiplied by the grid cell area using the spatial analyst extension's raster calculator. The result was the rate of carbon sequestration in grams carbon removed per year per cell (Figure 8). Thus, rates represent averages from several different studies with various degrees of accuracy. It should be noted that the carbon sequestration rates are carbon incorporated into biomass or net primary production and do not reflect long-term carbon storage or burial rates as this carbon becomes incorporated into soil or wood products.

The value of carbon sequestration was estimated using the social cost of carbon. The social cost of carbon is an estimate of the monetized damages associated with an incremental increase in carbon emissions for a given year. It is intended to include, but is not limited to, changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ES. The dollar value of carbon reductions in the form of the greenhouse gas carbon dioxide was estimated as $20 per ton ($0.01 per lb) of carbon dioxide in 2010 (US Government 2010). We applied this 2010 estimate to our 2009 scenarios without year-specific corrections for inflation. Even without year-specific cost adjustments, the $20 per ton of carbon dioxide represents a conservative estimate that has been recalculated as 12 times larger using a less severe discount rate more appropriate for intergenerational cost-benefit analysis (Johnson and Hope 2012). Carbon sequestration rates were multiplied by the social cost of carbon estimate to arrive at the total value of this ecosystem service that benefits humans by moderating climate change (Figure 8). Our Scenario A neighborhood was estimated to have a carbon sequestration service of 3,807 million kg C per year while Scenario B had 1,115 million kg C per year. This service is estimated to be worth $0.76 and $0.22 million US per year for Scenario A and B, respectively.

Table 2. Land Use Specific Carbon Sequestration.

Description	FLUCCS	Carbon Fixed into Biomass Map Value [g C/m2/yr]	Reference
Residential Low Density	1100	148	See Methods
Residential Med Density	1200	139	See Methods
Residential High Density	1300	91	See Methods
Commercial And Services	1400	57	See Methods
Institutional	1700	73	See Methods
Recreational	1800	128	See Methods
Open Land	1900	133	See Methods
Cropland And Pastureland	2100	423	(Ajtay et al. 1979)
Other Open Lands	2600	673	(Ajtay et al. 1979; Milesi et al. 2005)
Herbaceous	3100	743	(Ajtay et al. 1979)
Shrub And Brushland	3200	945	(Ajtay et al. 1979)
Upland Coniferous Forest	4100	698	(Ajtay et al. 1979; Kroeger 2008)
Pine Flatwoods	4110	698	(Ajtay et al. 1979; Clark et al. 1999)
Hardwood Conifer Mixed	4340	660	(Ajtay et al. 1979; Kroeger 2008)
Streams And Waterways	5100	180	(Ajtay et al. 1979)
Lakes	5200	397	(Carpenter et al. 1998; Carrick et al. 1993)
Reservoirs	5300	368	(Carpenter et al. 1998; Carrick et al. 1993)
Stream And Lake Swamps	6150	808	(Lugo et al. 1988)
Freshwater Marshes	6410	618	(Smith and De Laune 1983)
Wet Prairies	6430	142	(Kroeger 2008)
Emergent Aquatic Vegetation	6440	142	(Kroeger 2008)
Intermittent Ponds	6530	142	(Kroeger 2008)
Transportation	8100	96	See Methods
Communications	8200	106	See Methods
Utilities	8300	133	See Methods

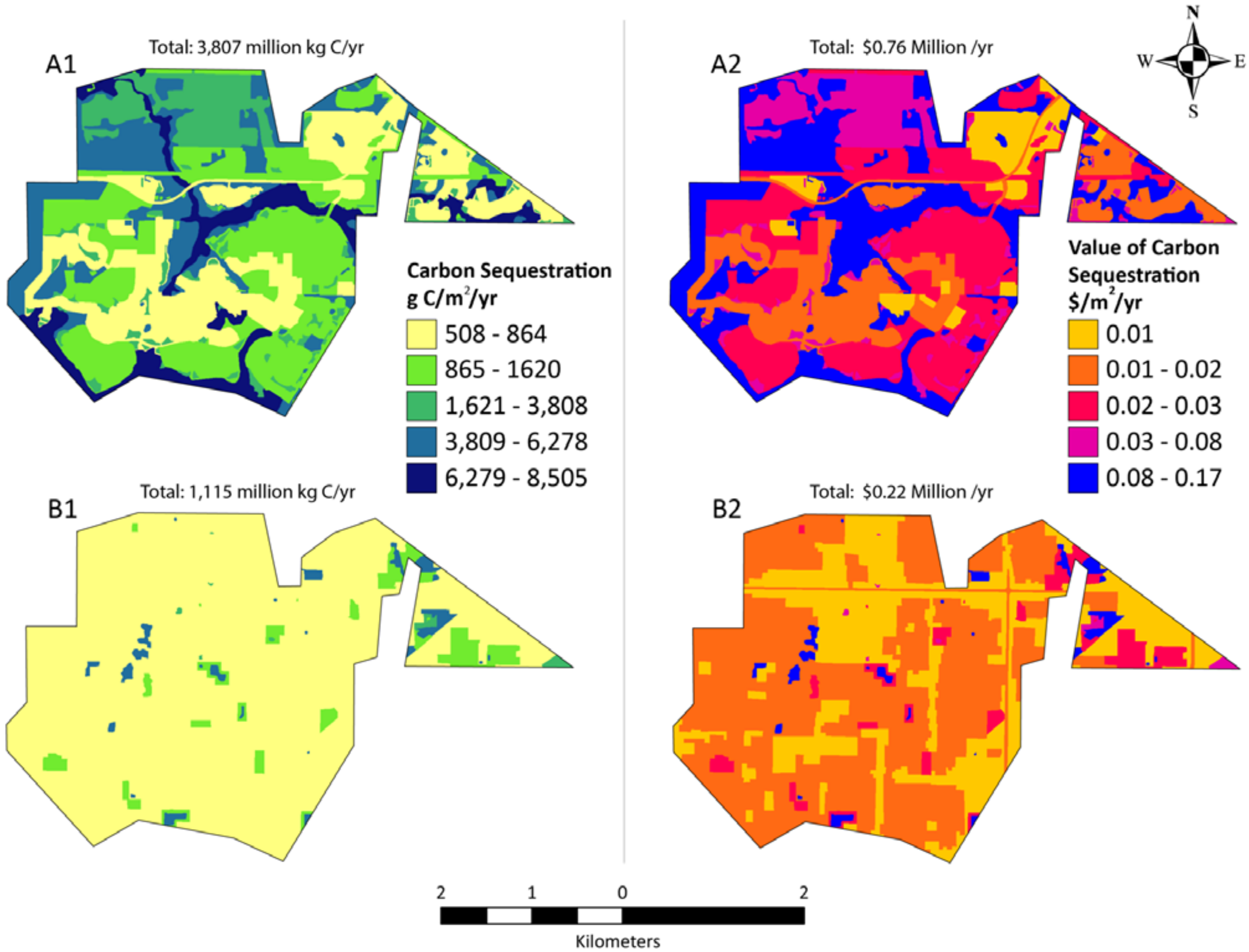

Figure 8. Development scenarios A and B for carbon sequestration (A1and B1) and corresponding Ecosystem Service value (A2 and B2).

NITROGEN REMOVAL

Excess reactive nitrogen in water results in eutrophication and ground water contamination (Vitousek et al. 1997). Nitrogen removal helps maintain downstream waters at a sufficient quality for the designated use of the water body. Appreciable amounts of nitrogen can be removed from the landscape through enzymatic denitrification. Scientific literature has reported estimates of this landscape process for land use types, based on case studies in settings in the Florida area or in similar landscapes. Similar to carbon, the rate of denitrification was estimated using literature rates assigned to undeveloped areas and calculated rates for urbanized areas (Table 3). As denitrification occurs in the soil, the mass of nitrogen denitrified in the previous area was calculated by:

$$Urban\ Denitrification = (1 - \%Imp) * DenLawn * CellSize$$

where *DenLawn* is the denitrification rate published for urban lawns (Raciti et al. 2011). The *%Imp*, percent impervious surface, was derived from a 1 m^2 resolution land cover map. Similar to the method used for estimating carbon sequestration, each land use area was reclassified using the denitrification flux rates (Table 3) multiplied by area. The result was the rate of nitrogen removed via denitrification in grams nitrogen removed per year (Figure 9).

Costs for removing a pound of nitrogen in water coming from various sources range from less than $10 to as high as $855. Costs increase as the nitrogen becomes harder to route towards treatment areas and as simpler, more cost efficient mechanisms for removing nitrogen need to be replaced by more centralized advanced waste water treatment facilities. Compton et al. (2011) reviewed the cost of removing nitrogen from a wide range of sources and concluded that costs ranged from $1.22 - $43.54 per pound of nitrogen ($2.71 - $96 kg^{-1}). Abatement costs of reducing nitrogen from point sources are estimated as $8.16 per pound ($18 kg^{-1}) of nitrogen (Birch et al. 2011). We use $8.16 per pound as our conservative estimate of what it would cost to replace the ecosystem service of removing nitrogen for the purpose of maintaining usable water based on using traditional waste water treatment to remove nitrogen from upstream point sources (Figure 9). We applied this 2011 estimate to our 2009 scenarios without year-specific corrections for inflation. Our Scenario A neighborhood was estimated to have a carbon sequestration service of 5.143 million kg N per year while Scenario B had 1.321 million kg N per year. This service is estimated to be worth $0.93 and $0.24 million US per year for Scenario A and B, respectively.

