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Measuring the Impacts of Sea-Level Rise on Coastal Real Estate in North Carolina

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Abstract

This study uses a unique integration of geospatial information and economic data to estimate the impacts of sea level rise on North Carolina coastal real estate. North Carolina's coastal plain is one of several large terrestrial systems around the world threatened by rising sea level. Rates of sea level rise in this region are approximately double the global average due to local subsidence. Projected sea level rise is expected to significantly affect the natural and economic systems. We use high-resolution topographic LIDAR (Light Detection and Ranging) data to provide accurate inundation maps in order to identify all property that will be lost under different sea level rise scenarios assuming no adaptation. The sea level rise scenarios adjusting for regional subsidence include an 11 cm increase in sea levels by 2030, a 16 cm increase by 2030, a 21 cm increase by 2030, a 26 cm increase by 2080, a 46 cm increase by 2080, and an 81 cm increase by 2080. Geocoded parcel data from the county tax office provide assessed property values measured in 2004. Additional geospatial attributes that describe the distance of a property to shoreline and elevation are also generated using GIS and entered into a database of corresponding property values. The results indicate that the northern part of the North Carolina coastline is comparatively more vulnerable to the effect of sea level rise than the southern part. Low-lying and heavily developed areas in the northern coastline of North Carolina are especially at high risk from sea level rise.

Keywords: Climate change, coastal real estate, Geographic Information System, sea level rise

Introduction

Recent scientific research shows that the global sea level is expected to rise 9 to 88 centimeters over the next century (Intergovernmental Panel on Climate Change (IPCC) 2007). The relatively dense development and abundant economic activity along much of the U.S. coastline is vulnerable to risk associated with sea level rise including coastal flooding, shoreline erosion, and storm damages. The amount of developed property along the North Carolina coastline has steadily increased over the last several decades due to a strong preference for coastal locations. The number of building permits in Carolina Beach, North Carolina over the last four years exceeds the number of permits issued over the past 20 years, and the average selling price for residential properties in Wrightsville Beach, North Carolina has increased more than 200 percent since 2001. The growth coupled with soaring property values in North Carolina brought greater vulnerability to rising sea levels. The Heinz Center (2000) estimated that the average cost of coastal erosion losses to property owners will be $530 million per year for the next several decades.

Understanding the interaction of global climate change and socio-economic system is of increasing importance. In this study we examine the impacts of sea-level rise on coastal real estate in New Hanover, Dare, Carteret and Bertie County, which represent a cross-section of the North Carolina coastline in geographical distribution and economic development. Coastal North Carolina has been identified as one of the most vulnerable regions to climate change in the U.S. The study area covers from high-development to rural-economies with shoreline dominated by estuarine to marine environments. This study provides a high potential for providing relevant information for climate change policy. For example, a formal benefit cost analysis of a climate change policy would compare the benefits of avoiding climate change with the costs. One component of the benefits of climate change policy is the avoided costs of sea level rise. This study develops estimates of the property value costs of sea level rise.

We obtain the real estate data from each county tax office which maintains property parcel records that contain assessed values as well as other structural characteristics of the property. High-resolution topographic LIDAR (Light Detection and Ranging) data are used to provide accurate inundation maps in order to identify all property that will be lost under different sea level rise scenarios assuming no adaptation. Adjusting for regional subsidence, we consider a range of modest sea level rise scenarios based on the IPCC projection. Additional geospatial attributes that described the distance of a property to shoreline and property elevation are also generated using GIS (Geographic Information System) and entered into a database of corresponding tax values.

The results indicate that the impacts of sea level rise on coastal property values vary across different portions of the North Carolina coastline. The most significant loss is occurring in Dare County (northern), followed by Carteret (central), New Hanover (southern), and Bertie (rural) counties. Depending on the sea level rise scenarios, the residential property value at risk in Dare County ranges from 2.98% to 14.69% of the total residential property value. The residential property value at risk in Carteret County ranges from 0.72% to almost 3.49%. New Hanover and Bertie counties show relatively small impacts with less than one and a half percent loss in residential property value. Overall, we find that the northern part of the North Carolina coastline is comparatively more vulnerable to the effect of sea level rise than the southern part. Considering just four coastal counties in North Carolina, the residential property value at risk in 2080 is about $2.2 billion. The result of this study demonstrates that as sea level rise contributes to increased inundation and shoreline erosion, coastal economies may experience significant economic losses in the absence of mitigation and local adaptation.

Methods for Coastal Impacts Analysis

North Carolina's coastal plain is one of several large terrestrial systems around the world threatened by rising sea level (Moorhead and Brinson, 1995; Titus and Richman, 2001). Over 5000 km^2 of land area below one meter elevation and rates of sea level rise in this region are approximately double the global average due to local isostatic subsidence (Douglas and Peltier, 2002; Poulter and Halpin, in press). In the northern region of the state, rates of sea level rise are up to 0.4 meters per century, decreasing somewhat to 0.32 meters per century in the southern coastal region (Figure 1). Continued and projected sea level rise is expected to significantly impact natural and socio-economic systems with estimates anywhere between 0.3 to 1.1 meters likely (Church et al., 2001).

The study area considered ranges from approximately 75-78° W and 34-35° N latitude. The climate is humid, sub-tropical with an annual temperature of around 16° C and annual precipitation of around 1100 mm (Christensen, 2000). The natural landscape is well-known for its high biodiversity and includes habitat for American alligator, red-cockaded woodpecker, and black bear as well as numerous plant species (Schafale and Weakley, 1990). In addition, there are significant sources of carbon stored in extensive coastal peatlands that are vulnerable to erosion and decomposition from increasing sulphates concentrations introduced by rising sea level (Poulter et al., 2006; Henman and Poulter, in review).

Tax parcel spatial and tabular attributes were acquired for four counties representing a variety of geomorphic and economic resources. These counties were Bertie, Dare, Carteret, and New Hanover (Figure 2). The centroid for each tax parcel was calculated (restricting its location to within the tax parcel boundary) assuming that it represented average conditions within the tax parcel (Figure 3). Oceanfront and estuarine-front properties were identified for all four counties for current sea level. Attributes were added to these tax parcels indicating what type of shoreline position they currently occupy. Distance to shoreline was created for each inundation scenario. We used Euclidean distance to describe the proximity of a tax parcel to the shoreline. Tax parcel centroids were then used to sample the seven distance surfaces (current and 6-scenarios).

