

COSTS AND BENEFITS OF LAND USE ADAPTATION WITH PROJECTIONS OF
WETLAND MIGRATION

by

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(Under the Direction of Craig E. Landry)

ABSTRACT

As climate change threatens to intensify the frequency and strength of coastal storms, and populations and development in these areas increase, the need for enhanced resiliency is paramount. Salt marshes and wetlands act as a natural buffer between hazardous storms and coastal communities, and as the sea level rises they will migrate in a landward direction. This migration, however, can be impeded by human development. This study analyses the costs and benefits of pre-emptively protecting open space to facilitate the migration of wetlands for a coastal county in Georgia based on projections of wetland migration and predicted locations of new development 30 years into the future.

INDEX WORDS: Cost-Benefit Analysis, Meta-Analytic Benefit Transfer, Hedonic Valuation, Conservation Easements, Spatial Planning, Climate Change Adaptation, Wetland Migration, Sea Level Rise

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

In 2017, the United States experienced its most expensive hurricane season on record. Three major hurricanes – Harvey, Irma, and Maria – caused an estimated \$202.6 billion in damages (Bloomberg Business, 2017). Dollar losses from tropical storms and flood events have tripled over the past 50 years in the United States. Increases in the frequency and severity of hazardous storm events and increases in population and development along the coast are the primary reasons for these higher levels of loss. Nearly a quarter of the United States population lives in coastal communities, with populations along the Gulf of Mexico and Southeast coast experiencing the most growth at a rate faster than the national average. These are the same areas that are most often hit by major hurricanes. As climate change threatens to intensify the strength of coastal storms and rising sea levels expose more developed areas to their damaging effects, the need for enhanced coastal resiliency is paramount (NRC, 2014).

There are several options for mitigating risk associated with hazardous coastal storms. Engineered strategies, such as seawalls, breakwaters, and levees, have historically been the preferred method. However, these approaches can be expensive and require frequent maintenance. Hardened structures like these can also have adverse environmental impacts, essentially relieving one problem while causing another. For example, seawalls are built along the shoreline to protect structures on land from storm surge, but can accelerate erosion on the

seaward side and in adjacent, unprotected beaches. Levees are built further inland and are designed to reduce flooding, but can increase flooding in nearby areas. They can also alter the flow of water, eliminating wetlands and causing significant changes to biological communities (NRC, 2014; Jones, Hole, & Zavaleta, 2012).

More and more we are realizing the importance of maintaining natural features such as salt marshes, barrier islands, and other wetlands as a more cost-effective approach to risk mitigation and climate change adaptation. Coastal wetlands and their vegetation minimize storm surge wave impacts by stabilizing sediment and mitigate flooding by storing stormwater (Jones, Hole, & Zavaleta, 2012; Shepard, Crain, & Beck, 2011; Gedan et al., 2011). The coast of Georgia is fortunate in that it still contains significant areas of natural buffer between storm hazards and human development with approximately 400,000 acres of saltwater marshes and fourteen barrier islands. Although Georgia's coastline extends only one-hundred miles, it contains nearly one-third of all existing salt marshes along the entire eastern coast of the United States. Additionally, only three of its barrier islands are heavily developed (Edwards, Ambrose, & Kirkman, 2013; Seabrook, 2018).

Tidal wetlands in Georgia are currently protected by both the state government (through the Coastal Marshlands Protection Act) and the federal government (through the Clean Water Act) (DNR, 2018; EPA, 2018). It is not enough, however, to only provide protection of existing wetlands in the interest of enhancing coastal resiliency. Because of their low topography, coastal areas in Georgia are highly susceptible to sea level rise and erosion caused by waves and storm surge. Coastal marshes and barrier islands naturally respond to these degrading forces by moving in a landward direction. This migration, however, can be impeded by human development, thereby inhibiting the natural resiliency of coastal communities to storm and

flooding events (Enwright, Griffith, & Osland, 2016; Kirwan & Megonigal, 2013; Gedan et al., 2011).

Georgia, with its wealth of salt marshes and slower development rates, has the potential to capitalize on its natural marshes and wetlands. By recognizing that marsh migration due to sea level rise is critical to the long-term survival of Georgia's wetlands, we can mitigate risk in a pro-active manner and minimize potential barriers to migration from human development processes. By identifying and prioritizing intervention strategies now, rather than allowing future development to proceed unabated, Georgia's coastal communities can better adapt to climate change and rising sea levels.

1.2 Research Objectives

The overall goal of this research project is to analyze the costs and benefits of an open space protection plan that will facilitate the migration of wetlands in a coastal community in Georgia. Since human development pressure poses the greatest threat to migration, we have chosen Chatham County as the location for this analysis. Chatham County is significantly more developed than the other five counties lining Georgia's coast, and its total population has increased by much larger numbers over the past 7 years (U.S. Census, 2017). Recognizing that public financing of infrastructure works on 30-year cycles, we will identify the best sites for open space protection now based on the movement of wetlands and development of vacant land over the next 30 years. Then, using both market and non-market valuation techniques, we can estimate the current costs of acquiring those open land areas and quantify the future benefits of wetlands that will occupy them in year 2045. Based on these estimates, we can target the most cost-effective areas for preservation and coastal risk mitigation.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 Examples in the Literature

Benefit-cost analysis provides a reasonable framework for evaluating investments in environmental policy and coastal risk reduction (NRC, 2014; Ferraro, 2003), such as the acquisition of open land areas that will ensure the protection of wetlands as the sea level rises. Despite the apparent value of wetlands and the need for their protection for shore stabilization and storm risk reduction, there are few studies that quantify both the costs and benefits of protecting them in a real-world setting. There are even fewer benefit-cost studies that consider the dynamic nature of wetlands and their ability to adapt to environmental change, particularly in the economics literature.

Feagin et al. (2010) estimate the ecological and economic effects of changes in coastal wetlands in response to varying rates of sea level rise. They quantify the value of salt marshes using value-transfer methods based on their plant community zones and five ecosystem service categories, including recreation, carbon sequestration, and storm protection. Although they do make comparisons of wetland migration and associated benefits with and without anthropogenic barriers, they do not attempt to quantify the costs of minimizing or controlling them.

A study by Runting et al. (2017) claims to be the first to quantify the costs of preserving migrating wetlands under exponential sea level rise and the potential payments for wetland ecosystem services that can mitigate those costs. Specifically, they aim to determine if the cost

of preserving coastal wetlands is higher with sea level rise compared to current sea levels in Australia. To determine the cost of protecting wetlands, they find the relationship between elevation and land prices, considering reduced flood risk as the driver of change in land value. They do this by converting unimproved land values in 2012 to a value per hectare per year at the same resolution as their elevation data to calculate a mean land value for every 10 cm of elevation. Then, they estimate change in wetland area through the year 2100 under different sea level rise scenarios using the Sea Levels Affecting Marsh Model (SLAMM). Based on these estimates, they determine that the cost to maintain wetland area into the future could range from \$40,000 to \$271,000 (lowest to highest rate of sea level rise). Since they find a positive relationship between land values and elevation, and wetlands will migrate into areas of higher elevation under higher levels of sea level rise, the cost of pre-emptively preserving wetlands will increase with higher rates of sea level rise. To quantify payments for carbon sequestration in wetlands, they use voluntary carbon market prices and conclude that these payments alone could cover the cost of protection under the low sea level rise scenario, but additional payments would be needed in the cases of higher rates of sea level rise. Their consideration of elevation alone as the determinant of land prices, however, prompts the need to use more robust economic valuation techniques. Additionally, we aim to evaluate the benefits of wetlands as more than just carbon sinks.

Although their analysis does not involve coastal wetlands or their adaptability, Kousky et al. (2013) examine the benefits and costs of preserving open space along the Lower Fox River Basin in Wisconsin for flood damage reduction. They estimate benefits as avoided flood damages associated with preventing development on vacant parcels between 2010 and 2025. Costs of preserving parcels slated for development are calculated using assessed property values

based on two preservation options: fee simple acquisition and conservation easement purchase (estimated at 60% of fee-simple costs). Their results suggest that targeting investments to preserve only certain parcels based on the ratio of preservation cost to avoided flood damage would yield net benefits. Our approach to benefit-cost analysis of open space protection is similar, but we attempt to better estimate a wider range of preservation costs using market-based approaches rather than assessed values. We also aim to quantify wetland ecosystem benefits in addition to avoided flood damages.

2.2 Options for Protecting Open Space

Policy options for protecting open space have been established across the United States in response to growing public concern over the negative environmental and social effects of urban sprawl and unregulated development. Some of these options include land use planning requirements, minimum density zoning, and preferential tax assessment (Bengston, Fletcher, & Nelson, 2004). In this paper, we will be focusing on another set of options that have been used by both public and private entities: fee title acquisition and conservation easement purchase. If a government agency or non-governmental organization (NGO) is interested in permanently protecting a parcel of land, they have the option to purchase full ownership of the land (fee title, or fee simple). This option can be costly, however, and may not be necessary for accomplishing conservation goals. An alternative option is to purchase a conservation easement, which represents a permanent, partial interest in land. The landowner retains ownership of the land but relinquishes certain rights, such as the right to develop, to the easement owner. In order to analyze a range of potential costs of open space protection, this paper will estimate the costs of both fee title acquisitions and conservation easement purchases in Chatham County.

2.3 Value of Land and Property

Fee title acquisition of a property requires a government agency or other entity to pay the landowner an amount equal to the value that he or she places on the property. This can typically be derived from the value placed on property in the market, or the fair-market value. Real estate property markets are organized around trading parcels of land, including any improvements made upon them (buildings, driveways, etc.). Real estate markets are characterized by project heterogeneity, as each parcel is somewhat unique in its individual locational and physical characteristics. Under these circumstances, economic theory predicts an equilibrium price schedule, describing the market value of a property based on its individual characteristics and depending on conditions (e.g. supply, demand, access to credit) within the market. The hedonic pricing method can be used to understand how the individual characteristics and attributes of a property influence its price. Since the explicit value of individual property characteristics cannot be observed, this method relies on market transactions of differentiated parcels to determine the underlying value, or implicit price, of their varying characteristics. These implicit prices represent a consumer's willingness to pay (WTP), and a seller's willingness to accept (WTA) compensation, for individual parcel attributes (DiPasquale & Wheaton, 1996). Entities interested in conserving land can use these estimates of underlying value to predict the price of land they want to acquire.

