Data Report on SLAMM Model Results for Ten National Wildlife Refuges in South Carolina and Georgia:

Wassaw NWR, Georgia

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Acknowledgements

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Introduction

Tidal marshes are among the most susceptible ecosystems to climate change, especially accelerated sea level rise (SLR). Sea level is predicted to increase by 30 cm to 100 cm by 2100 based on the International Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) (Meehl et al. 2007). Rising sea level may result in tidal marsh submergence (Moorhead and Brinson 1995) and habitat migration as salt marshes transgress landward and replace tidal freshwater and brackish marsh (Park et al. 1991).

The data contained in this report were derived from a broader study, "Effects of Sea level Rise and Climate Variability on Ecosystem Services of Tidal Marshes, South Atlantic Coast." The research team, led by Chris Craft (Indiana University) and funded through an EPA grant, used GIS and simulation modeling to predict the effects of different scenarios of accelerated SLR on tidal marsh area and delivery of select ecosystem services along the Georgia and South Carolina coast. The basic rationale, methods and limitations of the approach as presented herein were described by Craft et al. (in review).

Methods

Changes in tidal marsh area and habitat type in response to SLR were modeled by Jonathan Clough using the Sea Level Affecting Marshes Model (SLAMM) that simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise (Park et al. 1989; www.warrenpinnacle.com/prof/SLAMM). SLAMM was developed as a model that integrates elevation-submergence and wave action-erosion. SLAMM5 also incorporates a salinity algorithm, based on freshwater discharge and cross-sectional area of the estuary, to model saltwater intrusion in river-dominated estuaries. Model inputs included the USGS National Elevation Dataset (NED) (http://ned.usgs.gov), NOAA tidal data, and USFWS National Wetlands Inventory (NWI) data (http://wetlandsfws.er.usgs.gov). SLAMM, a cell-based model, was run at 28 m resolution based on NED characteristics within the study region.

Model simulations were based on the SRES A1B mean (39 cm) and maximum (69 cm) increase in SLR in the next 100 years, with a time step of 25 years. The SRES A1 scenario assumes rapid economic growth, low population growth and rapid introduction of new and more efficient technology (Church et al. 2001, Meehl et al. 2007). The SRES A2 scenario, that assumes a lower rate of economic growth, fewer technological advances but greater population growth, predicts a similar increase in sea level rise during the next century (Church et al. 2001). A third scenario, based on a 100 cm increase, was also modeled.

SLAMM accounts for localized conditions within its spatial domain, through the use of parameters such as tide range, historical trend, and NAVD-88 correction (see below table). This provides for site-specificity of the SLR scenario being applied. For example, while the global average of SLR is 1.8 mm/yr (Church et al. 2001), the measured rate of SLR (historical trend) around Wassaw is 3.05 mm/yr. Accounting for all of these localized conditions, the following SLR scenarios were used for Wassaw NWR: 61 cm (A1B mean), 92 cm (A1B maximum), and 122 cm (corresponding to 1 m globally) by 2100[1].

[1] About 22 cm of additional SLR is predicted based on the local conditions at this site vs. global SLR trends.

The table that follows includes the parameters used in the SLAMM Model Runs:

SLAMM Parameter	**Value**	**Units**
Initial Condition	1999	(yyyy)
NED Source Date	1975	(yyyy)
NWI_photo_date	1973	(yyyy)
Direction_OffShore	E	(N|S|E|W)
Historic_trend	3.05	(mm/yr)
NAVD88_correction	-0.116	(MTL-NAVD88 in meters)
Water Depth	2.0	(m below MLW; aggrading beaches only)
TideRangeOcean	2.25	(meters: MHHW-MLLW)
TideRangeInland	2.25	(meters)
Mean High Water Spring	1.69	(m above MTL)
Marsh Erosion	2.0	(horz meters/year)
Swamp Erosion	1.0	(horz meters/year)
TFlat Erosion	6.0	(horz meters/year) [from 0.5]
Salt marsh vertical accretion	1.9	(mm/yr)
Brackish March vert. accretion	4.3	(mm/yr)
Tidal Fresh vertical accretion	4.8	(mm/yr)
Beach/T.Flat Sedimentation Rate	0.5	(mm/yr)
Frequency of Large Storms	25	(yr/washover)
Use Elevation Preprocessor for Wetlands	TRUE	TRUE/FALSE
Notes: Historic Trend Source: http://www.co-ops.nos.noaa.gov/sltrends/sltrends_states.shtml?region=ga Range Source: http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=BR0078 Water Depth means the average water depth 15 m off-shore.		