Elevation was sampled and assigned as an attribute to each tax parcel using the centroid. The LIDAR-derived Digital Elevation Model (DEM) was used as the source of elevation measures. This DEM has had buildings systematically removed although there may still be errors that are greater than the average +/- 0.25 m. Therefore, it is most likely that the elevation values reported for tax parcels in dense urban areas represent an over-estimate for elevation. The six inundation grids representing the new shoreline-ocean interface following sea level rise was sampled by the tax parcel centroids. Attributes reflecting whether a tax parcel was inundated were added to each parcel record for the impact analysis.

Coastal Real Estate at Risk

define coastal !

Coastal areas in the U.S. have seen growing populations and increased economic activity in recent years. Population in the coastal region grew 37% between 1970 and 2000. The coastal zone contains only 4% of the U.S. land area, but the economic activity measured by employment and value added in the coastal zone contributed 11% to the U.S. economy in 2000 (Colgan, 2004). Population growth has been accompanied by unparalleled growth in property values. The value of coastal real estate has appreciated at an average 7 percent per year over the last 50 years. According to the Heinz Center (2000), a typical coastal property is worth from 8% to 45% more than an otherwise comparable inland property. The relatively dense populations and valuable coastal properties are vulnerable to substantial risks associated with climate change and sea level rise.

This study estimates the impacts of climate change induced sea level rise on property values in coastal North Carolina. Data on property values come from the county tax offices which maintain property parcel records that include assessed value of property. Six scenarios for future sea level rise are developed from the recent IPCC report (2007). These scenarios are adjusted for regional subsidence that is geologically important in North Carolina (Tushingham and Peltier, 1991). Table 1 presents an 11 centimeters (cm) increase in sea level by 2030 (2030-Low), a 16 cm increase by 2030 (2030-Mid), a 21 cm increase by 2030 (2030-High), a 26 cm increase by 2080 (2080-Low), a 46 cm increase by 2080 (2080-Mid), and an 81 cm increase by 2080 (2080-High). Figure 4 provide inundation of coastal North Carolina with detailed examples for each of the counties investigated in this study. This particular example uses the high scenario for the year 2080 which includes both eustatic and isostatic sea level rise.

The results indicate that the impacts of sea level rise vary among different portions of North Carolina coastline. Table 2 shows the distribution of current property values at risk from sea level rise. Displayed are the current property values that will be lost under the inundation scenarios. The most significant loss is occurring in Dare County, followed by Carteret, New Hanover, and Bertie counties. For Dare County, the percentage of the loss to the total property value ranges from 6% to 19%. Dense development along the Outer Banks in Dare County is subject to the most dynamic geological process in North Carolina. Carteret County has the loss ranging from 2% to 5% while New Hanover County has a relative small impact between less than one and a half percent. The impact on Bertie County is also similar to that of New Hanover County.

Dare County locates in the northern part of the NC coastline and represents one of the highly developed areas on the NC coastline. The area is low-lying and vulnerable to various coastal natural hazards. For a total of 25,870 residential properties, the average property value is $456,058. Geocoded data provide an indicator for coastal water frontage and other important spatial measures. Given the location of the county and substantial development on the Outer Banks, Dare County has about eight percent of the properties on the ocean front and about twelve percent on the sound/estuarine front. The mean distance to nearest shoreline is about 1360 feet and the elevation of the properties is on average 7.9 feet above sea level. The distance to the nearest shoreline is measured as the Euclidean distance in feet from the edge of each property to the nearest coastline. Most homes are located close to shorelines and have lower elevations. Depending on the sea level rise scenarios, the residential property value at risk in Dare County ranges from $366 million (2.98%) to $1.8 billion (14.69%). The impacts on nonresidential properties range from $777 million (11.88%) to $1.7 billion (26.66%).

Carteret County is located in the central part of the NC coastline. The total property value in the county is about half of that of Dare County. The average property value is about $171,934. About three percent of the properties have an ocean-frontage and thirteen percent have the sound/estuarine frontage. The mean distance to nearest shoreline is about 1123 feet and the elevation of the properties is on average 13 feet above sea level. The residential property value at risk in loss in Carteret County ranges from $43 million (0.72%) to $208 million (3.49%). The impacts on nonresidential properties range from $129 million (5.73%) to $225 million (9.98%).

New Hanover County is located in the southern part of the NC coastline and is highly developed relative to other coastal counties. The average residential property value is $176,554. About one percent of the properties have ocean frontage and two percent have a sound/estuarine frontage. The mean distance to the nearest shoreline is about 1812 feet and the elevation of the properties is on average 26 feet above sea level. New Hanover County has the estimated residential property value loss between $62 million (0.53%) and $167 million (1.43%), and nonresidential property value loss between $18 million (0.41%) and $60 million (1.35%).

Bertie County represents a rural and underdeveloped county in the data. The total property value is about $1 billion which is only about 5% of the total property value for Dare County. More than half of the properties are located outside one mile from the shoreline. There are no ocean front properties in the county, but about four percent of the observations have an estuarine water frontage. The mean distance to nearest shoreline is about 2065 feet and the elevation of the properties is on average 29 feet above sea level. New Hanover and Bertie counties show relatively smaller impacts. Depending on the sea level rise scenarios, the residential property value at risk in Bertie County ranges from $3 million (0.44%) to $8 million (1.05%). The impacts on nonresidential properties range from $2 million (0.74%) to $5 million (1.79%).

Methods for Real Estate Impact Analysis[1]

Since the pioneering work by Rosen (1974), hedonic property models have been extensively used to infer the preferences of real estate and other market participants. The models assume that values of heterogeneous bundles of property attributes are reflected in differential property prices. Given that residential property can be distinguished based upon structural, neighborhood, and environmental characteristics, one can assume that utility (i.e., happiness) derives directly from these attributes rather than consumption of the property itself. The market price of property, which is observable, thus represents the value of the collection of attributes. Residential homes are composite goods that contain different amounts of a variety of attributes, and observing how property values change as the level of various attributes change provides a

[1] This section is taken from Bin et al. (2007).

way of estimating the marginal value of these attributes to property owners. Palmquist (2004) provides a useful summary of the hedonic property models.

