ADDING DYNAMIC INFORMATION TO RESILIENCY PLANNING: IDENTIFYING AND REDUCING FUTURE CONFLICTS FROM WETLAND MIGRATION DUE TO SEA LEVEL RISE

Elizabeth Kramer[1] and Kevin Samples[2]

AUTHORS: Public Service Associate[/1], Research Associate[/2], Natural Resources Spatial Analysis Laboratory, Department of Agricultural and Applied Economics, College of Agricultural and Environmental Sciences, University of Georgia, Athens, GA 30602
REFERENCE: *Proceedings of the 2017 Georgia Water Resources Conference*, held April 19–20, 2077, at the University of Georgia.

Abstract. Coastal marshes and barrier islands are, by nature, highly dynamic, and the forces that degrade them on the seaward side tend to transfer them in a landward direction. It is this transference that can be impeded by human development, often resulting in the reduction in the ability of marshes and sediments to migrate and thereby inhibiting the potential for natural resiliency of coastal communities to storm surge and wave action.

In addition, sea level rise puts additional inland areas at risk to flooding as surficial water tables rise over time. Activities such as infrastructure planning often ignores the dynamic nature of our coasts. Public financing of infrastructure works on 30-year cycles, and therefore, locating new infrastructure would benefit from including information regarding these future dynamics for decision making.

The overall goal of this project is to identify and prioritize the best sites for wetland protection, mitigation, restoration, and migration along the Georgia Coast, taking account of potential future land use change and the impacts of sea level rise. We identified and prioritize wetlands sites that could be restored, created, or protected based upon their location and condition 30 years from now.

Our analysis shows that approximately 125,000 acres along the Georgia coast will be converted to wetlands by 2045 due to sea level rise; of those, 12,774 acres currently in urban land use. In addition, future wetland change will put 507 miles of existing roadways at risk of flooding over the next 30 years. An additional 5,800 acres of potential future development are highly likely to be at risk due to sea level rise if this information isn't included in future decision making. It is hoped that this information will be used to support resiliency planning for coastal counties.

INTRODUCTION

The United States has experienced extensive and growing loss from natural disasters with dollar values due to tropical storms and floods tripling over the past 50 years. There are two reasons for this dramatic increase in natural disaster-related losses: an increase in people and property along the coasts and an increase in the frequency or severity of hazardous events.

Currently coastal populations along the eastern US coast account for almost a quarter of the US population and most of this growth has occurred in the Southern US. The Southeast is highly vulnerable to climate change as it is most frequently affected by tropical storms, hurricanes, and nor'easters and its low topography, limits the natural protection from storm surges. Finally, ocean levels are rising, exposing more developed areas to flooding and deteriorating beaches and wetlands (primarily due to storm surges and wave action) (NRC 2014).

Engineering approaches, such as armament, jetties, and beach renourishment, have been used to mitigate storm impacts. These solutions are expensive to construct, require frequent maintenance, and often induce spatial externalities (essentially moving the problem from one area to another). These engineered responses will not prevent inland wetland formation due to already high surficial water tables where drainage is further reduced as sea level rises. Recent hurricane events, like Katrina and Sandy, have led to a realization that maintaining and restoring natural landscape features such, as marshes and other wetlands, could be much more cost effective for natural hazard mitigation and coastal resiliency (NRC 2014, Gerdan et al 2011, Shepard et al. 2011).

Fortunately, Georgia still maintains large areas of natural buffer between human development and storm surge hazards within its current configuration of barrier islands, natural areas, and salt marshes. In fact, Georgia has one-third of the existing east coast salt marshes and only three barrier islands along the coast are heavily developed. Because of their low topography, however, these areas are still highly susceptible to sea level rise and eroding forces of wave action and storm surges.

Coastal marshes and barrier islands are, by nature, highly dynamic, and the forces that degrade them on the seaward side tend to transfer them in a landward direction. It is this transference that can be impeded by human development, often resulting in the reduction in the ability of marshes and sediments to migrate and thereby inhibiting the natural resiliency of coastal communities to storm surge and wave action.