Limitations of the Approach

As with any study, there are caveats associated with the tools and approaches we used. Second, there are limitations associated with the data inputs used in the SLAMM SLR simulations. For example, (NED) elevation data that covers the entire coast has moderate resolution. Third, the SLAMM model lacks feedback mechanisms that may come into play as SLR accelerates. For example, increasing inundation of salt marshes may increase macrophyte production and lead to increased vertical accretion (Morris et al. 2002). Conversely, increasing salt water intrusion into tidal freshwater marshes may accelerate decomposition, (Weston et al. 2006), and lead to reduced vertical accretion. Despite these caveats, our approach provides first-order and important insights into how accelerated SLR may affect tidal marshes and their delivery of ecosystem services in the future.

Results

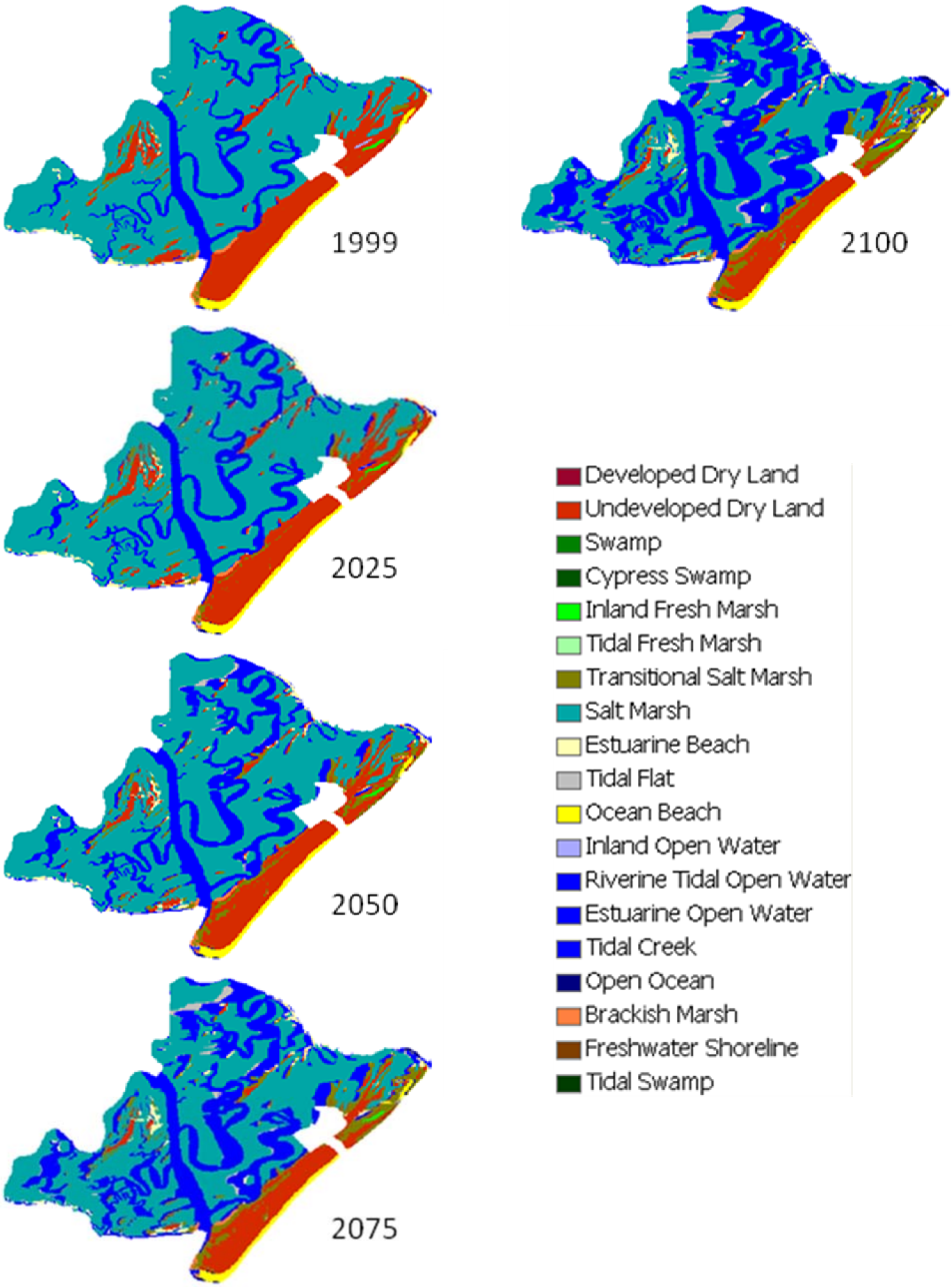
The results of the SLAMM model runs are presented below, with sets of two tables and a series of map graphics for each of the three global SLR scenarios: A1B Mean, A1B Maximum, and a 1 meter increase.