Suppose that $\boldsymbol{S}$ represent a matrix of structural characteristics such as lot size, age, and number of bathrooms. Let $\boldsymbol{N}$ represent neighborhood characteristics such as township and distance to nearest shoreline. Also, let $\boldsymbol{E}$ represent environmental characteristics such as ocean/sound frontage and property elevation. Given a vector of observed property values, $\boldsymbol{R}$, the hedonic price function can be written as:

$$\boldsymbol{R} = \boldsymbol{R}(\boldsymbol{S}, \boldsymbol{N}, \boldsymbol{E}). \qquad [1]$$

The housing market is assumed to be in equilibrium, which requires that households optimize their residential choice (determining $\boldsymbol{S}$, $\boldsymbol{N}$, and $\boldsymbol{E}$) based on the exogenous price schedule for available housing in a market. Estimation and partial differentiation of the hedonic price function with respect to an attribute reveals the average household's marginal willingness to pay (WTP) for that attribute. The analysis is only useful for estimating WTP for marginal (i.e., small) changes in environmental quality (e.g., long term shoreline erosion). Additional data on demand-shifting parameters (i.e. income and other socioeconomic variables) are necessary to estimate the welfare impacts from non-marginal environmental changes.

This study estimates the following hedonic price function:

$$\ln \boldsymbol{R} = \alpha + \sum_i \beta_i \boldsymbol{S}_i + \sum_j \gamma_j \boldsymbol{N}_j + \sum_k \phi_k \boldsymbol{E}_k + \varepsilon, \qquad [2]$$

where $\ln \boldsymbol{R}$ is the log of assessed property value, α, β, γ, and ϕ are the unknown parameters to be estimated, and $\boldsymbol{\varepsilon}$ is an independent random error term. Both reported sales prices and market assessed values have been used in the hedonic literature as proxies for the true sales prices.

Reported sales prices may not reflect the true sales prices because they may not incorporate the price adjustments in the sales negotiation process or they may be intentionally misreported (Mooney and Eisgruber 2001). Many state statutes require that all property be valued at 100 percent of current market value for their property tax purpose. In fact, Dare County recently implemented countywide re-evaluation of property values to reflect the real market prices. This study uses the market assessed values as the dependent variable in the hedonic regression because these values are highly correlated with the reported sales prices (for a limited number of the records with recent sales transactions) and result in a larger sample size for econometric analysis.

We use quadratic specifications for non-dichotomous property attributes such as age of the property and total structural square footage in order to capture the diminishing marginal effect. The effect of these attributes on property values is assumed to decline as the level of these attributes increase. The primary results are robust across several alternative specifications, and the current specification provided the best overall model fit. We report the standard errors and p-values based upon the consistent estimator of the covariance matrix corrected for potential heteroskedasticity.

Equation [2] is estimated using all observations that locate within a mile from the coastline.[2] Separate hedonic price schedules are estimated for residential and non-residential properties. The estimated hedonic price functions are then used to simulate the property value loss for various sea level rise scenarios. We use a method similar to Parsons and Powell (2001). The net loss in property values from sea level rise in year t can be represented by

$$Net\,Loss_t = \delta \cdot \{R_{LOST,t} - A_{LOST,t} + \Delta R_{INV,t}\}. \qquad [3]$$

The first term $R_{LOST,t}$ is the value of lost properties in year t. The second term $A_{LOST,t}$ is the amenity value of the lost properties in year t, which is purged from the total value. The property at the time of loss would not have the peak value which stems from the amenities associated with its current waterfront location. The third term $\Delta \mathbf{R}_{INV,t}$ is the change in the value of other properties in the inventory due to a permanent change in location and the market condition of the developed area, and δ is the discount factor.

We focus on the first two terms because estimating the third term requires additional data as it depends on the perception and behaviors of coastal property owners (i.e. discounting and risk preference), communities, and regulatory agencies. The third term relates to adjustments induced by sea level rise, and the impacts are relatively small compared to the first two categories. The net loss in [3] is measured by the following steps. First, the hedonic price models are estimated to predict the contribution of each attribute to the value of the property. Second, the value of risks and amenities of the lost properties are purged from the total value of the lost properties. It is assumed that each lost property has the same structural characteristics but no water frontage and that it has the distance from the shoreline and the elevation evaluated at the sample mean. Third, the predicted value of each lost property is inflated to 2030 or 2080.[3] The value is then discounted to present using various discount rates (no discounting, 2%, 5%, and 7%) for sensitivity analysis.

Results

New Hanover County

The baseline hedonic property model is estimated using the 39,546 residential property records. The natural log of assessed property values are used as the dependent variable, giving the hedonic regression the common semilog functional form. The regression model controls for

[2] With an exception of Bertie County, almost all observations in Dare, Carteret, and New Hanover counties locate within a mile from the shoreline. In Bertie County, coastal property owners may not consider the adjacent inland properties as potential substitutes. All properties at risk are within a mile from the coastline.

[3] The adjustment is based on a Special Report on Emissions Scenarios (SRES) by the IPCC. Per capita personal income level in 2004 is compared to the 2030 and 2080 income levels, which provides 1.517 for inflating the 2004 lost values to 2030 dollars and 3.172 for the inflating 2004 lost values to 2080 dollars.

heterogeneity across townships using a set of dummy variables representing four townships in New Hanover County. The coefficient estimates are reported in table 3. Adjusted R^2 is 0.86, indicating overall a good fit. Most structural and neighborhood variables are statistically significant at any conventional level of significance (p-value < 0.0001), with an exception of the multistory indicator. Most coefficient signs are consistent with common findings in the hedonic literature.

Proximity to shoreline has a strong positive effect on property values. Water frontage also commands a substantial premium and raises the property values by about 55% for ocean frontage and 35% for sound frontage. Milon, Gressel, and Mulkey (1984) estimated a large positive value from being close to the shore. They found that property values declined 36% in moving 500 feet from the Gulf of Mexico. Other studies have also found positive values for water proximity (Shabman and Bertelson 1979; Earnhart 2001).