Several lifecycle estimates, however, including upgrading and maintaining existing or building additional advanced wastewater treatment facilities and drainage structures to remove nitrogen, put the cost as high as $855 per pound ($388 kg^{-1}) of nitrogen removed (Roeder 2007). This higher ecosystem replacement value may be more appropriate than our more conservative number if one wants to illustrate the potential future value of bay habitats under a scenario of increasing demand for nitrogen removal.

Table 3. Land Use Specific Denitrification Rates.

Description	FLUCCS	Denitrification Map Value [g N/m2/yr]	Reference
Residential Low Density	1100	1.3	See Methods
Residential Med Density	1200	1.13	See Methods
Residential High Density	1300	0.85	See Methods
Commercial And Services	1400	0.62	See Methods
Institutional	1700	0.87	See Methods
Recreational	1800	1.4	See Methods
Open Land	1900	1.4	See Methods
Cropland And Pastureland	2100	0.72	(Barton et al. 1999; Espinoza 1997; Robertson et al. 1987; Tsai 1989)
Other Open Lands	2600	0.82	(Barton et al. 1999; Tsai 1989)
Herbaceous	3100	0.06	(Tsai 1989)
Shrub And Brushland	3200	0.06	(Tsai 1989)
Upland Coniferous Forest	4100	0.12	(Barton et al. 1999; Robertson et al. 1987)
Pine Flatwoods	4110	0.12	(Barton et al. 1999; Robertson et al. 1987)
Hardwood Conifer Mixed	4340	0.19	(Barton et al. 1999)
Streams And Waterways	5100	20.73	(Piña-Ochoa and Álvarez-Cobelas 2006; Seitzinger et al. 2006)
Lakes	5200	12.29	(James et al. 2011; Piña-Ochoa and Álvarez-Cobelas 2006; Seitzinger 1988)
Reservoirs	5300	7.5	(Brenner et al. 2001; Seitzinger 1988)
Stream And Lake Swamps	6150	25.5	(Martin and Reddy 1997; Pinay et al. 2007; Seitzinger 1994; Walbridge and Lockaby 1994)
Freshwater Marshes	6410	28.26	(Ensign et al. 2008; Martin and Reddy 1997; Pinay et al. 2007; Reddy et al. 1989; Seitzinger 1994)
Wet Prairies	6430	25.48	(Ensign et al. 2008; Martin and Reddy 1997; Pinay et al. 2007)
Emergent Aquatic Vegetation	6440	26.22	(Ensign et al. 2008; Martin and Reddy 1997)
Intermittent Ponds	6530	17.44	(Ensign et al. 2008)
Transportation	8100	1.2	See Methods
Communications	8200	1.16	See Methods
Utilities	8300	1.4	See Methods

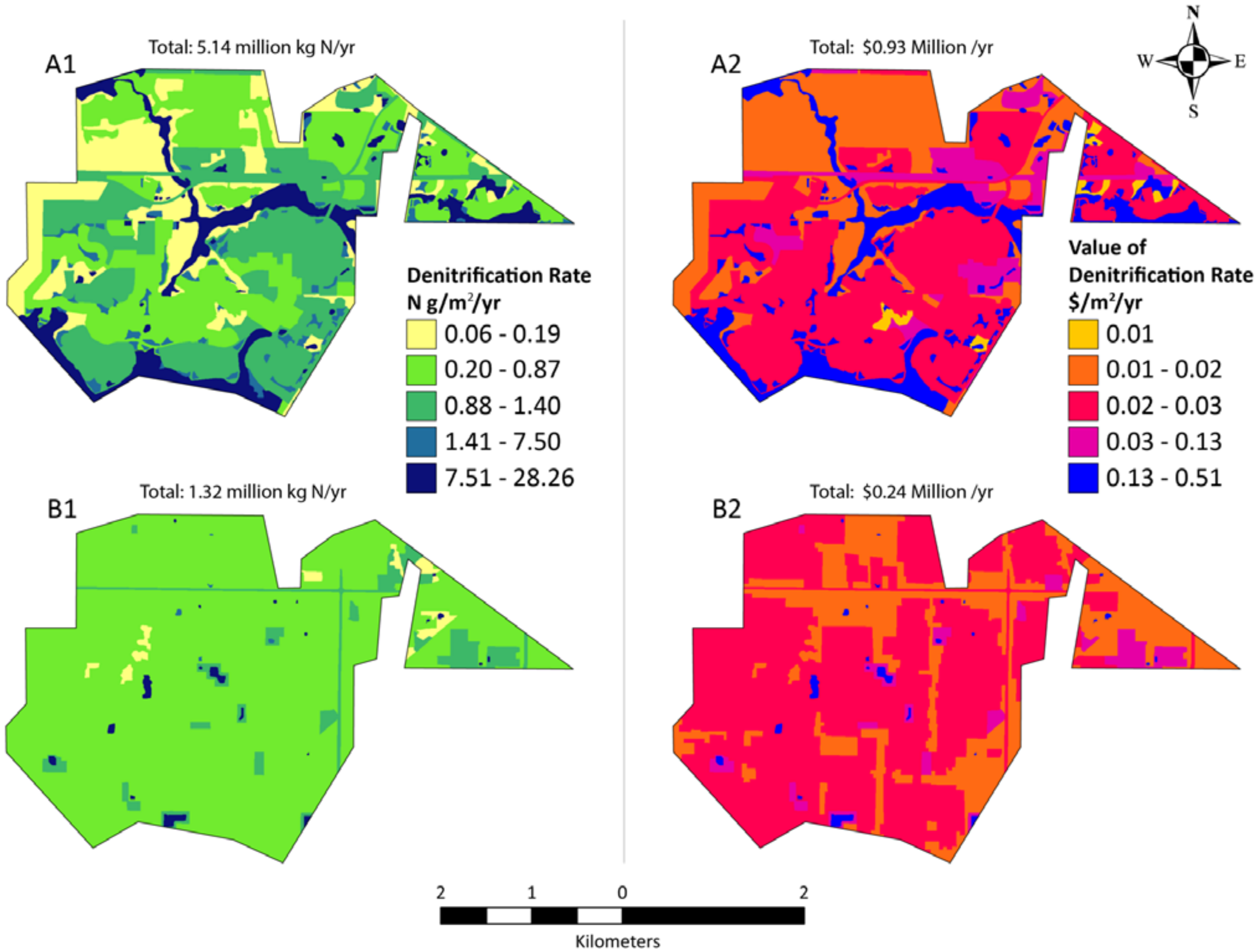

Figure 9. Development scenarios A and B for denitrification rates (A1 and B1) and corresponding Ecosystem Service value (A2 and B2).

SECTION 2. ECOSYSTEM GOODS

There are numerous physical things that ecosystems produce that are of benefit to humans. Some of these ecosystem goods are structural components of the environment and are direct inputs into the market system, such as edible fish, wild berries and wild game, as well as wood for timber production. Other ecosystem structural components are harder to break down into discrete, tangible units, and so are often not marketable as such. Some ecosystem goods are mosaics of ecosystem attribute that, when combined, generate something greater than the sum of their parts. Such mosaics include areas of green space that provide opportunities for recreation, wildlife and other green/blue landscapes providing pleasant views, and even biologically diverse areas that may provide greater stability in the production of other ecosystem goods. Most of the time, benefits from ecosystem goods to humans are only manifested when humans physically or emotionally interact with a tangible component of the ecosystem. This interaction usually takes place on local scales such as having greenspace within a comfortable walking distance or being able to look out your window and see a tree or lake. This required close proximity can be found within a neighborhood and should be accounted for at that scale. Interaction with ecosystem goods at the neighborhood scale is often dependent on how individual parcels are arranged. Thus, most ecosystem good’s value is wholly dependent on demand for, and current levels of use of, that good. Lack of demand or inaccessibility equates to zero ecosystem good value in most cases. Value of ecosystem goods is estimated at a given time and place like a stock, unlike ecosystem services, which have rates of value production and are, thus, more dynamic. The temporal scales and associated valuation approach is really what separates the concept of ecosystem goods from ecosystem services. Most ecosystem services are valued using estimates of what it would cost to replace beneficial biophysical functions using conventional means, while ecosystem goods are typically valued using willingness to pay valuation approaches, with the value being interpreted as what individuals are willing to pay for a set quantity or condition of something at a specified point in time. Here we quantify the value of several locally important ecosystem goods at the neighborhood scale.

WALKABILITY AND ACCESS TO GREEN SPACE

The availability of green spaces for recreation is a valuable attribute for neighborhood residents as is their access to commercial destinations. Walk Score (http://www.Walk Score.com/) helps people find a walkable place to live (Sidebar 1). Walk Score is a number between 0 and 100 that indicates the walkability of any location (Figure 10).

