Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Laguna Atascosa NWR

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Introduction

Tidal marshes are among the most susceptible ecosystems to climate change, especially accelerated sea level rise (SLR). The Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) suggested that global sea level will increase by approximately 30 cm to 100 cm by 2100 (IPCC 2001). Rahmstorf (2007) suggests that this range may be too conservative and that the feasible range by 2100 is 50 to 140 cm. Rising sea levels may result in tidal marsh submergence (Moorhead and Brinson 1995) and habitat "migration" as salt marshes transgress landward and replace tidal freshwater and irregularly flooded marsh (R. A. Park et al. 1991).

In an effort to address the potential effects of sea level rise on United States national wildlife refuges, the U. S. Fish and Wildlife Service contracted the application of the SLAMM model for many coastal Region 2 refuges. This analysis is designed to assist in the production of comprehensive conservation plans (CCPs) for each refuge along with other long-term management plans.

Model Summary

Changes in tidal marsh area and habitat type in response to sea-level rise were modeled using the Sea Level Affecting Marshes Model (SLAMM 6) that accounts for the dominant processes involved in wetland conversion and shoreline modifications during long-term sea level rise (Park et al. 1989; www.warrenpinnacle.com/prof/SLAMM).

Successive versions of the model have been used to estimate the impacts of sea level rise on the coasts of the U.S. (Titus et al. 1991; Lee et al. 1992; Park et al. 1993; Galbraith et al. 2002; National Wildlife Federation & Florida Wildlife Federation 2006; Glick et al. 2007; Craft et al. 2009).

Within SLAMM, there are five primary processes that affect wetland fate under different scenarios of sea-level rise:

- **Inundation:** The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level (MTL) constant at zero. The effects on each cell are calculated based on the minimum elevation and slope of that cell.
- **Erosion:** Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open ocean. When these conditions are met, horizontal erosion occurs at a rate based on site- specific data.
- **Overwash:** Barrier islands of under 500 meters (m) width are assumed to undergo overwash during each specified interval for large storms. Beach migration and transport of sediments are calculated.
- **Saturation:** Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.

- **Accretion:** Sea level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain and can be specified to respond to feedbacks such as frequency of flooding.

SLAMM Version 6.0 was developed in 2008/2009 and is based on SLAMM 5. SLAMM 6.0 provides backwards compatibility to SLAMM 5, that is, SLAMM 5 results can be replicated in SLAMM 6. However, SLAMM 6 also provides several optional capabilities.

- Accretion Feedback Component: Feedbacks based on wetland elevation, distance to channel, and salinity may be specified. This feedback will be used in USFWS simulations, but only where adequate data exist for parameterization.
- Salinity Model: Multiple time-variable freshwater flows may be specified. Salinity is estimated and mapped at MLLW, MHHW, and MTL. Habitat switching may be specified as a function of salinity. This optional sub-model is not utilized in USFWS simulations.
- Integrated Elevation Analysis: SLAMM will summarize site-specific categorized elevation ranges for wetlands as derived from LiDAR data or other high-resolution data sets. This functionality is used in USFWS simulations to test the SLAMM conceptual model at each site. The causes of any discrepancies are then tracked down and reported on within the model application report.
- Flexible Elevation Ranges for land categories: If site-specific data indicate that wetland elevation ranges are outside of SLAMM defaults, a different range may be specified within the interface. In USFWS simulations, the use of values outside of SLAMM defaults is rarely utilized. If such a change is made, the change and the reason for it are fully documented within the model application reports.
- Many other graphic user interface and memory management improvements are also part of the new version including an updated *Technical Documentation*, and context sensitive help files.

For a thorough accounting of SLAMM model processes and the underlying assumptions and equations, please see the SLAMM 6.0 *Technical Documentation* (Clough et al. 2010). This document is available at http://warrenpinnacle.com/prof/SLAMM

All model results are subject to uncertainty due to limitations in input data, incomplete knowledge about factors that control the behavior of the system being modeled, and simplifications of the system (Council for Regulatory Environmental Modeling 2008). Site-specific factors that increase or decrease model uncertainty may be covered in the *Discussion* section of this report.

Sea Level Rise Scenarios

SLAMM 6 was run using scenario A1B from the Special Report on Emissions Scenarios (SRES) – mean and maximum estimates. The A1 family of scenarios assumes that the future world includes rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. In particular, the A1B scenario assumes that energy sources will be balanced across all sources. Under the A1B scenario, the IPCC WGI Fourth Assessment Report (IPCC 2007) suggests a likely range of 0.21 to 0.48 m of SLR by 2090-2099 "excluding future rapid dynamical changes in ice flow." The A1B-mean scenario that was run as a part of this project falls near the middle of this estimated range, predicting 0.39 m of global SLR by 2100. A1B-maximum predicts 0.69 m of global SLR by 2100.

The latest literature (Chen et al. 2006; Monaghan et al. 2006) indicates that the eustatic rise in sea levels is progressing more rapidly than was previously assumed, perhaps due to the dynamic changes in ice flow omitted within the IPCC report's calculations. A recent paper in the journal *Science* (Rahmstorf 2007) suggests that, taking into account possible model error, a feasible range by 2100 of 50 to 140 cm. This work was recently updated and the ranges were increased to 75 to 190 cm (Vermeer and Rahmstorf 2009). Pfeffer et al. (2008) suggests that 2 m by 2100 is at the upper end of plausible scenarios due to physical limitations on glaciological conditions. A recent US intergovernmental report states "Although no ice-sheet model is currently capable of capturing the glacier speedups in Antarctica or Greenland that have been observed over the last decade, including these processes in models will very likely show that IPCC AR4 projected SLRs for the end of the 21st century are too low" (Clark 2009). A recent paper by Grinsted et al. (2009) states that "sea level 2090-2099 is projected to be 0.9 to 1.3 m for the A1B scenario…" Grinsted also states that there is a "low probability" that SLR will match the lower IPCC estimates.

To allow for flexibility when interpreting the results, SLAMM was also run assuming 1 m, 1.5 m, and 2 m of eustatic SLR by the year 2100. The A1B- maximum scenario was scaled up to produce these bounding scenarios (Figure 1).

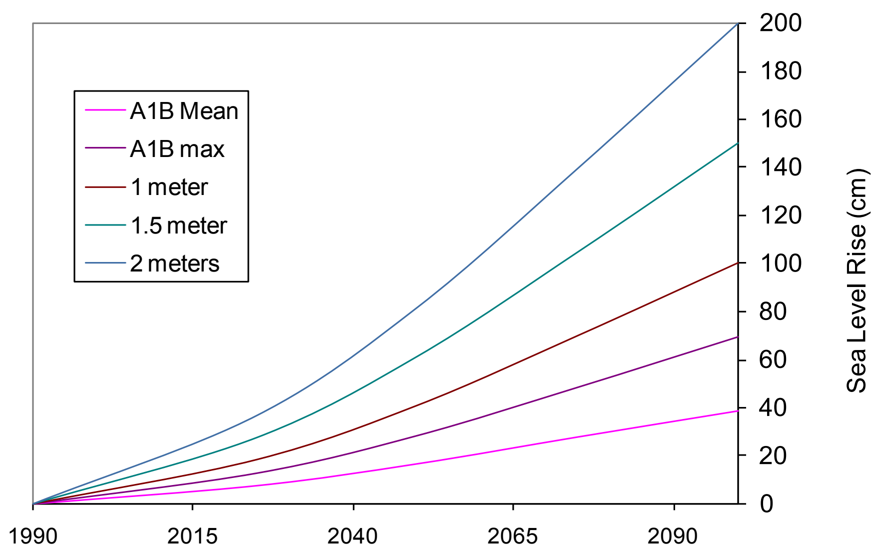


Figure 1. Summary of SLR scenarios utilized

Data Sources and Methods

Wetland layer. Figure 2 shows the most recent available wetlands layer obtained from a National Wetlands Inventory (NWI) photo dated 1994. Converting the NWI survey into 30 m cells indicated that the approximately 230,000 acre Laguna Atascosa NWR (approved acquisition boundary including water) is composed of the following categories:

