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Research Paper

Integrating ecosystem services and local government finances into land use planning: A case study from coastal Georgia

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HIGHLIGHTS

- Forested wetlands generate relatively little revenue, but have very high ecosystem service value.
- Forest lands overall contribute much more in revenue than they receive in services.
- Residential properties cost more in services, than they generate in revenue.
- Ecosystem services benefits, hazard reduction, and lower costs result from floodway buffers.

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ABSTRACT

This work presents a novel approach to assessing the impact of future growth in rural regions faced with rapid growth. We investigate one of the most rural counties on the eastern coast of the U.S. (McIntosh County, Georgia) from the dual perspective of (1) ecosystem services and (2) costs assumed by local government. As land cover in our focal locality is overwhelmingly forest or wetland, we compiled estimates from multiple sources to map the value per ha/year of (1) timber sales and recreational leases to private landowners and (2) a suite of non-market public amenities: rare species habitat, carbon sequestration, flood control, pollution treatment, water supply, and storm protection. We then quantified, based on county budgets, expenditures and revenues deriving from major land use categories (residential, commercial/industrial, agricultural/open-space). Results indicate that (1) forested wetlands generate relatively little revenue to either private landowners or in taxes to the county from extractive uses, but have very high value relative other land cover types in the provision of ecosystem services, (2) forest lands contribute much more in revenue than they receive in services, whereas residential properties cost more in services, than they generate in revenue, and (3) significant gains in both ecosystem service preservation, hazard reduction, and in lower costs to the county in municipal services could be achieved by restricting new development from within the Federal Insurance Rate Map (FIRM)-determined 500 year floodplain.

1. Introduction

In a process echoed in many other parts of the world, over the last 60 years, a major driver of land use change in the United States has been suburban and exurban development. Prior to 1950, land use moved typically from wild land where resources were extracted to agriculture then finally to suburban or urban uses. Since 1950, low-density housing (6–10 homes/km^2) set within a landscape of native vegetation has become the fastest growing form of land use (Brown, Johnson, Loveland, & Theobald, 2005; Hansen et al., 2005). Low-density development is often welcomed by rural and suburbanizing counties/municipalities for its perceived benefits to the local economy and to municipal level tax revenues, and because of the returns to politically influential landowners from subdividing and selling land. As it has spread and been replicated across many regions, low-density development patterns resulting from the conversion of forest and agricultural lands to primarily residential uses, often dubbed "sprawl", has come under attack from planners and environmentalists.

On the fiscal side, critics have often made the case that the economic benefits of low-density residential development in the form of tax revenues to local communities may be significantly outweighed by the costs of providing municipal services such as roads, schools, police and fire protection to newcomers. Furthermore, the burden of funding infrastructural improvements or expansion of services is often borne by current rather than incoming residents

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(e.g. Carruthers & Úlfarsson, 2008). A second set of concerns relate to the loss or impairment of natural amenities such as water quality, wildlife habitat, and recreational opportunities with increased development, and the concurrent decline of traditional economic activities such as agriculture, forestry, and fishing. (See Pejchar, Morgan, Caldwell, Palmer, & Daily, 2007; Real Estate Research Corporation, 1974, for a detailed introductions to both sets of critiques.)

Cost of Community Service (CCS) studies have been used to estimate the fiscal impact of development. The American Farmland Trust (AFT) first developed the CCS methodology in the mid-1980s, following two seminal publications, The Fiscal Impact Handbook (Burchell & Listokin, 1978) and Cost of Sprawl (Real Estate Research Corporation, 1974), which demonstrate the importance and cost-effectiveness of land-use planning. The CCS approach partitions land uses into three classes: residential, commercial/industrial, and agricultural/open-space, and then allocate expenditures and revenues from the municipal budget to each category. Although the specific assignment of funds may differ among CCS studies, the final result is always a ratio of expenditures to revenues for each of the three land uses. For example, a ratio of 1.2 for residential land means that for every $1.00 of revenue raised from these areas, that $1.20 is spent (Dorfman, 2006).

The issue of lost environmental amenities as a countervailing cost to the expected benefits of development has received increasing attention with the emergence of ecosystem services as an organizing principle. As a concept, "ecosystem services" addresses the need to adequately represent the value to humans and human society of vital functions performed by natural systems when, for example, making decisions that determine future land use. How ecosystem services are defined has evolved over the last two decades as various frameworks have been developed (Boyd & Banzhaf, 2006; Brown et al., 2007; Costanza et al., 1997; de Groot et al., 2002, Daily, 1997; Fisher & Turner, 2008; Millenium Ecosystem Assessment, 2005; Wallace, 2007). Broadly, we may define ecosystem services as products of nature that directly benefit humans. Practically, estimating the value of ecosystem services often faces a crucial limitation in the availability, format, and quality of relevant data. Furthermore, the availability, format, and quality of socioeconomic data from which valuation must ultimately be inferred (Polasky, Nelson, Pennington, & Johnson, 2011). Deriving values for ecosystem services in such a way that they can be compared in similar units to the fiscal gains and losses stemming from development is most straightforward when the services are directly linked to markets as is the case with timber, fisheries, or agricultural products ("provisioning services" in the MEA scheme). Estimating values is much more challenging when the services of interest, such as biodiversity or maintenance of water quality, cannot be readily linked to markets (Barbier, 2007; Mangi et al., 2011; Mendelsohn & Olmstead, 2009; Polasky & Segerson, 2009). Whereas increasing intensity of use leads, it is generally believed, to reduced flows of regulating ecosystem services (e.g. climate change mitigation by carbon sequestration, absorption of flood waters) (de Groot et al., 2010), we often lack information on "production functions" or the relationship between changes in land use and these flows (Polasky et al., 2011), and, importantly, whether such functions may exhibit non-linear or threshold responses to land-use changes (Barbier et al., 2008; Koch et al., 2009). In addition, we often do not have a means for handling potential trade-offs among ecosystem services (Polasky et al., 2011), e.g. between conservation of biodiversity and carbon sequestration. The challenges above notwithstanding, existing valuation approaches allow land use changes to be broadly assessed in terms of likely gains or losses in specific services.

However, an additional issue relates to the potential mismatch between opportunity costs and benefits of ecosystem services that are often managed at a local scale yet valued more at statewide/regional, national or global scales (Hein, van Koppen, de Groot, & van Ierland, 2006). For example, the protection of nursery habitat for fisheries may require local planning efforts, but the value may accrue to a larger regional or statewide group of stakeholders. Therefore, while attention may focus on the value of natural amenities to stakeholders defined broadly, these benefits may not be sufficient to influence local policy or development decisions which are often determined by vested interests, and incentives or benefits (perceived or actual) that apply locally. To the extent that these differences in local versus regional to global valuation have been addressed by policy-makers, a system of payments for environmental services (PES) may be incorporated into taxes or other policy tools. PES schemes are economic incentives to landowners or resource managers that take a variety of forms from tax relief to direct payments but seek to increase the flow of ecosystem services (see Farley & Costanza, 2010; Jack, Kousky, & Sims, 2008 for an overview of PES schemes and issues related to them). Thus, to effectively guide land use decisions such that ecosystem services are optimally preserved, constraints and incentives at the local level need to be accounted for (Polasky et al., 2011).