It is also beneficial to make distinctions between different types of property markets, such as residential and non-residential. Although the prices and locations of alternate property types can be related, participants in each market behave differently and government regulations, such as zoning, can impact them in distinct ways (DiPasquale & Wheaton, 1996). Since parcel subdivision and new development threatens to block the migration of wetlands on all types of

privately owned properties in Chatham (discussed further in following sections), we will be analyzing property prices in agricultural, residential, and commercial/industrial markets separately.

2.4 Value of Conservation Easements

The estimation of prices for conservation easements is not as straight-forward since no well-functioning markets for conservation easements exist to determine fair-market value. Even in active programs such as the Wetlands Reserve Program or local farmland protection programs, the circumstances of each easement can vary significantly, making them difficult to compare or analyze. Theory suggests that encumbering a parcel with a conservation easement will reduce its value by restricting the allowable activities, such as development, on the property. Therefore, the value of a conservation easement must be indirectly observed as the difference between the value of the underlying property with and without the restrictions imposed by the conservation easement. A government or non-government entity can use this estimated difference in value to determine the price of a conservation easement on the land they desire to protect (Anderson & Weinhold, 2008; Weibe, Tegene, & Kuhn, 1996).

Land appraisers estimate the value of conservation easements by comparing the “highest and best use”¹ value of a property before and after being encumbered with an easement. There are three typical professional appraisal methods for estimating these values. First is the sales comparison approach, the preferred method for property valuation, but the lack of comparable sales of properties encumbered by easements renders this method nearly impossible. Second, the cost approach estimates property value by adding the land-only value of the property (based on

¹ Highest and best use is defined as “the highest and most profitable use for which the property is adaptable and needed or likely to be needed in the reasonably near future” (Interagency Land Acquisition Conference, 2016).

comparable sales) to the depreciated cost of replacing improvements on the property. Again, this is of limited use without comparable sales of vacant eased land. Lastly, the income capitalization approach is based on the income generated by land before and after being encumbered by an easement. This requires information on expected returns, expenses, and capitalization rates for individual properties, which cannot be quantified with certainty and does not apply to all types of property (Interagency Land Acquisition Conference, 2016; Weibe, Tegene, & Kuhn, 1996).

Some attempts have been made to empirically estimate the effect of development restriction in the economics literature, although few have produced strong, compelling results. Nickerson and Lynch (2001) find no statistically significant reduction in price of farmland in Maryland sold between 1994 and 1997. Lynch, Gray, and Geoghegan (2007) analyze an expanded set of sales of farmland over 10 acres in Maryland and find statistically significant price reductions of 11 to 17 percent using hedonic price models and 14 to 24 percent using propensity score matching, but a more refined probit model yielded statistically insignificant results. Anderson and Weinhold (2008) find no statistically significant effects among property sales in Wisconsin until restricting the sample to only vacant agricultural properties, in which they observe a 42% price reduction. Schilling, Sullivan, and Duke (2013) attempt to provide reasoning for the paradoxical conclusions of these three studies and conclude that when easements on farmland allow some minor development and continuation of farming practices, they have significant and positive effects on sale price. The type of conservation easement we are interested in analyzing for this study, however, would restrict all development and farming rights, at least on portions of the parcel where wetlands are predicted to emerge. Therefore, it is likely that our proposed conservation easements will have a negative effect on property values.

Lawley and Towe (2014) estimate the effect of conservation easements on vacant parcels that permanently remove the right to develop or farm wetland habitats in the prairie pothole region of Manitoba, Canada. Using propensity score matching, they find that land values decrease by \$86 per acre for every acre of eased habitat, on average, or 12.6%. This region of Canada is quite remote and faces little development pressure, however, which is a notable difference compared to our study area.

After performing a very thorough search of deeds, conservation easement databases, and property record cards, I recovered only 6 sales of properties encumbered with permanent conservation easements in Chatham County. Without adequate market sales data, we are unable to use either empirical or appraisal methods to estimate the price of conservation easements in our study area. Due to similar data limitations, other cost-benefit studies assume that conservation easements are equal to a specified percentage of the appraised or fee value of the encumbered property (Kousky et al., 2013; Ferraro, 2003). Easements, however, can have a wide range of values. In a review of properties encumbered by conservation easements in Massachusetts, Stockford (1990) found that the assessed values of those properties decreased by 13 to 95 percent compared to their unencumbered assessed values. The Maryland Agricultural Land Preservation Foundation purchased farmland easements at an average per-acre price equal to approximately 60 percent of average property values in 2009-2010, but as competition for easement payments among landowners has increased that average has declined. In 2014, they established a floor and ceiling set at 25 and 75 percent of fair market value, respectively. (MALPF, 2011; MALPF, 2015). Two preservation agencies that purchase conservation easements in the prairie pothole region of Manitoba typically compensate landowners with payments equal to 30-40% of the assessed per-acre value of surrounding land parcels (up to a

maximum of \$100/acre) (Lawley & Towe, 2014). This variation in conservation easement values and payments likely reflects differences in development pressure and differences in the level of restrictions imposed by the easements. The conservation easements that we analyze are more restrictive than many in the existing literature, and they will be placed on parcels facing high development pressure. Thus, they are likely to have relatively large effects on property value, though the exact values are still unclear. Because of this, we will analyze the cost of purchasing conservation easements in Chatham County based on a range of possible values.

2.5 Value of Wetland Services

When considering the decision of a government agency or nonprofit organization to acquire land, or certain rights to land, it is necessary to consider the value of resulting benefits to society. In our proposed protection plan, investments will be made in open space protection now in order to increase acreage of wetlands 30 years from now. Therefore, we need to estimate the economic value of wetlands in Chatham County in order to quantify their benefits and potentially rationalize the cost of their protection.

Coastal wetland ecosystems provide an array of services in addition to storm protection, including scenic views, water purification, biological diversity, and carbon sequestration (Barbier et al. 2011). Although they offer many valuable ecosystem services to human beings, both directly and indirectly, private incentives to manage wetlands are limited. Wetlands have a public goods nature in that they provide goods and services at no cost, so it is people's willingness to pay (WTP) for these goods and services that describes the economic value of wetlands, whether or not they actually make a payment. Since the nature of public goods (i.e. non-exclusiveness and non-rivalry), prevents them from being properly valued in a marketplace,

nonmarket valuation techniques must be used to elicit estimates of their value (Champ, Boyle, and Brown, 2003).

Nonmarket valuation techniques can generally be placed in one of two categories, depending on the nature of the data used. Stated preference methods refer to methods based on statements made by individuals in response to survey questions about hypothetical scenarios. Alternatively, revealed preference methods rely on observations of people's behavior in a real-world setting (Champ, Boyle, & Brown, 2003). Studies of both types have been used to estimate the value of wetlands, and there is an extensive and growing literature on the use of these methods and values (Barbier, Acreman, & Knowler, 1997; Bardecki, 1998; Kazmierczak, 2001; Barbier et al., 2011). Typically, when valuing wetlands at a particular site, such as the coast of Georgia, it is preferred to conduct an original nonmarket valuation study. However, this can be costly and time consuming. Instead, existing data or results from previous research can be used to inform decisions within a different context. This practice is referred to by economists as benefit transfer (Champ, Boyle, & Brown, 2003).

For the purposes of this study, we will use regression results from existing meta-analysis studies of wetland values to estimate the value of wetlands in our study area. Studies in the wetland valuation literature vary widely in their use of techniques, choice of ecosystem goods and services being valued, types of wetlands being considered, and geographic extent. With such an array of values reported in the literature, several researchers have attempted to synthesize them using meta-analysis. The purpose of a meta-analysis is to explain variation in the dependent variable across the various studies using explanatory variables, or specified characteristics of each study. Specifically, a standardized shadow price, such as the dollar value per year of 1 hectare of wetland area, is summarized from a series of similar empirical studies

and the variation in estimates is subjected to regression analysis. There are four existing wetland valuation meta-analysis in the literature: Brouwer et al., 1999; Woodward & Wui, 2001; Brander, Florax, & Vermaat, 2006; Ghermandi et al., 2010. We use regression results from the two most recent meta-analysis papers to estimate wetland benefits in our analysis. Although the use of benefit transfer for the valuation of ecosystem services is somewhat controversial and has some weaknesses (Bergstrom & Taylor, 2006; Plummer, 2009; Johnston & Rosenberger, 2010), other studies have used meta-analytic benefit transfer to value wetland services (Moeltner & Woodward, 2009; Brander et al., 2011; Yoskowitz et al., 2016).

CHAPTER 3

DATA AND METHODS

3.1 Identifying Areas of Conflict

The overall goal of this paper is to analyze the currently undeveloped land areas in Chatham County that are likely to be developed in the next 30 years and are also likely to witness wetland migration due to sea level rise. In order to identify these potential areas, we must make some predictions about the future. This can be done with a slew of methods using Geographic Information Systems (GIS) data and mapping tools, coupled with knowledge of human development patterns and the hydrology of wetlands.

To identify areas of new development, we use future land use maps of Chatham County generated by Kramer and Samples (2017) using GIS software and a SLEUTH cellular automata model for urban growth. Model inputs include gridded land cover maps, road density data, topography data, and development exclusion zones (i.e. water bodies, wetlands, and permanently protected areas). The historical land cover maps were created as part of the Georgia Land Use Trends (GLUT) Project for 1991, 1998, 2001, and 2008.² The model uses these inputs to forecast the probability that any undeveloped grid cell will become developed in the future. These results were used to create a map of areas of new development in Chatham County for the year 2045. For a depiction of these new development areas, see Figure 1.

² More information on the GLUT Project can be found on the University of Georgia's Natural Resources Spatial Analysis Lab webpage at <http://narsal.uga.edu/glut>.

Future wetlands in Chatham County were also mapped by Kramer and Samples (2017) using a Sea Level Affecting Marsh Model (SLAMM). The model incorporates the effects of inundation, erosion, accretion, salinity distribution, and elevation to predict how wetlands and marsh area are influenced by alternate levels of sea-level rise. Based on estimates of rising sea level over the next 30 years, the model was used to develop a map of future wetlands distribution in Chatham County for the year 2045. For a depiction of these new wetland areas, see Figure 2.

Using these maps, we were able to identify those areas of conflict where new development and new wetlands are likely to appear over the next 30 years. By layering current land cover, future land use, and future wetlands maps on top of one another in ArcMap, we were able to extract the overlap areas of new development and new wetlands in 2045 compared to the “current” map of Chatham in 2008³. Then, using GIS parcel boundary data from Chatham County, we identified which parcels have boundaries that intersect these areas of conflict and calculated the acreage of land we are interested in protecting in each parcel.