Land cover type		Area (acres)	Percentage (%)
	Undeveloped Dry Land	118773	51
	Estuarine Beach	44757	19
	Tidal Flat	21961	10
	Inland Fresh Marsh	20796	9
	Inland Open Water	7215	3
	Developed Dry Land	5735	2
	Irregularly Flooded Marsh	4598	2
	Inland Shore	3542	2
	Estuarine Open Water	1399	<1
	Regularly Flooded Marsh	690	<1
	Open Ocean	497	<1
	Riverine Tidal	419	<1
	Swamp	193	<1
	Transitional Salt Marsh	177	<1
	Ocean Beach	139	<1
	Total (incl. water)	**230891**	**100**

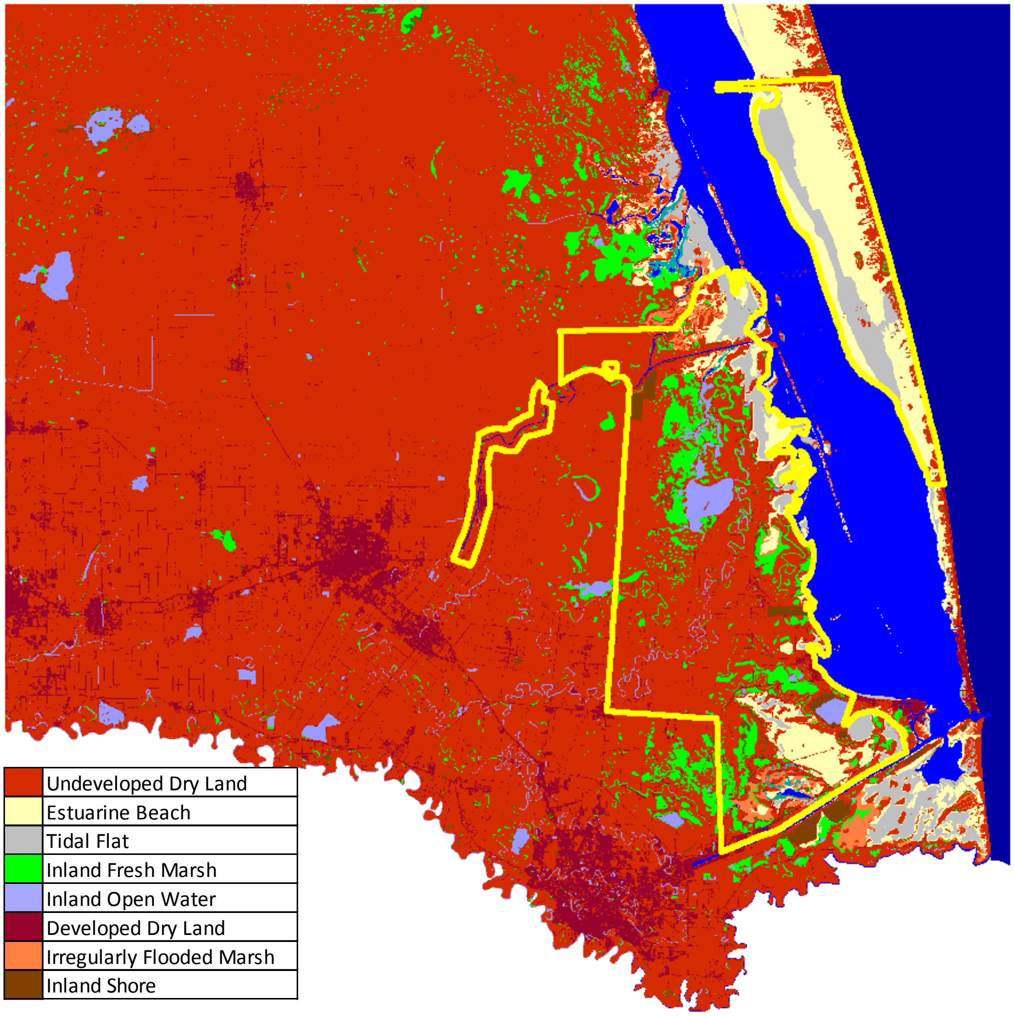


Figure 2. Wetland coverage of the study area. Modeling boundaries indicated in yellow

Elevation Data. The digital elevation map used in this simulation, shown in Figure 3, is a bare-earth dataset that was derived by combining data from a 2006 Texas Water Development Board LiDAR, and an International Boundary and Water Commission LiDAR dated 2005.

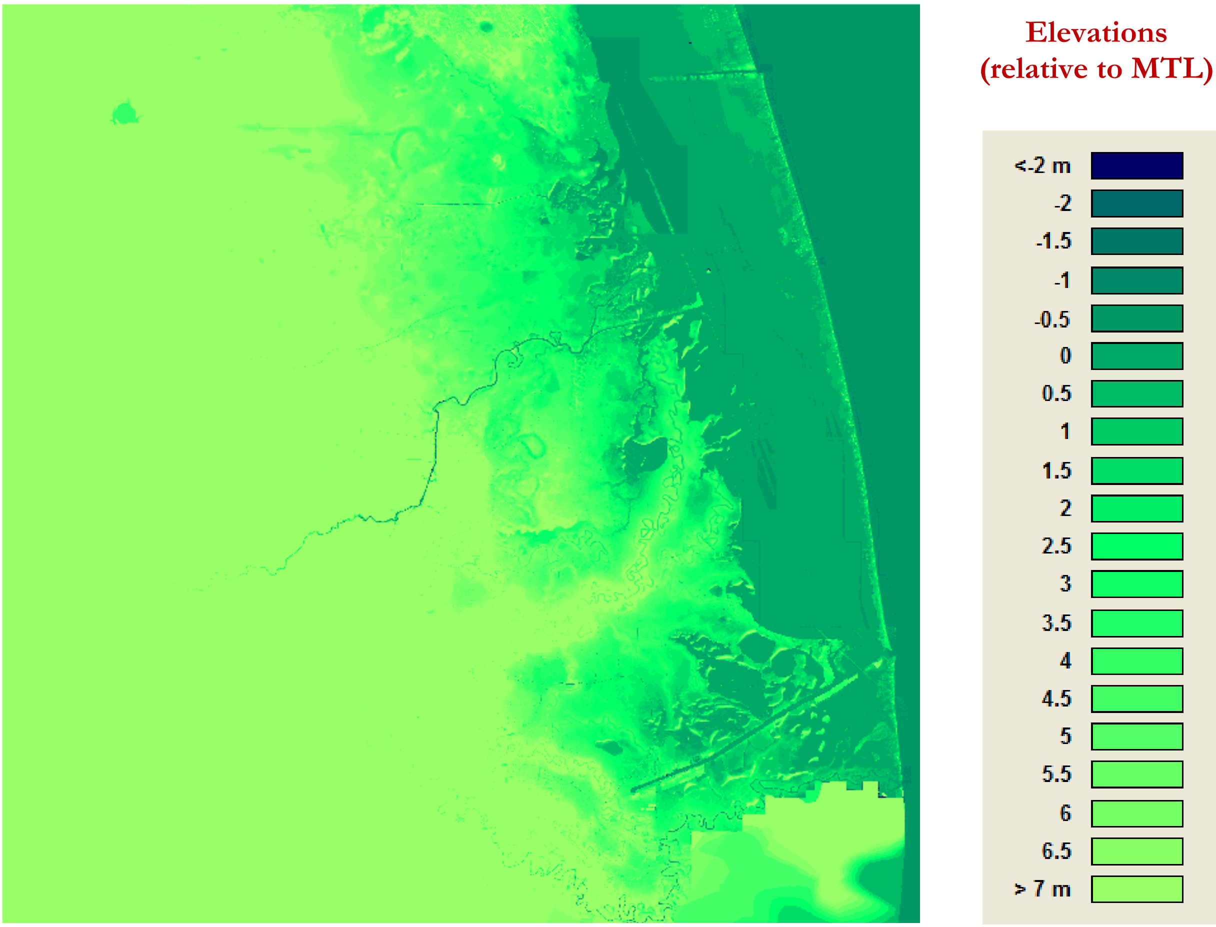


Figure 3. Shade-relief elevation map of the study area.

Model Timesteps. Model forecast outputs were chosen at years 2025, 2050, 2075 and 2100 with the initial condition date set to 1994 (the most recent wetland data available).

Dikes and Impoundments. According to the National Wetland Inventory, there are some inland fresh marsh and open water areas that are protected by dikes, as shown in Figure 4 for the entire contextual area.