Walk Score	Description
90 - 100	**Walker's Paradise** Daily errands do not require a car
70 - 89	**Very Walkable** Most errands can be accomplished on foot.
50 - 69	**Somewhat Walkable** Some amenities within walking distance
25 - 49	**Car-Dependent** A few amenities within walking distance
0 - 24	**Car-Dependent** Almost all errands require a car

Figure 10. Description of Walk Score

Sidebar 1:

Walk Score (www.Walk Score.com) uses Google maps to compute the distance between residential addresses and nearby destinations. The Walk Score algorithm looks at destinations in nine categories and awards points for each destination that is between one-quarter mile and one and a half miles of the subject residential property:

- grocery stores
- restaurants
- shopping
- coffee shops
- schools
- **parks**
- banks
- bookstores
- entertainment

(http://www.Walk Score.com/ Accessed 5/2012)

We used the Walk Score algorithm to quantify the walkability of each neighborhood in Scenario A and B (http://www.walkscore.com/methodology.shtml). We found that Walk Score does not currently include many of the smaller parks or green space access trails that are evident in Scenario A so we digitized the neighborhood, roads, sidewalks, and trails and recalculated the distance to park metric. For Scenario B we present walk scores as sections, without including small parks not evident from aerial photography, since there are so many more roads with no clear grouping.

Walk Scores for Scenario A are reflective of how easy or difficult it is to walk to a suite of amenities including shopping, entertainment, and parks. Higher scores are more preferable for walkers. Distance to parks in Scenario A has a different pattern than Walk Score since the Walk Score web site currently only incorporates larger publicly available park location datasets, while our analysis included our own hand digitization of nature trails and small neighborhood parks (Figure 11).

Walk Scores are generally higher in Scenario B's community configuration (Figure 12) than in Scenario A, but the distances to parks are longer because of the lack of easily identifiable green trails and pocket parks. It is, however, somewhat difficult to identify small green spaces, that serve the same role as formal pocket parks. Ballparks or other open spaces associated with schools were not included as publically assessable green spaces in this analysis since they are not considered as being conserved in at least a semi-natural state, many being part of school grounds that may not be open to the public for recreation. A gridded neighborhood structure does not necessarily preclude inclusion of small, easily accessible green spaces and the choice of a different location for Scenario B would have most likely influenced our distance to park scores. Higher overall Walk Scores in Scenario B, however, are reflective of easier access to other amenities such as shopping.

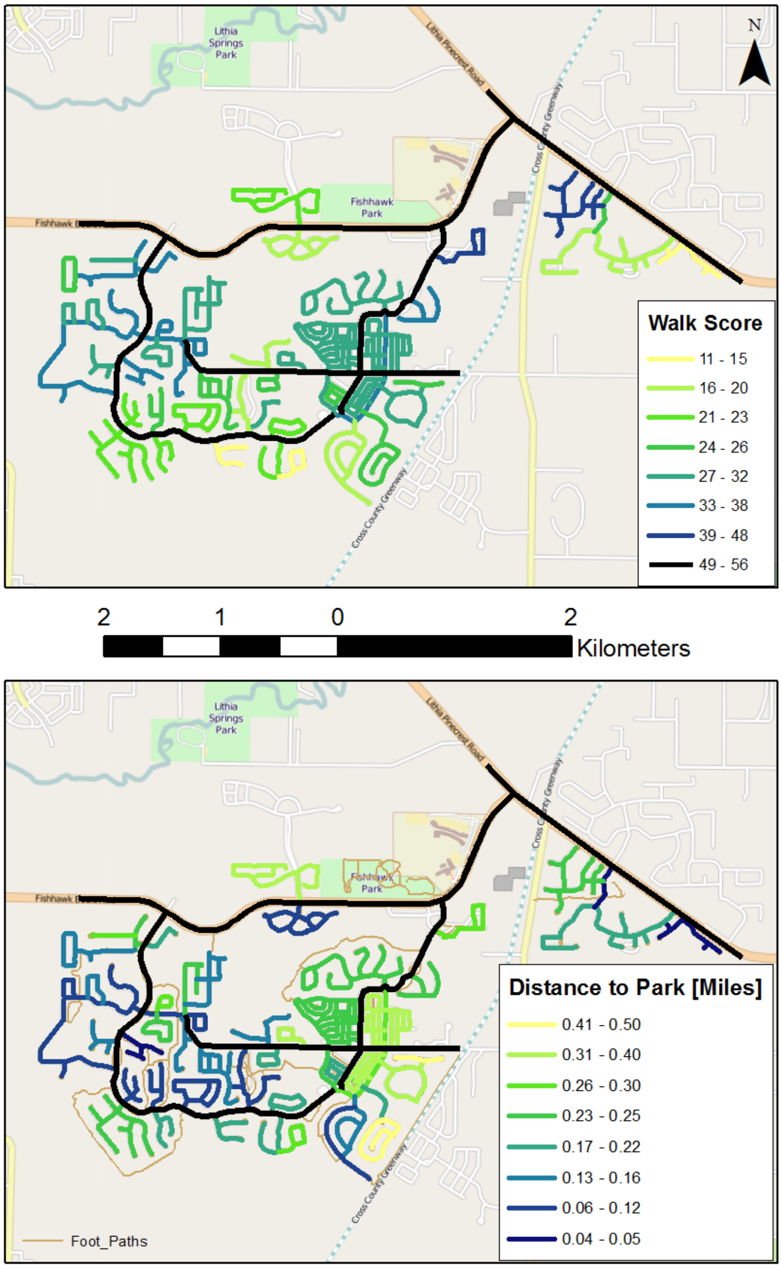

Figure 11. Walk Scores (upper panel) and distance to park (lower panel) for Scenario A streets.

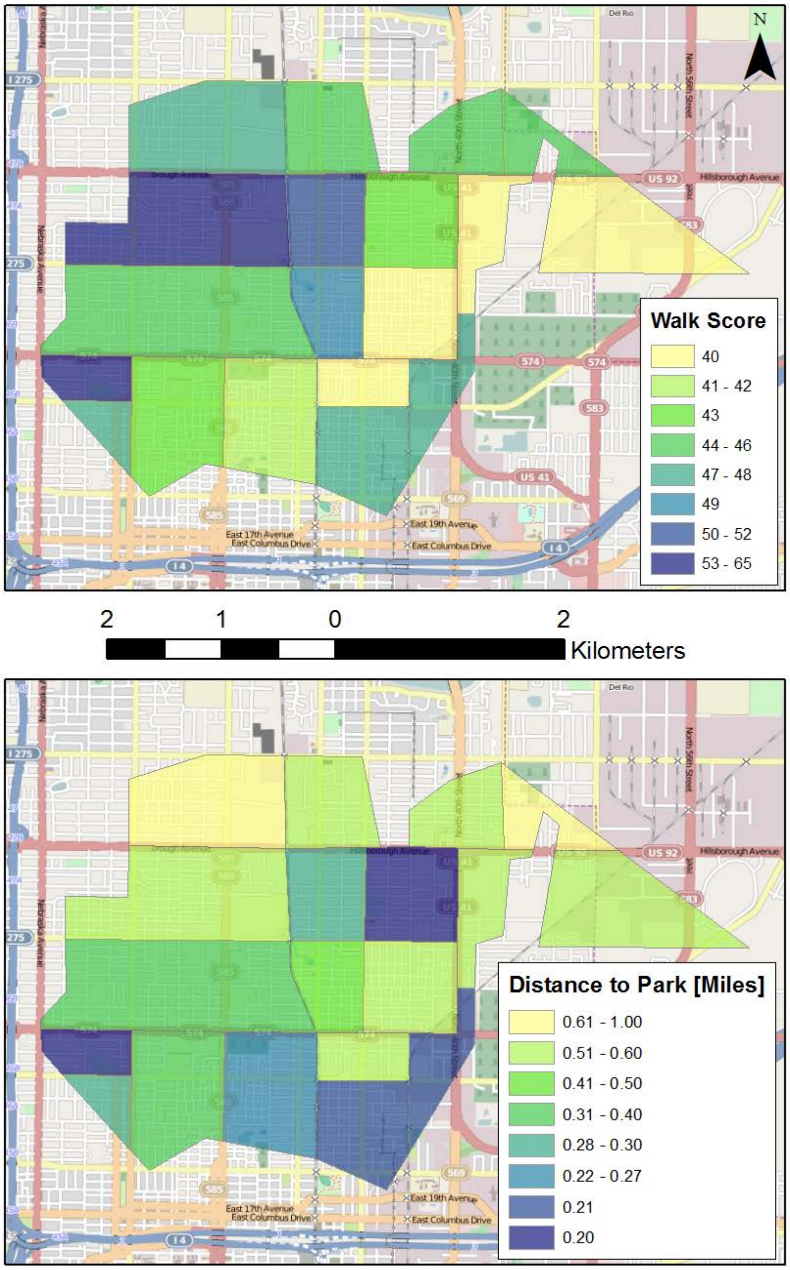

Figure 12. Walk Scores (upper panel) and distance to park (lower panel) for Scenario B sections.

The walkability of a neighborhood is reflected in the value of property. In a study of 15 separate housing markets it was determined that for every one point increase in Walk Score the value of property increases between $700 and $3,000 depending on particular housing markets and local preferences (Cortright 2009). In the Jacksonville, FL market, a one point increase in Walk Score equated to an increase of $809 per property. Cortright estimated an average home value of $179,873 with an average size of 1,660 ft^2 in Jacksonville in 2007. Jacksonville's median Walk Score was 36 with a 25th and 75th percentile of 20 and 51. The estimated value increase from an identical home with a median Walk Score of 36 versus one in the 75th percentile with a Walk Score of 51 was $12,951. These values place Jacksonville on the lower end of market price and in the middle range of Walk Scores as compared to other assessed cities (Cortright 2009). The use of marginal value increase estimates for each increase in Walk Score, based on the Jacksonville market, means our estimates of our scenario neighborhood's Walk Score value should be thought of as conservative since our study areas have generally higher home values but with a similar Walk Score range as the Jacksonville market.