Initially, we assumed that only agricultural land would be of interest for this project since agricultural parcels are generally large and mostly undeveloped. It became clear after further analysis, however, that other types of properties should be considered for open space protection as well. The threat of new development and inundation by wetlands applies to all types of privately owned property in Chatham County, so we later chose to expand our analysis and include residential, commercial, and industrial property in addition to agricultural. The consequences of this decision will be discussed in the following section.

³ Because 2008 is the most recent map created by the GLUT Project, it was the best representation of current land cover that could be used.

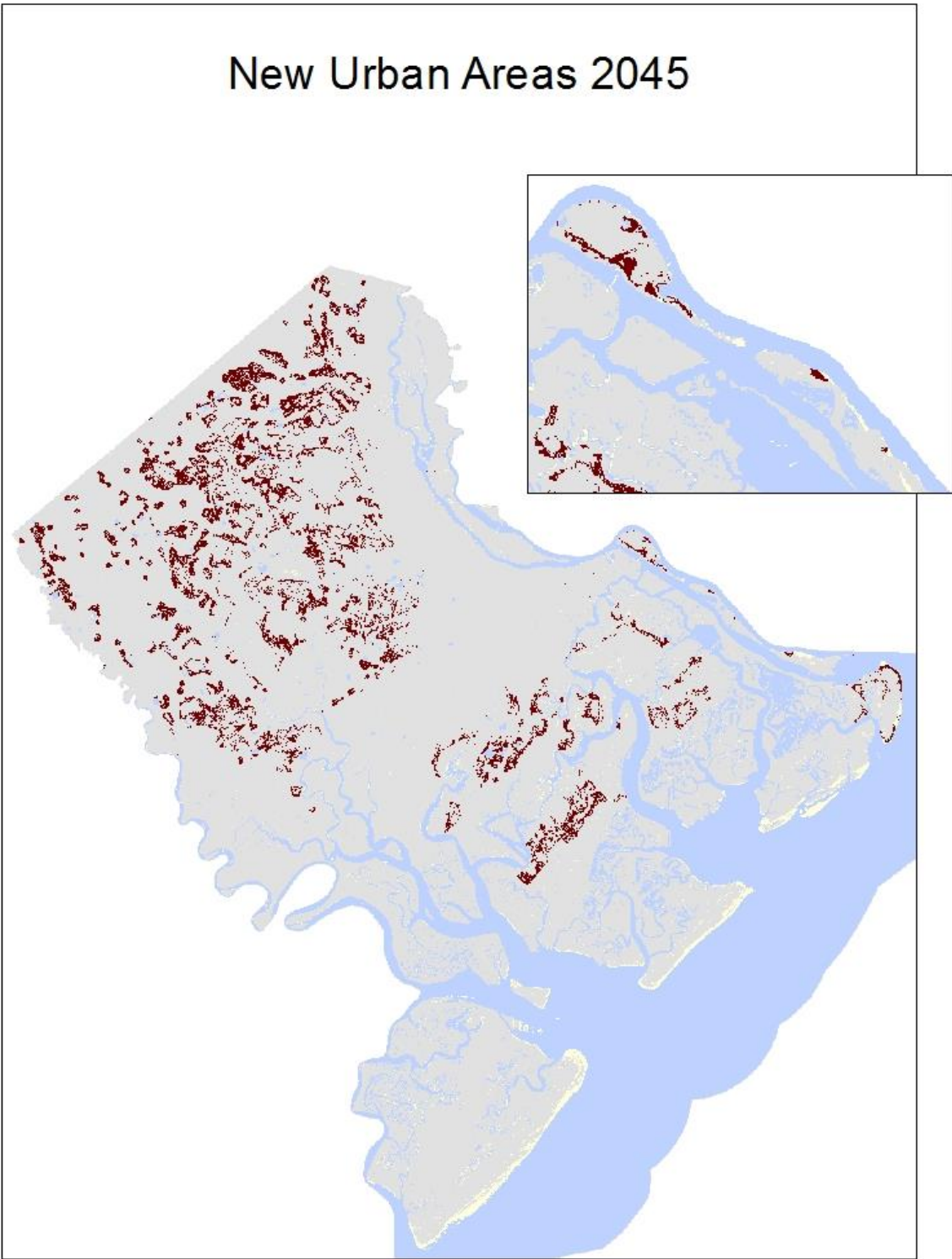


Figure 1. Chatham County New Development Areas 2045

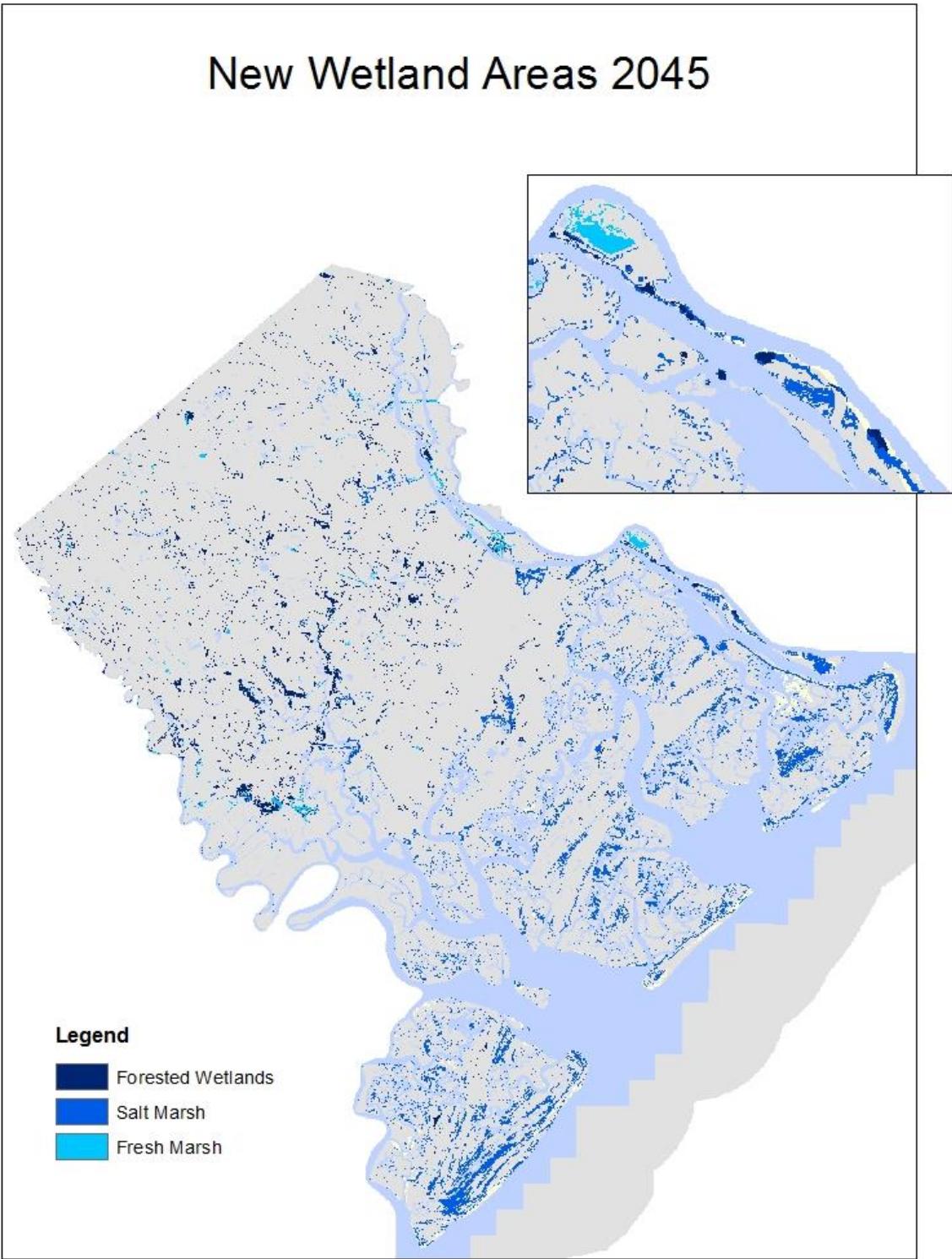


Figure 2. Chatham County New Wetland Areas 2045

3.2 Estimating Costs

In this study, we want to explore a range of possible options for open space protection in Chatham County. As discussed in Chapter 2, we analyze the costs of two types of options: fee-title acquisition and conservation easements. Land in our study area is separated into parcels, some of which are predicted to be developed as well as witness wetland migration 30 years from now. These areas of future conflict, however, may only be witnessed on a portion of these parcels. To protect these currently open spaces from future development, a government or nongovernmental entity has the option to acquire fee-title ownership of either the full parcel or just the threatened portion (assuming parcel splits are permitted). Alternatively, a government or nongovernmental entity can place a conservation easement on those portions of a parcel, allowing the owner to retain full ownership, but restricting his or her rights to develop or farm the area. We estimate the potential costs of using each of these three options for open space protection in the county.

3.2.1 Full Parcel Purchase

To predict the cost of acquiring fee-title ownership of an entire parcel, we first estimate three hedonic price equations using Chatham County sales data for agricultural, residential, and commercial/industrial properties separately. Using sales price as the dependent variable, and a set of parcel characteristics as the explanatory variables, we model the price effects of these characteristics in each type of property. The three resulting fitted regressions are equations that can be used to calculate the price of any agricultural, residential, commercial or industrial parcel in the county by multiplying the observed value of each parcel characteristic by the value of the associated coefficient and adding these values together.

3.2.2 Partial Parcel Purchase

To predict the cost of acquiring fee-title ownership of only the piece of a parcel at risk of future wetland/development conflict, we again use the results of our three hedonic price models. In this instance, we are only interested in the value of land within a parcel, not any of its improvements. We estimate the land-only value of each parcel by setting the value of improvements equal to zero in the fitted hedonic regression equation. This predicted land value for each parcel is then divided by the parcel's area to retrieve a per acre price, and multiplied by the acres of future conflict area within a parcel. The result is a price estimate for acquiring the land area we are interested in protecting, rather than the price of the entire parcel.

3.2.3 Conservation Easement Purchase

Lastly, we predict the cost of placing conservation easements on the areas we want to protect. As discussed in chapter 2, methods for estimating the value and associated purchase price of conservation easements are not well defined or easily applied. We elect to estimate the potential costs of conservation easements using a range of values. Specifically, we use three values for proportion of the fee-title partial purchase price to analyze their costs. These percentages, 85%, 55%, and 25% represent a high, average, and low easement cost, respectively. Although these percentages were chosen somewhat arbitrarily, it is likely that easement values on the properties we are analyzing would be relatively high (i.e. 55%-85%) because these easements would restrict all development or farming rights and will be placed on lands facing high development pressure.