In this study, we focus on McIntosh County, a rural county on the Georgia coast. Because the county lacks large industries or major towns and a sizeable portion of the land-base is in public ownership, McIntosh is currently one of the least developed on the east coast. As with many coastal communities, the area faces development pressures as scenic and recreational amenities attract retirees, second-home buyers, and exurban commuters. The rapid connection via Interstate-95 to nearby communities and workplaces has spurred population growth in the county over the last two decades (http://www.rupri.org/Profiles/Georgia2.pdf, http://georgiastats.uga.edu/counties/191.pdf). The hiatus in growth following the crash of 2008 affords an opportunity to plan more comprehensively for future growth by evaluating different scenarios in terms of both fiscal and ecological impact. In this paper, we combine a CCS survey with measures of a set of ecosystem services toward the goal of identifying where outcomes have the potential to both maintain ecosystem service flows and limit municipal costs. We first categorize both local revenue sources and local government expenditures as flowing from rural versus commercial/industrial versus residential sources, and summarize the values for each class. Then, for forested lands and wetlands, the two major classes of rural land in McIntosh County, we map and sum the value of a set of ecosystem services as a means of identifying portions of the county landscape with high value for either commodity production or the provision of non-market ecosystem services, and therefore, candidate sites or features for development restrictions such as buffers, easements or overlay zoning.

Motivated by these results, we consider, in terms of fiscal gains and the value of ecosystem service flows, the potential impact of preserving critical elements of the landscape as "green infrastructure". Green infrastructure is an approach to conserving these components not only as natural amenities, but as features essential to ecological functioning and long-term sustainability (e.g. riparian buffers promote water quality and wildlife habitat) (Benedict & McMahon, 2002, 2006). To investigate likely differences in the cost of providing municipal services and in the value generated by natural systems in the form water quality/waste assimilation, carbon sequestration, timber production, wildlife habitat/biodiversity, and storm protection, we apply values from the relevant literature on land-use patterns, municipal expenditures, and ecosystem services to metrics derived from geographic models with and without green infrastructure. Our goals are to demonstrate how growth in McIntosh County can be best managed to maintain the provision of ecosystem services and limit the growth in costs to county

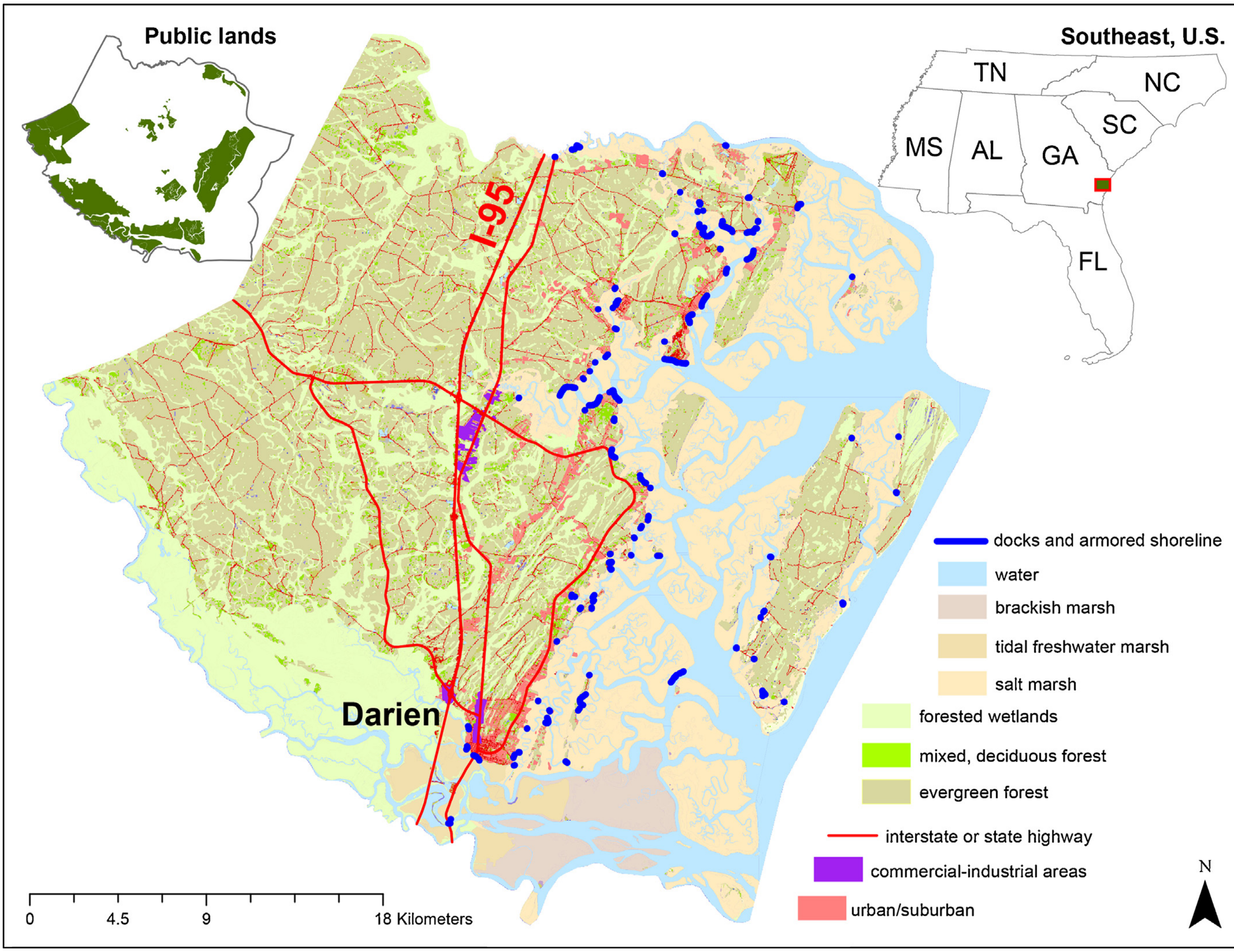

Fig. 1. McIntosh County land-use/landcover. Urban/suburban is derived from land-ownership parcels data and includes the non-wetland portions of all lots with structures. A pink overlay indicates land cover of any type within the boundaries of either public lands or conservation easements. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

government, but also more broadly the potential applicability of a CCS plus ecosystem service valuation methodology, and the utility of value transfer for estimating the value of ecosystem services in this context. We believe this study is unique in considering both local incentives and drivers of land use change, and, in addition, the ecosystem service flows at risk.

2. Materials and methods

2.1. Site

McIntosh County, population 14,333 (2010), land area 1122.6 km^2, is the least populous county on the coast of Georgia and one of the least-developed on the east coast of the U.S. Forests cover 76,841 ha, and intertidal marshes 30,547 ha. The Altamaha River estuary is located in the county. Sapelo Island, a barrier island located just offshore and the site of Sapelo Island National Estuarine Research Reserve (SINERR), is also part of the county. When marshes are included, total public lands comprise 46.7% of the county, and in addition to Sapelo Island, include bottomlands and swamps bordering the Altamaha River, and the coastal marshlands. Of the uplands and forested wetlands that make up the remainder of McIntosh County, 26.5% are in public ownership. At present the county is largely rural with most of the developed area restricted to Darien, the county seat, and its environs, an area of roughly 5% of the upland area of the county. However, Interstate 95 (I-95) traverses the county, and before the real estate collapse of 2008, McIntosh had begun to see increased residential development concentrated along the marsh at the eastern side of the mainland of the county. Income produced within the county is derived mainly from services related to tourism, construction, and to a smaller extent, timber and fisheries (http://www.georgiastats.uga.edu/). Fig. 1 shows current land-use and public ownership.

