ECOSYSTEM SERVICES AND DIS-SERVICES FROM SEA LEVEL RISE DRIVEN FORESTED WETLAND TRANSITIONS

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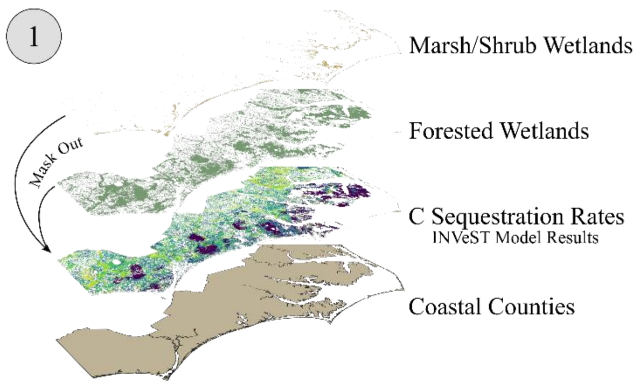
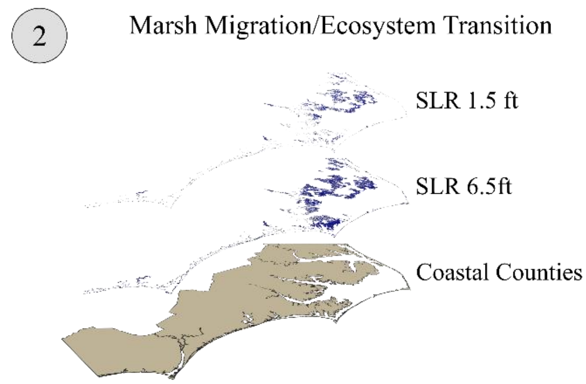
CONTEXT

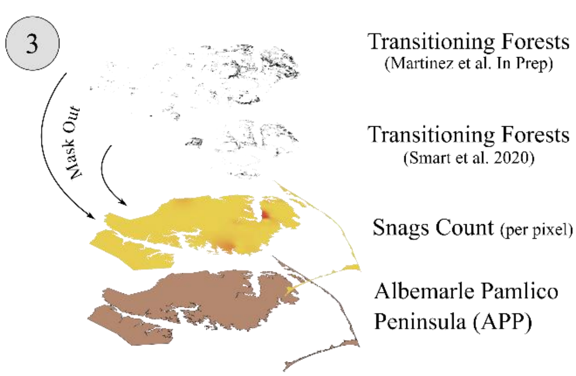


Sea level rise and changes in frequency of storms are altering coastal wetlands (Tully et al. 2019). Some estimates suggest that sea level rise will lead to the loss of 40-60% of coastal wetlands by 2100 (Blankespoor et al. 2014). However, recent studies suggest that coastal wetland areas might expand with sea level rise, as long as land is available for the landward migration of coastal wetlands (Ensign and Noe 2018; Schuerch et al. 2018). Researchers at the Nicholas Institute have worked on mapping carbon sequestration in the North Carolina coast (Map 1), estimating that marshes store 80 million metric tons of C and sequester 400,000 metric tons of C each year (Working lands report).



Researchers at the Nicholas Institute, using the INVeST model, also estimated that if migration space for marshes is protected (Map 2), approximately 20-35 million metric tons of C could be sequestered by new marshes under low (1.5 feet) or high (6.5 feet) scenarios of sea level rise. However, these estimates of new C sequestration provided by new marshes does not account for some of the ecosystem dis-services that could occur due to the transition from forested wetlands to marshes (the migration space) as sea levels rise. Here, we incorporated our measurements of C sequestration, N sequestration, and greenhouse gas (GHG) emissions from forested wetlands undergoing transition, in order to better account for both the services and disservices from sea level rise driven transitions in North Carolina coastal wetlands, specifically focusing on wetlands along the Albemarle Pamlico peninsula (APP). Sampling for these measurements were taken within Swanquarter and Alligator Fish and Wildlife Refuges, and state preserves and/or game lands through a permit process.

GREENHOUSE GAS EMISSIONS FROM STANDING DEAD TREES



Forest Inventory and Analysis (FIA) data, from USDA Forest Service, was used to interpolate the number of standing dead trees or snags per pixel across the North Carolina coastal wetland spatial extent (Map 3). We calculated snag stem surface GHGs using CO_2 equivalents for CH_4 and N_2O fluxes. We estimated emissions from snag stems up to 2 m using an average diameter at breast height of 0.1524 m (6 in). Snag stem surface CO_2 emissions were extrapolated to two ghost forest (forest transitioning) spatial extents along the APP landscape (Smart et al. 2020, Martinez et al. *In Prep*) and combined with the snag count interpolation (Map 3). Smart et al. (2020) estimated 16,797 ha of forested wetlands have transitioned from 2004 to 2014, while Martinez et al *In Prep* estimated 39,828 ha of forested wetlands are currently transitioning up to 2020.