Distance and ease of travel on foot to parks is one of nine metrics used to calculate the Walk Score Index. Distance to parks and or green space is weighted as having a 1/15 influence on Walk Score along with several other amenities, but distance to grocery stores and restaurants has a 3/15 weight, and distance to shopping has a 2/15 weight. Each single unit of increase in Walk Score for a property is roughly equivalent to saying that property has $54 ($809/15) of increased value due to greater access to green space. We applied this 2009 estimate to our 2009 scenarios. We determined the per-unit distance to greenspace relationship to Walk Score value independent of the other amenities by measuring the distance to parks noted by Walk Score of 49 different streets in our Scenario A neighborhood.

The graph below illustrates that for every tenth of a mile increase in distance to a park we estimate there is a respective decrease in Walk Score of approximately one unit (Figure 13). This relationship was used as a calibration of the Walk Score's distance decay function for access to greenspace in our neighborhood analyses. Using the conservative value estimates from Jacksonville, every tenth of a mile (about one city block) to green space beyond the 0.25 mile minimum walking distance is thus equivalent to a $54 decrease in a property's assessed real estate value. The Walk Score calculation assumes that being closer than 0.25 miles to a park or green space does not add further value to a home than if that home was at 0.25 miles away. Few, if any, residential areas were found to be more than 1.5 miles away from green space in either scenario thus we did not have to limit value generation to just parcels within this maximum easy walking distance.

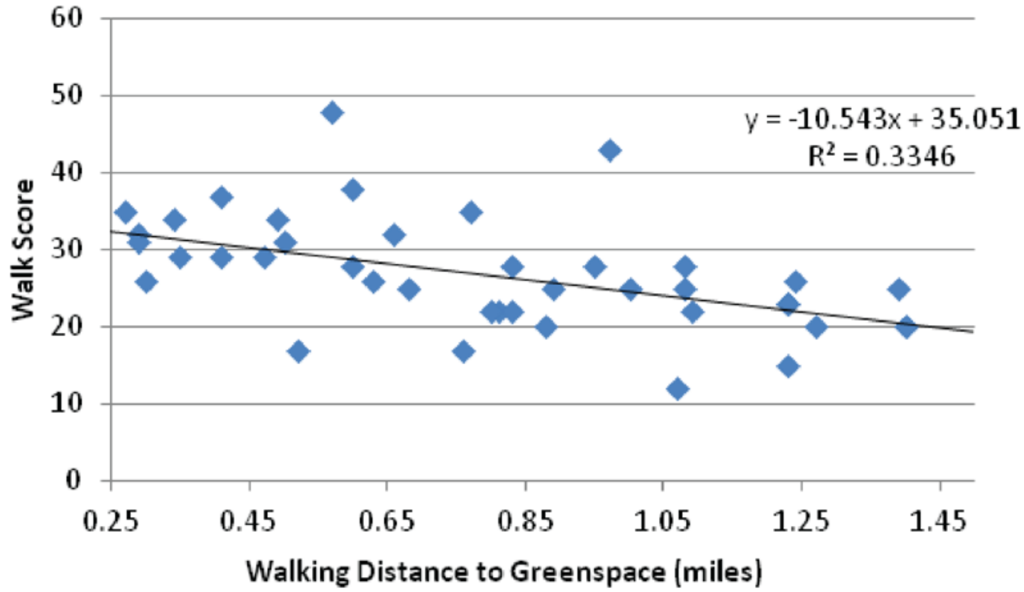

Figure 13. Distance to green space's relationship to Walk Score for Scenario A streets.

The sums of estimated increase in residential parcel value ($54 for each tenth of a mile closer than 1.5 miles) generated by nearby green spaces per street or neighborhood area were apportioned to each street or neighborhood's closest accessible green space access point and then divided by that corresponding green space's area (Figure 14). Green spaces included both natural areas reserved for walking trails and parks, but not ball fields. Our Scenario A neighborhood was estimated to have a level of access to the ecosystem good of green space worth $7.74 million US while Scenario B had $0.84 million US. Much of the value in Scenario A was generated by parcels within walking distance of a trail entrance or small pocket park that were not as easily identified in Scenario B.

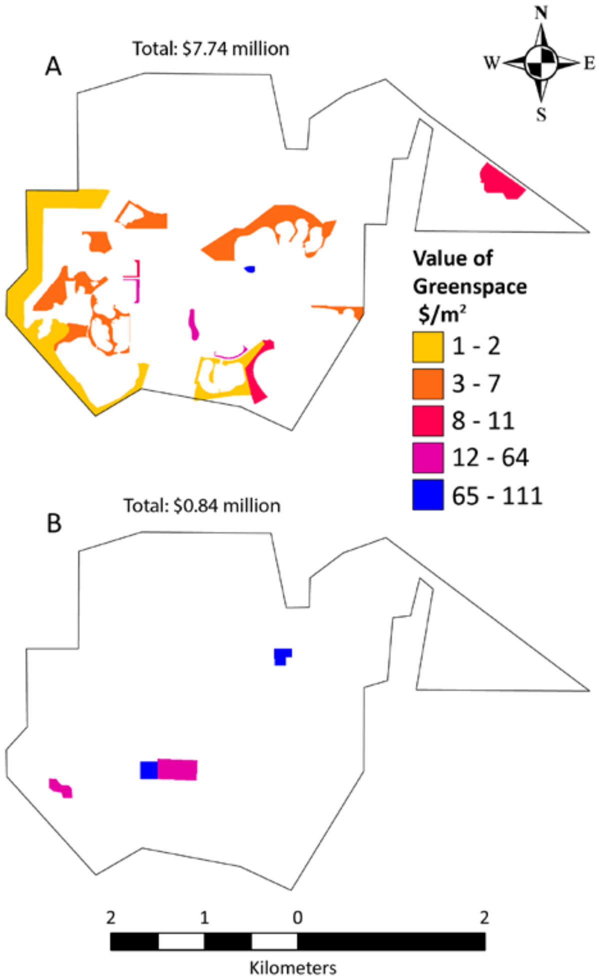

Figure 14. Development Scenarios A and B for distance weighted accessible green space value derived from residential parcels within walking distance.

AESTHETIC VALUE OF RESIDENTIAL TREES

There are several benefits from ecosystem goods that are best summarized as a marginal increase in value, such as the fact that humans have been shown to be willing to pay an additional 1% in property costs per large tree present within view when they are assessing a property (Anderson and Cordell 1988). We calculated the area of canopy cover in every parcel and divided that by 80 m^2, the area of a typical mature tree in our Scenario A neighborhood (Figure 15), to estimate the number of viewable large trees or smaller trees with equivalent canopy cover per parcel. For Scenario B we divided each parcel's canopy cover by 120 m^2 to correct for the older age of this neighborhood, and consequently larger more mature tree canopies. Our Scenario A neighborhood parcels were estimated to have a total tree canopy cover equivalent to 10,000 mature trees while Scenario B had canopy cover equivalent to 31,500 mature trees. This ecosystem good is estimated to be worth $22.63 and $3.79 million US for Scenario A and B, respectively. The large difference here is mainly driven by lower property values for parcels in Scenario B that are almost 3 times lower on average than in Scenario A. The correction factor we chose for the older tree canopy structure in Scenario B could also be too large (Figure 21).

WATER FEATURE VIEWSCAPES

Residences in Scenario A that enjoy water views were identified by hand selecting parcels that have an unobstructed line-of-sight to a lake, reservoir, or pond water feature, taking into account views being blocked by other residences and areas of vegetation (Figure 16). The valuation approach for water features is similar in theory to that used for estimating the value of benefits derived from viewable mature trees. Landscape psychologists Kaplan and Kaplan (1989) state that “Water is a highly prized element in the landscape” and a large-scale evaluation of hedonic pricing valuation concluded that 8-10% of the value of houses overlooking water can be attributed to the pleasant view that water features offer (Luttik 2000). Similarly Schultz and Schmitz (2008) estimated, from a large sample of homes with views of artificial lakes, that these houses had premiums that ranged between 7.6-8.3% due to the view. If we assume that 8% of the value of each parcel in this area of the country is attributable to water views, then each water feature generates, on average, around $30,000 of value per parcel having a water view, with the actual number depending on each parcel's assessed value for the 2009 distribution of home values. This ecosystem good dominates the total value attributed to the three ecosystem goods assessed in this study. Each water feature's total value was estimated as the sum of value generated from all parcels with views of that water feature. The value of a water view can be thought of as the present value of that natural capital that would be lost if that water feature was removed or its view-ability degraded or blocked. This ecosystem good is estimated to be worth $538.95 and $0.32 million US for Scenario A and B, respectively.