2.2. Land-use/land cover data sources

To map the value of ecosystems in McIntosh County we relied on two sources of land-use/landcover (LULC) classification: 2008 Georgia Land Use Trends (GLUT) data from the Natural Resources Spatial Analysis Lab at the University of Georgia (http://narsal.uga.edu/) for LULC data on upland portions of the landscape, and updated NWI for more detailed wetlands data. GLUT data divides land use into 13 categories based on a classification of 30 m pixel Thematic Mapper data. Forested lands are classified as evergreen, mixed, deciduous, forested wetland, or clearcut. Developed land is classified as urban or suburban according to percent impervious surface estimated by methods developed for the National Land Cover Database (Homer, Huang, Yang, Wylie, & Coan, 2004). NWI wetlands data were digitized from 1:12,000 scale air photos, and, therefore, provide greater accuracy than the GLUT data. In addition, newly released NWI data for Georgia provides detailed information on wetlands type, e.g. forested, shrub, emergant, freshwater, brackish, saltmarsh, and connectivity, e.g. riparian, tidal, isolated (Tiner, 2010, 2011). In our mapping, wetland LULC classes are assumed to be much more accurate spatially and more finely distinguished as classes than the upland LULC classes.

2.3. Crosswalking land use and land-cover types

In combining a CCS study with measures of market and non-market ecosystem services we rely on data compiled using contrasting land use/landcover groupings. Therefore, as a preliminary step, we must clarify how LULC terms across analyses are related, noting, first, that in the CCS study we cannot take estuarine marshland directly into account. [Because marshlands cannot be developed under Georgia law (Coastal Marshlands Protection Act, O.C.G.A. § 12-5-280, 1970); are not subject directly to management such as biomass harvesting, ditching or drainage; and do not require services. Nor, because marshlands are *de facto* property of the state of Georgia, do the marshes yield tax revenue. Marsh area and integrity is related by production functions to the size and quality of fisheries which do generate a return to the county in the form of sales tax, but we were unable to find existing estimates of this production function.] In the CCS study, therefore, we are concerned mainly with forested land ownership parcels. Thus, the CCS classes, commercial/industrial, residential, and rural farm/forest, correspond to urban, suburban, and rural, respectively, in the summary of ecosystem services from forests. (Very little agricultural or pasture land exists in the county.) Urban and suburban forests are defined as forest stands within areas of high (120 units/km^2) or moderate (25–120 units/km^2) housing density. The area of either urban or commercial/industrial land use in McIntosh County is small and roughly coincides. Therefore, nearly all forest within the county is classed as either suburban or rural which are lumped together for the forest ecosystem services we quantify.

2.4. Cost of community services

We reviewed the McIntosh County budget, fiscal year 2010 (final), fiscal year 2011 (adopted), and fiscal year 2012 (projected budget), and assigned revenue sources and expenditures to one of three categories, residential, commercial/industrial, or farm/forest. In most cases, judgments as to the appropriate land use category were straightforward. For example, revenue from sales tax on timber was assigned to the farm/forest category, and spending on county leisure services was placed in the residential category. Property tax revenues were separated according to parcel type, and payments in lieu of taxes (PILT) from the U.S. Fish and Wildlife Service were assigned to farm/forest.

Where costs were not easily separated we used several approaches. Following a standard ratio (Dorfman, 2006), sales tax revenues were assumed to come mostly (80%) from county residents with 15% contributed by non-residents, and 5% by businesses within the county. County administrative costs, emergency management, sheriff's department, the county jail, fire protection, and ambulance service were assigned based on the relative number of parcels in residential, commercial/industrial or farm/forest categories rather than population density. Currently, McIntosh County does not provide water and sewer to areas outside of the city limits of the county seat, Darien, which is a separate taxing municipality, and dwellings outside of Darien rely on wells and septic rather than county infrastructure. Therefore, water and sewer expenditures were not included in CCS calculations. Road maintenance costs were divided as follows. Interstates and state highways were removed from the county road inventory (available at http://georgiainfo.galileo.usg.edu/DOTmaps/mcintoshDOTmap2.htm) because they receive state and federal funding. Using GIS to overlay GDOT roads on current land-use for McIntosh County (available from Coastal Georgia Regional Development Corporation), county-maintained roads were labeled as residential if they served an entirely residential land-use, and commercial/industrial if they served generally commercial areas such as Darien's small downtown, and commercial areas adjacent to I-95. All other roads were assigned to the farm/forest category. Lastly, costs associated with county-funded courts were apportioned to categories based on guidance from the county manager as to how much service each sector receives.

Once all revenues and expenditures had been assigned, we compared the ratio of expenditures to costs for each land-use class. In addition to calculating CCS, we calculated the cost of farm/forest preservation in McIntosh County where 10% of the rural land area is enrolled in programs (Conservation Use Assessment, CUA, Agricultural Preferential, AG PREF, or Forest Land Protection Act, FLPA) that provide tax abatement in exchange for a commitment from the landowners to maintain the current use for a term of 10 years. The tax relief provided by these programs is meant to reduce the pressure on rural landowners to sell or subdivide land as tax rates increase with nearby development (https://etax.dor.ga.gov/ptd/cas/cuse/assmt.aspx). However, because the result is to shift the tax burden to homeowners within the county, we were interested in determining the additional costs to local residents of this tax policy.

2.5. Ecosystem services

For forested lands (including forested wetlands) within the county, we compiled estimates from multiple sources to map the value per hectare per year of (1) timber sales and hunting leases on private lands and (2) a suite of non-market public amenities: rare species habitat, carbon sequestration, flood control, pollution treatment, and water supply. For non-forested wetland, we used newly refined National Wetlands Inventory (NWI) data produced for the Coastal Resources Division of the Georgia Department of Natural Resources (Tiner, 2011) and accompanying attributes to categorize wetland types and, based on values from the literature, assign values for carbon sequestration, nitrogen removal, and storm protection.

2.5.1. Forests

2.5.1.1. Market value of timber. To estimate the value of timber (per ha) held by private landowners in the county, we first estimated average annual removals by forest type (pine vs. bottomland hardwood and swamp) for McIntosh County since 1998 from Forest Inventory and Analysis data (FIA, http://www.fia.fs.fed.us/) compiled by the U.S. Forest Service. We converted average values from volume to mass by assuming an average conversion factor of 560.65 kg/m^3 for pine, and 640.74 kg/m^3 for hardwoods (Haynes, 1990). We then estimated the value of this timber from records of the average price per mass unit in the state of Georgia since 1990 from Timber Mart-South (http://www.timbermart-south.com/). FIA volumes, Timber Mart-South prices, and conversions from volume to weight are all based on green weight (15% moisture content). We derived values for pine by performing weighted averages of pine pulpwood (15–23 cm dbh), chip n saw (23–33 cm dbh), and sawtimber (>36 cm dbh) prices, and weighted averages of hardwood sawtimber and pulpwood prices. Weights were determined by the relative proportions of each diameter class within the results of a FIA data query on the average volume of live timber by diameter classes and species groups in McIntosh County 1997–2010. Finally, we validated these estimates by comparing them to the recorded value of timber sales from the McIntosh County tax digest for the years 1999–2011.

