Planning for Sea Level Rise in the Matanzas Basin

Appendix C:

Application of the Sea Level Affecting Marshes Model (SLAMM) in the Matanzas Basin

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Introduction

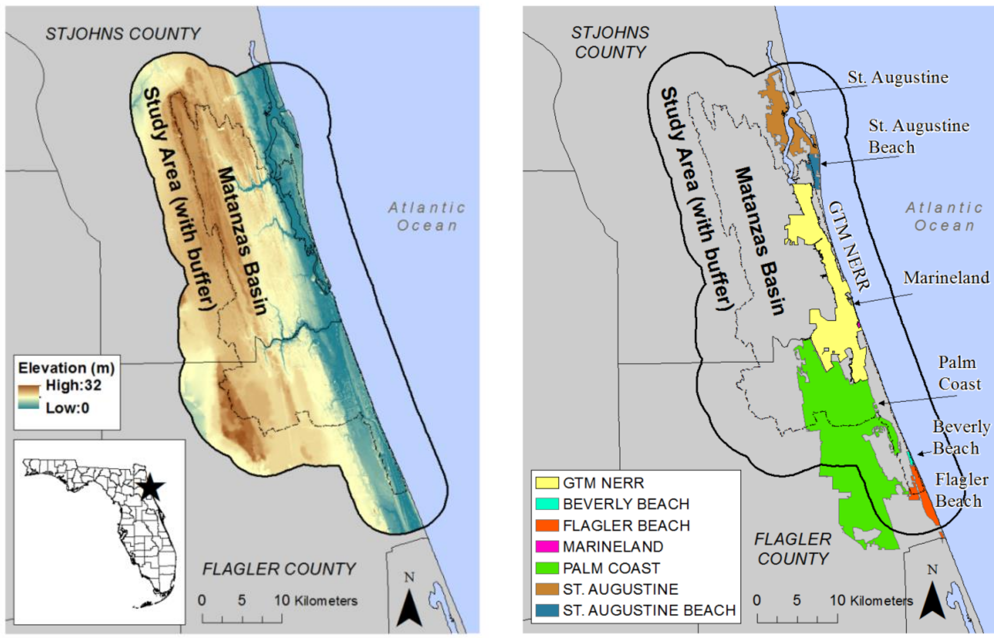
Coastal ecosystems are forecasted to be greatly impacted by sea level rise. The IPCC reports that there is a very high confidence that stress to coastal areas from climate and sea level rise currently exists and that this stress will increase (IPCC AR4 WG2 2007). Global forecasts project that coastal wetlands will lose 33% of their area between 2000 and 2080 under 36 com of sea level rise (IPCC AR4 WG2 2007). Adaptation and readiness for these impacts are currently low (IPCC AR4 WG2 2007). The threat that sea level rise poses is especially important for Florida because of its low topography, extensive coastline, valuable natural areas, and large coastal populations. Because of these threats it is important to identify the areas and habitats that are the most vulnerable to sea level rise in order to plan for a sustainable future.

The Matanzas area, located in northeast Florida, is an area where planning for sea level rise is especially important because of its environmental and cultural characteristics. This area includes the historic city of St. Augustine which is the oldest European-founded city in the continental US (est. 1565). The area is also home to the Guana Tolomato Matanzas National Estuary Research Reserve (GTM NERR) which provides protection for 11,688 ha (28,882 acres) of high quality coastal and estuarine habitat.

Here we describe the application of Sea Level Affecting Marshes Model (SLAMM) to the Matanzas Study Area. The following is a description of SLAMM, the model inputs, and the model results for the Matanzas Study Area.

Study Area

The study site is the Matanzas Basin including an additional 5 km buffer (135,158 ha) (Figure 1). The Matanzas Basin is located in northeast Florida on the Atlantic Coast. The buffer is included in this study to account for adjacent habitats and municipalities. Elevation in the study site ranges from 0 to 32 m above sea level (Figure 1a). There are approximately 62 km of ocean coastline within the site. The site spans two counties: Flagler and St. Johns. The western portion of the study area is largely rural and agricultural. The northeastern portion of the study site includes the cities of St. Augustine and St. Augustine Beach (Figure 1b). The middle eastern portion includes the Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) and the southeastern portion includes the cities of Beverly Beach and large portions of Palm Coast and Flagler Beach (Figure 1b).



a. *b.*

Figure 1. Location map of the Matanzas Watershed Study Area showing (a) the elevation and (b) the incorporated cities and GTM NERR.