The specification used to generate the results for nonresidential properties is identical to the one used to generate table 3. However, the parcel records for nonresidential properties such as governmental properties normally do not contain structural information (e.g. number of room, fireplace, etc). Thus, the hedonic regression is estimated with fewer independent variables.[4]

The simulation results under different sea level rise scenarios are reported in table 4 for both residential and non-residential observations. The discount rates of 2%, 5%, and 7% as well as a zero discount rate are used to provide the present value of the loss. Without discounting, the residential property value loss in New Hanover County ranges from $62 million (0.35%) to $354 million (0.96%), and the non-residential property value loss ranges from $33 million (0.49%) to $155 million (1.09%).

Based on a 2% discount rate, the residential property value loss ranges from $37 million (0.21%) to $212 million (0.57%), and the non-residential property value loss ranges from $20 million (0.29%) to $92 million (0.65%). Based on a 7% discount rate, the residential property value loss ranges from $11 million (0.06%) to $61 million (0.16%), and the non-residential property value loss ranges from $6 million (0.08%) to $27 million (0.19%). The non-residential properties display a smaller impact, although the percent terms are quite comparable to those of the residential properties.

Dare County

The baseline hedonic regression results are reported in table 5. The natural log of assessed property values is used as the dependent variable, and the quadratic specification is used for non-dichotomous independent variables to capture diminishing marginal returns. The regression model controls for heterogeneity across townships using a set of dummy variables representing 12 townships on the Outer Banks. Omitted category is the townships located on the mainland. Table 3-6 shows that most structural and neighborhood variables are statistically significant at any conventional level of significance with the exception of the squared age and elevation. Lower elevation of property is likely to provide easy access to coastal water, yet at the

[4] The results are available upon request.

same time higher vulnerability to storm surge flooding or shoreline erosion. Again, increasing distance from the shoreline has a strong negative impact on property values. Water frontage also commands a substantial premium and raises the property values substantially.

The simulation results for the impact on property values are shown in table 6. Without discounting, the residential property value loss in Dare County ranges from $406 million (2.18%) to $4.5 billion (11.59%), and the non-residential property value loss ranges from $248 million (2.50%) to $5.7 billion (27.84%). Based on a 2% discount rate, the residential property value loss ranges from $242 million (1.30%) to $2.7 billion (6.93%), and the non-residential property value loss ranges from $148 million (1.50%) to $3.4 billion (16.42%). Based on a 7% discount rate, the residential property value loss ranges from $70 million (0.38%) to $776 million (2.00%), and the non-residential property value loss ranges from $43 million (0.43%) to $981 million (4.73%). The results indicate that Dare County has the most significant impact from sea level rise among the North Carolina coastal counties.

Carteret County

The baseline hedonic regression results are reported in table 7. The regression model controls for heterogeneity across townships using a set of dummy variables representing 14 townships in Carteret County. The omitted category is Beaufort. Most structural and neighborhood variables are statistically significant at any conventional level of significance with the exception of lot size and elevation, and the coefficient signs are consistent with common findings in the hedonic literature. Adjusted R^2 from the regression is 0.69.

The simulated property value losses are shown in table 8 for the entire county including both residential and non-residential properties. Without discounting, the residential property value loss in Carteret County ranges from $44 million (0.48%) to $488 million (2.58%), and the non-residential property value loss ranges from $25 million (0.73%) to $230 million (3.21%). Based on a 2% discount rate, the residential property value loss ranges from $26 million (0.29%) to $292 million (1.54%), and the non-residential property value loss ranges from $15 million (0.44%) to $137 million (1.92%). Based on a 7% discount rate, the residential property value loss ranges from $7 million (0.08%) to $84 million (0.44%), and the non-residential property value loss ranges from $4 million (0.13%) to $40 million (0.55%).

Bertie County

The baseline hedonic regression results are reported in table 9. The estimated hedonic price function is used to simulate the property value loss, and the results are shown in table 10. The loss of property values in Bertie County is relatively smaller than those of the other counties discussed above. Without discounting, the residential property value loss in Bertie County ranges from $3 million (0.29%) to $12 million (0.51%), and the non-residential property value loss ranges from $1 million (0.32%) to $26 million (2.99%). Based on a 2% discount rate, the residential property value loss ranges from $2 million (0.17%) to $7 million (0.30%), and the non-residential property value loss ranges from $1 million (0.19%) to $16 million (1.79 %). Based on a 7% discount rate, the residential property value loss ranges from $1 million (0.05%)

to $2 million (0.09%), and the non-residential property value loss ranges from $0.2 million (0.06%) to $4 million (0.52%).

Discussions

In this study we estimate the impacts of sea level rise on coastal real estate in four coastal counties including the three most populous on the North Carolina coast. The results indicate that the magnitude of the impacts depends on the geographic location and the level of development in the areas. The northern part of the North Carolina coastline is comparatively more vulnerable to the effect of sea level rise than the southern part. Low-lying and heavily developed areas in the northern coastline of North Carolina are especially at high risk from sea level rise.

Care must be taken with the interpretation of the results. The current study focuses on the loss of property value from permanent inundation. Temporary inundation caused by high tides and storms occurs much sooner in time than permanent flooding, and the costs associated with it can be quite large relative to those associated with permanent flooding. Measuring the impacts of temporary flooding requires additional data such as the distribution of the partial damage extents due to storm surge, frequency and intensity of storms, and timing of storms. Flood insurance may change the estimated loss, although the insurance covers only the structures (not the land) and does not cover the loss due to sea level rise. The current flood insurance coverage is limited to $250,000 for single family residence.

In this study, we do not consider the adaptation that coastal communities and property owners undertake as they observe sea level rise over time. They may decide to relocate their communities in response to sea level rise or pursue beach nourishment. There might be additional costs associated with increased distance to the shoreline for new development. The value of lost public infrastructure is another component that is not included in the current study, although it likely to be small especially in the rural areas.

It is important to point out that a large portion of undeveloped land in coastal North Carolina is wetlands that provide a wide range of services such as habitat for fish and wildlife, flood protection, water quality improvement, opportunities for recreation, education and research, and aesthetic values. These functions and services are economically and ecologically valuable. Since these values are unlikely to be fully reflected in the private property values, the estimated impacts in this study provide only a limited measure of total economic costs associated with sea level rise.

