ADAPTING TO CLIMATE CHANGE: COMBINING ECONOMICS AND GEOMORPHOLOGY IN COASTAL POLICY

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How is climate change affecting our coastal environment? How can coastal communities adapt to sea level rise and increased storm risk? These questions have garnered tremendous interest from scientists and policy makers alike, as the dynamic coastal environment is particularly vulnerable to the impacts of climate change. Over half the world population lives and works in a coastal zone less than 120 miles wide, thereby being continuously affected by the changes in the coastal environment [6]. Housing markets are directly influenced by the physical processes that govern coastal systems. Beach towns like Oak Island in North Carolina (NC) face severe erosion, and the tax assesed value of one coastal property fell by 93% in 2007 [9]. With almost ninety percent of the sandy beaches in the US facing moderate to severe erosion [8], coastal communities often intervene to stabilize the shoreline and hold back the sea in order to protect coastal property and infrastructure.

Beach nourishment, which is the process of rebuilding a beach by periodically replacing an eroding section of the beach with sand dredged from another location, is a policy for erosion control in many parts of the US Atlantic and Pacific coasts [3]. Beach nourishment projects in the United States are primarily federally funded and implemented by the Army Corps of Engineers (ACE) after a benefit-cost analysis. Benefits from beach nourishment include reduction in storm damage and recreational benefits from a wider beach. Costs would include the expected cost of construction, present value of periodic maintenance, and any external cost such as the environmental cost associated with a nourishment project (NOAA). Federal appropriations for nourishment totaled $787 million from 1995 to 2002 [10].

Human interventions to stabilize shorelines and physical coastal dynamics are strongly coupled. The value of the beach, in the form of storm protection and recreation amenities, is at least partly capitalized into property values. These beach values ultimately influence the benefit-cost analysis in support of shoreline stabilization policy, which, in turn, affects the shoreline dynamics. This paper explores the policy implications of this circularity. With a better understanding of the physical-economic feedbacks, policy makers can more effectively design climate change adaptation strategies.

What is the economic value of beaches?

A large part of the coastal economics literature focuses on estimating the value of beach width, which is capitalized in coastal property values. Introduced by Rosen (1974), the hedonic pricing method is the most common method used by economists to estimate the value of environmental amenities that are reflected in property values [12]. The hedonic pricing model decomposes the value of a residential (or commercial) property into a bundle of individual characteristics. The market price of a property is expressed as a function of its individual attributes, which include property characteristics such as lot size, number of bedrooms and bathrooms, the age of the property, and type of construction; neighborhood characteristics such as quality of the school district, crime rate, and proximity to city services; environmental amenities such as air or water quality, amount of open space nearby, and proximity to a beach; and disamenities such as proximity to a hog farm. The implicit value of a particular attribute is the partial derivative of the implicit price function with respect to that attribute.

Coastal management policies are based on economic studies that have shown that there are significant benefits from maintaining beach quality and preventing the shoreline from shifting landward. Economic studies have consistently shown that wider beaches, lower storm risks, and proximity to the beach are all sources of value [2, 4, 7, 11]. However, previous work has not considered the dynamic nature of beach width and the feedback that policy intervention via beach nourishment has on the coastal dynamics, and in turn, on property values. Nourishment alters the shoreface profile and leads to temporarily increased rates of erosion as the shoreface returns to an equilibrium profile. We explicitly incorporate this feedback due to beach nourishment in isolating the value of beach width.

We construct a unique dataset that combines real estate data and physical beach attributes for ten beaches in North Carolina.

TCS 22 SHIFTING SHORELINES: ADAPTING TO THE FUTURE
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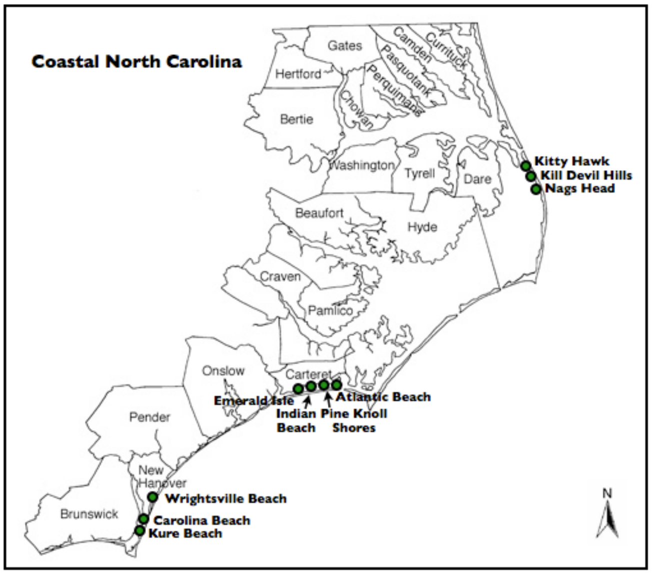

Figure 1: Study Region

Our study covers ten beaches in three counties along the coast of North Carolina, including Nags Head, Kill Devil Hills and Kitty Hawk in Dare County (Outer Banks); Atlantic beach, Emerald Isle, Indian Beach and Pine Knoll Shores in Carteret county; and Carolina Beach, Kure Beach and Wrightsville Beach in New Hanover County. Our study focuses on the three most populated regions of the NC coast and represent locations situated on different parts of its cuspate cape features. Our study covers regions in the Outer Banks that have never undertaken beach nourishment and regions, such as Wrightsville Beach, that have been periodically undertaking beach nourishment for over fifty years. Our analysis is based on 1448 observations across the ten beaches.