Model Description

We use Sea Level Affecting Marshes Model (SLAMM) (Warren Pinnacle, Inc.) to simulate sea level rise and wetland migration in the study area. SLAMM is a spatially explicit model where land cover and elevation data are assigned to each cell. Each land cover type is given boundary conditions related to elevation, salinity, and proximity to open water. Vertical accretion and horizontal erosion for the land cover types are also specified. Sea level rise causes the wetland types to migrate inland according to those boundary conditions. Sea level rise scenarios are based on the curves produced by the IPCC 2007 Climate Change Report (IPCC AR4 WG1 2007) and may be scaled to any level. SLAMM produces maps of inundation and land cover annually for the simulation period. We use a 10 m spatial grid in this study and simulate a period of record from 2008 to 2100. Due to the small cell size, the overwash function was turned off. Due to the low occurrence of mangroves, the site was not considered tropical and new mangrove land cover types were not produced (Clough et al. 2010). In order to see the full range of affects from sea level rise the model was run assuming that wetlands can migrate onto developed lands.

Previous work using SLAMM describes its advantages and disadvantages, shows the model to be competent in its simulations, and describes its most important inputs. Mcleod et al. (2010) compared several sea level rise models and noted that advantages of SLAMM include its flexibility in scale, ability to describe the vulnerability of habitats and species, and ability to simulate the effect of saltwater intrusion on land cover. Chu-Agor et al. (2011) conducted a sensitivity analysis of SLAMM in an application to the Florida Panhandle. They showed that approximately 90% of the variability in the results can be attributed to the uncertainty in vertical error, historic sea level rise, accretion, and sedimentation. Geselbracht et al. (2010) conducted a hindcast to assess SLAMM's competence in depicting changes in wetland land cover due to sea level rise in Florida. They found that the simulations showed a similar pattern to observed changes in land cover.

Model Parameterization

The two spatial inputs for SLAMM are land cover and elevation. For this study we used a composite of land cover data from the St. Johns Water Management District Land Use and Cover dataset (SJWMD 2004) and the emergent vegetation dataset from GTM NERR (Kinser et al. 2007). Land cover classifications from both datasets were crosswalked to SLAMM land cover classifications, field checked, and converted to a 10 m grid. Elevation data was also produced on a 10 m grid as a composite from St. Johns County LiDAR (2008), Palm Coast LiDAR (2008), and FWC-FWRI (2009). For this analysis, the SLAMM land cover classification 'developed land' was assigned to any government, industrial, or institutional property as well as any residential property with medium to high densities. Residential properties with low densities (less than 2 units per acre) were defined as 'undeveloped land.'

Table 1. Percent land cover of SLAMM categories in 2008

Developed Dry Land	15.0%
Undeveloped Dry Land	45.1%
Swamp	25.8%
Cypress Swamp	2.0%
Inland-Fresh Marsh	0.8%
Transitional Saltmarsh	1.4%
Regularly-Flooded Marsh	3.1%
Tidal Flat	1.2%
Vegetated Tidal Flat	0.5%
Beach	0.2%
Open Water	4.9%

Non-spatial model inputs in SLAMM include tidal ranges, historic sea level rise, and accretion (Table 2). Tidal range was determined from the NOAA Ft. Matanzas, Matanzas River station (Station Id 8720686). Historic sea level rise was from the NOAA Fernandina Beach station (Station Id 8720030). Accretion and erosion rates were parameterized from Callaway et al. (1997), NWF (2006), Craft (2007), and Clough et al. (2010).

Table 2. SLAMM Inputs

Input	**Value**
Historic Sea Level Rise (m)	2.02
Great Diurnal Tidal Range (m)	1.33
Marsh Erosion (horiz. m)	2.0
Swamp Erosion (horiz. m)	1.0
Tidal Flat Erosion (horiz. m)	0.5
Regularly Flooded Marsh Accretion (m)	2.3
Irregularly Flooded Marsh Accretion (m)	4.5
Tidal Fresh Marsh Accretion (m)	6.0
Inland Fresh Marsh Accretion (m)	6.0
Mangrove Accretion (m)	4.6
Tidal Swamp Accretion (m)	1.1
Swamp Accretion (m)	0.3
Beach Sedimentation (m)	0.5