Site	Wassaw, GA
Scenario	**A1B**
Parameters	**Mean**, Protect Developed Lands

Wassaw	Hectares of Cover by Year				
Cover Type	Initial	2025	2050	2075	2100
Developed Dry Land	1.80	1.80	1.80	1.80	1.80
Undeveloped Dry Land	681.92	619.67	512.74	394.90	353.27
Inland Fresh Marsh	4.78	4.78	4.78	4.78	4.78
Scrub-shrub	67.03	108.43	176.56	247.82	270.56
Salt Marsh	2834.94	2706.37	2460.27	2125.19	1765.02
Estuarine Beach	46.33	52.76	62.17	73.70	73.62
Tidal Flat	0.94	3.53	18.74	48.37	77.85
Ocean Beach	69.93	69.62	70.64	71.58	71.74
Inland Open Water	3.14	0.71	0.00	0.00	0.00
Estuarine Water	514.85	657.54	920.34	1256.44	1601.79
Tidal Creek	7.13	7.13	7.13	7.13	7.13
Open Ocean	2.12	3.14	3.68	7.37	11.60
Brackish Marsh	17.25	16.70	13.33	13.09	13.01

Wassaw	Init. Cond. (ha)	Year 2050 (ha)	Year 2100 (ha)	Percent of Init. Cond.	Percent Loss 2050	Percent Loss 2100
Developed Dry Land	2	2	2	0%	0%	0%
Undeveloped Dry Land	682	513	353	16%	25%	48%
Inland Fresh Marsh	5	5	5	0%	0%	0%
Scrub-shrub	67	177	271	2%	(163%)	(304%)
Salt Marsh	2835	2460	1765	67%	13%	38%
Estuarine Beach	46	62	74	1%	(34%)	(59%)
Tidal Flat	1	19	78	0%	(1,892%)	(8,175%)
Ocean Beach	70	71	72	2%	(1%)	(3%)
Inland Open Water	3	0	0	0%	100%	100%
Estuarine Water	515	920	1602	12%	(79%)	(211%)
Tidal Creek	7	7	7	0%	0%	0%
Open Ocean	2	4	12	0%	(74%)	(448%)
Brackish Marsh	17	13	13	0%	23%	25%