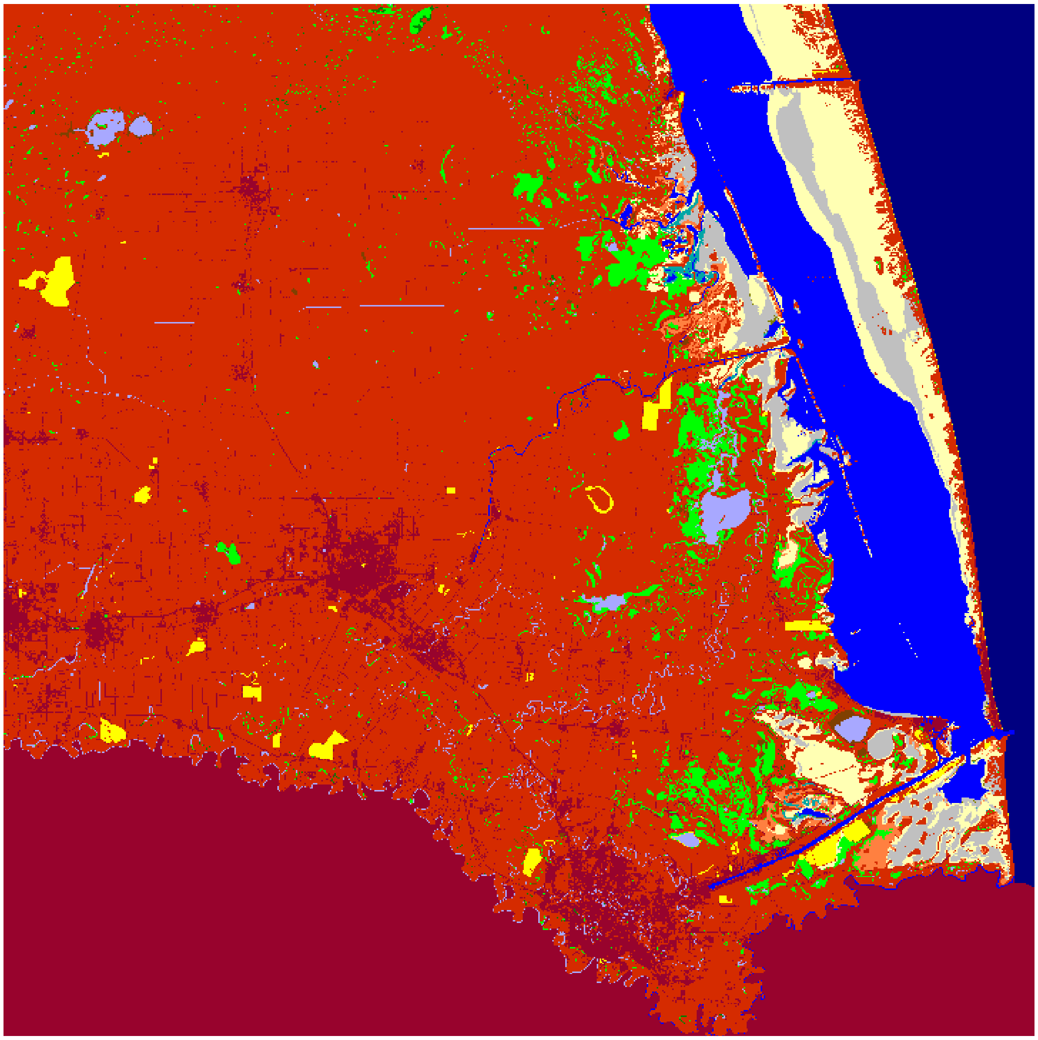


Figure 4. Dikes present in the study area (represented in yellow)

Historic sea-level rise rates. In the southern portion of the study area, at the NOAA gauge stations of Port Isabel (ID 8779770) and Padre Island (ID 8779750), measured historic rates of SLR are similar and average 3.64 mm/yr. Further north, at the Port Mansfield, gauge station (ID 8778490), just in front of the water pass connecting Red Fish Bay and the Gulf of Mexico, the recorded trend is 1.93 mm/yr. At Rockport, in Aransas Bay, historic SLR is 5.16 mm/yr on average. These rates of SLR are higher than the global average for the last 100 years (approximately 1.7 mm/year, IPCC 2007a), potentially reflecting land subsidence at this site. The values recorded at Port Isabel and Padre Island were chosen for this SLAMM simulation they are site-specific and intermediate between other trends measured in this part of the Gulf of Mexico.

Tide Ranges. Figure 5 shows the locations of the 4 tide gauge stations (red marks) within the study area used to define the tide ranges for this site.

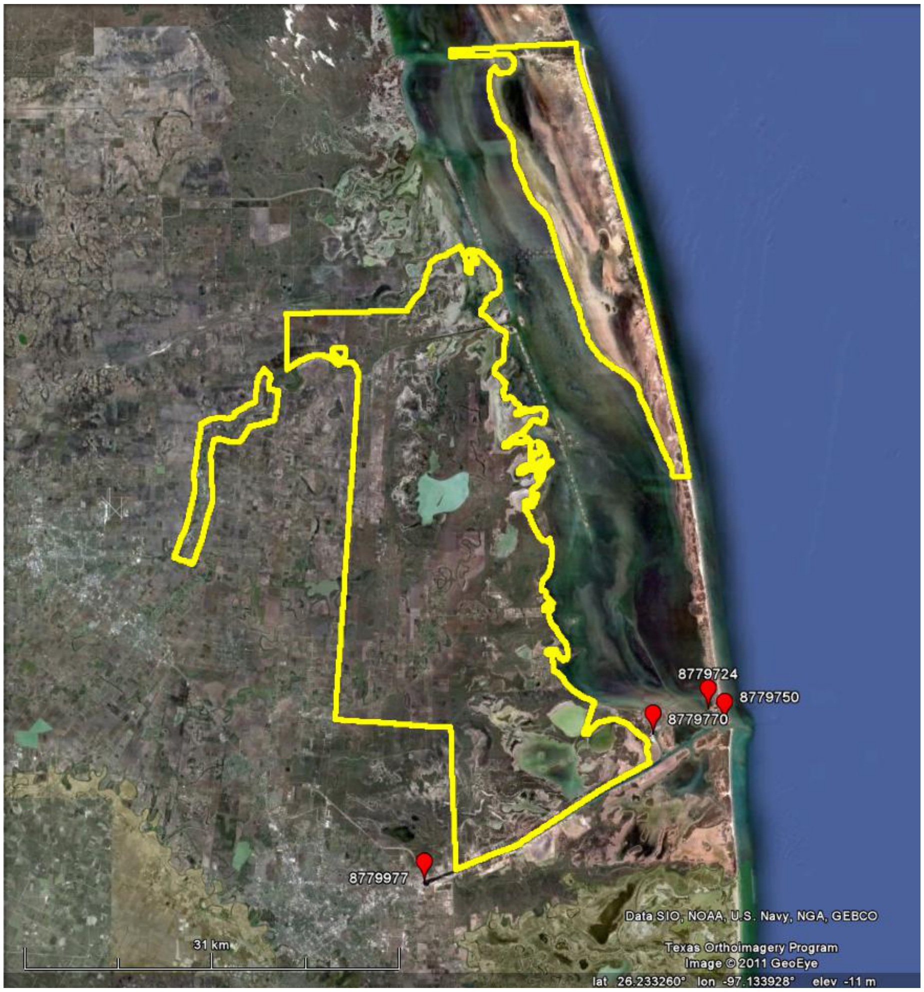


Figure 5. Location of NOAA tides gages used for Laguna Atascosa NWR

The great diurnal tide range was derived by taking the average value of all the four stations observed values, summarized in Table 1, and subsequently
set to 0.4 m.

Table 1. NOAA tide gauges and values.

Station ID	Site Name	Tide Range (m)
8779977	Brownsville, TX	0.462
8779770	Port Isabel, TX	0.425
8779750	South Padre Island C.g Station, TX	0.48
8779724	Queen Isabella Causeway, TX	0.391

Salt elevation. This parameter within SLAMM designates the boundary between wet lands and dry lands or saline wetlands and fresh water wetlands. As such, this value may be best derived by examining historical tide gage data. For this application, the salt boundary was defined as the elevation above which inundation is predicted less than once per thirty days using data from the gauge station at Brownsville, TX (ID 8779977) and Port Isabel, TX (ID 87779770). Estimated salt elevation are very similar, approximately 2.1 Half Tide Units (HTU). As the great tide range is estimated to be uniform in the study area, 0.4 m above MTL, salt elevation is set to 0.42 m above MTL.