Sea Level Rise Scenarios

Estimating the effects of sea level rise is a fundamentally uncertain task because of the uncertainty in the forecasts of sea level rise. Historic sea level rise from the NOAA Fernandina Beach station (Station Id 8720030) shows a linear rise in sea level over the last 100 years of 2.02 mm/yr (NOAA 2012). At this rate, with no acceleration, sea level would rise by 0.19 m between 2008 and 2100. The current projections of sea level rise by the IPCC are between 0.18 to 0.59 m by 2100 (IPCC AR4 SYR 2007). Other models project higher rates of sea level rise due to added factors such as melting ice sheets. For example, some additional sea level rise projections by 2100 include: 0.62-0.88 m (Horton et al. 2008), 1.4 m (Vermeer and Rahmstorf 2009), and up to 2 m (Allison et al. 2009; Pfeffer et al. 2008). Allison et al. (2009) accounts for increasing greenhouse gas emissions since 1990 and the acceleration of melting ice-sheets, glaciers, and sea ice and states that sea level rise could reach a maximum of 2.0 m by 2100. Pheffer et al. (2008) notes that when accounting for glacial activity, it is possible for sea level rise to reach 2.0 m by 2100 but it is more likely to be in the range of 0.8 m.

Due to the uncertainty in sea level rise forecasts we consider several sea level rise scenarios. We ran simulations for 0.2, 0.5, 1.0, 1.5, 2.0, and 2.5 m sea level rise by 2100. This range includes high and low scenarios accounting for the current rate of sea level rise with no projected increases (0.2 m) (NOAA 2012) to an exceptionally high scenario (2.5 m).

Results

Results from the SLAMM simulations show a general band of change in land cover from sea level rise running along the coast and extending approximately 2 to 4 km inland (Figure 2). In the more northern and southern portions of the study area, which are occupied by the cities of St. Augustine and Palm Coast, land cover change extends further inland (approximately 4 km). While in the middle portion of the study area, occupied by GTM NERR, land cover change generally extends 2 to 2.5 km inland.

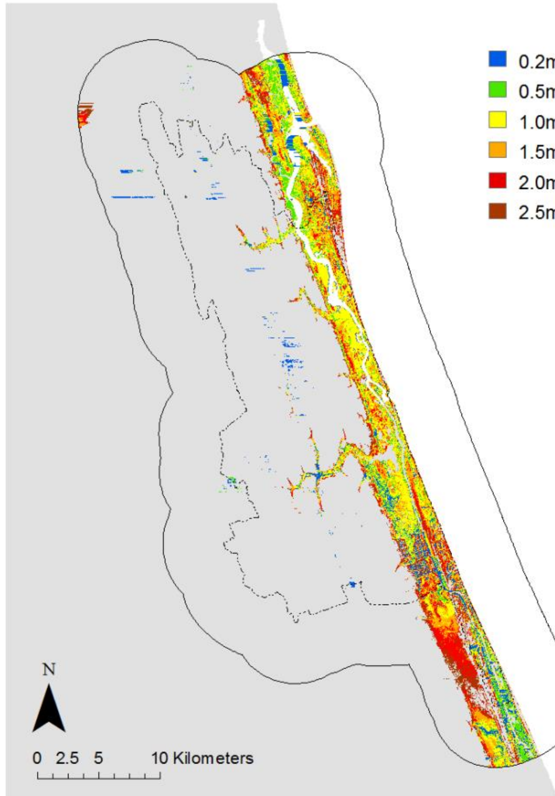


Figure 2. Area of change in land cover shown for each sea level rise scenario (0.2, 0.5, 1.0, 1.5, 2.0, and 2.5 m) at 2100.

Statistics were calculated to show the extent of changes in wetland area within the study area (Table 2), GTM NERR (Table 3), as well as encroachment of wet habitats onto dry land in the municipalities (Table 4). Within the study area the largest losses in land cover occur in developed dry land, and vegetated tidal flats. Conversely, transitional saltmarsh, tidal flats, and beaches show large increases in area. However, in these simulations developed land is allowed to convert to wetlands and in reality many of these gains in wetland area will not be allowed to occur because of human intervention. Within GTM NERR under a scenario of 1 m sea level rise by 2100, the simulations forecast that there will be a 35% loss of saltmarsh area and a 9% loss of tidal flat area. The simulations also show that 1,500 ha of saltmarsh, tidal flats, and water may encroach onto dry lands in St. Augustine under a scenario of 1 m sea level rise by 2100. Similarly, 363 ha of saltmarsh, tidal flats, and water encroach onto dry lands in Palm Coast.