3.3 Property Sales Data

Data on parcels sold between 2009 and 2017 were retrieved from the Chatham County Board of Assessors' website. The data includes information such as parcel number, sale price, deed book and page, property class, and qualification of sale. Property class codes include residential, commercial, industrial, utility, historical, agricultural, and conservation. The qualification code allowed us to easily identify which sales were considered arms-length⁴, indicated by the word "qualified" and whether a parcel was sold as a single parcel or as part of a multiple-parcel sale, indicated by the word "multiple". Only the most recent, qualified, and single-parcel sales with unique deed book and page numbers were kept. To keep observations of sales containing multiple parcels, it is necessary to combine data from each parcel involved in the sale, which is very time consuming. This was done for certain multiple-parcel sales of agricultural land, however, which I will address later. Additionally, some parcel sales in the data were listed with the same deed book and page number, despite being labeled as a single-parcel sale. The information in this dataset is recorded based on current pin number and classification of each parcel, rather than at time of sale. Therefore, it is likely that these parcels were split after being sold. They were not included in our analysis due to similar issues faced by the use of multiple-parcel sales. Sales prices were converted to 2017 US\$ using yearly CPI data downloaded from the St. Louis Federal Reserve Economic Database (FRED).

⁴ A sale is considered arms-length when both the buyer and seller are acting in their own self-interest, with no collusion between parties. Non arms-length sales include foreclosures, sales between family members, and estate sales.

3.3.1 Historical Parcel Attributes

Again, since the information in the sales data is reflective of a parcel's current classification, we could not rely on the property class labels to separate the data into the three groups we want to analyze. We downloaded historical (2009-2016) and current (2017) parcel digest data from Chatham County's Savannah Area GIS (SAGIS) website. Each dataset includes the pin number, property class, zone, size, and assessed value of each parcel in the county during that tax year. We were then able to match each parcel in the sales data with its digest data from the same year it was sold based on its pin number. Therefore, we could better determine how the parcel was being used at the time it was sold, as well as its acreage and the assessed value of its improvements. Some of these parcels have been split or combined and assigned new pin numbers since being sold, so we are unable to use these observations. Values of improvements were converted to 2017 US\$ using yearly CPI data downloaded from FRED, then divided by 10,000. Some parcels with \$0 improvement values had an unusually high price per acre. These are likely parcels that were vacant at the time the parcel digest was created, but then built on quickly and sold within the same year. Vacant parcels with a price per acre value greater than \$500,000 were excluded from the data.

3.3.2 GIS Attributes

A number of additional parcel attributes were calculated by Kevin Samples at the Natural Resources Spatial Analysis Lab (NARSAL) using GIS software. Acreage of wetlands, forest, open water, and crop cover were calculated using the 2008 GLUT land cover map. Percent slope and elevation were calculated at the centroid of each parcel using USGS 3DEP data. Several parcels were too small for either land cover, slope, or elevation data to be

calculated (although not necessarily all three). In this instance, land cover acreage for the four categories analyzed was assumed to be zero, but observations with missing slope and elevation data could not be corrected or imputed. Two locational variables were measured in miles from the centroid of each parcel, one to the coastline of Tybee Island (the only public beach in the county), and one to the nearest incorporated place. Coastline and incorporated place boundaries were retrieved from the U.S. Census TIGER files for 2010. The National Commodity Crop Productivity Index Overall number at the centroid of a parcel was also retrieved to be used for the agriculture hedonic regression. Parcels with missing soil class data (usually urban areas) were given a value of zero.

Each of these attributes were generated using Chatham County parcel boundary data from the year 2016, meaning some parcels with different pin numbers in the sales data could not be matched with these GIS-generated attributes. These observations could not be used in the analysis. Additionally, some parcels that have not changed pin numbers have changed size over time. This raises an issue with the land cover values. If a parcel was much smaller when it sold 5 years ago compared to its 2016 parcel boundary, its land cover variables would not be representative of the current parcel area. To address this issue, parcels with a difference in acreage of more than 2.5% were excluded⁵. Additionally, the 2008 land cover map is comprised of 30 by 30 meter pixels while the parcel boundary data is at a much finer resolution. This caused some estimates of land cover acreage to be larger than the actual parcel size. Agricultural land with wetland, forest, and crop acreage larger than parcel size were excluded. Residential, commercial, and industrial property with wetland and forest size larger than parcel size were dropped as well.

⁵ This percent value was chosen somewhat arbitrarily, but regression results generated with this data performed better than alternative data with either 1 or 5 percent change.

3.3.3 Agricultural Property

Data used for the hedonic regression to estimate agricultural land includes sales of parcels designated as either agricultural or conservation by its property class. A parcel is classified as conservation when enrolled in the Conservation Use Assessment (CUVA) program, meaning part or all of the parcel will remain in a “bona-fide” agricultural use for a minimum of 10 years.⁶ Properties that qualify for this program can be actively producing crops, or simply covered by forest. Were we to only consider the most recent sale of parcels (rather than including repeat sales) and focus only on single-parcel sales, we would have sales of only 2 agricultural parcels and 1 conservation parcel. Few parcels are sold while actively enrolled in the CUVA program. According to the current parcel digest in 2017, over 80 percent of the parcels enrolled in CUVA are zoned “RA”, or residential-agriculture.⁷ We make the assumption that parcels classified as residential, but zoned for residential-agriculture, have the potential to be enrolled in the CUVA program and should be included for our agricultural hedonic regression. This adds an additional 1,347 observations to the data.

As mentioned above, we previously intended to only analyze agricultural land in this study. This previous dataset was initially populated with every property record card in the county that was ever classified as agricultural or conservation in any of the parcel digests. Property record cards contain a sales history and yearly assessed values, as well as notes about pin number changes, parcel combinations or splits, and the date that any structures were built. All qualified sales, including qualified multiple-parcel sales, were collected off the record cards.

⁶ For more information on Conservation Use Assessment, see <https://dor.georgia.gov/conservation-use-assessment-information>.

⁷ The purpose of this district is to protect rural areas from all future development, except some low density residential development. More information on zoning in Chatham County can be found on their Metropolitan Planning Commission webpage at <https://www.thempc.org/Forms/Zoning>.

The value of improvements at the time of sale was also recorded while paying special attention to whether a property was actually vacant or not. Looking at a combination of deeds, plats, notes in the record cards, and the Savannah-Area interactive map viewer, we were able to determine which parcels in our GIS data would have covered the same area as the parcels in this sales data at the time they were sold. This meant we could retrieve GIS variable values for parcels that had changed pin numbers, and combine values for parcels that were split or sold together with other parcels (identified by same deed book and page number). Parcel size and land cover acreage were simply added together, while the average was taken of slope, elevation, soil quality, and distance values. In the interest of obtaining more observations, we repeated this same process with residential parcels zoned RA for reasons already discussed. Due to the incredible amount of time it took to check each observation and combine data when necessary, this was only done for parcels larger than 5 acres. Eventually, it was decided that attempting to create accurate data for every single sales observation was not worth the time. Moving forward, only observations that resulted from the data creation and cleaning specifications outlined in sections 3.3.1 – 3.3.3 were considered for the analysis.

The final data used for the hedonic regression of agricultural land included 49 sales from the initial dataset and 1,226 from the new data creation method. It should be noted that values created in the previous dataset were chosen over values in the new data in the case of duplicate observations. To estimate the hedonic model for agricultural land, we use natural log of price as the dependent variable, as is common in hedonic regression models. Explanatory variables include parcel size in acres, value of improvements, slope, elevation, percent cropland, percent wetlands, percent forest, and percent water. Location variables are distance to the coast of Tybee Island and distance to nearest incorporated place. Indicator variables include a variable equal to

1 if a parcel's productivity index is greater than the median (0.48), indicating high quality soil, as well as a variable equal to 1 if the parcel has no value of improvements and is considered vacant. Yearly and seasonal dummy variables were also included in the regression. Slope and/or elevation data were missing from 223 of these observations, leaving the final regression to be estimated using 1,052 observations. For descriptive statistics of the sales data used to estimate the agricultural hedonic model, see Table 1.

Table 1: Summary statistics for agricultural sales data

Variable	<i>n</i>	mean	std. dev.	min	max
price	1,052	279,288	380,537	1,500	9,453,746
acres	1,052	2.535	17.03	0.0261	381.4
improvements	1,052	179.5	144.7	0	1,309
vacant	83	-	-	0	1
slope	1,052	0.599	0.656	0	6.298
elevation	1,052	3.983	1.614	0.314	12.29
hqsoil	311	-	-	0	1
pctcrop	1,052	0.0266	0.121	0	0.969
pctwetlands	1,052	0.0552	0.174	0	0.971
pctforest	1,052	0.181	0.296	0	0.999
pctwater	1,052	0.00576	0.0464	0	0.933
tybee_dist	1,052	19.13	6.557	1.348	31.35
inc_dist	1,052	3.410	4.401	0	14.29

3.3.4 Residential Property

Observations on sales of parcels classified as residential, except for those zoned RA, were used to estimate the hedonic regression for residential property. Prices were logged and used as the dependent variable. Explanatory variables include size of parcel in acres, value of improvements, slope, elevation, percent wetlands, percent forest, and percent water. Distance variables used are distance to the coast of Tybee Island and distance to nearest incorporated place. An indicator variable equal to 1 was also created to designate vacant parcels. Yearly and

seasonal dummy variables were also included in this hedonic regression. Slope and/or elevation data were missing from 4,062 of the observations, leaving 7,884 to be used to estimate the residential hedonic regression. For descriptive statistics of the sales data used to estimate the residential hedonic model, see Table 2.

Table 2: Summary statistics for residential property sales data

Variable	<i>n</i>	mean	std. dev.	min	max
price	7,884	242,968	195,869	3,500	2,700,000
acres	7,884	0.368	1.976	0.00688	142.3
improvements	7,884	166.6	134.7	0	2,324
vacant	344	-	-	0	1
slope	7,884	0.616	0.704	0	6.446
elevation	7,884	4.778	1.936	0.303	16.72
pctwetlands	7,884	0.0265	0.132	0	0.991
pctforest	7,884	0.126	0.274	0	1.000
pctwater	7,884	0.00346	0.0458	0	1.468
tybee_dist	7,884	16.91	6.572	0.0528	31.20
inc_dist	7,884	2.323	4.196	0	14.98

3.3.5 Commercial and Industrial Property

Sales of parcels classified as either commercial or industrial were included to estimate our third hedonic equation. Log of sale price was used as the dependent variable. Explanatory variables include parcel size, value of improvements, slope, elevation, percent wetlands, and percent forest. Only 7 parcels contained water bodies, so percent water was not used in this model. Distance to the coast of Tybee Island was also excluded from this regression. It is assumed that people value being closer to the beach where they live, rather than where they shop and work. However, distance to nearest incorporated place is included. Indicator variables for vacant lots and commercial properties are also included. Slope and/or elevation data was

missing from 142 of the observations, leaving us with a total of 443 sales of commercial and industrial property. For descriptive statistics of the sales data used to estimate the commercial/industrial hedonic model, see Table 3. For a description of variables used in all three hedonic models, and their hypothesized sign, see Table 4.