Accretion/erosion rates. Accretion and erosion rates for marshes are summarized in Table 2 and were set to the values used in a recent study of Aransas NWR (Callaway et al. 1997), a little further north of the Lower Rio Grande Valley NWR.

Elevation correction. The MTL to NAVD88 correction of -0.035 m was derived using NOAA gauge stations in the area that have this datum, Port Isabel and Queen Island Causeway (ID 8779739).

Refuge boundaries. Modeled USFWS refuge boundaries for Texas are based on Approved Acquisition Boundaries as published on the FWS National Wildlife Refuge Data and Metadata website. The cell-size used for this analysis was 30 m by 30 m cells.

Input subsites and parameter summary. Based on the different dates of the DEM, 5 different simulation input subsites were identified as illustrated in Figure 6. Table 2 summarizes all SLAMM input parameters for each subsite of the study area. Values for parameters with no specific local information were kept at their default value.

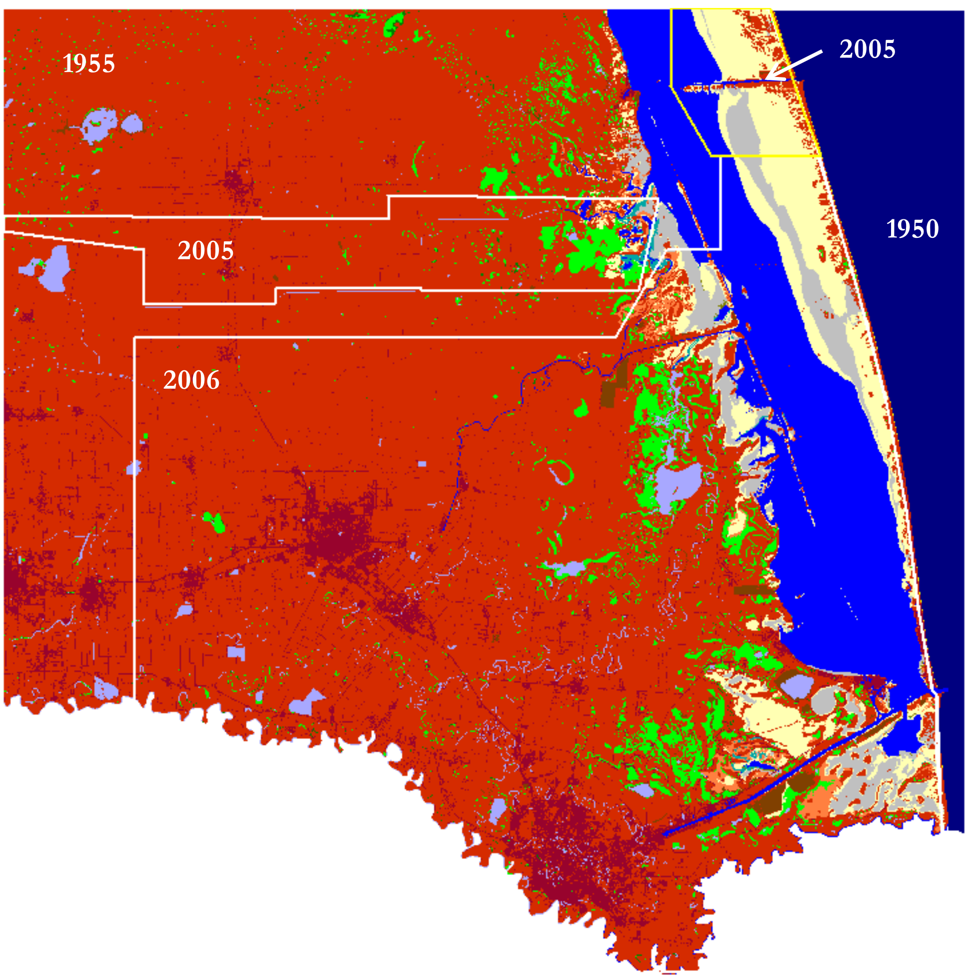


Figure 6. Input subsites for model application.

Table 2. Summary of SLAMM input parameters for Laguna Atascosa NWR

Description	Inland	North Barrier	Lidar 2006	Lidar 2005	Open Ocean
NWI Photo Date (YYYY)	1994	1994	1994	1994	1994
DEM Date (YYYY)	1955	2005	2006	2005	1950
Direction Offshore [n,s,e,w]	East	East	East	East	East
Historic Trend (mm/yr)	3.64	3.64	3.64	3.64	3.64
MTL-NAVD88 (m)	-0.036	-0.036	-0.036	-0.036	-0.036
GT Great Diurnal Tide Range (m)	0.4	0.4	0.4	0.4	0.4
Salt Elev. (m above MTL)	0.42	0.42	0.42	0.42	0.42
Marsh Erosion (horz. m /yr)	1.8	1.8	1.8	1.8	1.8
Swamp Erosion (horz. m /yr)	1	1	1	1	1
T.Flat Erosion (horz. m /yr)	0.5	0.5	0.5	0.5	0.5
Reg.-Flood Marsh Accr (mm/yr)	4.4	4.4	4.4	4.4	4.4
Irreg.-Flood Marsh Accr (mm/yr)	4.4	4.4	4.4	4.4	4.4
Tidal-Fresh Marsh Accr (mm/yr)	5.9	5.9	5.9	5.9	5.9
Inland-Fresh Marsh Accr (mm/yr)	5.9	5.9	5.9	5.9	5.9
Mangrove Accr (mm/yr)	7	7	7	7	7
Tidal Swamp Accr (mm/yr)	1.1	1.1	1.1	1.1	1.1
Swamp Accretion (mm/yr)	0.3	0.3	0.3	0.3	0.3
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5	0.5
Freq. Overwash (years)	0	0	0	0	0
Use Elev Pre-processor [True,False]	TRUE	FALSE	FALSE	FALSE	TRUE

Results

This simulation of the Laguna Atascosa NWR predicts that refuge wetlands will be significantly impacted for all SLR scenarios. Table 3 presents the predicted loss of each wetland category by 2100 for each of the five SLR scenarios examined.

Table 3. Predicted loss rates of land categories by 2100 given simulated scenarios of eustatic SLR at Laguna Atascosa NWR

Land cover category	Initial coverage (acres)	Land cover loss by 2100 for different SLR scenarios				
		0.39 m	0.69 m	1 m	1.5 m	2 m
Undeveloped Dry Land	118773	4%	7%	9%	16%	25%
Estuarine Beach	44757	43%	76%	92%	95%	98%
Tidal Flat	21961	70%	93%	83%	79%	75%
Inland Fresh Marsh	20796	0%	2%	6%	15%	47%
Developed Dry Land	5735	3%	5%	7%	14%	23%
Irregularly Flooded Marsh	4598	3%	30%	62%	81%	91%
Inland Shore	3542	15%	18%	24%	34%	45%
Regularly Flooded Marsh	690	-154%([1])	-442%	-513%	-630%	-1255%
Swamp	193	0%	0%	1%	7%	22%
Ocean Beach	139	-141%	-436%	-666%	-430%	-160%

([1]) A negative loss indicates a gain with respect to initial coverage

Approximately 20,000 to 60,000 acres of the refuge are predicted to be converted into open water by 2100, depending on the SLR scenario considered. Undeveloped-dry land, that today covers approximately 50% of the area, is predicted to be relatively resilient with a maximum predicted loss of 25% (29,000 acres) of the current coverage. Similar fractional losses are observed for developed dry land.