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Table 1
Summary of sea level rise for the low, mid, and high climate change scenarios

Year	Scenario	Projected sea level rise, including both eustatic and isostatic components, measured in meters
2030	Low	0.11
	Mid	0.16
	High	0.21
2080	Low	0.26
	Mid	0.46
	High	0.81

Table 2
Current property values at risk in North Carolina

	Total Values	Sea Level Rise Scenarios					
		2030-Low	2030-Mid	2030-High	2080-Low	2080-Mid	2080-High
New Hanover							
Total	$16,154,421,910	$80,363,644	$84,415,484	$88,871,520	$95,187,467	$123,010,639	$227,704,809
*(n)	85,786	495	516	544	574	680	1,063
**(%)		0.50%	0.52%	0.55%	0.59%	0.76%	1.41%
Residential	$11,688,362,599	$62,149,975	$66,201,267	$70,590,850	$72,850,081	$90,724,269	$167,398,608
(n)	74,984	345	360	385	403	476	773
(%)		0.53%	0.57%	0.60%	0.62%	0.78%	1.43%
Nonresidential	$4,466,059,311	$18,213,669	$18,214,217	$18,280,670	$22,337,386	$32,286,370	$60,306,201
(n)	10,802	150	156	159	171	204	290
(%)		0.41%	0.41%	0.41%	0.50%	0.72%	1.35%
Dare							
Total	$18,800,008,900	$1,142,866,500	$1,241,804,000	$1,332,870,500	$1,622,998,600	$2,224,747,700	$3,544,751,100
(n)	38,780	1,506	1,725	1,965	2,331	4,004	7,716
(%)		6.08%	6.61%	7.09%	8.63%	11.83%	18.86%
Residential	$12,262,755,500	$365,991,100	$410,835,300	$461,919,900	$521,547,700	$906,674,500	$1,801,992,600
(n)	27,006	825	927	1,051	1,225	2,143	4,371
(%)		2.98%	3.35%	3.77%	4.25%	7.39%	14.69%
Nonresidential	$6,537,253,400	$776,875,400	$830,968,700	$870,950,600	$1,101,450,900	$1,318,073,200	$1,742,758,500
(n)	11,774	681	798	914	1,106	1,861	3,345
(%)		11.88%	12.71%	13.32%	16.85%	20.16%	26.66%
Carteret							
Total	$8,217,336,284	$172,082,588	$176,378,147	$185,818,633	$202,376,889	$260,333,900	$433,401,826
(n)	55,509	1,077	1,140	1,225	1,322	1,977	3,890
(%)		2.09%	2.15%	2.26%	2.46%	3.17%	5.27%
Residential	$5,960,237,380	$42,828,093	$45,528,169	$49,406,827	$56,115,882	$92,285,041	$208,047,285
(n)	34,073	192	207	228	261	468	1,204
(%)		0.72%	0.76%	0.83%	0.94%	1.55%	3.49%
Nonresidential	$2,257,098,904	$129,254,495	$130,849,978	$136,411,806	$146,261,007	$168,048,859	$225,354,541
(n)	21,436	885	933	997	1,061	1,509	2,686
(%)		5.73%	5.80%	6.04%	6.48%	7.45%	9.98%
Bertie							
Total	$1,001,181,659	$5,248,975	$6,057,921	$6,631,122	$6,748,592	$8,450,076	$12,571,118
(n)	17,502	72	81	93	99	126	174
(%)		0.52%	0.61%	0.66%	0.67%	0.84%	1.26%
Residential	$727,088,075	$3,215,894	$3,731,251	$3,919,220	$4,035,716	$4,988,806	$7,660,841
(n)	15,777	55	61	68	73	91	126
(%)		0.44%	0.51%	0.54%	0.56%	0.69%	1.05%
Nonresidential	$274,093,584	$2,033,081	$2,326,670	$2,711,902	$2,712,876	$3,461,270	$4,910,277
(n)	1,725	17	20	25	26	35	48
(%)		0.74%	0.85%	0.99%	0.99%	1.26%	1.79%

* The number of property at risk
** The percentage to the total property value

Table 3
Estimation Results for the New Hanover Residential Hedonic Model

Variable	Coefficient	Standard Error	P-value
Constant	10.612	0.012	<.0001
WRIGHTS	0.837	0.010	<.0001
CAROLINA	0.128	0.007	<.0001
KURE	0.272	0.007	<.0001
FIGEIGHT	-0.168	0.008	<.0001
LOTSIZE	2.44E-06	8.44E-08	<.0001
LOTSIZE^2	-1.40E-12	1.26E-13	<.0001
SQFT	0.001	3.74E-06	<.0001
SQFT^2	-2.39E-08	4.04E-10	<.0001
AGE	-0.005	1.68E-04	<.0001
AGE^2	1.97E-05	1.82E-06	<.0001
BATHRM	0.200	0.006	<.0001
BATHRM^2	-0.016	0.001	<.0001
AIRCOND	0.155	0.005	<.0001
FIREPLCE	0.144	0.003	<.0001
MULTISTR	-4.66E-04	0.003	0.8817
DETGAR	0.058	0.004	<.0001
OCEAN	0.545	0.014	<.0001
SOUND	0.345	0.010	<.0001
DIST	-2.97E-05	3.42E-06	<.0001
DIST^2	5.04E-09	6.78E-10	<.0001
ELEV	-0.009	4.47E-04	<.0001
ELEV^2	8.92E-05	7.26E-06	<.0001

Notes: Number of observations is 39,546. Dependent variable is the log of assessed property values. Omitted category for township is Wilmington. Adjusted R^2 is 0.8641.