Table 3: Summary statistics for commercial and industrial property sales data

Variable	<i>n</i>	mean	std. dev.	min	max
price	443	2,395,893	60,94,946	12,500	47,648,748
acres	443	3.072	7.098	0.0107	98.30
improvements	443	1,742	6,673	0	105,601
vacant	63	-	-	0	1
slope	443	0.825	0.971	0	13.74
elevation	443	6.132	2.965	0.983	16.34
pctwetlands	443	0.0462	0.138	0	0.967
pctforest	443	0.0671	0.167	0	0.919
inc_dist	443	0.229	1.333	0	12.09
commercial	358	-	-	0	1

Table 4. Description of variables used in hedonic models and hypothesized sign

Variable	Description	Expected Sign
acres	Parcel area in acres	+
sq_acres	Square of parcel area in acres	-
log_acres	Log of parcel area in acres	+
improvements	Value of improvements in year of sale divided by 10,000 (2017 US\$)	+
vacant	Binary=1 if no improvements on parcel	-
slope	Percent slope at centroid of parcel	-
inv_slope	Inverse of percent slope at centroid of parcel	+
elevation	Elevation at centroid of parcel	+
inv_elevation	Inverse of elevation at centroid of parcel	-
hqsoil	Binary =1 if soil class greater than 0.48	+
pctcrop	Acres of crop divided by parcel acres	+/-
pctwetlands	Acres of wetland divided by parcel acres	+/-
pctforest	Acres of forest divided by parcel acres	+/-
pctwater	Acres of open water divided by parcel acres	+
tybee_dist	Distance to Tybee coast from centroid in miles	-
log_tybee_dist	Log of distance to Tybee coast from centroid in miles	-
inc_dist	Distance to nearest incorporated place from centroid in miles	-
inv_inc_dist	Inverse of distance to nearest incorporated place from centroid in miles	+
commercial	Binary=1 if commercial property	+/-

3.4 Estimating Benefits

To estimate the potential benefits to society from an open space protection plan, we use results from two previous wetland valuation meta-analyses (Brander, Florax, & Vermaat, 2006; Ghermandi et al., 2010) and employ function transfer techniques to predict the value of future wetlands that will be free to migrate as a result of pre-emptive protection. These wetland valuation meta-analyses synthesize the outcomes of various studies using summary statistics reduced to a common metric, i.e. wetland value per hectare per year, as the dependent variable and natural resource, socioeconomic, and study characteristics as the independent variables. The results of these two meta-regression analysis models are used to predict the value per hectare per year of new 2045 wetland areas in our study site. This is done for each continuous patch of future wetland area that is also predicted to be developed over the next 30 years. Variable characteristics of these wetland patches are multiplied by the coefficient estimates produced by the meta-regression models, then aggregated, to elicit values. Steps for conducting both a meta-analysis and meta-analysis function transfer are outlined in Champ, Boyle, and Brown (2003), although we will make some minor modifications to their suggested methods.

Once a value has been predicted for each of these future wetland patches, we translate these values into a per parcel benefit value that can be compared to our cost estimates. These continuous wetland patches will cover multiple parcels in the future, so we first identify which of these unique wetland patches intersect each parcel using GIS. Then, the estimated yearly per hectare value of each wetland patch can be converted to a yearly per parcel benefit value by multiplying this estimate by the hectares of the wetland patch that will be present on that parcel in the future.

Based on our methods, we cannot assume that these wetland areas will provide benefits until the year 2045. To calculate benefit-cost ratios for each parcel analyzed for protection, we use discounted values of wetlands benefits, beginning in year 2045 and accrued in perpetuity. We use two discount rates, 2.95 and 3.45, associated with 30-year municipal bond rates.

3.5 Wetland Data

Our proposed protection plan involves the acquisition of land areas, or their development rights, on a per parcel basis. This means we want to quantify the potential benefits of these future wetland areas in each parcel individually. However, these new wetland areas in each parcel will be connected to larger, continuous wetlands and may be connected to each other as well. Both studies by Brander, Florax, and Vermaat (2006) and Ghermandi et al. (2010) evaluate values of large, continuous wetland areas. Some are from studies that value entire wetland areas, while some value marginal changes in wetland areas. To properly estimate benefit values for our analysis, it is necessary to evaluate the marginal changes in continuous wetland areas that will result from our proposed protection plan.

Using the GIS maps of future development areas and future wetlands distribution for the year 2045, each continuous patch of new wetlands covered by new development was extracted and given a unique wetland identification number. Since these land cover maps are classified using the same categories as the historical GLUT maps, wetland patches were separated into three categories: forested wetland, salt marsh, and freshwater marsh. Each of these unique wetland areas are treated as a marginal change in wetland area in our meta-regression benefit transfer. The result of each benefit transfer is a value per hectare per year for each unique wetland patch. This value can be translated into a value per parcel per year depending on the

value of the unique wetland and the size of its area that is within a parcel's boundaries. Based upon these methods, we are making the underlying assumption that all continuous areas of conflict within a wetland will be protected under our plan. Since both meta-regressions exhibit decreasing returns to scale, this assumption may cause downward bias to benefit estimates.

Certain explanatory variables used in the meta-regressions were also calculated using GIS software, in addition to wetland size. Because these wetland areas emerge in year 2045⁸, variable attributes used to estimate their value should reflect the future, where possible. Population within a 50 km radius around each wetland site was calculated using population projection estimates for the year 2050 provided by Hauer, Evans, and Alexander (2015). Wetland area within a 50 km radius was calculated using the 2045 map produced with SLAMM. To create a binary variable indicating whether or not a wetland was in an urban area, data from U.S. Census 2017 Cartographic Boundary files were used. Finally, the latitude of each wetland's location was calculated.

3.5.1 Meta-Regression A

In their meta-analysis study, Brander, Florax, and Vermaat (2006) gather information from 190 different wetland valuation studies, resulting in a total of 215 value observations. They standardize these values into value per hectare per year in 1995 US\$. The average annual value in their data is just over \$2,800, while median annual value is only \$150. The valuation studies used in their data encompass six different continents and a wide range of wetland types, wetland services, and valuation method used. They include several binary variables in their final model in an attempt to control for these large differences in values.

⁸ These wetlands will slowly migrate over the next 30 years, but we only have data on their location in 2045, so we must assume that this is the first year wetland benefits will be provided.

Several variables were created and transformed to coincide with the data used by Brander, Florax, and Vermaat (2006). Socio-economic variables used in their meta-regression were GDP per capita and population density in a 50km radius. The authors used state-level per capita income for studies performed in the United States. Therefore, we used per capita income estimated for the state of Georgia (U.S. Census, 2016), put into 1995 US\$ to conform to their data. We calculated population density using the 2050 population estimates generated for each wetland. Geographic characteristic variables we needed were wetland size (in hectares), latitude (absolute value), latitude squared, and the binary variable equal to 1 for urban wetlands. Many of the wetland patches in our data are small (significantly less than one), particularly when converted to hectares. Since the variable for wetland size is expressed as the log of hectares, we change all decimal values to 1 to avoid negative values. The binary variable for North America was omitted from the meta-regression, so we can ignore the continent coefficients. We can also ignore the RAMSAR site coefficient since no wetlands in Chatham County qualify.

The remainder of the variables used in the regression are binary variables for valuation method, value type, wetland type, and wetland service. Champ, Boyle, and Brown (2003) suggest using the proportion of values in the meta-regression data generated by each valuation method to control for their effects. We choose to ignore these coefficients, however, since they are mostly not statistically significant (except for stated preference, which is large and positive and could induce upward bias into our estimates). The binary variable for value type is equal to 1 for estimates of marginal wetland values. This applies to all wetlands in our study, so each are given a value of 1. Fortunately, the authors include wetland type categories that correspond perfectly with the three classes of wetlands in our data. Three binary variables were created for each wetland in our data, with a value equal to 1 for whichever variable indicated its class. The

other two wetland type coefficients, mangrove and unvegetated sediment, were ignored. Lastly, the wetland service variables we deemed reasonable for characterizing wetlands in Chatham County were flood control, water supply, water quality, habitat and nursery, hunting, fishing, amenity, and biodiversity. All wetlands in our data were given a value of 1 for these variables. Material and fuelwood were not considered descriptive of services provided by the wetlands in our analysis, since they will be protected and vegetation will be left in its natural state. Table 5 lists each of these variables, their coefficients, and the variable values used to describe the wetlands in our data.

3.5.2 Meta-Regression B

One of the primary goals in the meta-analysis study by Ghermandi et al. (2010) is to capture the value of human made wetlands, which does not apply to the wetlands we are interested in valuing. Nonetheless, they use an expanded dataset and make some improvements to the model specification compared to Brander, Florax, and Vermaat (2006). We will be using the results of “Model B” reported in their paper. This reduced model uses all 416 observations of values they gathered from primary data studies, but does not include the binary variables indicating valuation study type due to their statistical insignificance in the full model. The dependent variable is a standardized measure of value per hectare per year in 2003 US\$.