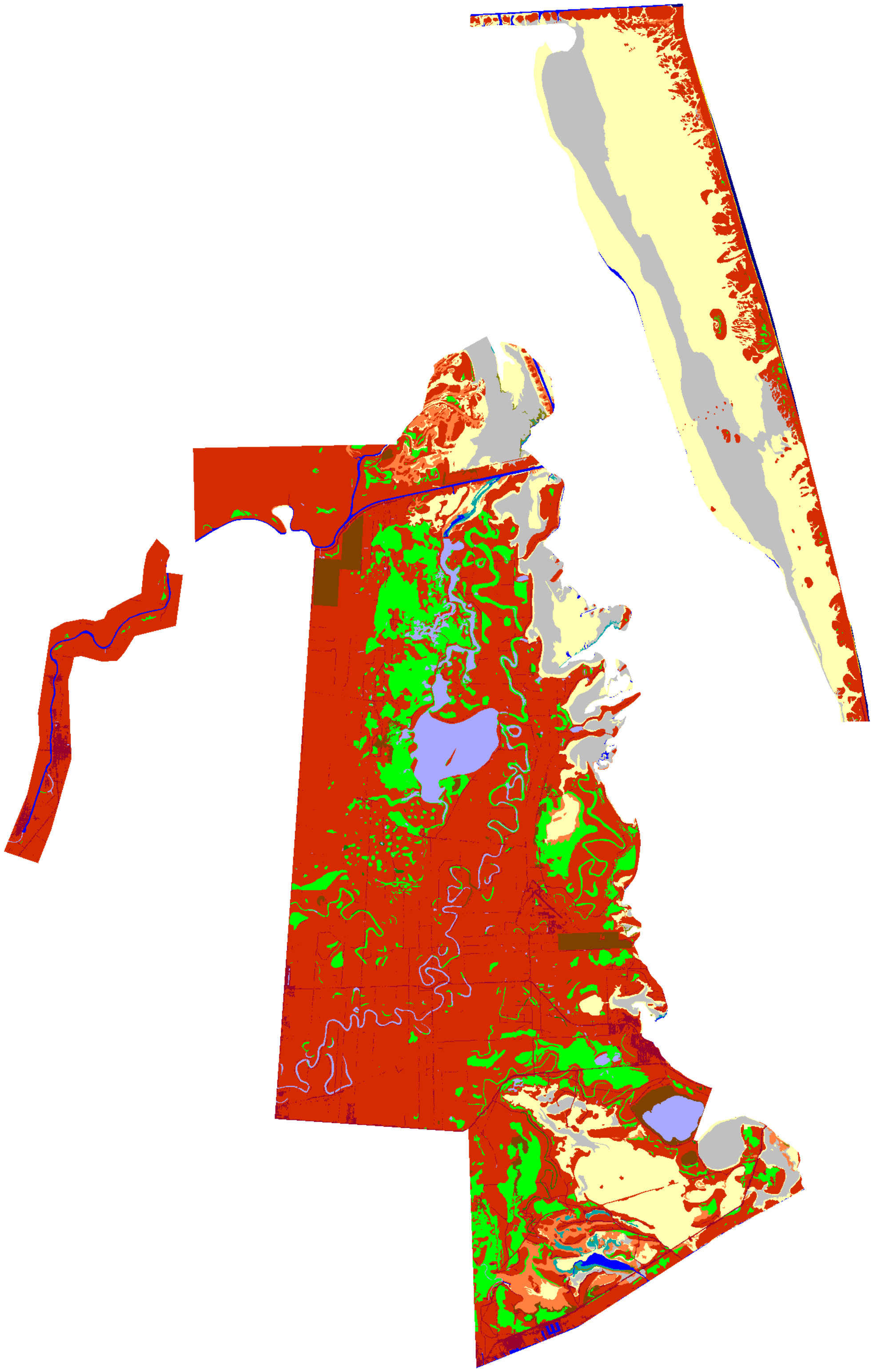
Other land cover types, although they currently cover a smaller fraction of the refuge, are predicted to be significantly affected.

- The beaches facing the Intracoastal Waterway, in particular on South Padre Island, may experience a loss ranging from 43% to 98%.
- For SLR higher than 1 m predicted losses for irregularly-flooded marshes are above 60%. Most of these high marshes are converted to regularly-flooded marsh, a land cover that is predicted to have significant gains for all SLR scenarios considered.
- Inland-fresh marsh, because of high elevations and inland location, appears to be resilient to SLR; only above 1.5 m SLR by 2100 do predicted losses for inland-fresh marsh exceed 15%.
- Swamp is also predicted to be resilient with losses of only 7% under SLR of 1.5 m, although the current coverage is only 190 acres.

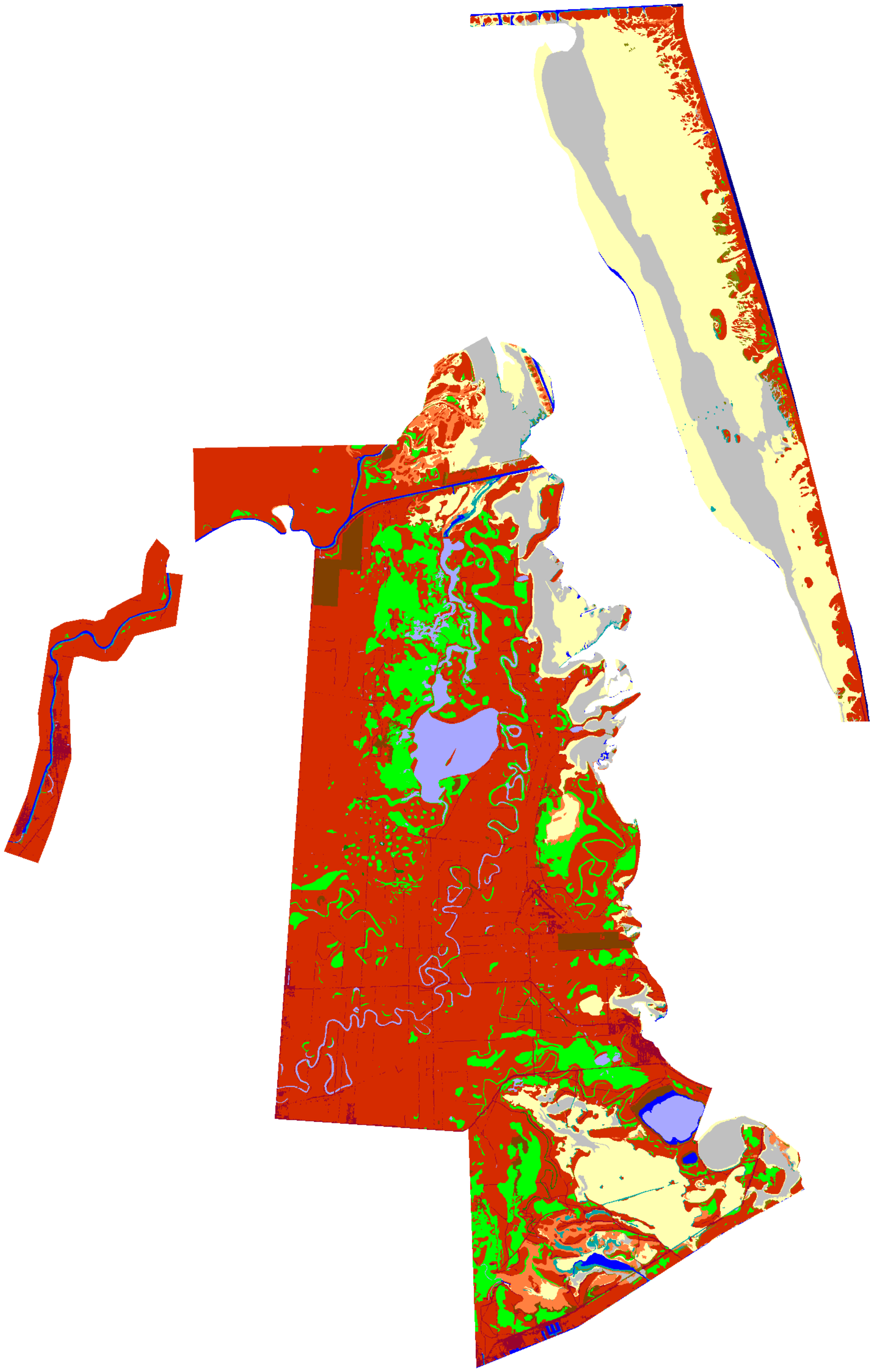
Laguna Atascosa NWR
IPCC Scenario A1B-Mean, 0.39 m SLR eustatic by 2100