Table 4
Present Value of Property Value Losses for New Hanover County

Residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$61.82	0.35%	$36.94	0.21%	$17.39	0.10%	$10.64	0.06%
2030-Mid	$65.49	0.37%	$39.14	0.22%	$18.42	0.10%	$11.28	0.06%
2030-High	$69.72	0.39%	$41.66	0.23%	$19.61	0.11%	$12.00	0.07%
2080-Low	$151.56	0.41%	$90.57	0.24%	$42.62	0.11%	$26.10	0.07%
2080-Mid	$194.37	0.52%	$116.15	0.31%	$54.66	0.15%	$33.47	0.09%
2080-High	$354.14	0.96%	$211.63	0.57%	$99.60	0.27%	$60.98	0.16%
	Discount Rate							
Non-residential	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$33.01	0.49%	$19.73	0.29%	$9.28	0.14%	$5.68	0.08%
2030-Mid	$33.01	0.49%	$19.73	0.29%	$9.28	0.14%	$5.68	0.08%
2030-High	$33.28	0.49%	$19.89	0.29%	$9.36	0.14%	$5.73	0.08%
2080-Low	$78.81	0.56%	$47.09	0.33%	$22.16	0.16%	$13.57	0.10%
2080-Mid	$103.96	0.73%	$62.13	0.44%	$29.24	0.21%	$17.90	0.13%
2080-High	$154.62	1.09%	$92.40	0.65%	$43.49	0.31%	$26.63	0.19%

Notes: 2030-Low, 2030-Mid, and 2030-High represent an 11 cm, a 16 cm, and a 21 cm increase in sea level by 2030, respectively. Similarly, 2080-Low, 2080-Mid, and 2080-High represent a 26 cm, a 46 cm, and an 81 cm increase in sea level by 2080, respectively. Dollars are measured in million. Reported are the percent to the total property values.

Table 5
Estimation Results for the Dare Residential Hedonic Model

Var iable	Coefficie nt	Standard Error	P- value
Con stant	1 1.750	0 .020	< .0001
AV ON	0 .171	0 .010	< .0001
BU XTON	0 .073	0 .014	< .0001
DU CK	0 .588	0 .009	< .0001
FRI SCO	0 .097	0 .012	< .0001
HA TTERAS	0 .232	0 .014	< .0001
KD H	0 .157	0 .007	< .0001
KIT TY	0 .223	0 .009	< .0001
NA GS	0 .257	0 .007	< .0001
RO DANT	0 .331	0 .017	< .0001
SA LVO	0 .314	0 .015	< .0001
SO UTHERN	0 .572	0 .009	< .0001
WA VES	0 .284	0 .020	< .0001
LO TSIZE	3 .69E-07	3 .28E-08	< .0001
LO TSIZE2	- 3.17E-14	3 .19E-15	< .0001
AG E	- 0.004	3 .43E-04	< .0001
AG E2	3 .87E-06	3 .91E-06	0 .3226
BE DRM	0 .220	0 .008	< .0001
BE DRM2	- 0.004	0 .001	< .0001
AIR COND	0 .141	0 .008	< .0001
MU LTISTR	0 .163	0 .005	< .0001
HD WDFL	0 .162	0 .008	< .0001
OC EAN	0 .730	0 .008	< .0001
SO UND	0 .321	0 .007	< .0001
DIS T	- 9.52E-05	7 .37E-06	< .0001

DIST2	9.54E-09	1.82E-09	<.0001
ELEV	0.001	0.001	0.4799
ELEV2	-9.37E-05	2.34E-05	<.0001

Notes: Number of observations is 25,870. Dependent variable is the log of assessed property values. Mainland townships are omitted. Adjusted R^2 is 0.7082.

Table 6
Present Value of Property Value Losses for Dare County

Residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$405.77	2.18%	$242.48	1.30%	$114.12	0.61%	$69.87	0.38%
2030-Mid	$454.85	2.45%	$271.81	1.46%	$127.92	0.69%	$78.32	0.42%
2030-High	$514.30	2.76%	$307.33	1.65%	$144.64	0.78%	$88.56	0.48%
2080-Low	$1,231.93	3.17%	$736.17	1.89%	$346.47	0.89%	$212.13	0.55%
2080-Mid	$2,200.69	5.66%	$1,315.09	3.38%	$618.92	1.59%	$378.95	0.97%
2080-High	$4,507.78	11.59%	$2,693.75	6.93%	$1,267.77	3.26%	$776.22	2.00%
Non-residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$248.16	2.50%	$148.29	1.50%	$69.79	0.70%	$42.73	0.43%
2030-Mid	$277.69	2.80%	$165.94	1.67%	$78.10	0.79%	$47.82	0.48%
2030-High	$304.11	3.07%	$181.73	1.83%	$85.53	0.86%	$52.37	0.53%
2080-Low	$718.21	3.46%	$429.19	2.07%	$201.99	0.97%	$123.67	0.60%
2080-Mid	$1,099.95	5.30%	$657.31	3.17%	$309.35	1.49%	$189.41	0.91%
2080-High	$5,698.54	27.48%	$3,405.33	16.42%	$1,602.66	7.73%	$981.26	4.73%

Notes: 2030-Low, 2030-Mid, and 2030-High represent an 11 cm, a 16 cm, and a 21 cm increase in sea level by 2030, respectively. Similarly, 2080-Low, 2080-Mid, and 2080-High represent a 26 cm, a 46 cm, and an 81 cm increase in sea level by 2080, respectively. Dollars are measured in million. Reported are the percent to the total property values.

Table 7
Estimation Results for the Carteret Residential Hedonic Model

Vari able	Coefficie nt	Standard Error	P- value
Cons tant	1 0.215	0 .021	< .0001
ATL ANTIC	- 0.347	0 .022	< .0001
CED AR	- 0.447	0 .033	< .0001
DA VIS	- 0.383	0 .030	< .0001
HA RKERS	- 0.062	0 .015	< .0001
HA RLOWE	- 0.188	0 .019	< .0001
MA RSHALL	- 0.212	0 .025	< .0001
ME RRIMON	- 0.293	0 .024	< .0001
MO REHEAD	0 .053	0 .009	< .0001
NE WPORT	- 0.098	0 .012	< .0001
SEA LEVEL	- 0.392	0 .034	< .0001
SM YRNA	- 0.258	0 .025	< .0001
STA CY	- 0.391	0 .040	< .0001
STR AITS	- 0.244	0 .015	< .0001
WHI TE OAK	0 .148	0 .009	< .0001
LOT SIZE	1 .01E-07	1 .37E-07	0 .4602
LOT SIZE2	1 .46E-12	3 .89E-13	0 .0002
SQF T	0 .001	1 .15E-05	< .0001
SQF T2	- 7.66E-08	2 .12E-09	< .0001
AGE	- 0.002	3 .40E-04	< .0001
AGE 2	1 .62E-05	3 .64E-06	< .0001
BAT HRM	0 .279	0 .013	< .0001
BAT HRM2	- 0.025	0 .002	< .0001
OCE AN	0 .665	0 .015	< .0001
SOU ND	0 .497	0 .008	< .0001

DIS T	- 8.07E-05	8 .67E-06	< .0001
DIS T2	1 .58E-08	2 .25E-09	< .0001
ELE V	0 .001	0 .001	0 .3144
ELE V2	- 1.92E-04	4 .02E-05	< .0001

Notes: Number of observations is 27,789. Dependent variable is the log of assessed property values. Category omitted for township is Beaufort. Adjusted R^2 is 0.6898.