We find that incorporating the feedbacks due to nourishment substantially increases the impact of beach width on coastal property values. A one percent increase in the width of the beach can lead to 0.7% increase in the value of oceanfront property, which is much larger than previous estimates of 0.2% ignoring the feedback [11]. In dollar terms, we find that the value of an average oceanfront property in North Carolina (valued at $500,000) will increase by $7,400 with an additional foot of beach width. An additional foot of beach width can add $9,990 to the value of an average oceanfront house in Wrightsville Beach (valued at $675,000). Further, the average value of coastal property is higher in towns that have undertaken nourishments projects. The average beach house in Wrightsville Beach (where shoreline stabilization has been undertaken since 1939) is valued more than 50% higher than the average house in Nags Head (that has never been nourished), also suggesting that the effect of policy intervention is capialized in the housing market. For details of the hedonic price analysis refer to [5].

Optimal Beach Management

Shoreline dynamics are influenced by the cross-shore and alongshore movement of beach sand caused by local wave action, the direction of waves approaching the shoreline, and the relative angle they make with the shoreline [1]. Human intervention to stabilize shorelines also influences shoreline dynamics; stabilization at one location can affect the rate of shoreline-change at other locations as far as tens of kilometers away. An integrated model can provide insights for the design of long-term coastal policy. Beaches are dynamic natural resources that provide amenity value. Beach managers choose the frequency (how often to nourish the beach) and extent (how far out to build the beach) of nourishment with the objective of maximizing a stream of net benefits. Coastal erosion is a natural resource problem that can be analyzed using dynamic optimization models that combine the effect of physical coastal processes as well as economic decisions by humans who depend on the coastal resource.

Viewed as a dynamic resource problem, the optimal nourishment frequency depends on the baseline erosion rate (influence by sea level rise rate), the nourishment effect on erosion rate, the baseline value of coastal property, the benefits and costs of re-nourishment and the rate at which future costs and benefits are discounted [13]. Using the estimates for beach value from the empirical study to parameterize this dynamic model, we find that the nourishment frequency in towns that have undertaken at least six nourishment projects (Wrightsville Beach, Carolina Beach, Emerald Isle) is very close to the predicted optimal frequency. This further supports our belief that housing markets (which reflect beach value) adjust to capitalize the policy feedbacks. These feedbacks are strengthened as the external climate system changes. Increased rates of sea level rise and altered storm patterns can increase the demand for erosion control. The future availability of appropriate sand for beach nourishment is a serious concern for coastal managers. A series of simulations under increased erosion and higher nourishment costs indicates that the long-run value of coastal property can fall by over 50% if beach nourishment remains the dominant policy to combat erosion [5].

As a next step towards understanding this coupled physical-economic system, we develop a spatial dynamic model incorporating spatial interaction when multiple communities along the coast compete to dredge the available nourishment sand. When beach nourishment is undertaken at one location along the shoreline, it creates a bump and changes relative wave angles. On most beaches, wave driven sediment transport tends to smooth out the bump; as the nourished portion of the beach erodes, the shorelines flanking the bump build seaward. This ‘diffusion’ of the shoreline shape ultimately spreads the bump along the entire shoreline. Nourishment activity in one location will therefore have am impact on all communities along the coast. Our preliminary results suggest that a heterogeneous nourishment pattern can emerge across communities even with homogeneous initial conditions. We find that the coupled system moves to an optimal steady state where some communities continuously nourish the beach and other communities are able to free ride and maintain their beach as nourishment bumps spread along the shore.

Discussion

Our empirical analysis suggests that beach width accounts for a much larger portion of coastal property value than was previously believed. Housing markets are very sensitive to coastal processes and capitalize the effects of shoreline stabilization measures. The tight feedbacks between housing markets and coastal dynamics are further enhanced by climate change. If the demand for nourishment increases, our analysis questions the long-run sustainability of beach nourishment as a policy option. When human-natural systems are linked by spatial dynamic processes, there can be social benefits from a coordinated coastal policy. Although beach management is presently undertaken in a decentralized manner, we can begin to envision what our coastlines should look like if we can optimally adapt to climate change.

Acknowledgements

We thank the NSF Biocomplexity Program for funding this research.

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