Results in Acres

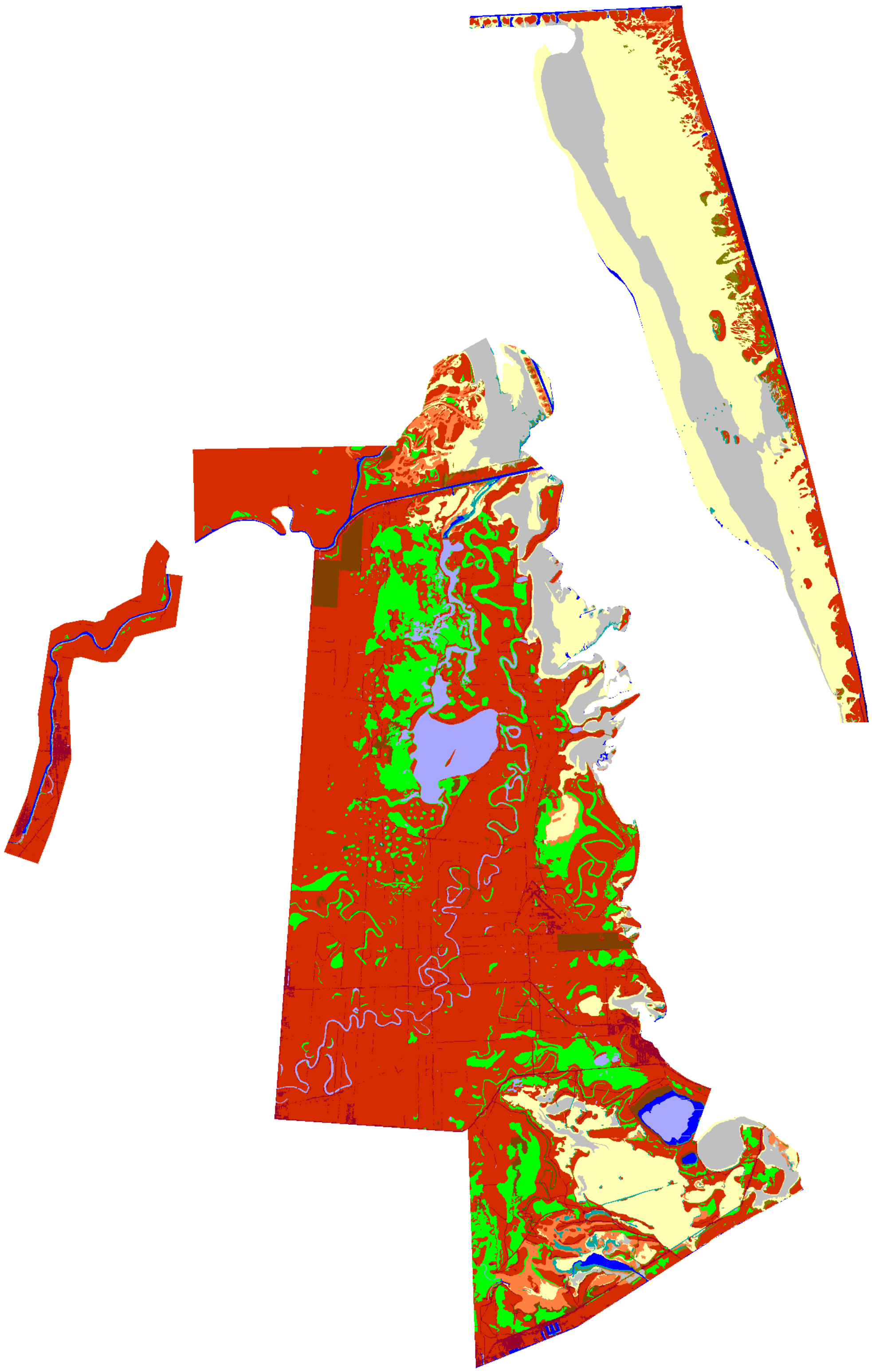
		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	118773	116390	115683	114707	113680
	Estuarine Beach	44757	44683	44556	32242	25436
	Tidal Flat	21961	21983	22201	14411	6695
	Inland Fresh Marsh	20796	20751	20743	20733	20729
	Inland Open Water	7215	7209	7002	6721	6626
	Developed Dry Land	5735	5629	5608	5579	5537
	Irregularly Flooded Marsh	4598	4494	4494	4490	4446
	Inland Shore	3542	3203	3193	3069	3013
	Estuarine Open Water	1399	2161	2590	23226	38015
	Regularly Flooded Marsh	690	1727	1562	1588	1756
	Open Ocean	497	514	535	547	557
	Riverine Tidal	419	169	168	167	164
	Swamp	193	193	193	193	193
	Transitional Salt Marsh	177	1683	2257	3026	3709
	Ocean Beach	139	103	106	195	337
	Total (incl. water)	**230891**	**230891**	**230891**	**230891**	**230891**