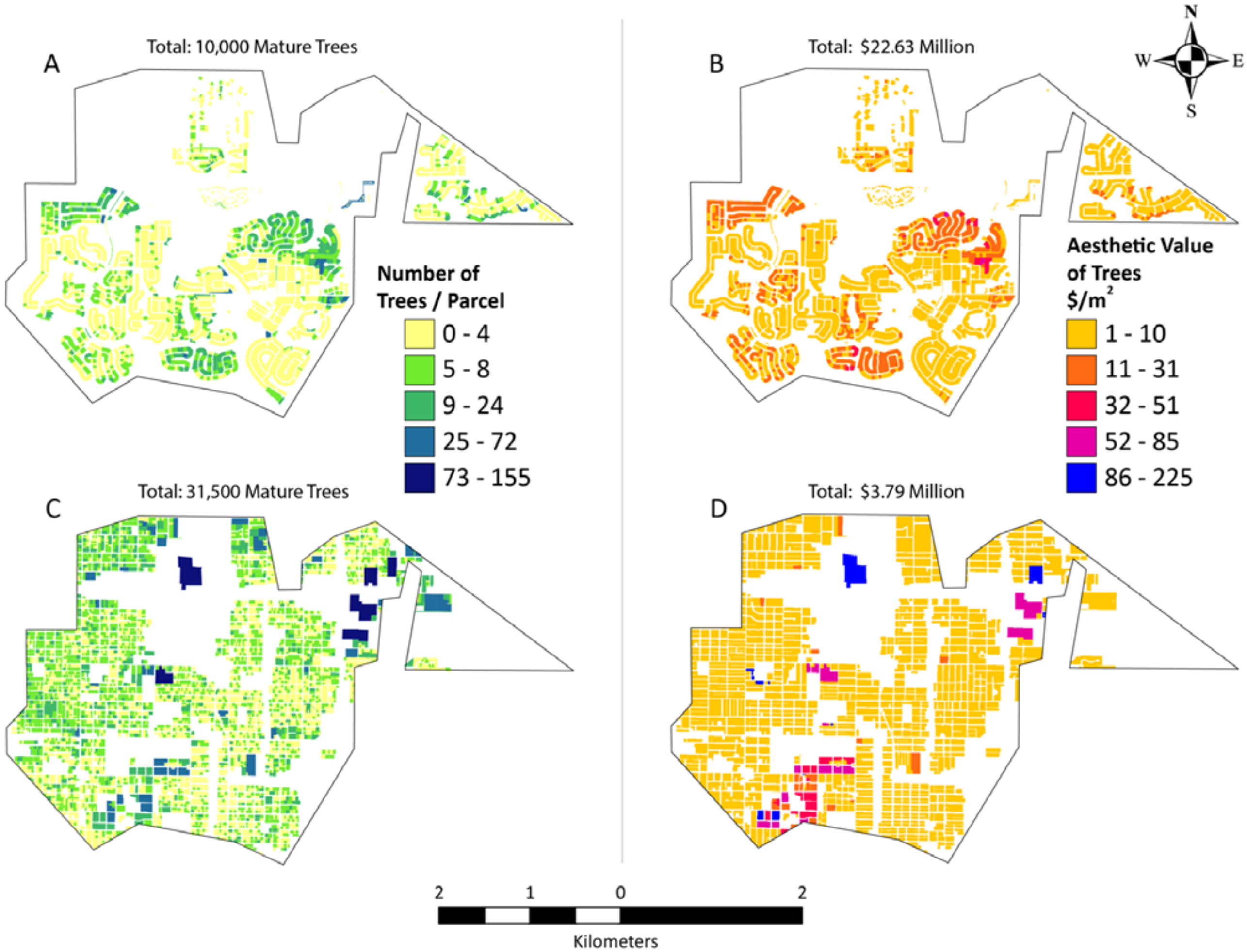

Figure 15. Development Scenarios A and B for trees per parcel (A1 and B1) and corresponding Ecosystem Good value (A2 and B2).

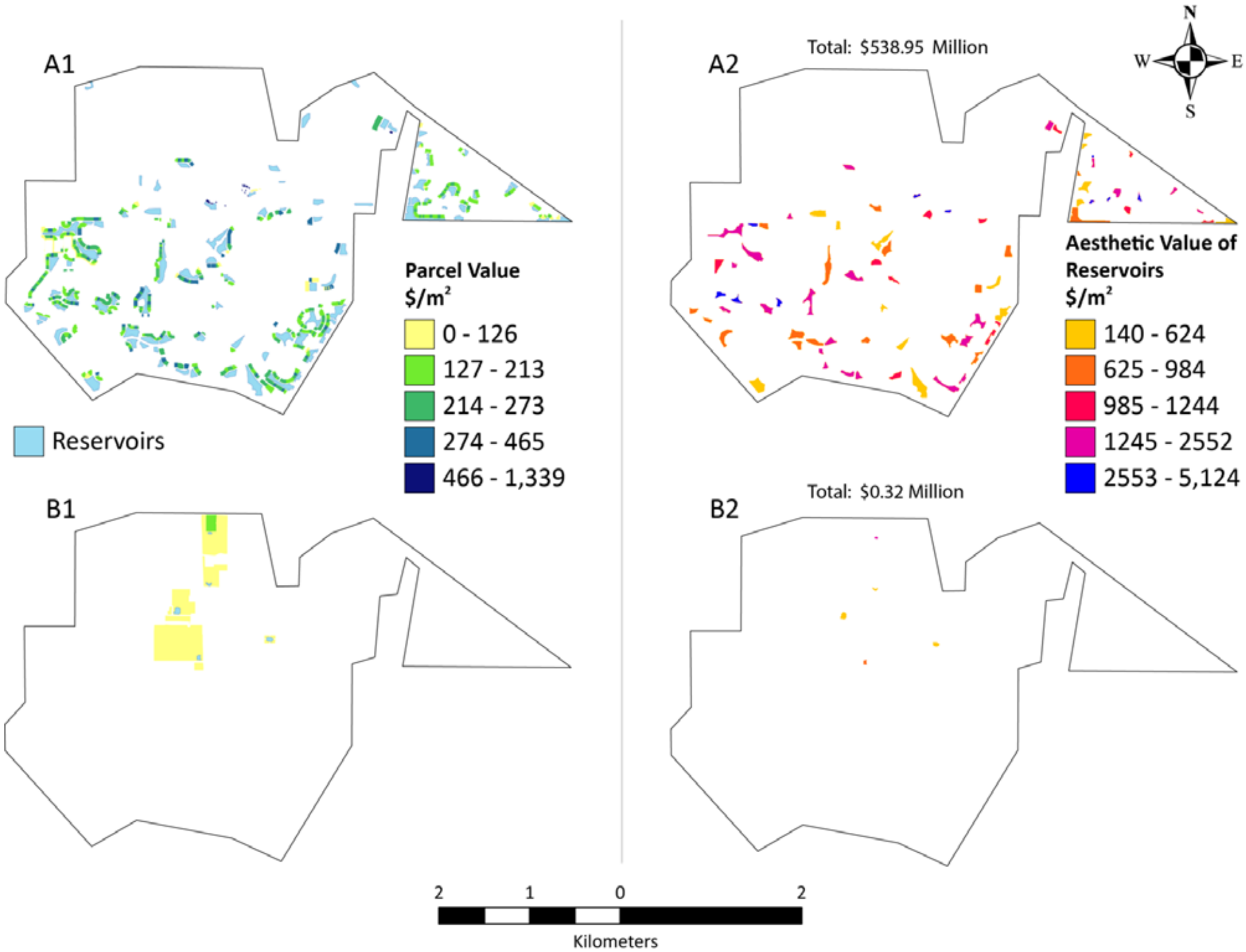

Figure 16. Per square meter value of parcels with views of reservoirs in Scenario A (A1) and Scenario B (B1). The corresponding reservoir Ecosystem Good value (A2 and B2) is the sum of value generated by all parcels within view divided by the reservoir area.

SECTION 3. NEIGHBORHOOD SCALE VALUE OF ECOSYSTEM GOODS AND SERVICES

Adding the three ecosystem goods values together (green space, viewable trees, and water views) allows us to compare estimates of, albeit not complete, cumulative values of ecosystem attributes for each scenario. The three ecosystem goods are valued at just over $571 million for Scenario A and just over $5 million for Scenario B (Figure 17). Likewise, the sum of the four ecosystem service values (air pollution removal, tree shading, nitrogen removal, and carbon sequestration) yields a rough estimate of $2.3 million worth of yearly production for the existing development and $1 million worth for the alternative scenario (Figure 18). Maps of these values allow us to see the spatial distribution of both ecosystem goods and ecosystem service value throughout the neighborhood (Figure 19).