Scenario A1B Mean

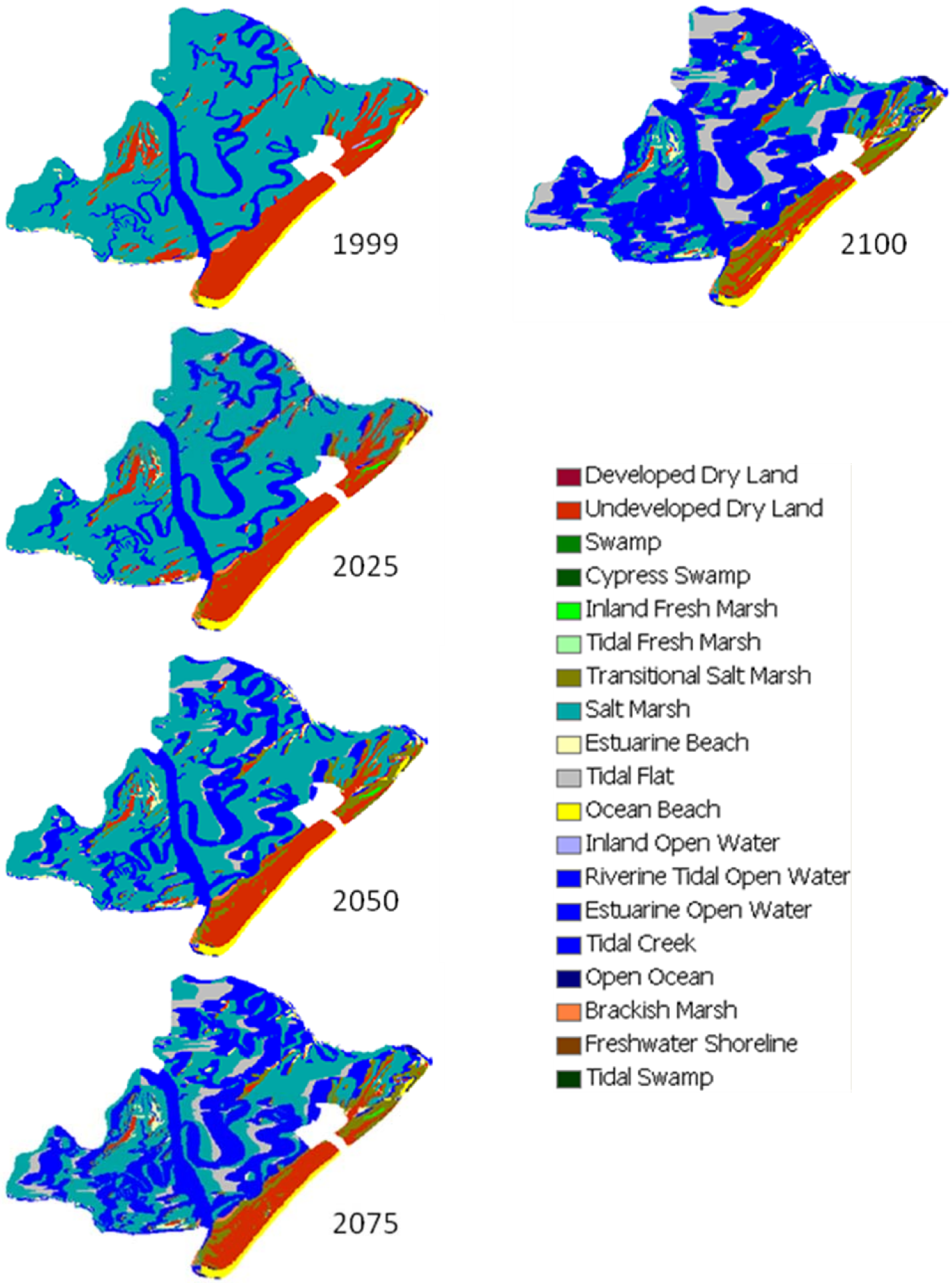


Site	Wassaw, GA
Scenario	**A1B**
Parameters	**Maximum**, Protect Developed Lands

Wassaw	Hectares of Cover by Year				
Cover Type	Initial	2025	2050	2075	2100
Developed Dry Land	1.80	1.80	1.80	1.80	1.80
Undeveloped Dry Land	678.00	579.22	420.22	347.00	259.58
Inland Fresh Marsh	4.78	4.78	4.70	4.00	2.51
Scrub-shrub	72.28	136.26	231.44	262.88	307.88
Salt Marsh	2801.15	2555.68	2074.46	1378.74	685.76
Estuarine Beach	42.88	53.86	68.76	72.28	74.79
Tidal Flat	2.04	17.64	125.20	329.28	510.62
Ocean Beach	69.93	69.54	70.56	71.58	78.87
Inland Open Water	3.14	0.63	0.00	0.00	0.00
Estuarine Water	549.58	808.62	1230.33	1756.55	2295.47
Tidal Creek	7.13	7.13	7.13	7.13	7.13
Open Ocean	2.20	3.37	4.47	9.17	17.72
Brackish Marsh	17.25	13.64	13.09	11.76	10.04

Wassaw	Init. Cond. (ha)	Year 2050 (ha)	Year 2100 (ha)	Percent of Init. Cond.	Percent Loss 2050	Percent Loss 2100
Developed Dry Land	2	2	2	0%	0%	0%
Undeveloped Dry Land	678	420	260	16%	38%	62%
Inland Fresh Marsh	5	5	3	0%	2%	48%
Scrub-shrub	72	231	308	2%	(220%)	(326%)
Salt Marsh	2801	2074	686	66%	26%	76%
Estuarine Beach	43	69	75	1%	(60%)	(74%)
Tidal Flat	2	125	511	0%	(6,042%)	(24,950%)
Ocean Beach	70	71	79	2%	(1%)	(13%)
Inland Open Water	3	0	0	0%	100%	100%
Estuarine Water	550	1230	2295	13%	(124%)	(318%)
Tidal Creek	7	7	7	0%	0%	0%
Open Ocean	2	4	18	0%	(104%)	(707%)
Brackish Marsh	17	13	10	0%	24%	42%