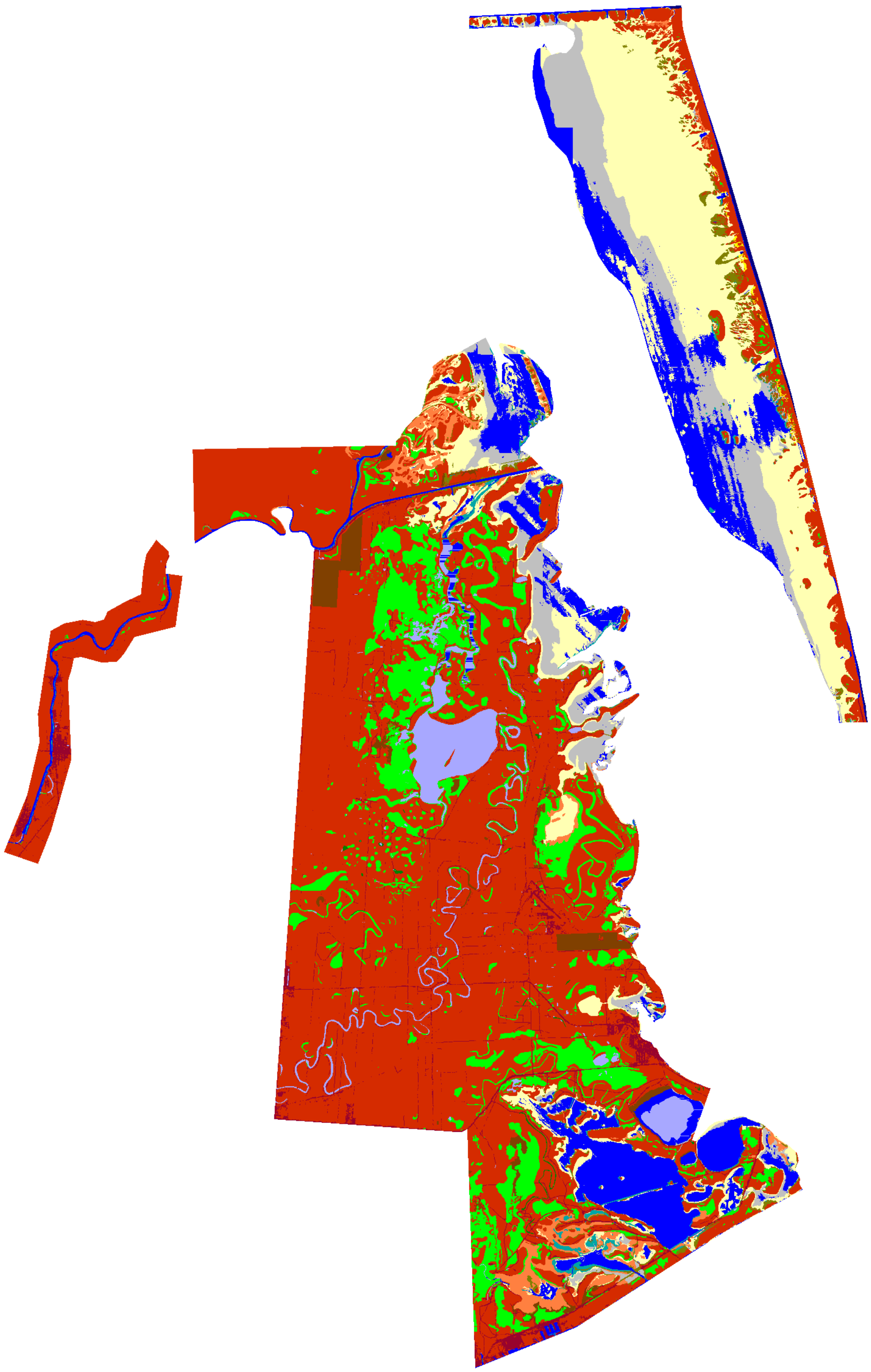
Laguna Atascosa NWR, Initial Condition



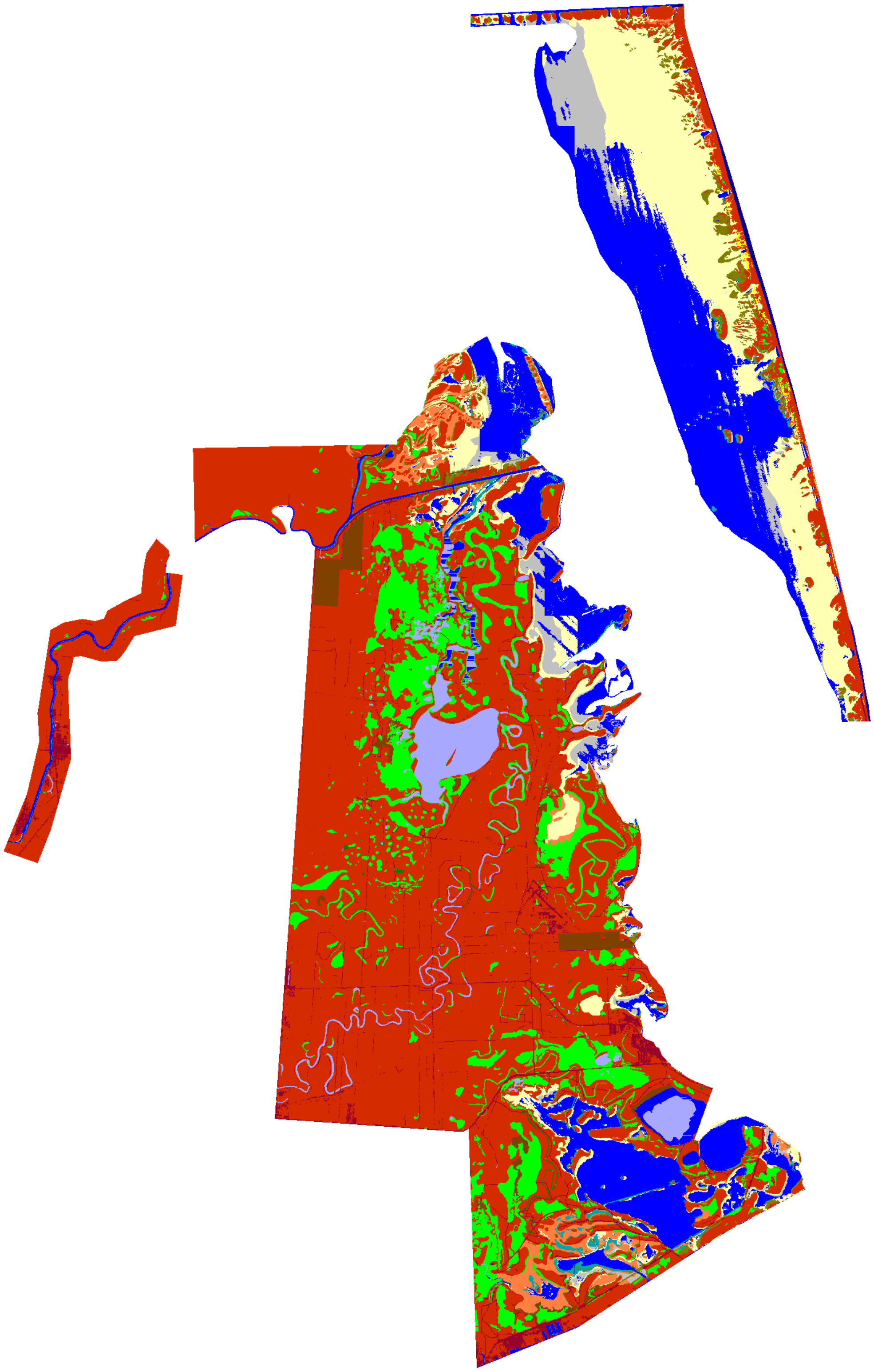
Laguna Atascosa NWR, 2025, Scenario A1B Mean, 0.39 m SLR