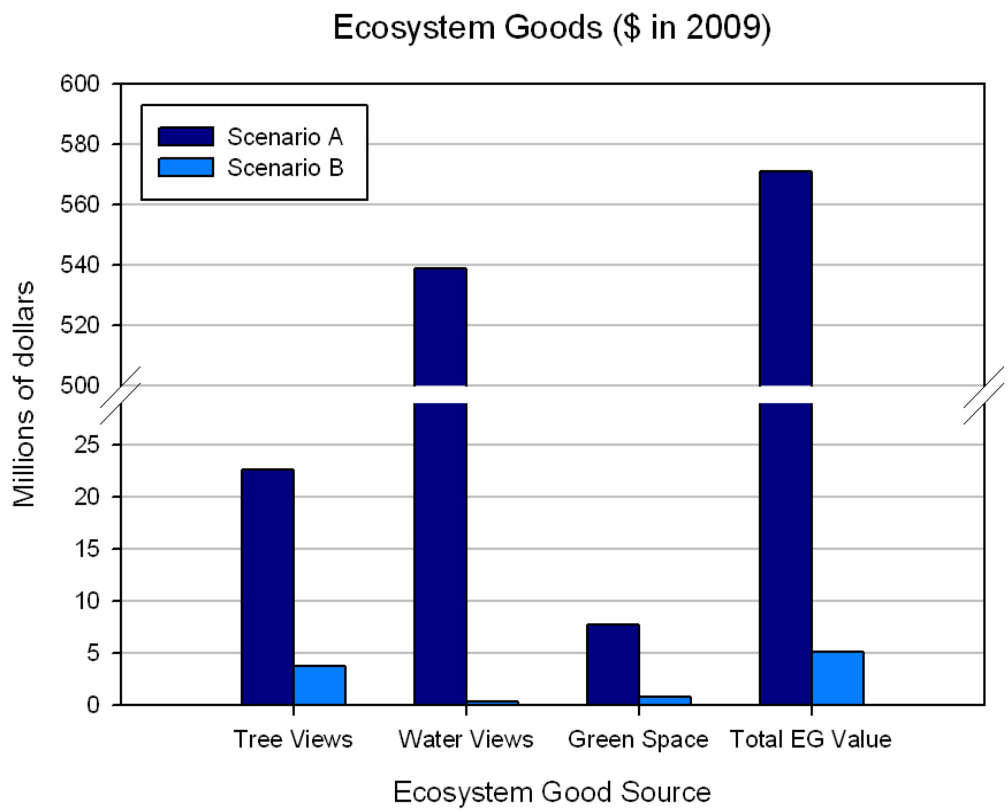

Figure 17. Total value of three ecosystem goods for each scenario.

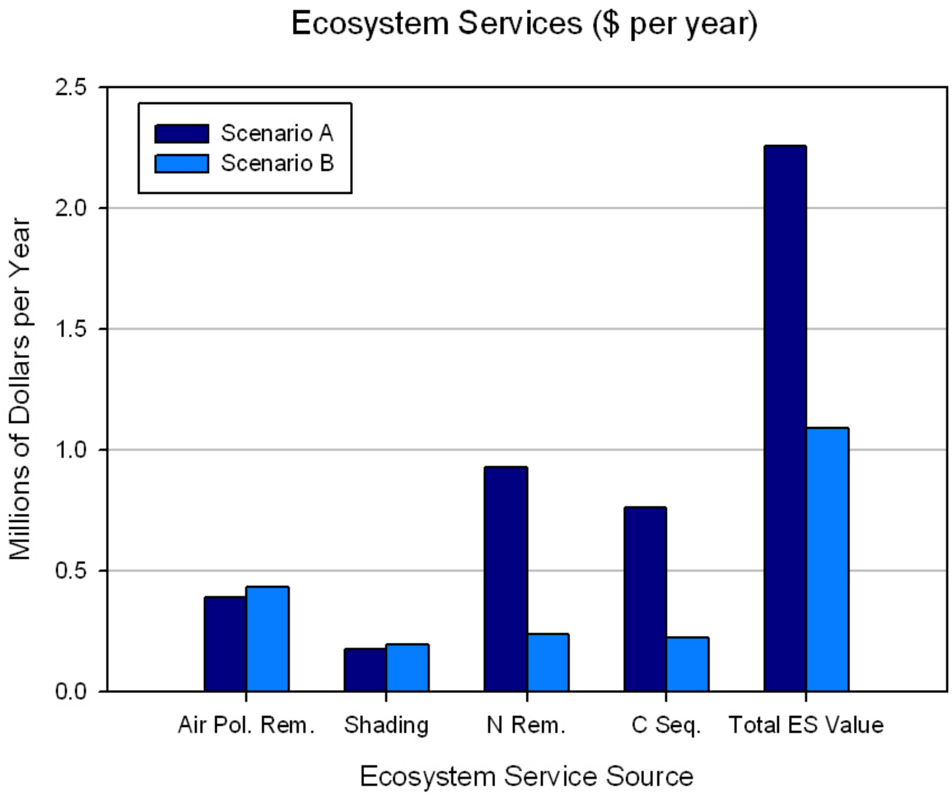

Figure 18. Total annual value of four ecosystem services for each scenario. (Air Pol. Rem. is Air pollution removal, N Rem. is Nitrogen removal, and C Seq. is Carbon sequestration).

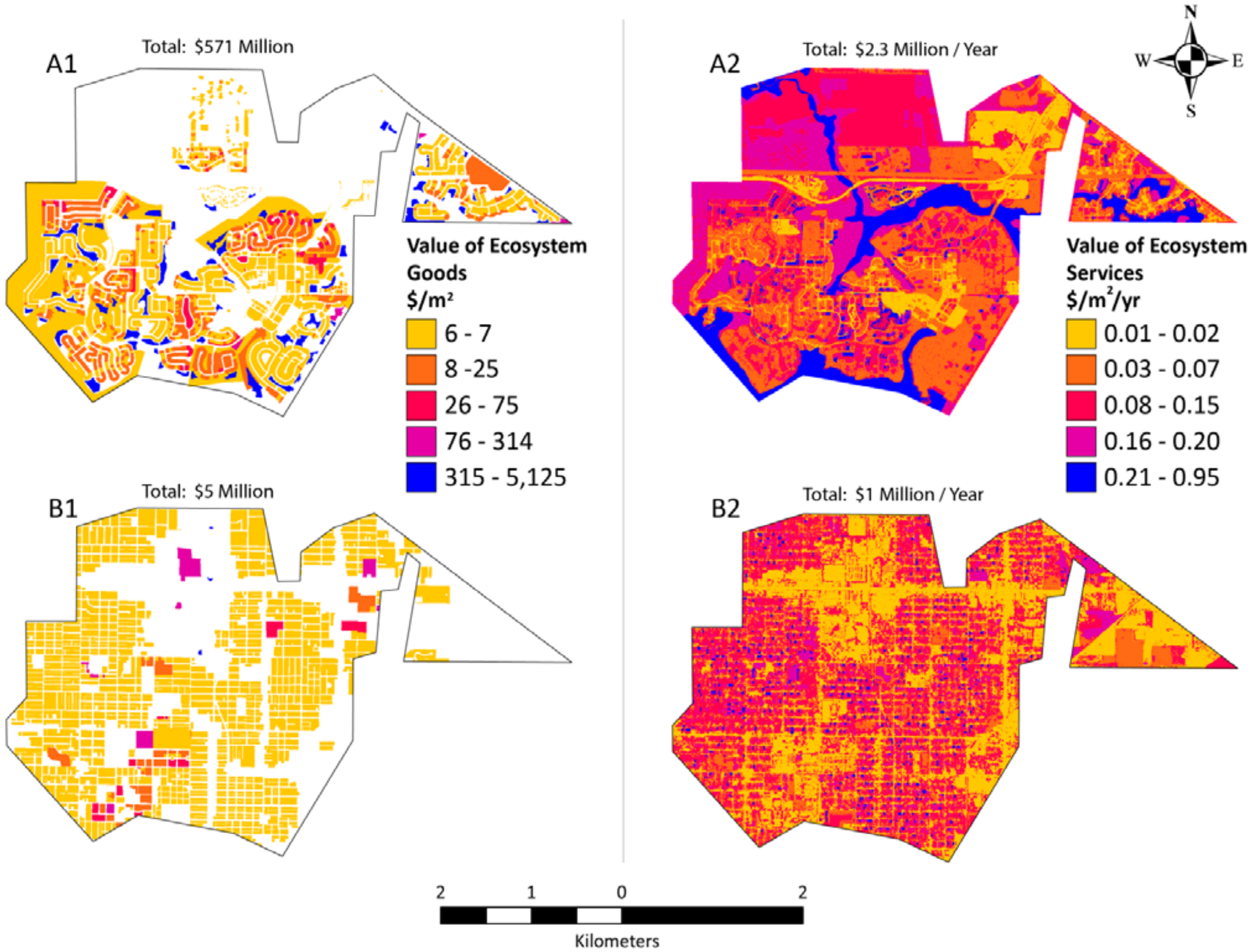

Figure 19. Development Scenarios A and B for cumulative Ecosystem Goods value in 2009 (A1 and B1) and annual Ecosystem Services value production (A2 and B2).

BIODIVERSITY AND ECOSYSTEM GOODS AND SERVICES RESILIENCE

The final ecosystem attribute presented is biodiversity. Biodiversity holds no direct use value to humans, other than existence value that is usually attributed to specific charismatic species, but it has been postulated as providing a form of insurance against fluctuations in the production of all other ecosystem goods and services. Baumgärtner (2007) concluded, using a stylized conceptual model combining ecological and economic factors, that biodiversity can serve as natural insurance for risk adverse ecosystem goods and services managers. Quantification of the value of biodiversity remains beyond current economic or ecological capability and is thus simply presented here as a relative change using the metric of species abundance. Species diversity was mapped by applying individual species abundance and presence/absence data (Table 4) from Layne et al. (1977) to each FLUCCS land type for each scenario (Figure 20). The distribution of land use/cover was then used to quantify the relative value of biodiversity for our two scenarios.