Scenario A1B Maximum

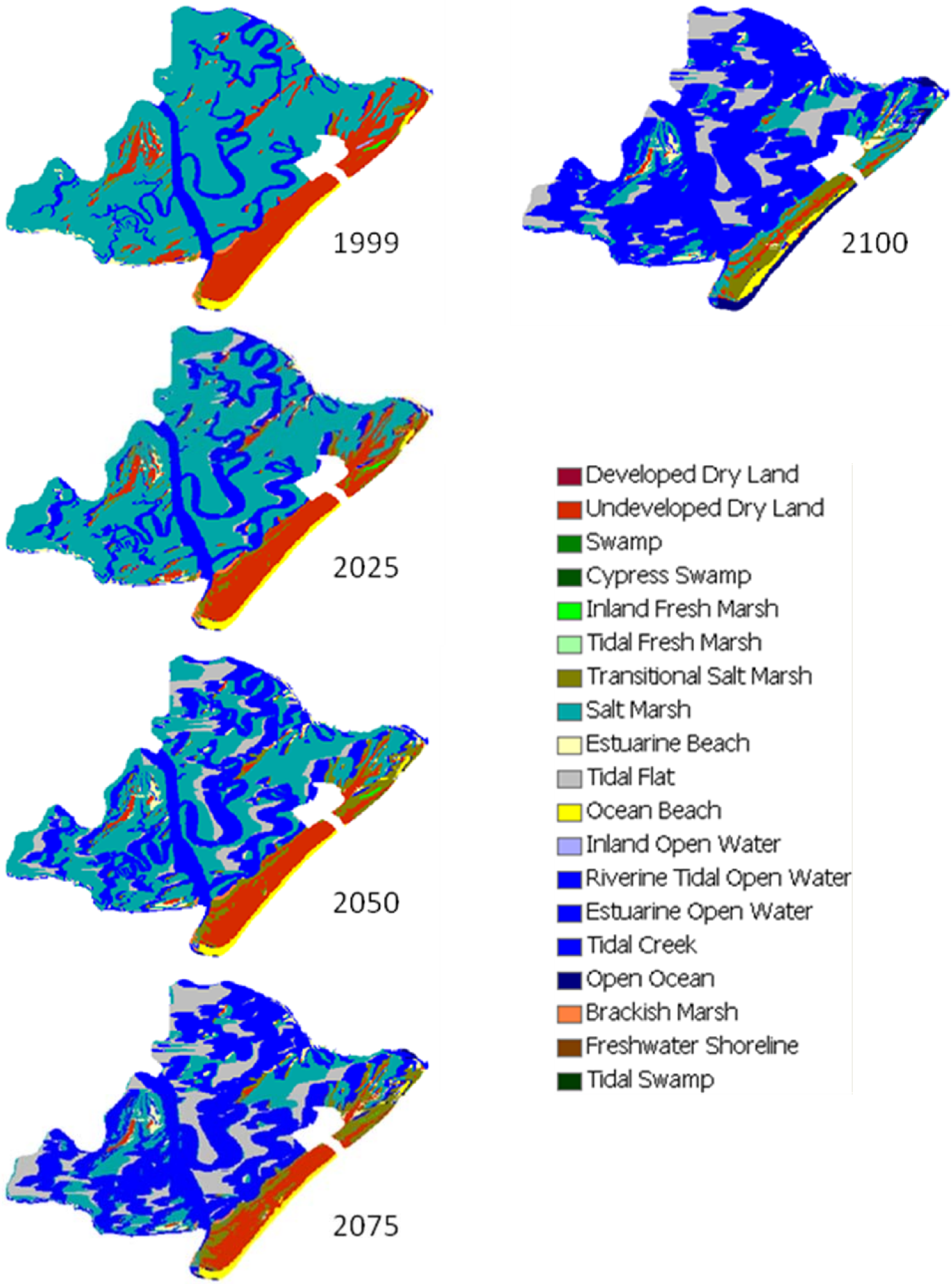


Site	Wassaw, GA
Scenario	**1 Meter** SLR
Parameters	Protect Developed Lands

Wassaw	Hectares of Cover by Year				
Cover Type	Initial	2025	2050	2075	2100
Developed Dry Land	1.80	1.80	1.80	1.80	1.80
Undeveloped Dry Land	673.14	531.71	373.89	307.17	93.69
Inland Fresh Marsh	4.78	4.78	3.92	1.25	0.00
Scrub-shrub	74.40	166.05	247.67	255.27	195.92
Salt Marsh	2761.33	2369.80	1622.41	652.68	543.16
Estuarine Beach	46.73	61.39	74.95	75.73	89.30
Tidal Flat	4.39	68.60	330.14	721.52	594.04
Ocean Beach	69.78	69.70	71.42	74.01	48.29
Inland Open Water	3.14	0.63	0.00	0.00	0.00
Estuarine Water	589.02	953.50	1501.83	2134.05	2572.38
Tidal Creek	7.13	7.13	7.13	7.13	7.13
Open Ocean	2.35	3.76	5.25	12.54	100.27
Brackish Marsh	14.19	13.33	11.76	9.02	6.19

Wassaw	Init. Cond. (ha)	Year 2050 (ha)	Year 2100 (ha)	Percent of Init. Cond.	Percent Loss 2050	Percent Loss 2100
Developed Dry Land	2	2	2	0%	0%	0%
Undeveloped Dry Land	673	374	94	16%	44%	86%
Inland Fresh Marsh	5	4	0	0%	18%	100%
Scrub-shrub	74	248	196	2%	(233%)	(163%)
Salt Marsh	2761	1622	543	65%	41%	80%
Estuarine Beach	47	75	89	1%	(60%)	(91%)
Tidal Flat	4	330	594	0%	(7,420%)	(13,430%)
Ocean Beach	70	71	48	2%	(2%)	31%
Inland Open Water	3	0	0	0%	100%	100%
Estuarine Water	589	1502	2572	14%	(155%)	(337%)
Tidal Creek	7	7	7	0%	0%	0%
Open Ocean	2	5	100	0%	(123%)	(4,163%)
Brackish Marsh	14	12	6	0%	17%	56%

Scenario 1 meter SLR



Literature Cited

Church JA, Gregory JM and others. 2001. Chapter 11: Changes in sea level. p. 639-693. In: JT Houghton and others (ed.), *Climate Change 2001: The Scientific Basis. Intergovernmental Panel on Climate Change*, Cambridge, UK: Cambridge University Press.