Again, several variables had to be generated and transformed to match the variable specifications and data used in this meta-analysis. The authors measure wetland size in log of hectares. For reasons stated previously, we change all hectare values in the unit interval to 1 before logging the values. Socioeconomic and geographic context variables used in this model are GDP per capita and population density and wetland abundance in 50 km radius. The authors

Table 5. Meta-analysis regression results A and application to wetlands in Chatham County, Brander et al. (2006)

Dependent variable: Natural log of value per hectare per year (1995 US\$)		
Variable	Coefficient	Chatham Wetland Measure
Contingent valuation method	1.49**	-
Hedonic pricing	-0.71	-
Travel cost method	0.01	-
Replacement cost	0.63	-
Net factor income	0.19	-
Production function	-1.00	-
Market prices	-0.04	-
Opportunity cost	-0.03	-
Marginal	0.95*	=1 for all
Mangrove	-0.56	-
Unvegetated sediment	0.22	-
Salt/brackish marsh	-0.31	=1 if salt marsh
Fresh marsh	-1.46*	=1 if fresh marsh
Woodland	0.86**	=1 if forested wetland
Wetland size	-0.11**	Log of hectares
Flood control	0.14	=1 for all
Water supply	-0.95	=1 for all
Water quality	0.63	=1 for all
Habitat and nursery	-0.03	=1 for all
Hunting	-1.10**	=1 for all
Fishing	0.06	=1 for all
Material	-0.83**	-
Fuelwood	-1.24***	-
Amenity	0.06	=1 for all
Biodiversity	0.06	=1 for all
RAMSAR proportion	-1.32*	-
Urban	1.11**	=1 if urban
GDP per capita	1.16**	Log of per capita income in GA (1995 US\$)
Population density	0.47***	Log of population in 50 km radius in 2050
Latitude	0.03	Absolute value of latitude
Latitude squared	-0.0007	Latitude squared
South America	0.23	-
Europe	0.84	-
Asia	2.01	-
Africa	3.51**	-
Australasia	1.75*	-
Constant	-6.98	=1 for all
<i>n</i>	202	
<i>R</i> ² adjusted	0.45	

use state-level per capita income in 2003 US\$. We use per capita income for the state of Georgia (U.S. Census, 2016) also put into 2003 US\$. Our population and wetlands values come from the GIS data.

The remainder of the variables are binary. The authors include a binary variable for marginal values of wetlands. This applies to all observations in our data, so each is given a value of 1. Wetlands are categorized into estuarine, marine, riverine, palustrine, lacustrine, and human-made. This presents the biggest issue faced with using this meta-regression for our analysis, since our classification of wetlands does not translate well into these categories. According to a report by the Georgia Department of Natural Resources (2012), however, 65 percent of wetlands in Chatham County are estuarine and 34 percent are palustrine. Estuarine wetlands can be more generally described as coastal wetlands, while palustrine are inland. Based on this, we elect to designate the salt marsh wetlands in our data as estuarine. Both forested wetlands and freshwater marsh are designated as palustrine.

The next set of wetland characteristic binary variables represent various wetland services. Of these, we consider flood control/storm buffering, surface and groundwater supply, water quality improvement, recreational hunting and fishing, non-consumptive recreation, amenity and aesthetics, and natural habitat/biodiversity to be services provided by wetlands in Chatham County. Commercial hunting and fishing, as well as natural materials and fuelwood were not considered to be characteristic of the wetlands in our study.

Lastly, the authors include binary variables indicating four levels of human pressure, ranging from 0 to 3. Each wetland is assigned a value of 0 or 1 based on natural vs. controlled hydrology, rural vs. urban, and protected vs. not protected. Each of these three values are then added together to determine a wetland's human pressure ranking. None of the wetlands in our

data are human made, and all will be protected under our hypothetical protection plan.

Therefore, the only wetlands that will receive a value of 1 are urban wetlands and all wetlands in our data will have either a low or medium-low pressure ranking. Since the low rank dummy is omitted from the regression, only urban wetlands will be affected by this piece of the model. See Table 6 for a list of these variables, their coefficients, and the associated value assigned to the wetlands in our data.

Table 6. Meta-analysis regression results B and application to wetlands in Chatham County, Ghermandi et al. (2010)

Dependent variable: Log of value per hectare per year (2003 US\$)		
Variable	Coefficient	Chatham Wetlands Measure
Year of publication (1974=0)	-0.041**	-
Marginal	0.713**	=1 for all
Estuarine	0.270	=1 if salt marsh
Marine	0.745***	-
Riverine	0.380	-
Palustrine	-0.480*	=1 if forested or freshwater marsh
Lacustrine	0.332	-
Human-made	1.023**	-
Wetland size	-0.234***	Log of hectares
Flood control, storm buffering	0.432	=1 for all
Surface and groundwater supply	-0.099	=1 for all
Water quality improvement	0.727***	=1 for all
Commercial fishing and hunting	0.266	-
Recreational hunting	-1.007***	=1 for all
Recreational fishing	-0.082	=1 for all
Harvesting of natural materials	-0.202	-
Fuel wood	-0.968**	-
Nonconsumptive recreation	0.670**	=1 for all
Amenity and aesthetics	0.529	=1 for all
Natural habitat, biodiversity	1.143***	=1 for all
Medium-low human pressure	0.572**	=1 if urban
Medium-high human pressure	1.243***	-
High human pressure	1.992***	-
GDP per capita	0.358***	Log of per capita income in GA (2003 US\$)
Population density	0.399***	Log of population in 50 km radius in 2050
Wetland abundance	-0.058	Log of hectares in 50 km radius in 2045
Constant	-0.681	=1 for all
n = 416	416	
R ²	0.47	
R ² adjusted	0.44	

3.6 Selection of Parcels for Analysis

Determinants of which parcels to include in our benefit-cost analysis are based on the results of the future maps of Chatham as well as the methods used in our hedonic regression estimation. We want to evaluate parcels in the county that are predicted to be developed and witness wetland migration by the year 2045. The GIS-calculated parcel data that contains this information was created using the older data on parcel boundaries and does not contain all of the information we need to properly apply the results of our hedonic regressions. To obtain this information and better understand the characteristics of these parcels in present day, we merged data from the 2017 parcel digest with the GIS-calculated data based on parcel pin number. Because of changes in pin numbers, as previously discussed, we could not retrieve current data on 65 of the parcels with areas of future wetland/development conflict in the GIS data.

The results of the hedonic regressions are used to calculate the costs of alternative options for land or entitlement acquisition. In order to conform to the data selection methods used to obtain sales observations, we do not consider parcels that have changed size by more than 2.5% between the old parcel boundary data and the 2017 data, or parcels with land cover acreage greater than parcel size. Parcels with missing slope or elevation data cannot be valued either.

Another issue in this data is that the calculated area acres of future development/wetland conflict in each parcel are sometimes greater than the parcel area acres, again due to differences in resolution between the two data. Improved parcels that face this issue are considered erroneous and excluded from the analysis. For these vacant parcels, however, we correct this issue by converting the acres of conflict area to be equal to the acres of parcel area prior to calculating any costs and benefits. This affected three vacant parcels.

Lastly, we identify which parcels are already in public hands, i.e. owned by a government entity, as indicated by the owner names listed in the 2017 parcel digest. We assume that these 72 parcels can be acquired for preservation at no cost and therefore are not included in the benefit-cost analysis. The resulting parcel data is separated into three property type groups based on their 2017 property class and zone, using the same classification as the sales data. In this way, we are left with 214 agricultural, 308 residential, and 232 commercial or industrial properties to be evaluated and analyzed for open space protection. Summary statistics on the size of these parcels and their areas of future conflict can be seen in Table 8, and a pie chart depicting the proportion of these parcels that are vacant in each property type can be seen in Figure 3.

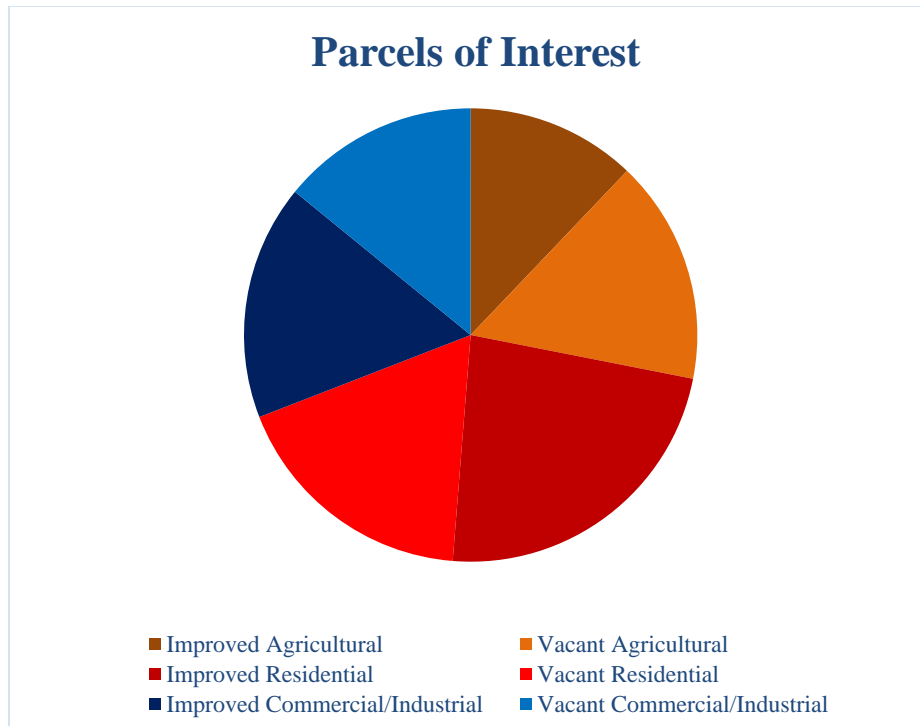


Figure 3: Pie Chart of Parcels Selected for Analysis

CHAPTER 4

RESULTS

4.1 Hedonic Regression Results

The results of our hedonic regressions for agricultural, residential, and commercial/industrial properties are presented in Table 7. All three models are estimated using the natural log of sales price in 2017 US\$ as the dependent variable. Each model varies slightly in its choice of functional form, which is reasonable considering they are modelling alternative types of properties.