It should be noted that the type of species noted for each FLUCCS type by Layne et al. (1977) was not used to weight the relative contribution to this metric of biodiversity and so species generally thought of as residential neighborhood nuisances such as feral cats, hogs, or alligators hold the same value in quantifying this indicator of ecosystem services resilience as song birds, bats, or butterflies. Quantification of the dollar value of biodiversity is beyond the scope of this paper but an assessment of biodiversity in each scenario is included here to allow comparison of our ecosystem goods and service values to this more familiar indicator of ecosystem integrity.

Table 4. Land Use Specific Species Richness

Description	**FLUCCS**	**Species Richness Map Value** [Number of species]	**Reference**
Residential Low Density	1100	16	(Layne et al. 1977)
Residential Med Density	1200	16	(Layne et al. 1977)
Residential High Density	1300	16	(Layne et al. 1977)
Commercial And Services	1400	16	(Layne et al. 1977)
Institutional	1700		
Recreational	1800	43	(Layne et al. 1977)
Open Land	1900	43	(Layne et al. 1977)
Cropland And Pastureland	2100	43	(Layne et al. 1977)
Other Open Lands	2600	37	(Layne et al. 1977)
Herbaceous	3100	22	(Layne et al. 1977)
Shrub And Brushland	3200	17	(Layne et al. 1977)
Upland Coniferous Forest	4100	50	(Layne et al. 1977)
Pine Flatwoods	4110	64	(Layne et al. 1977)
Hardwood Conifer Mixed	4340	50	(Layne et al. 1977)
Streams And Waterways	5100	59	(Layne et al. 1977)
Lakes	5200	68	(Layne et al. 1977)
Reservoirs	5300	76	(Layne et al. 1977)
Stream And Lake Swamps	6150		
Freshwater Marshes	6410	85	(Layne et al. 1977)
Wet Prairies	6430		
Emergent Aquatic Vegetation	6440		
Intermittent Ponds	6530		
Transportation	8100		
Communications	8200		
Utilities	8300		

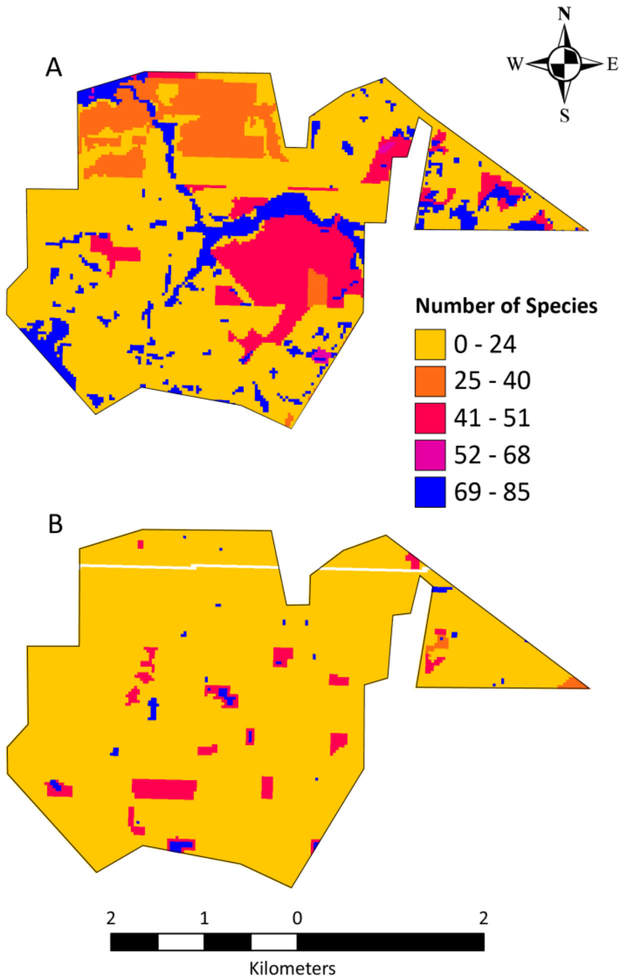

Figure 20. Biodiversity as a resilience indicator for ecosystem goods and services production for development scenario A and B.

PEOPLE AS PART OF THE ECOSYSTEM

There can be inherent tradeoffs between having higher density residential areas, such as that presented by our alternative development Scenario B, and maintaining a high level of benefits from ecosystem goods and services. Selective placement and preservation of natural features during development planning could greatly increase the potential long-term benefits to residents from ecosystem services. Consideration of how to optimize the use of existing ecosystem features during development, such as how to orient property to maximize benefits of shade trees and how to place accessible and/or viewable green spaces and water features, may produce more sustainable neighborhoods with residents whose well-being is maintained by more than human built components of the ecosystem. Our two development patterns are noticeably different in the number of residences they contain. Scenario A has 4,068 parcels with an average assessed value close to $175,000 while Scenario B has 3,603 more parcels but with only one-third of the average assessed value (Figure 21). Scenario A parcels have an average acreage of 0.21 per parcel for a total acreage of 846.97 while Scenario B has 7,671 parcels with a mean acreage of 0.19 per parcel for a total acreage of 1,422. To standardize the two scenarios' residential parcel footprints we would have to replace approximately 757 acres of open, forested, and or wetland area in Scenario A with residential parcels. This conversion would result in approximately $350 per acre less annual carbon sequestration and nitrogen removal services for a total of around $265,000 per year in lost value for global and watershed beneficiaries. This is roughly one-forth our estimated difference between the two scenarios for these two services. This loss in value may, however, be offset by dramatic increases in local value from residential tree viewscapes and access to green space depending on where and how the additional parcels were located in respect to forested areas and or parks. There are other complicating factors that can explain differences in average parcel value, such as the age of property, building materials, proximity to schools and crime, etc., so this relatively simplistic assessment of ecosystem goods and services differences should be used alone to explain value differences. Also, one of the potential advantages of denser developments does not present itself at neighborhood scales. The less extensive footprint produced by having smaller parcels or multifamily buildings may leave surrounding areas more undeveloped, assuming equal regional population numbers, than a development pattern that is more sprawling in nature. Many ecosystem services are produced on scales beyond the neighborhood, such as watershed, airshed, or region. Neighborhood scale comparison results should only be considered alongside broader regional spatial changes in ecosystem goods and services outside the neighborhood of interest. We only present these ecosystem goods and services analyses to demonstrate an approach for including them in development related decisions involving tradeoffs among ecosystem goods and services.

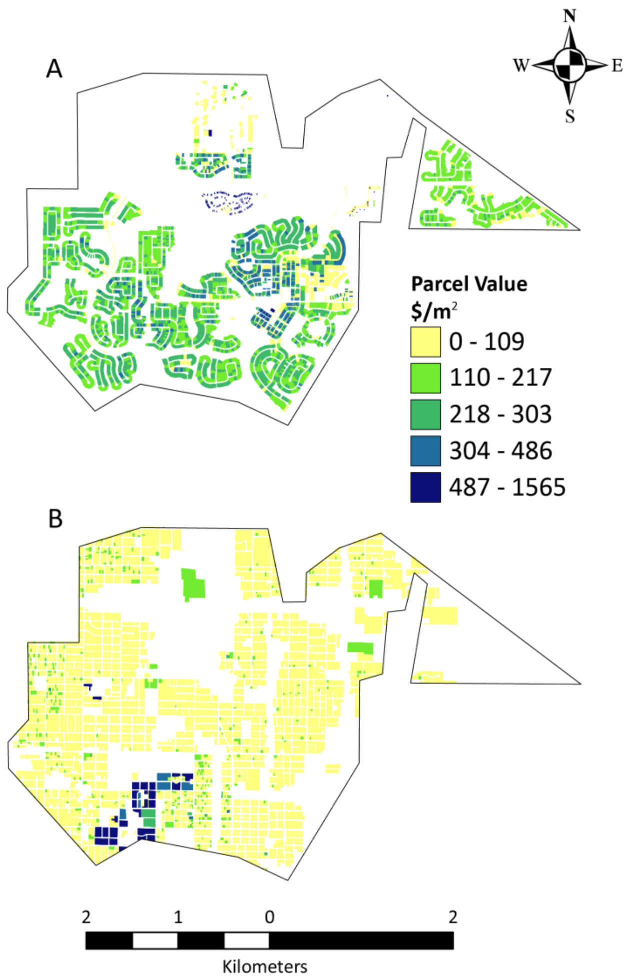

Figure 21. Parcel value for development scenario A and B.

DISCUSSION

While not a comprehensive comparison of the potential benefits derived from two alternative neighborhood development strategies, this study demonstrates, at the neighborhood scale, an approach for quantifying differences in the value of EGS. This study looked at both generation and delivery of benefits at the neighborhood scale. We also acknowledge that there are local benefits from ecosystem goods and services generated from beyond the confines of the neighborhood as well as regional and globally delivered benefits derived from the local area. The EGS used in this demonstration piece are also not all inclusive, but were selected to be representative of the types of ecosystem attributes that generate benefits to humans. Ecosystem goods and services not included in this analysis include soil fertility and pollinator habitats supporting agricultural production activities, access to aquatic ecosystems for recreational activities such as boating or fishing; recruitment and production of recreational and commercial produce; and precipitation, retention and infiltration by landscapes for recharging water supplies in aquifers and preventing flooding among others.