2.5.1.2. Non-timber value of forests. We applied the values derived by Moore, Williams, Rodriguez, and Hepinstall-Cymmerman (2011) for water regulation and supply, pollination, and habitat/refugia to McIntosh County LULC data. Moore et al.'s purpose was to estimate the non-timber value of forested lands in Georgia. Moore et al. transfer values from published studies (which provide sufficient information only for the services listed above) to private forests in Georgia based on the following set of factors, whether forests are (1) evergreen, deciduous/mixed, or wetland, (2) located in north, middle, or south Georgia, (3) riparian or not, (4) urban or suburban/rural, and (5) support low or mid to high rare species abundance (based on data from the Georgia Department of Natural Resources to a quarter quadrangle resolution) – which we map to forest lands in McIntosh County. Services included in value estimates include flood damage protection, water quality improvements, water supply, pollination, and habitat/refugia. Moore et al. used the best available data from primary studies of forests in similar regions, that modeled the value of ecosystem services either by production functions, replacement costs, or revealed preferences, to average values per unit area [via value transfer] for each unique combination of forest characteristics and each ecosystem service identified."

To quantify the value of forest carbon sequestration, we derived an estimate of C in aboveground biomass of Coastal Plain pine (intensively managed slash pine) and oak-gum-cypress forests from the Georgia Carbon Sequestration Registry (GCSR, http://www.gacarbon.org). Because biomass estimates are based on stand age, we determined the relative proportion of stands in major age classes (0–19, 20–39, 40–59, 60–79, 80–99) and major forest types (upland pine, bottomland/swamp) for McIntosh County from FIA. We then multiplied biomass estimates for the midpoint of each age class from GCSR by the proportion of stands falling within that age class and summed the results together for either forest type. Finally, to capture forest C stocks in soil, litter, understory, and woody debris, we relied on the average estimate for forests in Georgia supplied by FIA. We monetized these results using the methods given below for non-forested wetland C sequestration.

2.5.2. Wetlands

2.5.2.1. Carbon sequestration. For tidal marshes, the total mass of organic C in the upper 30 cm of tidal freshwater, brackish and saltmarsh soils were calculated from mean values reported by Loomis and Craft (2010). Carbon in aboveground biomass values for these three wetland communities were derived from Wieski, Guo, Craft, and Pennings (2010). Belowground biomass of freshwater marsh was estimated from values for control plots from Ket, Schubauer-Berigan, and Craft (2011). Because no other values were available, belowground biomass of brackish and salt marsh were estimated based on the ratio of below to aboveground biomass in freshwater marsh, 5/6 in Ket et al. All the calculations above were expressed as t (metric ton) C ha^{-1} (for soils this was done by first multiplying bulk density by C content on a percent mass basis). A conversion factor of 3/7 (based on values for aboveground biomass to C ratios in Wieski et al.) was used to convert biomass values to C where separate values of C were not provided. A value of $21/t C was applied based on Atkinson and Gundimeda (2006) and Moore et al. (2011) – who consider a range from $5/t C to $42/t C to be reasonable – to calculate a total value of C storage per hectare of marsh type. To convert C stocks to annuities, following Moore et al., the value of total C stocks per ha was divided by a discount rate of 7%. Given the potential for very long-term and irreversible effects on climate of GHG concentrations, all estimates are highly sensitive to the discounting model applied to future social costs from climate change (Atkinson & Gundimeda, 2006).

2.5.2.2. N assimilation. Loomis and Craft (2010) derive percent removal of N exported from the watershed to the Altamaha River estuary by estuarine wetland type (freshwater, brackish, and salt marsh). From percent removal values, the area for each wetland type provided by Loomis and Craft, and total annual N loading for the Altamaha River from Schaefer and Alber (2007), we calculated an annual per ha N removal rate by wetland type. We monetized these per ha values following the approach of Jenkins, Murray, Kramer, and Faulkner (2010) and Ribaudo, Heimlich, and Peters (2005) with the marginal value per kg of N removed estimated at $25.27. Although the value of N removal is included in estimates of the non-timber value of forested wetlands in Moore et al., we review estimates of N assimilation from reviews by Walbridge and Lockaby (1994) and Engle (2011) as additional relevant sources.

2.5.2.3. Storm protection value of estuarine marshes. We reviewed the literature to estimate the value of storm protection for estuarine marshes. Only a few studies have estimated the storm protection value of coastal marshes. In a meta-regression incorporating the frequency of storms for particular states, Costanza et al. (2008) value the storm protection provided by salt marshes in Georgia, where storm-risk is relatively low, at $1140 ha^{-1} yr^{-1}. Importantly, Costanza et al. derive a marginal rather than average value per ha of marsh, and base their values on damage estimates associated with the tracks of actual storms which have hit the Atlantic and Gulf coasts between 1980 and 2004. [As the estimate from Costanza et al. is a function of both the risk of storm hits and the value of property adjacent to marshes, a paradox is that marsh-edge development increases the protective value of estuarine marsh, but may in actuality diminish the effectiveness of marshes as buffers by causing degradation. This problem can be addressed using the approach of Liquete, Zulian, Delgado, Stips, and Maes (2013) which maps coastal protection in terms of three components: natural capacity, the service flow and the demand of that service.] Less informatively, Brouwer, Langford, Bateman, and Turner (1999) in a geographically generalized meta-analysis of contingent valuation studies estimate stakeholders' willingness to pay for the protective functions of wetlands in the U.S., Canada, and Europe at $196 ha^{-1} for freshwater wetlands. Without quantifying the area of wetland lost, Brody, Highfield, Ryu, and Spanel-Weber (2007) used multivariate regression analysis to evaluate the relationship between the number of permits granted to alter wetlands – by dredging, draining, or filling – and coastal watershed flooding over a 12 year period. Their results indicate that wetland alteration exacerbates flooding events in coastal watersheds even with the inclusion of control variables to account for socioeconomic, demographic, and environmental differences that might also influence the level of flooding. While all three of these studies highlight the importance of coastal marshes in dampening storm surges and absorbing floodwaters, the contrast is essentially wetland versus non-wetland so that the effect of adjacent development on the function and value of estuarine wetlands for storm protection cannot be easily evaluated. It is this question – the effect of development of adjacent uplands on wetland storm protection – that we take up for review in the discussion section below.

2.6. Green infrastructure

Using landownership parcels for McIntosh County data provided by the Coastal Georgia Regional Development Corporation (a regional planning agency) from which we were able to determine which parcels included dwellings, we examined the pattern of current residential development with respect to buffer distance from wetlands and creeks, and vulnerability to storms and floods. We buffered the wetland edge of the NWI GIS layer by 50 ft (15 m) to determine how many homes had been constructed within that recommended buffer (Wenger & Fowler, 2000). Then, based on Digital Flood Insurance Rate Map (DFIRM) models available from the Federal Emergency Management Agency as GIS layers, we determined how many homes had been built within the 100–500 year floodway. We then constructed an overlay that restricted development from either the 100–500 year floodway or within 75 ft (23 m)of the wetland edge. Finally, focusing on the portion of the county east of I-95 where development pressure is greatest, we measured the area of riparian and marsh-edge forest that would be preserved by restricting development from within this zone – and estimated its value in terms of ecosystem services.