Craft C, Clough J, Ehman J, Guo H, Joye S, Machmuller M, Park R, and Pennings S. Effects of Accelerated Sea Level Rise on Delivery of Ecosystem Services Provided by Tidal Marshes: A Simulation of the Georgia (USA) Coast. In review for *Frontiers in Ecology and the Environment.*

Meehl GA, Stocker TF, Collins WD, Friedlingstein P, Gaye AT, Gregory JM, Kitoh A, Knutti R, Murphy JM, Noda A, Raper SCB, Watterson IG, Weaver AJ and Zhao ZC. 2007. Global climate projections. Pp. 747-845. In: Solomon S, Qin, D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor, M and Miller HL, (eds.) *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Moorhead, KK and Brinson MM. 1995. Response of wetlands to rising sea level in the lower coastal plain of North Carolina. *Ecological Applications* 5: 261-271.

Morris, JT, Sundareshwar PV, Nietch CT, Kjerfve B and Cahoon DR. 2002. Response of coastal wetlands to rising sea level. *Ecological Applications* 83: 2869-2877.

Park RA, Lee JK, Mausel PW and Howe RC. 1991.Using remote sensing for modeling the impacts of sea level rise. *World Resources Review* 3: 184-220.

Park, RA, Trehan, MS, Mausel, PW, & Howe, RC. 1989. The Effects of Sea Level Rise on U.S. Coastal Wetlands. Pp. 1-1 to 1-55. In Smith, J.B. & Tirpak, D.A. (Eds). *The Potential Effects of Global Climate Change on the United States, Appendix B - Sea Level Rise*. U.S. Environmental Protection Agency, Washington, D.C.

Weston NB, Dixon RE and Joye SB. 2006. Ramifications of salinity intrusion in tidal freshwater sediments: Geochemistry and microbial pathways of organic matter mineralization. *Journal of Geophysical Research, Biogeosciences* 111: G0100, doi:10.1029/2005JG000071.