Table 2. Forecasted loss rates of land cover categories.

Land Cover Type	0.2m	0.5m	1m	1.5m	2m
Developed Dry Land	-0.7%	-2.5%	-7.7%	-14.7%	-20.8%
Undeveloped Dry Land	-1.2%	-2.2%	-3.5%	-5.5%	-7.1%
Swamp	0.6%	-0.1%	-2.5%	-4.3%	-6.4%
Cypress Swamp	-0.1%	-0.3%	-2.3%	-4.0%	-8.2%
Inland-Fresh Marsh	-0.1%	-0.1%	-2.2%	-4.5%	-5.7%
Transitional Saltmarsh	-19.9%	36.0%	81.4%	78.5%	56.1%
Regularly-Flooded Marsh	20.6%	-16.0%	-31.0%	-2.6%	12.1%
Tidal Flat	0.6%	82.5%	49.0%	62.6%	86.2%
Vegetated Tidal Flat	0.0%	-0.1%	-14.7%	-46.7%	-98.6%
Beach	-1.2%	9.0%	35.4%	101.3%	143.7%
Open Water	2.4%	8.3%	56.9%	89.3%	132.3%

Table 3. Changes in area of tidal flat and saltmarsh within GTM NERR under a scenario of 1 m sea level rise by 2100 (ha).

	2008	2100	% change
Saltmarsh	4848	3138	-35%
Tidal Flat	3583	3262	-9%

Table 4. Encroachment of tidal flat, saltmarsh, and open water onto developed and undeveloped dry land per municipality under a scenario of 1 m sea level rise by 2100 (ha).

	St. Augustine	Palm Coast
Saltmarsh on Developed Land	990	144
Saltmarsh on Undeveloped Land	504	191
Tidal Flat on Developed Land	2	13
Tidal Flat on Undeveloped Land	1	1
Water on Developed Land	2	8
Water on Undeveloped Land	1	6

Maps were created to show the difference in land cover between the initial condition (2008) and 1 m sea level rise by 2100 at various scales and for various locations within the study area (Figures 3, 4, and 5). These maps show significant changes in open water, saltmarsh, and beach land cover locations.