Table 8

Present Value of Property Value Losses for Carteret County

Residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$43.35	0.48%	$25.91	0.29%	$12.19	0.13%	$7.47	0.08%
2030-Mid	$46.37	0.51%	$27.71	0.31%	$13.04	0.14%	$7.98	0.09%
2030-High	$50.96	0.56%	$30.45	0.34%	$14.33	0.16%	$8.78	0.10%
2080-Low	$120.79	0.64%	$72.18	0.38%	$33.97	0.18%	$20.80	0.11%
2080-Mid	$206.69	1.09%	$123.52	0.65%	$58.13	0.31%	$35.59	0.19%
2080-High	$487.96	2.58%	$291.60	1.54%	$137.23	0.73%	$84.02	0.44%
Non-residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$24.98	0.73%	$14.93	0.44%	$7.02	0.21%	$4.30	0.13%
2030-Mid	$26.17	0.76%	$15.64	0.46%	$7.36	0.21%	$4.51	0.13%
2030-High	$28.48	0.83%	$17.02	0.50%	$8.01	0.23%	$4.90	0.14%
2080-Low	$64.26	0.90%	$38.40	0.54%	$18.07	0.25%	$11.07	0.15%
2080-Mid	$144.06	2.01%	$86.09	1.20%	$40.51	0.57%	$24.81	0.35%
2080-High	$229.85	3.21%	$137.35	1.92%	$64.64	0.90%	$39.58	0.55%

Notes: 2030-Low, 2030-Mid, and 2030-High represent an 11 cm, a 16 cm, and a 21 cm increase in sea level by 2030, respectively. Similarly, 2080-Low, 2080-Mid, and 2080-High represent a 26 cm, a 46 cm, and an 81 cm increase in sea level by 2080, respectively. Dollars are measured in million. Reported are the percent to the total property values.

Table 9
Estimation Results for the Bertie Residential Hedonic Model

Variable	Coefficient	Standard Error	P-value
Constant	9.976	0.088	<.0001
COLERAIN	-0.090	0.077	0.2426
INDIAN	-0.269	0.091	0.003
MERRY	-0.160	0.056	0.0043
MITCHELL	0.486	0.451	0.2813
ROXOBEL	-0.100	0.059	0.0914
SNAKEBITE	3.62E-05	5.70E-06	<.0001
WHITES	-4.86E-10	1.07E-10	<.0001
WOODVILLE	1.014	0.057	<.0001
LOTSIZE	0.769	0.094	<.0001
LOTSIZE2	-2.30E-04	4.81E-05	<.0001
MULTISTR	3.15E-08	8.96E-09	0.0004
SOUND	0.005	0.005	0.3673
DIST	-3.54E-05	8.25E-05	0.6679
DIST2	9.976	0.088	<.0001
ELEV	-0.090	0.077	0.2426
ELEV2	-0.269	0.091	0.003
ELEV*DIST	-0.160	0.056	0.0043

Notes: Number of observations is 3,279. Dependent variable is the log of assessed property values. Category omitted for township is Windsor. Adjusted R^2 is 0.1514.

Table 10
Present Value of Property Value Losses for Bertie County

Residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$3.23	0.29%	$1.93	0.17%	$0.91	0.08%	$0.56	0.05%
2030-Mid	$3.91	0.35%	$2.34	0.21%	$1.10	0.10%	$0.67	0.06%
2030-High	$4.34	0.39%	$2.59	0.24%	$1.22	0.11%	$0.75	0.07%
2080-Low	$9.98	0.43%	$5.96	0.26%	$2.81	0.12%	$1.72	0.07%
2080-Mid	$11.73	0.51%	$7.01	0.30%	$3.30	0.14%	$2.02	0.09%
2080-High	$11.66	0.51%	$6.97	0.30%	$3.28	0.14%	$2.01	0.09%
Non-residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$1.35	0.32%	$0.81	0.19%	$0.38	0.09%	$0.23	0.06%
2030-Mid	$1.55	0.37%	$0.92	0.22%	$0.43	0.10%	$0.27	0.06%
2030-High	$2.04	0.49%	$1.22	0.29%	$0.57	0.14%	$0.35	0.08%
2080-Low	$4.26	0.49%	$2.55	0.29%	$1.20	0.14%	$0.734	0.08%
2080-Mid	$9.11	1.05%	$5.45	0.63%	$2.56	0.29%	$1.569	0.18%
2080-High	$26.02	2.99%	$15.55	1.79%	$7.32	0.84%	$4.48	0.52%

Notes: 2030-Low, 2030-Mid, and 2030-High represent an 11 cm, a 16 cm, and a 21 cm increase in sea level by 2030, respectively. Similarly, 2080-Low, 2080-Mid, and 2080-High represent a 26 cm, a 46 cm, and an 81 cm increase in sea level by 2080, respectively. Dollars are measured in million. Reported are the percent to the total property values.

Figure 1

Observed rates of sea level rise along the NC coast (data from the Permanent Service for Mean Sea Level). From north to south, the gages are Hampton Roads, Duck Pier, and Charleston.