Ecosystem goods can potentially provide a large amount of value to residents at the neighborhood scale. The highest values in this study came from the aesthetics of water features and access to green spaces. The annual rates of ecosystem services production are of a seemingly much lower value than the value wrapped up in ecosystem goods but comparing them at a given point in time is unfair since services continue to produce value through time to both local and remote beneficiaries. Comparison of our two scenarios, which both include ecosystems with attributes that are ecosystem goods and processes that are ecosystem services, helps illustrate this point.

There are two main components of the landscape that provide both ecosystem services and ecosystem goods. Areas where water ponds or flows together to form streams, rivers, and other water features are valued for water views but also produce conditions favorable for nitrogen removal and carbon sequestration. Forested or other vegetated areas provide the structures needed to produce value as an ecosystem good by providing opportunities to access green space and for their aesthetic value while also functioning as pollution, carbon, and excess nitrogen removal zones. When the total value of ecosystem goods and services in Scenario A are examined we can determine the point in time when the accumulating value of annually produced ecosystem services will surpass the mostly static value of ecosystem goods.

For Scenario A, the value of ecosystem goods is approximately 250 times that of a year's worth of ecosystem services production. Another way of saying this is it will be around the year 2260 before Scenario A's ecosystem services generate a cumulative value equivalent to what is inherent in their ecosystem goods in the year 2009. Much of the value of ecosystem goods is generated at the initial building of a development. Scenario A, which is based on a neighborhood developed around 1990, could be assumed to have already enjoyed about 15-20 years of ecosystem service production and that it may take another 240 years before accumulated value of ecosystem services surpasses the initial generation of ecosystem goods value during neighborhood development. In comparison, Scenario B currently has about one-half the annual production of ecosystem services as Scenario A, but because of the low value of ecosystem goods present in Scenario B it will only take 5 years or so before the cumulative value of ecosystem services production surpasses the value of the ecosystem goods. The difference in annual production also implies that the differences in ecosystem goods and services value generated by each scenario will compound over time. Communities should consider the temporal aspect of value production from ecosystem services when making planning decision related to sustainability goals.

Out of the three ecosystem goods and four ecosystem services included in this study, the quantification of all three ecosystem goods (accessible green space, and viewable trees and water features) and one of the ecosystem services (reduced energy costs from shading) at the neighborhood scale required local and high resolution spatial data such as land cover, roads, trails, canopy cover, impervious surface, and sight lines combined with fairly customized or manual GIS operations that are not easily obtained or implemented for broader areas. Carbon sequestration and nitrogen removal process rates are easier to estimate on larger scales but are harder to accurately value at the neighborhood scale. Carbon sequestration, for example, is only beneficial, and thus generates value to humans indirectly through its influence on mitigating rapid climate change. This realization or "delivery" of ecosystem service value to human beneficiaries takes place in a dispersed way through the atmosphere. Nitrogen removal processes only generate value to specific beneficiaries as an ecosystem service if excess nitrogen, that otherwise would affect human health directly through the water supply or indirectly through decreased production of other ecosystem goods due to nitrogen's influence on downstream ecosystems, is being removed. The benefits of nitrogen removal are either delivered to beneficiaries through stream drainage networks using downstream ecosystems or to upstream beneficiaries that otherwise would have to worry about reducing their nitrogen loads to the system through engineered solutions. Thus, beneficiaries have to be connected to ecosystem service production areas to actually benefit in the same way as beneficiaries are connected to ecosystem goods through transportation networks or viewsheds. A more complete valuation of ecosystem goods and services at the neighborhood scale would have to consider both local and remote beneficiaries of ecosystem goods and services produced in that defined area.

The value of ecosystem goods are not really separated from ecological functions since they are often the result of ecosystem processes that took place in the past (e.g., tree and vegetative growth, soil production, etc.). The difference between ecosystem goods and ecosystem services is thus a temporal distinction with ecosystem goods assessed at a given point in time as a stock while ecosystem services are assessed through time as rates. Here we defined the value of ecosystem goods at a specific moment in time, but in reality their production through ecological processes continues to be generated. Essentially, we are placing a value on ecosystem function rates that happened in the past. If we could define how long it took to produce the ecosystem good, then a production rate could, theoretically, be calculated. Taking the current value of a tree and dividing it by the tree's age is used as an example of this. The value at any given time has been produced from the growth of trees over many years. This growth rate could be considered alongside ecosystem service rates instead of valuing the ecosystem good at a specific point in time. A laural oak, a typical tree planted by developers in the Tampa Bay region, for example, takes around 20-30 years to reach a mature size. Average 2009 detached house property value in the FishHawk Ranch neighborhood was $385,028 according to www.city-data.com (accessed June, 2012). Thus, each large tree, by generating 1% of that property value, may increase a property's value by as much as $3,850 just by being present and viewable on each parcel. We applied this 2009 value estimate to our 2009 scenarios and divided by the area of each parcel. Assuming a 20-year maturation period, the annual production of ecosystem good value from a maturing tree equates to around $192.50 per year per tree. This method, albeit with many assumptions, provides one way to compare the produced value of an ecosystem good, in this case roughly $2 m^{-2} $year^{-1}$, to other annual rates of ecosystem service value production as presented above.

Alternatively, if we could estimate the value of ecosystem services using future states or stocks of ecosystem attributes that are beneficial to humans at those specific points in time, we could avoid the difficulties in trying to sum their values presented by valuing ecosystem goods as stocks and ecosystem services as rates. While valuation of ecosystem goods and services at a specific point in time would be less confusing than dealing with rates and stocks, this approach would require many assumptions about future values.

In residential neighborhoods, where little of the preexisting landscape remains, it becomes difficult to think of many of the ecosystem goods and services presented in this report as actually derived from nature. Water retention ponds, for example, are a human construct. Many local parks are landscaped green spaces with vegetation different than existed pre-development. Most street and yard trees are planted post development with few previously existing mature trees remaining. Since these features required human intervention should they be included in value estimates for ecosystem goods and services? The answer to this question has dramatic ramifications for valuation estimates of ecosystem goods and service production. Water feature views generate the majority of ecosystem goods value in this study. If we were to discount those features wholly created by humans (e.g., retention ponds) then the combined value of the ecosystem goods present in Scenario A is reduced from over 80 to only 10 times more than that generated by the annual production of ecosystem services. This shift in how value is generated from ecosystem goods to annually produced ecosystem services could make significant differences to decisions on how to best manage these natural assets based on value generated from their ecosystem goods and services. The ecosystem goods and services paradigm developed from a need to account for those things in nature that we derive benefits from and are not already accounted for in our existing economic systems and markets. Thus, human input into producing ecosystem goods or services that is quantifiable as part of the existing economy and markets, such as fuel, equipment and labor costs, should theoretically be subtracted from value estimates for any ecosystem attribute. The net benefit derived from an ecosystem attribute after subtracting inputs from the market economy are nature's contribution within full cost benefit accounting. This concept is currently being discussed within the ecosystem goods and services discipline, so implementation is beyond the scope of this study.

An added complication for estimating the value of ecosystem goods and services production in specific ecosystems is that each will fall along a potentially non-linear production curve that is dependent on various gradients of characteristics impinging on the system. These relationships between external factors and functional responses are commonly referred to as ecological production functions. While an assessment of changes in ecosystem goods and services using an ecosystem replacement approach, such as used in this study, requires average values for that ecosystem type's production of each EGS, an assessment that takes into account ecological production functions requires estimates of production of each ecosystem good or service along at least one gradient. This added complexity in developing ecological production functions multiplies as one begins to assess the totality of an ecosystem's suite of EGS production, many of which respond to multiple gradients. This type of assessment requires complex system dynamics models operating both in space and through time and with the ability to account for multiple spatial connections and ecological function interactions.

CONCLUSIONS

There is something that draws humans to neighborhoods developed with a consideration of green space. Residents often pay higher prices for homes close to accessible green spaces and with pleasant views of outdoor landscapes. The ecosystem goods and services paradigm provides us with a defensible, transparent, and objective way of quantifying some of these relationships between humans and their environment. The utility of the methods we describe in this report is highest when used in relative comparisons between alternative management strategies or scenarios.

The application of our methods to a defined geographical space at a given moment in time helps to illustrate the differences between ecosystem goods and ecosystem services and how related benefits are delivered to humans. Tradeoffs between fostering the immediate production of value to residents from ecosystem goods versus sustaining the long-term production of ecosystem services can be assessed in a spatially explicit manner while taking into account which, where and when beneficiaries might realize benefits from nature. A developer might, for example, want to assess the tradeoffs between maintaining an area as a functional forested wetland continuously providing several widely distributed benefits through time versus opening it up to become a viewable water feature providing a discrete but concentrated increase in value to local beneficiaries.

The neighborhood scale quantification of ecosystem goods and services demonstrates the types of data and customized workup required for accessing benefit tradeoffs associated with commonplace realistic decisions. Assessment at this scale presents some challenges and there are few "out-of-the-box" tools that can meet those challenges. This scale, however, works well for identifying beneficial components of the landscape that are relevant to humans and manageable. The approach presented in this report is well suited to informing small-scale decisions such as where to locate a walking trail or how to route water flow from street runoff. We propose that the additional effort to generate geospatial data relevant at the neighborhood scale, and the somewhat time intensive methods needed to translate from biophysical measures into value to humans, is warranted since the results are easily relatable and informative for many real decision contexts.

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