3. Results and discussion

3.1. Ecosystem services

3.1.1. Market and non-market value of forests

The market value of timber is highest for upland pine sylviculture (195 $\$ ha^{-1} yr^{-1}$), the dominant forest type on private lands in the county, and much lower for hardwood forest or forested wetlands (40 $\$ ha^{-1} yr^{-1}$) (Table 1). Validating our methods, the recorded value of timber sales from the McIntosh County tax digest for the years 1999–2011 was $7,166,208 versus a value of $7,058,137 derived from FIA. In addition to forest type, information from consulting foresters in the area suggests that larger tracts, mostly dominated by pine silviculture, were able to generate greater returns to scale and command higher rents for hunting leases.

In contrast to market value, non-timber value of forests is highest in forested wetlands and riparian forests for C sequestration, N assimilation, and the suite of services (water regulation and supply, pollination, habitat refugia) covered by Moore et al. The value of riparian forests for flood damage protection, water quality improvement, and water supply increases the value of these forests, which range from 524 to 5345 $\$ ha^{-1} yr^{-1}$, by a factor of 4–9 over non-riparian forests depending on other factors (Table 2).

3.1.2. Value of C sequestration and N removal by wetlands

Carbon stocks are highest per ha in forested wetlands (147 $t ha^{-1} yr^{-1}$) and upland forest (123 $t ha^{-1} yr^{-1}$), similar in tidal brackish, and freshwater wetlands at 92–95 $t ha^{-1} yr^{-1}$, and lowest in tidal salt marsh (78 $t ha^{-1} yr^{-1}$). However, overall stocks are highest for upland forest which covers twice the area of forested wetland or salt marsh, and smallest in freshwater and brackish marsh which together cover an area ~20% that of salt marsh (Table 3). It is important to emphasize that tidal marshes likely store much more C than is reflected in the summaries of biomass in Table 3 which only include biomass and the upper 30 cm of soil. C is stored in sediments that may reach several meters in depth (McLeod et al., 2011), and C is also continuously accumulated through the accretion of sediments. Based on accretion rates measured by Loomis and Craft (2010) in Georgia, Cai (2011) estimates organic C accumulation rates of 4 and 12.4 $t C ha^{-1} yr^{-1}$ for salt and brackish marshes respectively. Engle (2011) in a review of ecosystem services provided by Gulf of Mexico emergent wetlands put mean C accumulation at 2.55 $t C ha^{-1} yr^{-1}$ with a range of 0.19–7.63 . Thus, C accumulation rates of tidal marshes are likely to be significantly greater than those of adjacent forests.

Of coastal wetlands, forested wetlands have the highest average nitrogen removal capacity per unit area. Engle (2011) reports a mean N removal rate for Gulf of Mexico forested palustrine forested wetlands of 1031 $kg N ha^{-1} yr^{-1}$ with a range of 109–2108. However, Walbridge and Lockaby (1994) provide a range of 0.05–350 $kg N ha^{-1} yr^{-1}$ for forested wetlands in the Southeast generally. We adopt the 350 kg value for estimating the monetized value of N removal in McIntosh County. If this value proves reliable, then the magnitude of N removal per ha is an order of magnitude higher for forested than emergent wetland types even though forest wetland covers an area only slightly larger than salt marshes (Table 3). Among the emergent wetlands, freshwater and brackish wetlands have twice the nitrogen removal capacity (0.067 and 0.066 vs. 0.033 $t ha^{-1}$). However, because the area of salt marsh is so much greater, salt marshes have >4 times the value for estuarine water quality maintenance over all.

3.1.3. Storm protection value of estuarine marshes

Among the ecosystem services performed by estuarine marshes for which we were able to estimate values from other studies, the value of storm protection was among the highest at 196–1140 $\$ ha^{-1} yr^{-1}$. In this context, a relevant question is the extent to which the potential for degradation of coastal marshes due to runoff from upland development reduces the protective functioning of marshes even when marsh area remains relatively stable. Unfortunately, little research has so far addressed these questions directly. Some experimental evidence suggests that N enrichment – a well-documented effect of increasing development caused by increased runoff from fertilized lawns and gardens, as well as animal wastes, and leaching from leaky septic systems although effects vary with sewer/septic system and type of land management – reduces allocation to belowground structures, and may therefore lead to increased erosion and reduced organic matter inputs to marsh soils (Ket et al., 2011; Turner, Howes, & Teal, 2009), and increase sediment respiration (Morris & Bradley, 1999). These changes could leave estuarine marshes more susceptible to disturbances associated with wind, waves, river flooding and rising sea level. Contradictory evidence, however, suggests that overall increases in the productivity of salt marsh macrophytes with increases in N and in atmospheric CO_2 concentrations could allow marshes to keep pace with sea level rise at least in some scenarios (Langley, Mozdzer, Shepard, Hagerty, & Megonigal, 2013), and, in some cases, nutrient enrichment may increase marsh productivity, and thereby the accretion of sediments (Morris, Sundareshwar, Nietch, Kjerfve, & Cahoon, 2002). The effect of land use change on the robustness of coastal marshlands and their ability to function as a seaward defense over time in the face of sea level rise is thus unclear at present.

Importantly, in the context of managing coastal development in the southeastern U.S., the physical alteration of estuarine marshes by shoreline armoring often associated with residential development and the construction of dock structures is likely to leave coastlines more vulnerable to both sea level rise and storm events (Kittinger & Ayers, 2010). Because they increase the energy as tides recede thereby causing erosion of the high marsh, engineered defenses have been shown to reduce, rather than enhance, the ability of systems to absorb and adapt to disturbances (Bengtsson et al., 2003; Elmqvist et al., 2003). More broadly, shoreline ecosystems form a critical buffer between terrestrial and coastal systems, and the degradation of shorelines may decrease resilience in the face of natural perturbations (Adger, 2006; Danielsen et al., 2005). And crucially, barriers alter the ability of marshes to migrate landward with sea level rise. How fixed those barriers remain will be significantly a function of the real estate values and returns to investors in the absence of major policy interventions (Feagin, Martinez, Mendoza-Gonzalez, & Costanza, 2010).

Table 1
Value of harvested timber to private landowners in McIntosh County, (1999–2011) and the revenue generated in county sales tax revenues. Results are given for (1) evergreen and (2) all other forest types.

	Evergreen (pine)	Mixed, deciduous, forested wetland	Total
Price ($/t)			
Pulpwood	9.6	6.3	
Chip n saw	24.3		
Sawtimber	35.7	17.6	
Weighted average	21.9	13.1	
Avg removals from FIA (t/yr)	228,734	61,841	290,575
Value of timber sold from FIA ($ yr^{-1})	6,076,209	981,927	7,058,137
Avg value of timber sold 1999–2011 from county tax digest ($ yr^{-1})	7,166,208		
Ha of forest (excluding protected)	31,105	24,672	55,776
Average value generated in $ yr^{-1} ha^{-1}	**195**	**40**	
Avg annual sales tax revenues to county 1999–2011 ($/yr)	554,700	112,476	667,176
Avg sales tax revenue to county ($ yr^{-1} ha^{-1})	18	5	

Table 2
The non-timber value of coastal forests from Moore et al. (2011) summarized for McIntosh County. Riparian forests have significantly higher value as a function of their role in absorbing flood waters, water quality/quantity improvement, and importance as habitat.