The agricultural model performed best using a quadratic specification for parcel size. These properties are larger on average than the other two property types, both because rural parcels tend to have greater land area and because observations of multiple-parcel sales are included in this data. Because we are simply using these results to project estimates of property values in the county, the significance of the coefficients is not as important as their sign and magnitude. Most variables perform well in this model and generate the hypothesized sign on their coefficients, namely the inverse of elevation. Coefficients on value of improvements, percent wetlands, percent water, vacant dummy, high quality soil dummy, and the distance variables also all have the expected sign. We had no expectations for the influence of crop cover on the value of agricultural land since the literature has produced mixed results. Not surprisingly, the coefficient estimate is insignificant. We expect increasing slope to have a negative effect on land prices, but that was not the case in this model. Inverse of slope was used

Table 7: Hedonic regression results

Dependent variable: Log of sale price (2017 US\$)

	(1) Agricultural	(2) Residential	(3) Commercial/Industrial
acres	0.0235*** (0.0044)		
sq_acres	-0.0000*** (0.0000)		
log_acres		0.1506*** (0.0127)	0.6737*** (0.0529)
improvements	0.0335*** (0.0019)	0.0341*** (0.0015)	0.0006*** (0.0002)
vacant	-0.6670*** (0.1261)	-0.6262*** (0.0559)	-0.7468*** (0.1526)
slope		-0.0370*** (0.0079)	
inv_slope	-0.0000 (0.0000)		0.0000** (0.0000)
elevation		-0.0269*** (0.0040)	0.1431*** (0.0209)
inv_elevation	-0.0018 (0.1581)		
hqsoil	0.0860*** (0.0313)		
pctcrop	-0.1455 (0.1232)		
pctwetlands	-0.1828 (0.1640)	0.1718*** (0.0366)	-1.5345*** (0.4257)
pctforest	0.1082** (0.0543)	0.1330*** (0.0217)	-0.2845 (0.2828)
pctwater	0.3935 (0.4073)	0.2424** (0.1120)	
tybee_dist	-0.0382*** (0.0055)		
log_tybee_dist		-0.1348*** (0.0075)	
inc_dist	-0.0213*** (0.0065)		
inv_inc_dist		0.0015 (0.0010)	0.0256* (0.0148)
commercial			0.5397*** (0.1044)
constant	12.4766*** (0.1675)	12.3399*** (0.0417)	12.1648*** (0.1812)
Obs.	1052	7884	445
R-squared	0.7318	0.6350	0.5997
Year Dummy	YES	YES	YES
Season Dummy	YES	YES	YES

Standard errors are in parenthesis

*** p<0.01, ** p<0.05, * p<0.1

in the final model specification in order to reduce the magnitude of slope effect on projected property values.

The residential model was estimated using the natural log of acres to determine the influence of parcel size. The coefficient on slope has the expected sign, as opposed to the agricultural model. Coefficients on improvement value, percent wetlands, percent forest, percent water, vacant dummy, and distance variables also all have the expected sign. The only variable that did not produce a coefficient with the expected sign is elevation, which is negative and significant at the 1% level. We expect property prices to increase at higher levels of elevation due to flood risk reduction. However, this was not the case for our residential model. Even when other indicator variables representing flood risk were tested, such as location in 500-year flood plain and 100-year flood plain, expected signs on coefficients were not produced. A similar problem was encountered by Atreya, Kriesel, & Mullen (2016), who observed a positive effect of location in 100-year floodplain on sale price until variables indicating dock and water access were added to the model. Due to data limitations, we cannot add these variables to our regression.

Our commercial and industrial model also performed best using natural log of acres to estimate the effects of parcel size. The coefficient on value of improvements is positive, as expected, but its value is low compared to the agricultural and residential models. This is likely because most businesses require specialized capital investments and typically have to modify or remove existing improvements. The coefficient on slope produced the expected sign when expressed as its inverse. Coefficients on vacant dummy, elevation, and distance to nearest incorporated place also have their hypothesized signs. Although we had no clear expectations about the effect of wetland or forest cover on commercial and industrial property prices, it is not

unreasonable that they would be negative since they reduce the amount of useable and developable space. Lastly, the coefficient on the dummy variable indicating commercial properties is positive and significant, suggesting that commercial properties are higher in value than industrial.

Using these three hedonic price equations, we estimate the full purchase price of each of the 754 parcels selected for analysis. Resulting price estimates for three very large agricultural parcels (925 to 1015 acres), however, were less than \$4. These price estimates are clearly unrealistic, therefore it was necessary to exclude these parcels from our analysis, leaving us with 751 parcels to be used for benefit-cost analysis. As discussed in Chapter 3, the hedonic regression equations were also used to estimate the land-only value of these parcels to derive the partial purchase and various conservation easement prices associated with the land areas in each parcel we are interested in protecting. Based on these methods and specifications, the average full purchase price for each of the 751 parcels is \$844,765 and the average partial purchase price is \$52,068. Descriptive statistics for parcel prices in each of the five cost specifications can be seen in Table 8.

4.2 Benefit Transfer Results

The result of our meta-regression benefit transfer provides two values per acre per year (converted to 2017 US\$) for each continuous wetland patch predicted to be developed over the next 30 years. Based on these results, the two potential average yearly per acre values of these wetland patches is \$57,521 (A) and \$15,330 (B). These values are incredibly high compared to most values reported in the wetlands valuation literature. Although we did calculate benefits at the continuous wetland patch level, several of these patches are quite small (mean size is 3.31

acres) compared to the size of wetlands used in the meta-analysis papers and therefore are not greatly impacted by the negative coefficients on wetland size. Also, the large difference in average value between the two benefit estimates is mostly due to the difference in classification of wetlands in the two studies. Forested wetlands in our study area were valued higher based on methods used to calculate A benefits (from Brander, Florax, and Vermaat, 2006) compared to B benefits (from Ghermandi et al., 2010). Of all the wetland patches valued in this study, nearly 60 percent are classified as forested.

In each of our parcels selected for analysis, we identify which of these wetland patches partially lies within its boundary. Then, we multiply that wetland's yearly per acre values by the number of its acres located within a parcel. The result is two yearly benefit values for each of the 751 parcels, one for each meta-analysis. The net present values of these parcels are calculated using discount rates of 2.95% and 3.45% to calculate benefit-cost ratios. Table 8 lists descriptive statistics for discounted parcel benefits in each of the four benefit specifications.

Table 8: Cost and benefit estimates for all parcels analyzed

Variable	<i>n</i>	min	max	mean	std. dev.	total
<i>Size measures</i>						
Parcel acres	751	0.103	1452.91	31.413	97.3	23591
Future conflict area acres	751	0.103	38.252	0.801	1.961	601.77
<i>Cost estimates</i>						
Full purchase cost	751	45,045	43,395,360	844,765	2,686,723	634,418,853
Partial purchase cost	751	107	934,979	52,068	79,157	39,103,248
High easement cost	751	91	794,732	44,258	67,284	33,237,761
Average easement cost	751	59	514,238	28,638	43,537	21,506,787
Low easement cost	751	27	233,745	13,017	19,789	9,775,812
<i>Benefit estimates</i>						
PV of benefit A (r = 3.45)	751	18,249	11,830,956	529,826	1,103,709	397,899,463
PV of benefit A (r = 2.95)	751	24,325	15,769,891	706,224	1,471,172	530,373,956
PV of benefit B (r = 3.45)	751	10,798	4,091,655	105,766	231,122	79,429,963
PV of benefit B (r = 2.95)	751	14,392	5,453,909	140,979	308,070	105,874,945

Three parcels with unreasonable prices excluded from analysis

4.3 Benefit-Cost Analysis

The final result of our cost analysis is five price estimates for each parcel, derived from methods used to calculate cost of full parcel purchase, partial parcel purchase, and three alternative conservation easement values. Additionally, we produce four estimates of benefits values by calculating net present value of benefits estimated from two different meta-analyses using two different discount rates. Each of these cost and benefit estimates are used to calculate twenty different benefit-cost ratios for each of the parcels in our analysis. The graphs in Figures 4 through 6 provide a depiction of these benefit-cost ratios for all 751 parcels, with a vertical line drawn between parcels with ratios greater than and less than 1 for comparison.

Since both government and nongovernmental entities want to distribute funds in a way that will maximize benefits to society, we focus our attention on those parcels and land areas that produce benefits that are greater than the cost of protecting them, indicated by a benefit-cost ratio greater than one. Even in the high-cost scenario of purchasing entire parcels, between 10 and 54 percent of the parcels prove to be cost efficient, with average costs ranging from \$131,247 to \$254,750. Of course, purchasing only the portions of parcels we are interested in protecting would allow funds to go much further. In this cost scenario, if all land areas with a benefit-cost ratio greater than one were acquired, between 513 and 593 acres of wetlands would be protected by the year 2045 at a total cost of \$17 million to \$35 million. Alternatively, if conservation easements were used to protect open space, and all cost-effective easements were purchased (based on 55% to 85% of fee value), between 528 and 602 acres of future wetlands would be protected at a total cost of \$14 million to \$31 million. If easements could be purchased for a low, 25% of fee, value, potentially all of the land areas included in our analysis could be cost-

effectively acquired. Table 9 lists acre, cost, and benefit numbers associated with all of the parcels with a benefit-cost ratio greater than one in each of the twenty benefit-cost specifications.

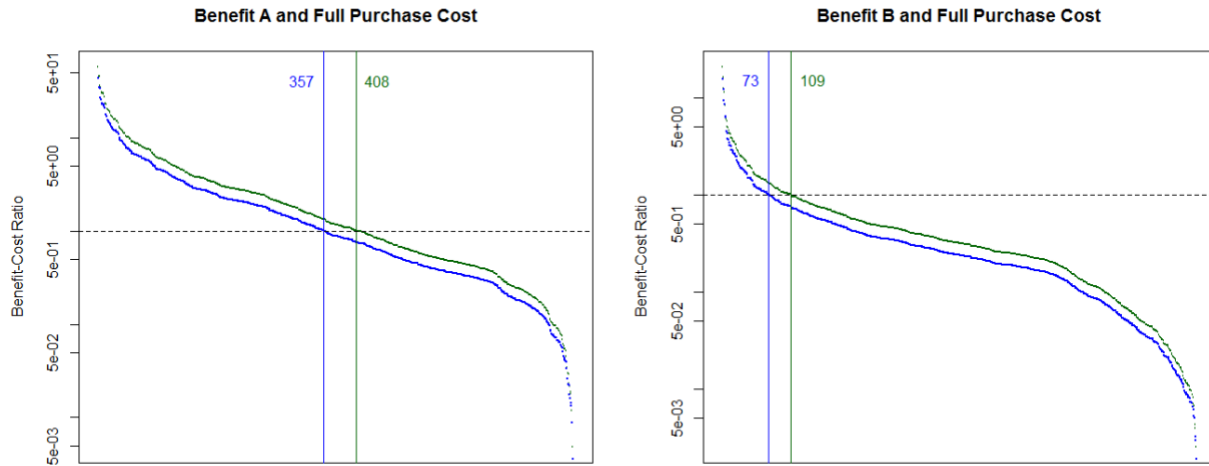


Figure 4: Benefit-Cost Ratios of Full Purchase (y-axis in log scale)