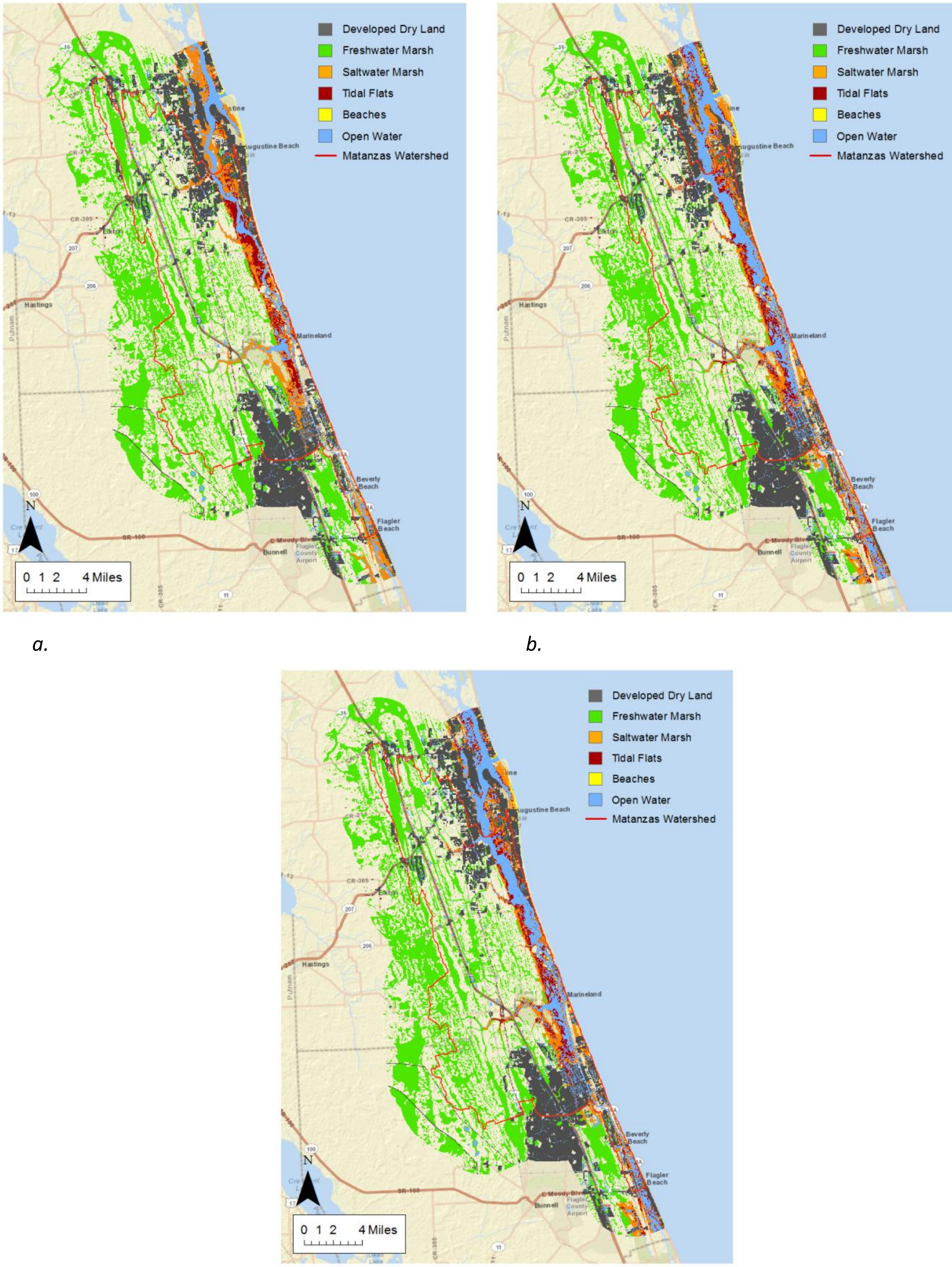
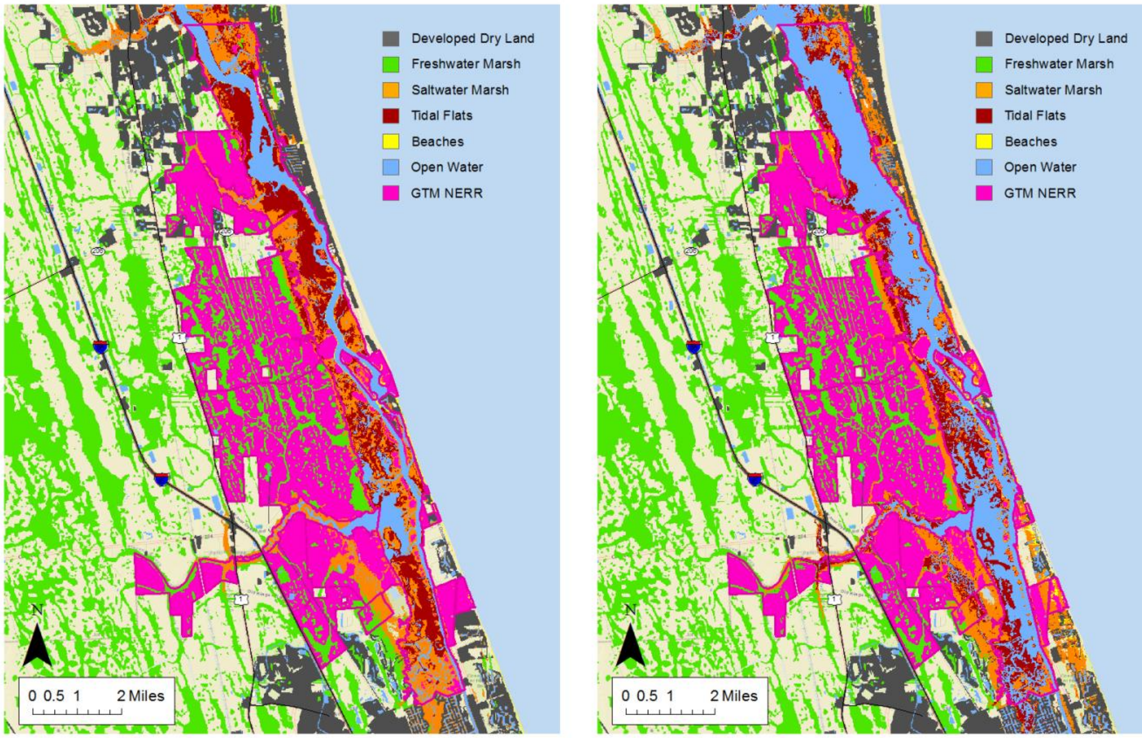