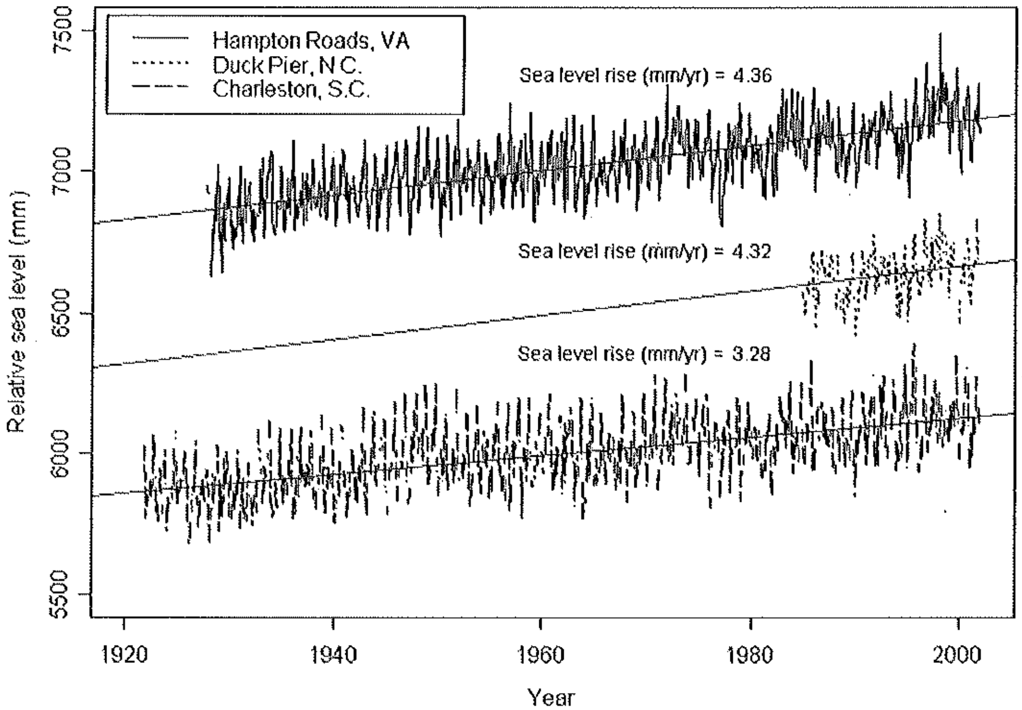

Figure 2
Location of counties analyzed for property impacts

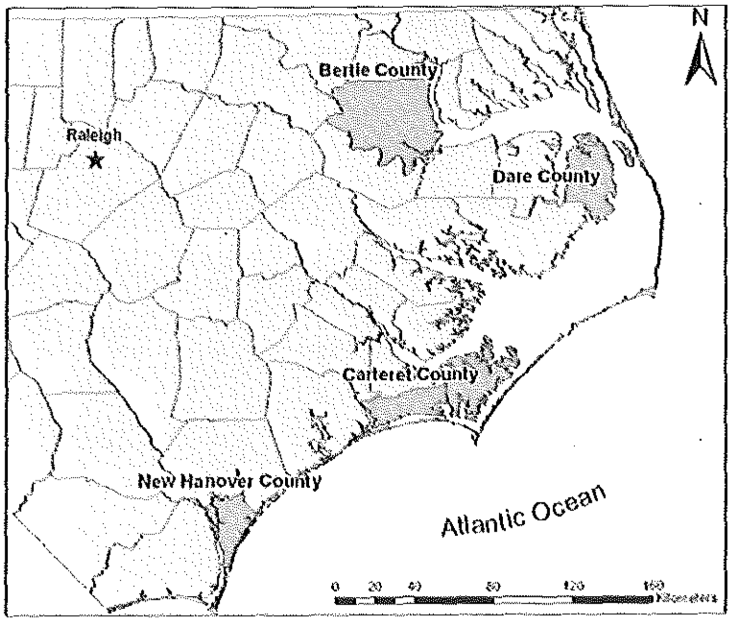

Figure 3
Example of data sampling for property values for Carteret County (a), lidar elevation surface (b), distance to shoreline example (c), and tax parcel centriods (d).

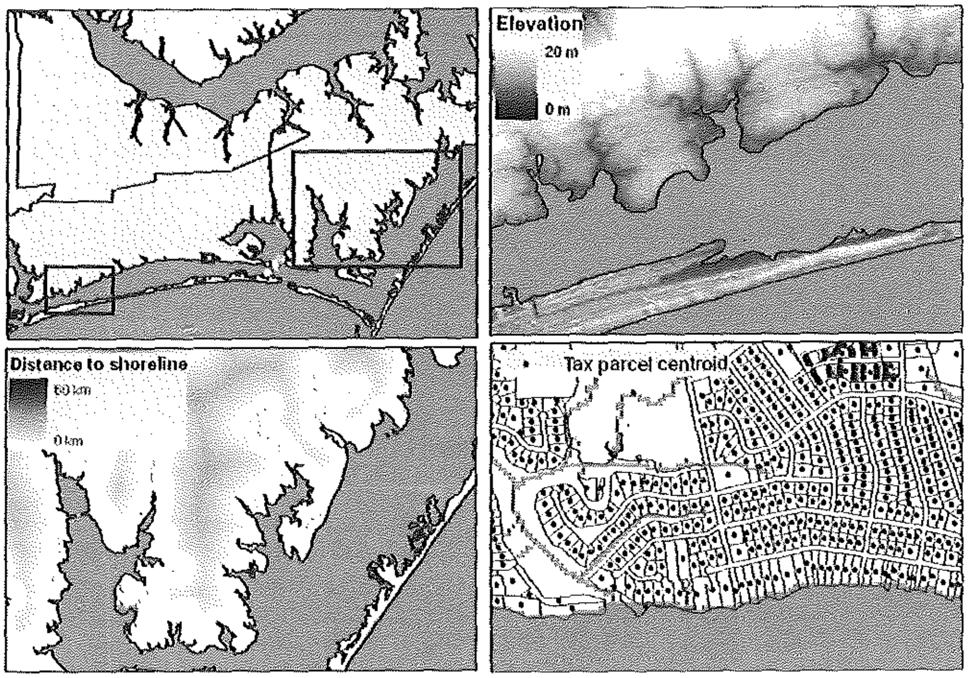

Figure 4
Inundation of coastal North Carolina with detailed examples for each of the counties investigated in this study. This particular example uses the high scenario for the year 2080 which includes both eustatic and isostatic sea level rise.