The focus on storm surge and wave action attenuation has been front-and-center since hurricane Katrina, yet, coastal marshes provide additional ecosystem functions such as the mitigation of other sources of flooding in coastal areas (by reducing flood peaks and storing waters associated with storms) (Jones, et al 2012, Shepard et al 2011).

Historically, coastal protection plans have relied on hardening infrastructure such as sea walls, groynes, and jetties often at the expense of coastal marshes and marsh migration strategies. These hardened infrastructure approaches are expensive and many times create additional unintended consequences such as need for costly maintenance and the movement of a problem from one area to another. Georgia - with its wealth of salt marshes and slower development rates than many of the other coastal states - however, has the potential to capitalize on natural marshes and wetlands to enhance local communities' resiliency to natural hazards such as flooding.

Recognizing that marsh migration due to sea level rise is critical to the long-term survival of salt water marshes, conservation requires minimization of barriers to future migration. Therefore, we will identify existing and likely future barriers to migration that may result from human development processes. By identifying and prioritizing intervention strategies now instead of allowing future development to proceed in a haphazard and uncoordinated manner, local governments can enhance resiliency in a pro-active manner, provide useful information for continued planning and development, reduce the cost of land acquisition, and minimize impact to service delivery to residents. In addition, local governments can integrate information into their long-term infrastructure plans to reduce costly interventions in the future and potentially improve their financing of infrastructure by assuring investors that due diligence on future risks has been addressed.

OBJECTIVES

The overall goal of this project is to identify and prioritize the best sites for wetland protection, mitigation, restoration, and migration along the Georgia Coast, taking account of potential future land use change and the impacts of sea level rise. Recognizing that local government financing of infrastructure has a 30-year life cycle, we will identify and prioritize wetlands sites that could be restored, created, or protected based upon their location and condition 30 years from now.

METHODS

Future land use was generated from a cellular automata model that uses transition probabilities to forecast the probability of any undeveloped grid cell to be developed in the future. Model inputs include land cover data, road density, topography, and development exclusion zones. The land cover data were developed as part of the Georgia Land Use Trends (GLUT) Project from 1991, 1998, 2001, 2005 and 2008. The data are derived from Landsat satellite data. These land cover datasets track 30 meter pixels in 13 categories of land cover over a period of 35 years (1974 – 2008), these categories include urban, agricultural lands, forests, open water, and wetlands in Georgia. Earlier land cover data from 1974 and 1985 were excluded from the analysis because they were derived from early Landsat technology, which has both lower spectral and spatial resolution.

Road data from US Census Bureau's TIGER files and Digital Elevation Models derived from LIDAR were used as input for transportation and topography. Exclusion (areas where development cannot occur) data includes wetlands, water bodies, and permanently protected conservation areas. The model is calibrated using a time series of land use data, transportation networks, and a digital elevation model.

The model employs a Monte Carlo simulation to identify the conditional transition probabilities for each of the land use change states. Future land use maps and infrastructure project are used in the exclusion layer with to reduce the overestimation of development, which is sometimes a problem with these models. The model results were converted to impervious surface estimates based upon zoning requirements for each county.

The Sea Level Affecting Marshes Model (SLAMM) was generated by Clarke Alexander at the Skidway Institute for coastal Georgia Counties. The mathematical model uses digital elevation data and other information to simulate potential impacts of long-term seal level rise on wetlands and shorelines. Outputs provide information on potential inundation, erosion, overwash, and changes in salinity. Thus, outputs provide information how wetlands distributions will change over time. We used results generated for the coastal counties to develop a map of future wetlands distribution in Georgia for the year 2045 (30-year projection). The future land use maps were then incorporated in the final assessment to identify areas of conflict.