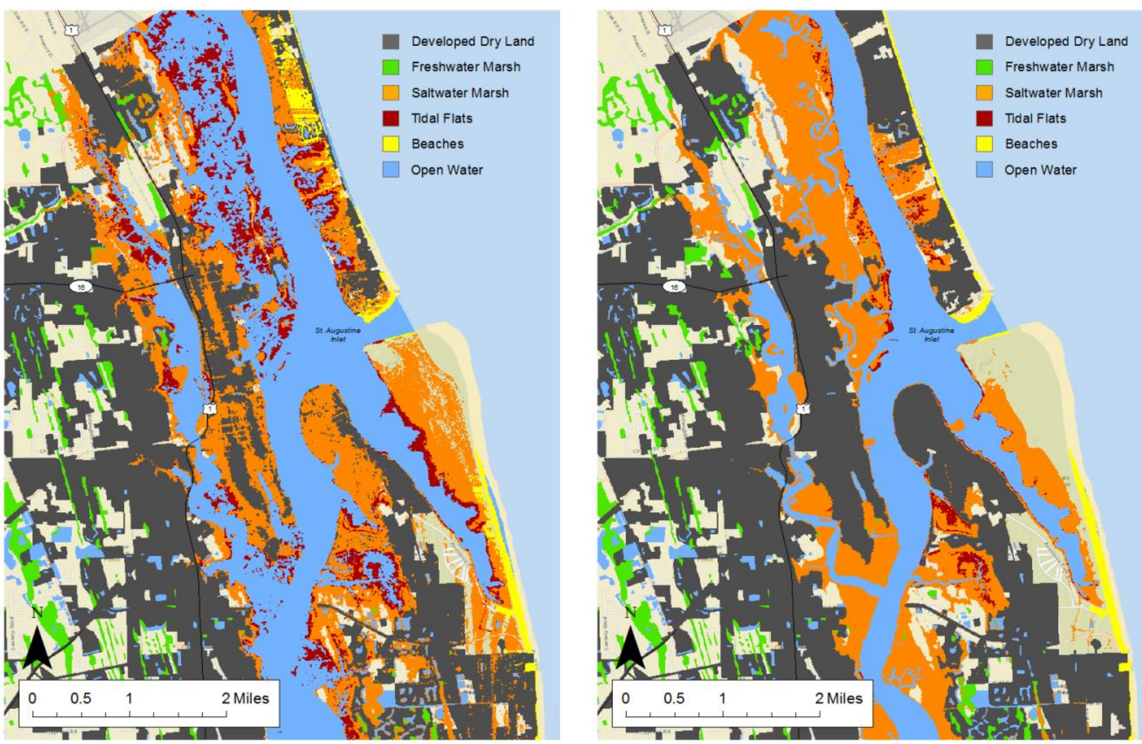