Rare species abundance	Riparian status	Development status	Hectares	$ ha^{-1} yr^{-1}	Total value ($ yr^{-1})
Low	Not riparian	Suburban & rural	12,963	524	6,790,690
Low	Riparian	Suburban & rural	4358	4794	20,893,749
Mid and high	Not riparian	Urban	323	1964	634,635
Mid and high	Not riparian	Suburban & rural	39,730	1075	42,706,401
Mid and high	Riparian	Suburban & rural	20,150	5345	107,697,669

Table 3
Estimated size of carbon stocks (above and belowground biomass and soil organic carbon in the top 30 cm of soil) by major land cover types, and value of stocks given an estimated price of $21 t^{-1} C and a 7% discount rate, and estimated magnitude and value of N removal by land cover type. Overall stocks are highest for upland forest which covers twice the area of forested wetland or salt marsh, and smallest in freshwater and brackish marsh which together cover an area ~20% that of salt marsh. Eagle (2011) in a review of ecosystem services provided by Gulf of Mexico emergent wetlands put mean C accumulation at 2.55 t C ha^{-1} yr^{-1} with a range 0.19–7.63 t.

Land cover	C stocks					N removal from estuarine waters				Storm protection
	ha	t ha^{-1}	t	$ yr^{-1}	$ ha^{-1} yr^{-1}	ha^{-1}	t	$ yr^{-1}	$ ha^{-1} yr^{-1}	$ ha^{-1} yr^{-1}
Freshwater marsh	2125	95	202,551	2,893,582	1362	0.067	142	40,375	19	196–1140
Brackish marsh	3037	92	278,317	3,975,954	1309	0.066	200	81,999	27	
Salt marsh	25,385	78	1,970,257	28,146,525	1109	0.033	838	2,843,120	112	
Forested wetland	26,402	147	3,881,094	55,444,200	2100	0.350	9241	32,949,696	1248	
Upland forest	50,440	123	6,204,080	88,629,710	1757					

3.2. Managing future growth in McIntosh County

Because our purpose was to consider together both the likely (1) fiscal and (2) ecological impacts of future development, we combined a CCS analysis with an ecosystem services valuation study. We consider the results of each of these studies in turn before considering how the two inform each other with respect to the establishment of a green infrastructure.

3.2.1. Cost of community services and future growth

The ratio of revenues to expenditures for residential land use was 1:1.43, 1:0.25 for commercial/industrial, and 1:0.65 for rural land uses (Table 4). Thus, residential parcels require 43% more in services than they yield in revenues, whereas commercial/industrial parcels generate nearly 4 times the revenue they require in services. Rural farm and forest, which currently comprise most of the area of the county, generate relatively little revenue (an average of $782,809 per year or 11% of all revenues), but because they require so little in services, they provide a surplus to county coffers. Moreover, state-level tax incentives to forest and agricultural landowners to maintain lands in an undeveloped state impose only a small additional tax burden on residential property-owners in the county: $9 for a $75,000 home, $20 for a $150,000 home, and $33 for a $250,000 home.

Our results are congruent with those from 17 other counties in Georgia ranging from rural to urbanized, and from 83 studies across the U.S. (Dorfman, 2006, http://www.farmland.org/documents/Cost-of-Community-Services-08-2010.pdf) where the median values for residential, commercial/industrial, and rural are 1:1.15, 1:0.27, and 1:0.36, respectively. These patterns – residential land uses tend to have ratios greater than one, while commercial/industrial and agricultural/open-space land uses tend to have ratios less than one – are further supported by the meta-analysis of Kotchen and Schulte (2009). Had we included the cost of schools in the calculation, the ratio of revenue to expenditures for residential land use would be even lower as has been shown across studies (Dorfman, 2006). In their analysis, Kotchen and Schulte (2009) found that including school costs lowered the ratio by an average of 15%. Furthermore, detailed spatial econometric models (Carruthers & Úlfarsson, 2008) measuring municipal spending (on education, fire protection, housing and community development, parks and recreation, police protection, roadways, sewerage, and solid waste disposal) reveal that spatially extensive land use patterns cost more to support.

Summarizing across major land use types (urban, suburban, rural) in McIntosh County, we found that rural lands generated more revenue to county government – through payments in lieu of taxes, property taxes and sales taxes from timber sales – than they required in services from the county. (Tidal marshes were excluded from this analysis since most of the tidal marsh area is *de facto* public land and is also not subject to biomass harvesting or development other than dock construction. Thus, tidal marshes neither require services nor directly generate revenues.) This was true even though assumptions were made which probably boosted contributions from the residential sector – 80% of local sales tax revenues were assumed to derive from local residents and were therefore

Table 4
Summary of McIntosh County government expenditures and revenues (2010–2012) by land use type.

Expenditures	Amount	Revenues sources	Amount	Rev./exp.
Suburban: residential				
Leisure services	380,185	Mobile home taxes	118,202	
Animal shelter	141,182	Cable franchise tax	80,214	
Fire protection	130,668	Real estate transfer tax	12,306	
Emergency management	75,506	Property taxes	4,235,826	
Roads, bridges	264,156	Sales taxes	822,606	
County extension	64,009			
Building inspections, zoning	101,507			
Sheriff's department	2,359,156			
County jail	846,252			
Ambulance service	626,732			
County administration	2,538,235			
Total	$7,527,587		$5,269,153	1:1.43
Urban: commercial, industrial				
Roads, bridges	38,166	Liquor licenses	100,530	
County extension	2110	Business licenses		
Fire protection	4308	Alcohol excise taxes		
Emergency management	2335	Property taxes	767,778	
Building inspections, zoning	3346	Sales taxes	51,413	
Sheriff's department	77,774	Real estate transfer tax	406	
Ambulance service	20,661			
County administration	83,678			
Total	$232,379		$920,126	1:0.25
Rural: farm, forest				
Roads, bridges	122,976	Payments in lieu of taxes	294,241	
County extension	4220	Timber taxes	69,693	
Fire protection	8615	Property taxes	418,064	
Emergency management	4670	Real estate transfer tax	811	
Sheriff's department	155,549			
Ambulance service	41,323			
County administration	167,356			
Total	$504,710		$782,809	1:0.65

assigned to the residential land use class – and despite the fact that property taxes from residential parcels amounted to three times those of commercial/industrial and rural parcels combined. Thus, residential growth in McIntosh County, in the absence of substantial commercial or industrial growth, is unlikely to provide a surplus to local government.

3.2.2. Value of ecosystem services and future growth

The value of ecosystem services for the two main classes of lands – forests and wetlands – were considered separately except where they overlapped as forested wetlands. Based on the work of Moore et al., we were able to consider the services provided by forests more comprehensively than those of non-forested wetland classes. Forests were classed in three different ways. First, based on LULC data available from SE GAP (http://www.basic.ncsu.edu/segap/), forests were classed as evergreen (mostly pine silviculture), deciduous, mixed, or forested wetland. To capture spatial differences in value, forests were sub-divided and classed as urban (a very small area), suburban, or rural depending on proximity to developed areas. Finally, forests were classed as riparian or not depending on whether forest pixels were <30 m from flowing water (which includes tidal marsh). The joint value estimated for rare species habitat, flood control, pollution treatment, and water supply was, not surprisingly, twice as high for riparian (which include all forested wetlands) as non-riparian forests, and the value/quantity of carbon sequestered was significantly higher in forested wetlands than upland forests. However, we did not attempt to quantify the value of many other ecosystem services provided by forests including air quality benefits and esthetic value. In addition to the non-timber values, we derived an average value of timber harvest per ha of private land in the county (1999–2011) which indicates that the value generated from timber sales is nearly five times higher for pine (generally upland, non-riparian and corresponding to the evergreen land-cover class) than for hardwood (generally riparian and including forested wetland and mixed land-cover classes). Thus, upland pine forests generate the most income to forest landowners and the most tax revenue to counties, but riparian forests and forested wetlands generate a much greater value of ecosystem services than do upland pine forest. Increased conservation of riparian forests and forested wetlands, therefore, through available or new incentives and payments for environmental services appears to be an important opportunity.