RESULTS AND DISCUSSION

Our results indicate that a sea level rise ranging from 0.5 to 1.5 meters will cause an increase in wetland areas across coastal and second tier counties. These low-lying areas will support an additional 124,000 acres of brackish and freshwater wetlands (Table 2). Much of these areas are currently not developed, however, 507 miles of roads and 18,000 acres of developed land has the potential of being flooded converted to wetlands over the 30 years along the coastal counties. Land development will continue to occur across the six coastal counties, however, some of the existing developed land is at risk for inundation due to flooding from sea level rise. With over 5,000 of at-risk acres, Chatham County has the greatest area with the most vulnerable at-risk developed areas due to future sea level rise. These areas include homes, businesses and transportation infrastructure.

Table 1. Acres of developed land that will be converted to wetlands due to sea level rise

County	Currently Developed (Acres)	Future Developed (Acres)	Total Acres Lost
Bryan	775	147	921
Camden	2,083	1,849	3,932
Chatham	5,147	1,466	6,613
Glynn	2,541	1,841	4,382
Liberty	1,168	228	1,396
McIntosh	1,060	341	1,401
Total	12,774	5,871	18,645

Table 2. County estimates of land losses due to wetland expansion from sea level rise. Counties include the 6 coastal and second tier counties that will be impacted due to their topography

County	Wetland Expansion (Acres)
Brantley	8,999
Bryan	9,375
Bulloch	126
Camden	26, 594
Charlton	6,412
Chatham	21,516
Effingham	3,491
Glynn	16,181
Liberty	10,375
Long	3,126
McIntosh	14,213
Wayne	4,349
Total	124,848

Table 1 provides a county level assessment of existing and future developed lands that will be at most risk to sea level rise. The ability to locate these areas provide local governments with information that will help reduce the cost of future relocation, retreat or adaptation, by assess future risks in their decision making. In addition, to residential areas at risk, the information identifies and visualizes future infrastructure at risk to sea level rise, allowing information to be incorporated into future transportation planning and maintenance.

Some of the potentially flooded areas will allow for engineered solutions such as flood control structures or raising grades on road. In some cases, the response will require the relocation of families and businesses. In addition, these data provide better information for supporting emergency responses from extreme events such as hurricanes and flooding and the potential for loss of access due to road flooding and closure.

We cannot predict the future, however, decisions made today provide a pathway to the future. Identifying potential high-risk areas now will reduce costs associated with relocation and damage in the future.

LITERATURE CITED

Brody, S D, and W E Highfield. 2013. Open space protection and flood mitigation: a national study. Land use policy 32:89-95.

Costanza R, O Perez-Maqueo, M L Martinez, P Sutton, SJ Anderson. 2008. The value of coastal wetlands for hurricane protection. Ambio 37:241-248.

Gedan, K B, M L Kirwan, E Wolanski, E B Barbier, B R Silliman. 2011. The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. Climatic Change 106:7-29.

Jones, H P, D G Hole, E S Zavaleta. 2012. Harnessing nature to help people adapt to climate change. Nature Climate Change 2:504-509.

Kramer, E A, S Carpenedo. 2009. A Statewide approach for identifying potential areas for wetland restoration and mitigation banking in Georgia: an ecosystem function approach. Proceedings of the 2009 Georgia Water Resources Conference, Athens Georgia.

Mcleod, E, G L, Chmura, S Bouillon, R Salm, M Björk, C M Duarte, C E Lovelock, W H Schlesinger, and B R Silliman. 2011. A Blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. Front Ecol Environ 9:522-560.

National Research Council. 2014. Reducing Coastal Risks on the East and Gulf Coasts. Prepublication copy.

Pérez-Maqueo, O, A Intalawan, M L Martinez. 2007. Coastal disasters from the perspective of ecological economics. Ecological Economics 63:273-284.

Shepard, C C, C M Crain, M W Beck. 2011. The protective role of coastal marshes: A systematic review and meta-analysis. PLoS ONE 6(11):e27374. Doi:10.1371/journal.pone.0027374

White, D and S Fennessy. 2005. Modeling the suitability of wetland restoration potential at the watershed scale. Ecological Engineering 24:359-377.