The marsh migration space for both sea level rise scenarios 0.45 and 1.98 m (1.5 and 6.5 ft) are expected to become ghost forests (transitioning areas) before becoming a marsh therefore greenhouse gas emissions from snags for these areas were calculated using the following equations:

$$g\ CO_2\ yr^{-1} = Snag\ Stem\ Surface\ Area\ (m^2) \times 20\ (\text{snags}\ pixel^{-1}) \times CO_{2(eq)}GHGs\ (g\ m^{-2}hr^{-1}) \times 24\ (hr) \times 152\ (days\ in\ growing\ season) \times MarshMigrationArea\ (pixels)$$

$$\frac{g\ CO_2\ yr^{-1} \times \frac{12}{44}}{1{,}000{,}000} = metric\ tons\ C\ yr^{-1}$$

The number of expected snags (20 snags pixel $^{-1}$) was used based on previous estimates from a study within the APP (Ury et al. 2021). The FIA mean snag count for the NC coastline is ~17 snags pixel^{-1}.

CARBON SEQUESTRATION AND GREENHOUSE GAS EMISSIONS

Study Area	Spatial Extent (Ha)	Carbon Sequestration Rate* (metric tons C yr^{-1})	Soil C Sequestration rate (metric tons C yr^{-1})	Soil N Sequestration rate (metric tons N yr^{-1})	Greenhouse Gas Emissions (metric tons C yr^{-1})
NC DEQ Classification					
Forested Wetlands	1,330,848	108,961,802	1,340,829	51,570	-
Marsh/Scrub	115,879	1,353,153	99,655	4,554	-
Smart et al. 2020					
APP – Forested	100,917	3,233,524	86,789	3,910	-
APP – Marsh	8,351		8,414	328	-
APP – Transitioning	16,797	235,854	113,884	537	168
Martinez et al. (*In Prep*)					
APP – Transitioning	39,828	851,207	270,035	1,274	380
Sea Level Rise Scenarios					
Increase 0.45 m (1.5 ft)	139,694	-	-	-	15,449
Increase 1.98 m (6.5 ft)	387,597	-	-	-	42,868

*Indicates cumulative C sequestration rates per pixel values using INVeST model (Map 1)

Cumulative C sequestration rates for forested wetlands were 80 times higher than marshes because of the larger spatial extent (Table 1). The spatial extent of the model output showed some discrepancies where areas classified as forest or marsh did not have a carbon sequestered value. This likely underestimates the total carbon sequestered by each wetland type. The total C sequestration rate (INVeST model) from areas classified as transitioning within the APP (Smart et al. 2020) was 13 times less than areas classified as forest due to smaller spatial extent of transitional areas. The C sequestrations rates (INVeST model output) for some forested areas were lower than expected, which is why we included our soil C and N sequestration rates from soils cores taken within the APP (Gundersen et al. 2021). Soil C sequestration rates indicated that transitioning (Smart et al. 2020 and Martinez et al. *In Prep*) areas sequester 1.3 and 13 more C than forested and marsh areas, respectively. Soil N sequestration rates were highest in forested areas (3, 910 metric tons N yr^{-1}). Greenhouse gas emissions from snag stems across the APP contributed an additional 168 – 380 metric tons C yr^{-1}, which is less than 1% of the C sequestration rate from soils in transitioning areas (113,884 – 270,035 metric tons C yr^{-1}). Future increases in sea level rise scenarios, 0.45 and 1.98 m (1.5 and 6.5 ft), indicated that as marshes migrate into forested wetland an initial 15,449 up to 42,868 metric tons of C yr^{-1} will be released into the atmosphere through snags. Because the majority of the APP is within 1.5 m of mean sea level an increase 0.45 m (1.5 ft) is projected to significantly impact forested wetlands through marsh migration, becoming a ghost forest first before becoming a marsh. An increase in 1.98 m (6.5 ft) would triple the C released into the atmosphere through snags (Table 1).

CONCLUSION

North Carolina is expected to experience among the most drastic coastal changes as sea level rises, especially along the APP, which is within 1.5 m of mean sea level. We can currently observe these drastic changes of marsh migration into forested wetland with the APP through ghost forests. Forested wetlands overall have higher C sequestration rates than the marshes migrating in their space. Although currently transitioning areas (ghost forests) emit less than 1% of the soil C sequestration rates to the atmosphere, future sea level rise scenarios 0.45 and 1.98 m (1.5 and 6.5 ft) increase this contribution to 15,449 and as high as 42,868 metric tons C yr^{-1}.

This analysis was supported by the Southeast Climate Adaptation Science Center as part of a suite of case studies investigating the application of ecosystem services mapping in support of regional partner needs. More information can be found at secasc.ncsu.edu/resources/ecosystem-services-case-studies. In addition, a project Story Map can be found at storymaps.arcgis.com/stories/076c683db5be454c8dec03187caa23c2.