In estimating the value of non-forested (generally tidal) wetlands, we were only able to find quantitative data on carbon sequestration, nitrogen removal, and storm protection. Freshwater and brackish marshes, which cover a relatively small area, sequestered significantly more carbon and removed more nitrogen than did saltmarsh, which however accounts for most tidal marsh. Yet, all three tidal marsh communities store large quantities of carbon – both by high intrinsic productivity and by forming deep marsh deposits by trapping and accreting sediments rich in organic matter transported by rivers and streams to the estuary. Therefore, the values presented in Table 3 that consider only above and below-ground biomass and the upper 30 cm of soil do not completely capture the value per unit area of tidal marshes relative to adjacent forests as carbon sinks. Tidal marshes also provide significant value by absorbing storm surges and decreasing the power of hurricanes and tropical storms before they reach developed uplands. (Therefore the value of storm protection is highest where more development borders tidal wetlands.) In addition, tidal wetlands are valued for a suite of services for which we were unable to find adequate estimates. These include nursery value to fisheries, scenic value, and value as wildlife habitat. Thus, due to their high biological productivity and position as a buffer between land and sea, tidal marshes generate a high value per unit area – a marginal value that is likely to be much higher than that of, for example, most temperate forests.

In relating the values we have estimated for ecosystem services by land-cover to current and future development and land ownership patterns in McIntosh County, we offer several initial observations. Public lands in the county (which include most of the Altamaha River floodplain) protect lands which are particularly valuable from the point of view of wildlife habitat, recreation, estuarine water quality improvement, and carbon sequestration while requiring little in the way of county expenditures, and generating at least as much in PILT payments as they would be likely to earn in tax revenues from timber sales. Similarly, large timber parcels in the interior portions of the county generate more revenue than they cost in county services while at the same time providing ecosystem services of a value – to stakeholders in the county and beyond – that far exceeds the annual per ha returns to either private landowners or to county coffers. The small additional tax burden ($20/yr on average) borne by county residents as a consequence of state-level incentives to forest landowners (to maintain land in an undeveloped state) is offset by the suite of amenities preserved. However, as development continues in the county, land prices and property taxes may go up on these undeveloped lands, creating additional pressure for landowners to convert undeveloped lands. So, while county residents currently bear only a small additional tax burden to support incentives to forest landowners, these incentives may need to increase if they are to be effective deterrents to rural land conversion in the future. Nevertheless, current policies and public land acquisitions appear win–win from the dual perspective of ecosystem services and local fiscal balance. Bolstering current policies, future planning which preserves the integrity of large forested tracts by permitting new development within or close to existing inland communities, would have the additional benefit of reducing infrastructure costs.

Large-scale changes to land-cover resulting from urban/suburban/exurban development are still relatively few in McIntosh County which remains largely rural despite being traversed by I-95. Land-cover mapping based on classification from Landsat (30 m pixel) satellite imagery showing (Fig. 1) indicates the rural character of the county. Development is concentrated on the immediate coastal margins – locations with views of the marsh and estuaries and access to water – rather than inland sites where both upland forests and forested wetlands are likely to be preserved over the foreseeable future. However, the sites currently developed – those with direct access to water and extensive views of the marsh – are the most vulnerable to storm and flood damage within the mainland portion of the county. In our analyses, we found that 20% of residential units built in the county east of I-95 during the last two decades are sited in the 100–500 year floodplain (Fig. 2). Based on our ecosystem service valuation, development at the marsh edge is altering or removing some of the highest value forest in the county – particularly wildlife habitat. Development near estuarine coastlines is the primary stressor on estuarine waterbird communities, and the integrity of estuarine ecosystems may be impaired at very low levels of exurban development (DeLuca, Studds, King, & Marra, 2008) and Brittain and Craft (2012) found that maritime shrub habitat in coastal Georgia is critical to the painted bunting (*Passerina ciris*), a species in decline. In addition, marsh edge development is often accompanied by docks and shoreline hardening that make marshes more vulnerable to erosion from major storms, and limits the ability of marsh to migrate inland with sea-level rise. Perhaps most immediately, development at the marsh edge brings the risk of damaging or degrading the marshes and estuarine waters. We found that 10% of new residential units in McIntosh County east of I-95 were built with little buffer on the marsh, and had frequently cleared forest to create lawns – both of which are likely to increase nutrient runoff into the marsh. Investigating changes in tidal creek or estuarine systems the Southeast, Sanger, Holland, and Hernandez (2004), Holland et al. (2004), DiDonato et al. (2009) and Xian, Crane, and Su (2007) related human population density and associated increases in the area of impervious surface to changes in hydrology and water quality. Holland et al. measured altered hydrography, changes in salinity variance, altered sediment characteristics, increased chemical contaminants, and increased fecal coliform levels when impervious cover exceeded 10–20%. Reduced abundance of stress-sensitive macrobenthic taxa, reduced abundance of commercially important shrimp, and altered food webs were documented when impervious cover exceeded 20–30%. Recent development in McIntosh County has therefore occurred in some of the most sensitive locations (exclusive of state-owned Sapelo Island) within the county from the perspective of habitat for sensitive species, estuarine water quality, marsh health, and the vulnerability of structures.

3.2.3. *Green infrastructure and future growth*

Given that scenic and recreational attractions will continue to attract development to the marsh border, how can growth be managed to preserve ecosystem services? Based on our CCS study of McIntosh County, the fiscal case for encouraging more compact residential growth and thus reduced infrastructure construction and maintenance costs is clear. As a response to these arguments, we have estimated the potential value of restricting construction from within mapped DFIRM flood zones and enforcing a 75 ft (22.86 m) riparian/wetland buffer (Fig. 2). Such a measure would be justified as green infrastructure that would mitigate the impact of new development on natural resources and decrease the vulnerability of new housing to storm and flood hazards, protect habitat, buffer marsh and estuary from development, and increase the potential for marshes to migrate inland with sea level rise. Enforcing this overlay zone would protect 8600 ha of forest from development with a value of $61 million for the suite of ecosystem services we have measured. The potential economic advantages to developers in coastal Georgia from clustering housing away from sensitive areas and setting aside the remainder of a subdivision as a conserved common area could be substantial (Kriesel & Mullen, 2010). At a minimum, municipal governments on the Georgia coast should enforce sizeable setbacks from marsh, tidal creek, and wetland edges, and restrict the construction of docks. Such measures would limit the need for shoreline armoring, and, as a result, improve the resilience of coastal development to both sea level rise and storm events (Kittinger & Ayers, 2010). Moreover, setbacks from the marsh, limits on impervious surface and measures to slow and filter runoff benefit marsh stability and the protective function and habitat provisioning of marshes.