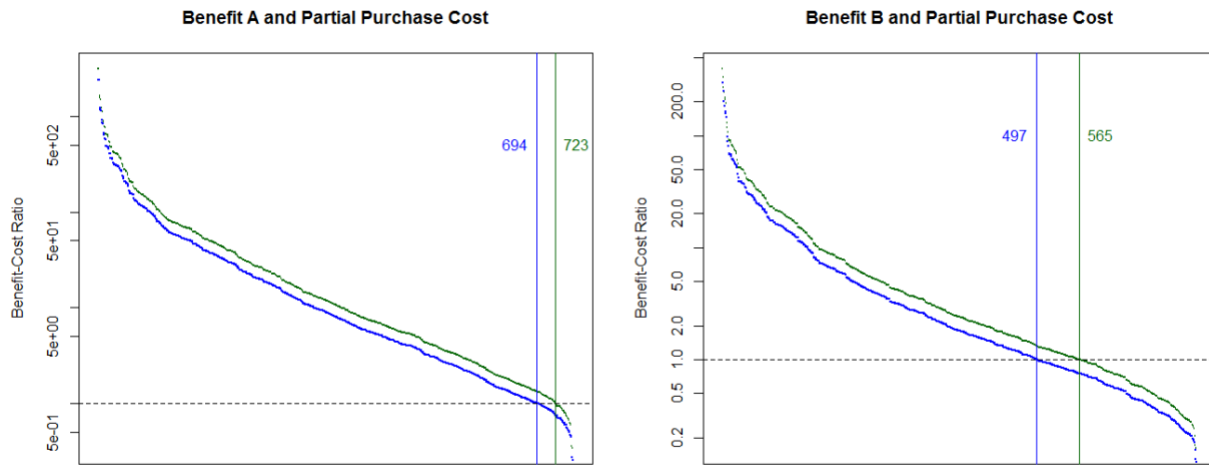


Figure 5: Benefit-Cost Ratios of Partial Purchase (y-axis in log scale)

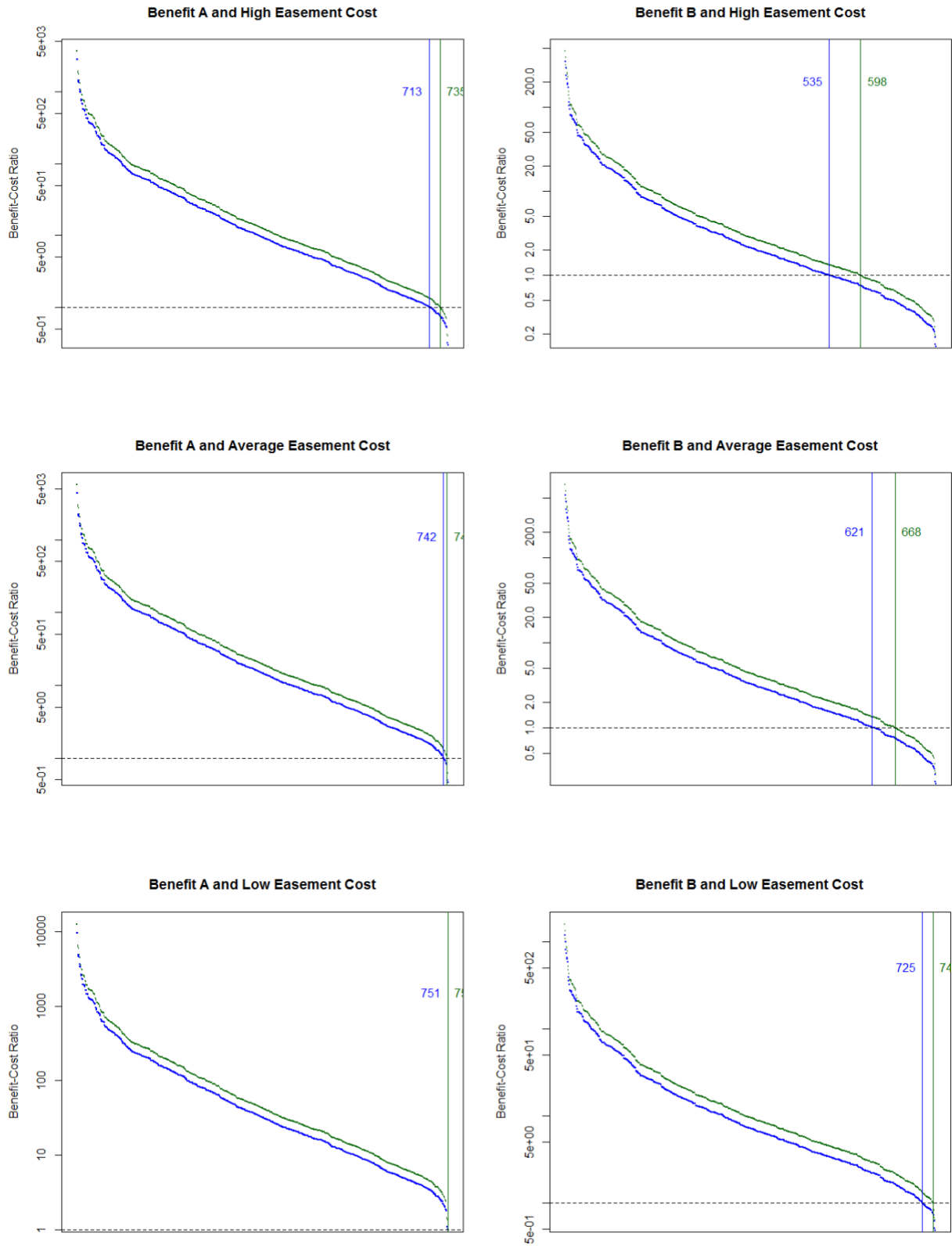


Figure 6: Benefit-Cost Ratios of Easement Purchase (y-axis in log scale)

Table 9: Results of benefit-cost analysis

Benefit-Cost Specification		Analysis of Cost Effective Parcels							
Cost type	Benefit type	<i>n</i>	Average wetland acres preserved	Total wetland acres preserved	Average cost	Total cost	Average benefit	Total benefit	Average benefit-cost ratio
Full purchase	A (r = 3.45)	357	0.969	346	228,258	81,488,154	775,998	277,031,164	4.442
	A (r = 2.95)	408	0.943	385	254,750	103,938,007	967,467	394,726,543	5.324
	B (r = 3.45)	73	1.840	134	131,247	9,581,057	298,436	21,785,798	2.524
	B (r = 2.95)	109	1.514	165	139,261	15,179,466	326,001	35,534,130	2.629
Partial purchase	A (r = 3.45)	694	0.843	585	48,327	33,538,901	567,936	394,147,606	56.45
	A (r = 2.95)	723	0.820	593	49,009	35,433,459	729,784	527,633,675	72.27
	B (r = 3.45)	497	1.032	513	34,546	17,169,300	137,318	68,247,198	12.01
	B (r = 2.95)	565	0.956	540	38,316	21,648,264	170,063	96,085,381	14.22
High easement (85% of fee value)	A (r = 3.45)	713	0.828	590	41,545	29,621,383	554,511	395,366,328	64.67
	A (r = 2.95)	735	0.810	595	42,125	30,962,093	719,138	528,566,197	83.65
	B (r = 3.45)	535	0.986	528	30,918	16,541,128	131,501	70,352,882	13.20
	B (r = 2.95)	598	0.926	554	34,871	20,852,751	165,177	98,776,000	15.86
Average easement (55% of fee value)	A (r = 3.45)	742	0.806	598	27,588	20,470,455	535,072	397,023,064	96.09
	A (r = 2.95)	749	0.803	602	28,510	21,354,279	707,982	530,278,405	126.89
	B (r = 3.45)	621	0.903	561	23,025	14,298,565	120,726	74,970,744	17.75
	B (r = 2.95)	668	0.863	576	24,493	16,361,123	153,187	102,328,832	22.08
Low easement (25% of fee value)	A (r = 3.45)	751	0.801	602	13,017	9,775,812	529,826	397,899,463	208.88
	A (r = 2.95)	751	0.801	602	13,017	9,775,812	706,224	530,373,956	278.42
	B (r = 3.45)	725	0.818	593	12,105	8,775,868	108,363	78,563,347	33.68
	B (r = 2.95)	746	0.805	601	12,911	9,631,407	141,770	105,760,564	43.66

Costs are in 2017 US\$

Benefits are expressed in net present value terms (2017 US\$)

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Policy Implications

The results of our study show that enhanced coastal resiliency *can* be achieved in a cost-effective manner. In a world that typically views climate change and sea-level rise as a “doom and gloom” type situation that we cannot overcome, we attempt to show that this is not necessarily the case. When the dynamics of coastal wetlands are considered in land-use decisions, we can pre-emptively protect these natural storm buffers from human development impacts and facilitate their migration inland as the sea level rises using alternative land acquisition and protection options, depending on their expected costs and benefits.

Based on the results of our benefit-cost analysis, future wetland migration in Chatham County that would otherwise be blocked by future human development, can be cost-effectively maintained. This approach to coastal resiliency is significantly less expensive compared to typical engineering approaches, and proves a viable option for the rapidly growing county. Our results indicate that 73 parcel land areas prove to be cost-effective investments for open space protection in all twenty of our benefit-cost specifications, and they can be protected with costs ranging from \$1.4 million⁹ to \$9.6 million, creating benefits to society between \$22 million and \$120 million.

⁹ Based on average conservation easement price used in our analysis

5.2 Future Research and Limitations

Future research regarding the incorporation of wetland dynamics into land use adaptation would benefit from considering more gradual changes in wetland migration over time, rather than in one 30-year increment as we have done here, and at a higher resolution. Additionally, better decisions could be made about the timing of land acquisition if changes in property prices were to be estimated over time. It is possible that some of the land in our analysis would become less costly over time as rising sea levels make them less inhabitable or useable.

Other costs not considered in this analysis include reduced tax revenue from downward reassessments of property values encumbered with a conservation easement. However, there is substantial evidence that areas of open space and wetlands raise nearby property values, resulting in little changes to the overall tax base (Correll et al., 1978; Nelson, 1985). Additionally, the opportunity cost of foregone development is often considered when evaluating open space protection plans such as this one. Any structures built on the land in our analysis, however, would face serious consequences in the future as surficial water tables rise and flooding becomes more frequent.

Likely the most significant drawback of our study is the use of benefit transfer methods to value wetland services. A primary valuation study, though more time consuming and costly, would be more accurate in measuring these values. Additional benefits of wetlands should also be considered for these benefit-cost analyses. For example, avoided storm damages from an increase in wetland area could result in a compelling argument for this type of open space protection plan. Lastly, other benefits associated with the ability of coastal wetlands to sequester carbon (McLeod et al., 2011) as well as their potential to produce profits in voluntary carbon markets could be considered.

Overall, it is our hope that this research will inform coastal communities on cost-effective, natural approaches to coastal resiliency and act as a guide to policy makers for incorporating coastal dynamics into land use decisions.

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