Figure 3. SLAMM results for Matanzas Study Area (a) 2008, initial conditions (b) 1m sea level rise in 2100 (c) 1m sea level rise in 2100 where there is no conversion of developed lands to wetlands or open water.



a. *b.*

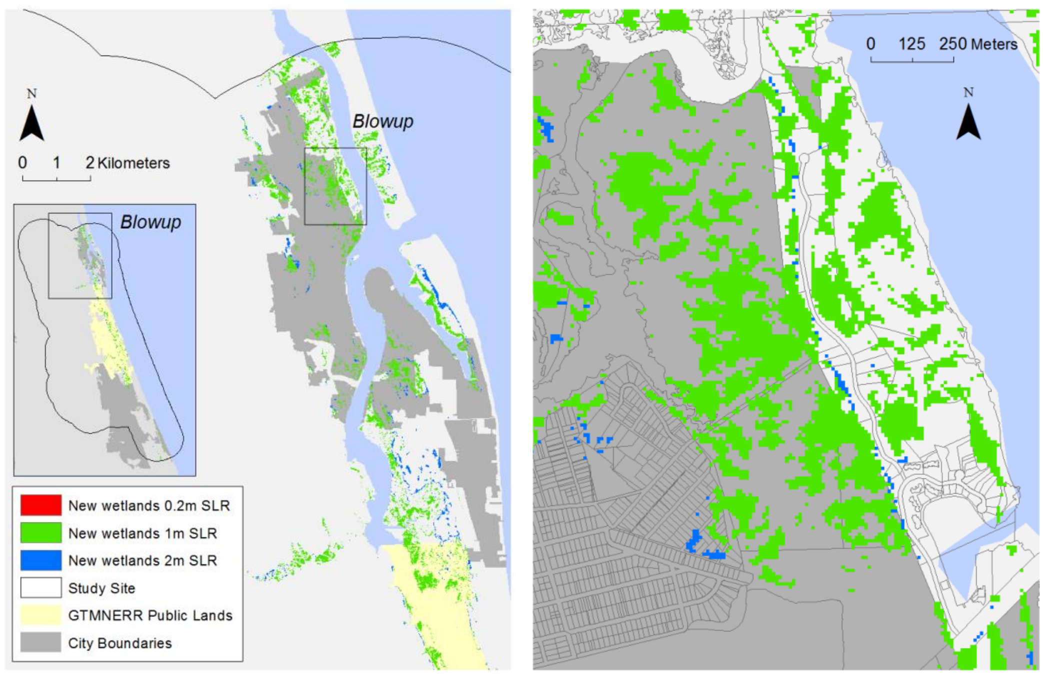
Figure 4. SLAMM results for GTM NERR (a) 2008, initial conditions (b) 1m sea level rise in 2100.



a. *b.*

Figure 5. SLAMM results for St Augustine area (a) 2008, initial conditions (b) 1m sea level rise in 2100.

The location of projected new wetland formation was mapped in relation to existing municipal boundaries and protected lands (Figure 6). These new wetlands are only shown where land cover was dry in the initial condition. Most new wetlands are created in the northern and middle portion of the band of change. The new wetlands that are created in the middle portion will be contained within the GTMN NERR protected lands and so conservation here is not an issue. The new wetlands that are created in the northern portion of the study area are contained within or adjacent to the cities of St. Augustine and St. Augustine Beach. Figure 6b overlays the parcel data onto the new wetlands created. This figure represents how conservation efforts may be targeted within parcels where wetland development is simulated. Large tracts of land near tidal water bodies where a considerable area of wetland generation is simulated may be good candidates for conservation. However, care should be taken when considering this type of analysis and it should only be used as an indication of likely wetland migration, rather than a prediction or forecast (Fuller and Cofer-Shabica 2011). SLAMM is most appropriate for considering overall wetland change. Zooming into specific parcels introduces additional uncertainty. And undoubtedly, SLAMM should not be used to assess single cells.



(a) (b)

Figure 6. New wetland creation under the 0.2, 1.0, and 2.0 m sea level rise (SLR) scenarios. (a) shows these wetlands in relation to existing municipal boundaries and GTM NERR conservation lands. (b) shows these wetlands in relation to specific parcels.

Discussion

In the 0.2 m sea level rise scenario only slight changes area seen in land cover. However, even under the 0.5 m scenario noteworthy changes are seen in saltmarshes and tidal flats. And under the 2 m scenario large changes are seen in developed dry land, transitional saltmarsh, tidal flats, vegetated tidal flats, and beaches. As previously mentioned, these changes are simulated assuming that developed land can transition to wetland and open water. In reality human intervention will likely prohibit much of the wetland migration on to developed and undeveloped lands. For example, in Figure 5, sizable portions of St. Augustine are shown to convert to saltmarsh and tidal flats. Because of the cultural importance of this historic city, it is likely that much of this land cover change will be prohibited by ditching, diking, and other such measures.

The conserved lands in GTM NERR appear to be wide enough to include the western most effects of sea level rise. As such, future acquisition of conservation lands by GTM NERR in an attempt to mitigate for sea level rise should be focused in either the northeastern or southeastern direction. Large tracts of land where areas of saltmarsh migration are simulated are best suited for conservation.

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