With a focus on Georgia and the southeastern U.S., Carter (2009) identifies a number of environmental, institutional and market constraints that limit the implementation of conservation developments and suggests means by which jurisdictions may overcome these constraints using both market-based incentives, which includ tax abatement or credits, and regulatory initiatives related to permitting and zoning codes. Beyond the issues addressed by Carter, the difficult process of conserving land permanently, usually by easement, including providing for monitoring and management in perpetuity is a major hurdle. And, perhaps the most critical constraint on conservation development is water supply and wastewater management. Where residential units must rely on well-water and septic systems, large minimum lots sizes force a

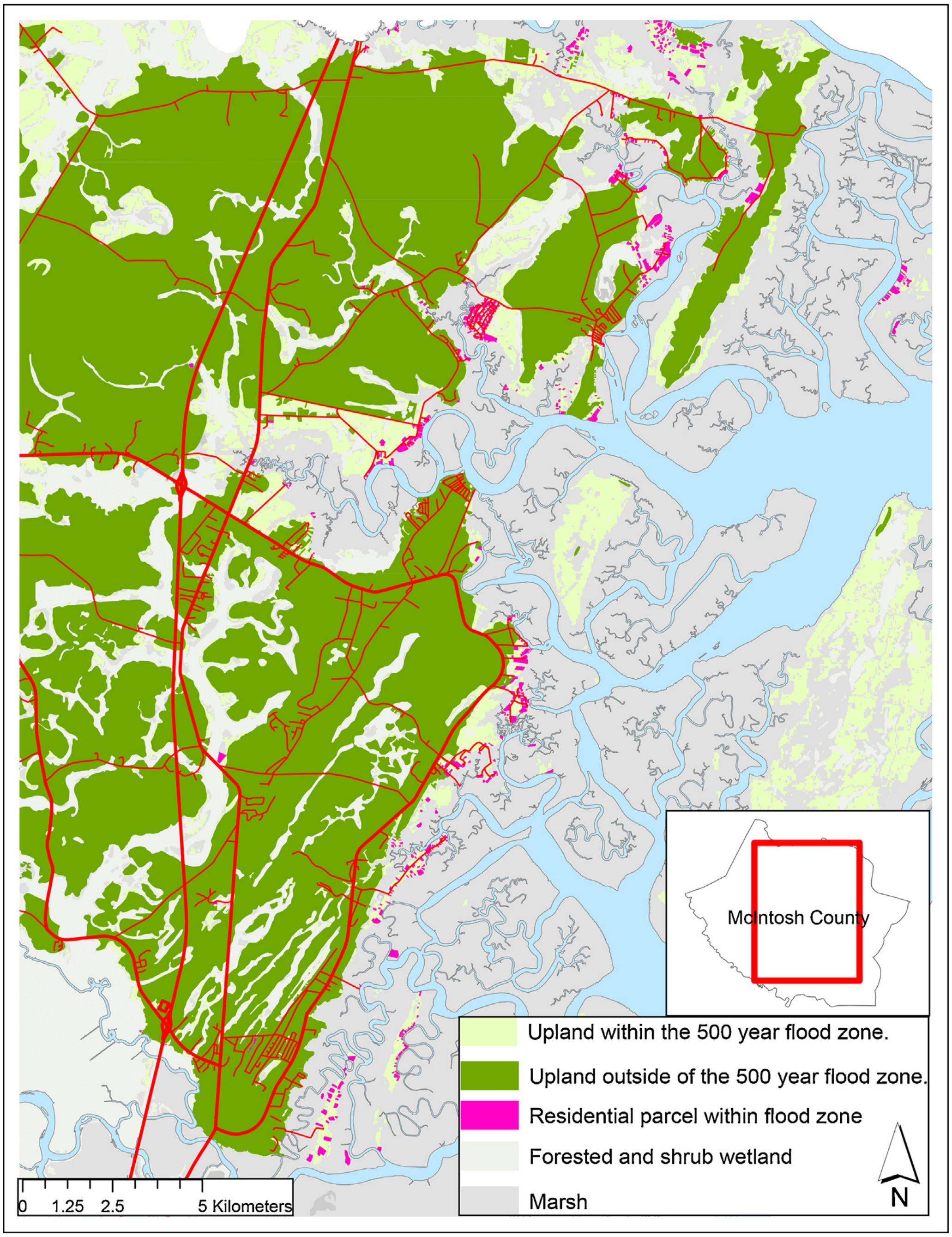

Fig. 2. Magenta polygons indicate parcels with structures currently that lie with the 500 year flood zone. Uplands outside the 500-year flood zone are colored dark green, uplands within are colored light green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

pattern of low-density, dispersed development. While municipal water can be supplied relatively inexpensively, providing sewer service to outlying residential development is generally too costly to rural counties, and sewer systems in the coastal setting can cause as many environmental problems as they alleviate (Paterson, Burby, & Nelson, 1991; Sheehan & Fowler, 2012). A potential solution to this constraint is the implementation of on-site wastewater treatment systems.

Can residential development designs that restrict lot sizes and set aside sensitive lands be saleable? In their hedonic study, Kriesel and Mullins found that deepwater access adds $81,000 to the value of a property. However, having a dock on the property adds only $24,000 to the value of a property, suggesting that access to communal docks may be a sufficient amenity. While proximity to marsh raises property values (a marsh view adds $11,700), access to marsh vistas from adjacent common property or open lands may also provide significant value as suggested by the fact that the presence of open land itself raises the value of properties in the analysis of Kriesel and Mullins. Thus, conservation development, Kriesel and Mullins suggest, can be more profitable for developers than conventional residential designs.

4. Conclusions and broader applications

McIntosh County, which is likely to face renewed growth pressures in the near future as the U.S. economy recovers, is fortunate to have a significant green infrastructure in place as the result of public land acquisition and conservation incentives at regional, state, and national levels. To manage growth such that costs to local government are minimized and the natural resources that draw tourists are best preserved, future development in the county should ideally be nodal (at the intersections of major roads and highways) rather than dispersed to maintain large forested tracts intact. Because current growth is centered on the tidal marsh border, protection of sensitive lands such as floodways and maritime forest at this nexus is paramount. We have shown that a network of protected lands, which can be achieved through a variety of means including overlay zoning, incentives for conservation easements, and restrictions incorporated into building codes, is likely to improve county fiscal balance, and provides multiple benefits in protecting natural, scenic, and recreational resources while reducing vulnerabilities to coastal hazards.

A larger goal was to demonstrate methods for identifying important concurrences between fiscal returns to local or regional governments from managing future growth and the maintenance of ecosystem service flows. CCS studies are one method of assessing the costs of growth and are particularly useful when the major driver of land use change is low-density residential growth as has dominated in many parts of the U.S. for decades. The value of ecosystem services at a locality may be very high, but in the absence of some form of payment representing that value to local decision-makers, the value ecosystem service flows may not determine development outcomes. As such, our approach could be expanded to larger scales contingent on the availability of data. For example, considering effects of shoreline development on fisheries would be much more practical at the state or regional level.

In this work, we have relied on value transfers from existing studies, a method frequently employed but, as with primary valuation studies also, still problematic in many ways (Plummer, 2009; Sagoff, 2011). However, our purpose was not to arrive at an exact monetization of particular resources, but rather a means to rank the value of ecosystem services provided by distinct portions of the landscape. Taking this approach, our results strongly suggest, as examples, that forested wetlands are, on a per ha basis, the most valuable resources for C sequestration and N removal, and that the value of estuarine marshes for storm protection may exceed the value of these wetlands as carbon sinks. While these findings are provisional, they indicate the utility of value transfer and ecosystem service valuation as a means of ranking the magnitude or importance of service flows.

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