Laguna Atascosa NWR, 2050, Scenario A1B Mean, 0.39 m SLR



Laguna Atascosa NWR, 2075, Scenario A1B Mean, 0.39 m SLR

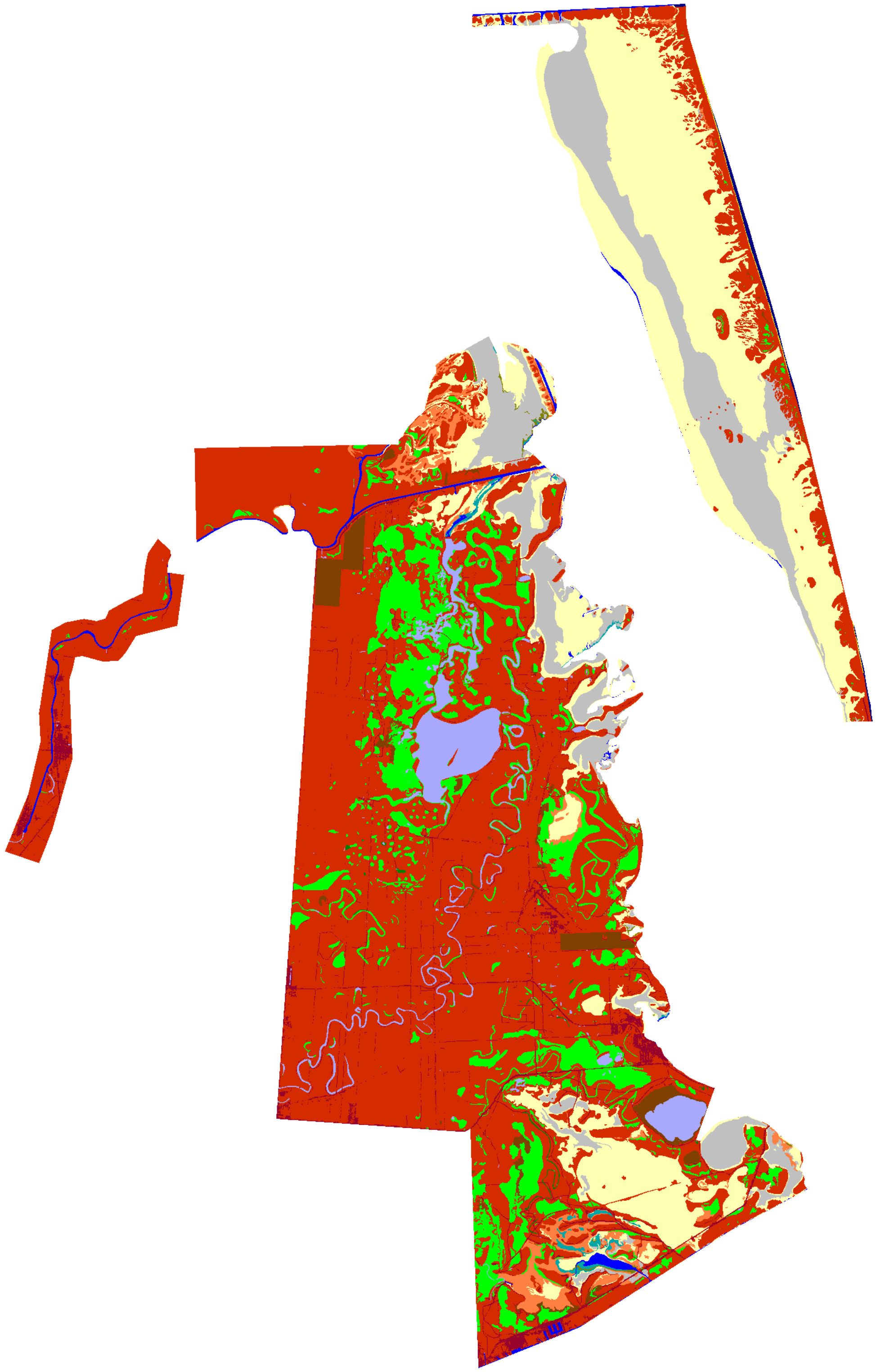


Laguna Atascosa NWR, 2100, Scenario A1B Mean, 0.39 m SLR

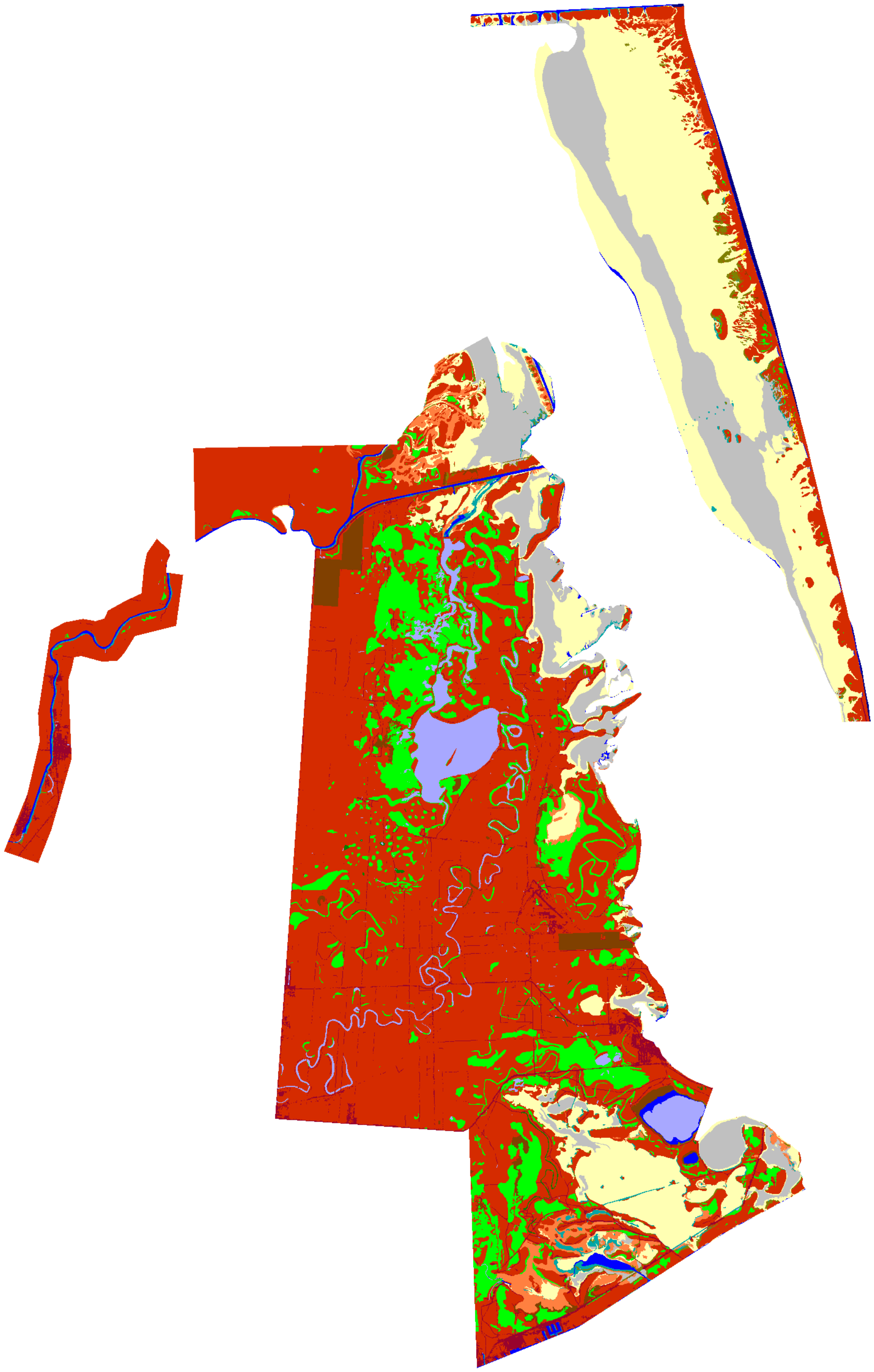
Laguna Atascosa NWR
IPCC Scenario A1B-Max, 0.69 m SLR eustatic by 2100

Results in Acres

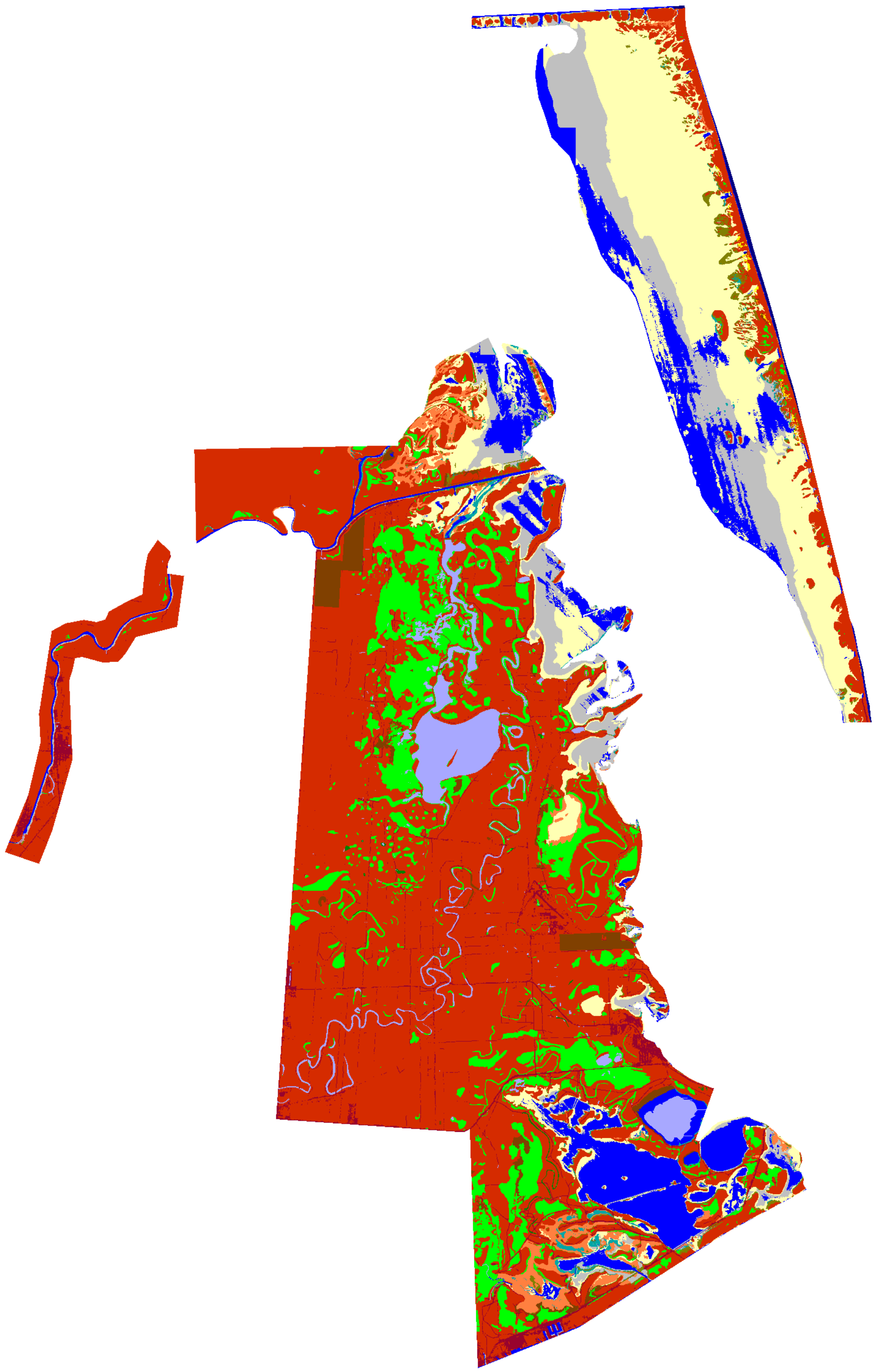
		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	118773	116051	114856	113052	110942
	Estuarine Beach	44757	44644	33064	22037	10669
	Tidal Flat	21961	21988	16100	4217	1519
	Inland Fresh Marsh	20796	20742	20704	20651	20429
	Inland Open Water	7215	7207	6996	6577	6419
	Developed Dry Land	5735	5620	5584	5523	5437
	Irregularly Flooded Marsh	4598	4476	4380	4024	3239
	Inland Shore	3542	3200	3085	2990	2890
	Estuarine Open Water	1399	2215	20890	45074	60703
	Regularly Flooded Marsh	690	1869	1516	2511	3740
	Open Ocean	497	523	562	583	618
	Riverine Tidal	419	169	167	164	159
	Swamp	193	193	193	193	193
	Transitional Salt Marsh	177	1876	2618	2888	3187
	Ocean Beach	139	118	177	408	747
	Total (incl. water)	**230891**	**230891**	**230891**	**230891**	**230891**



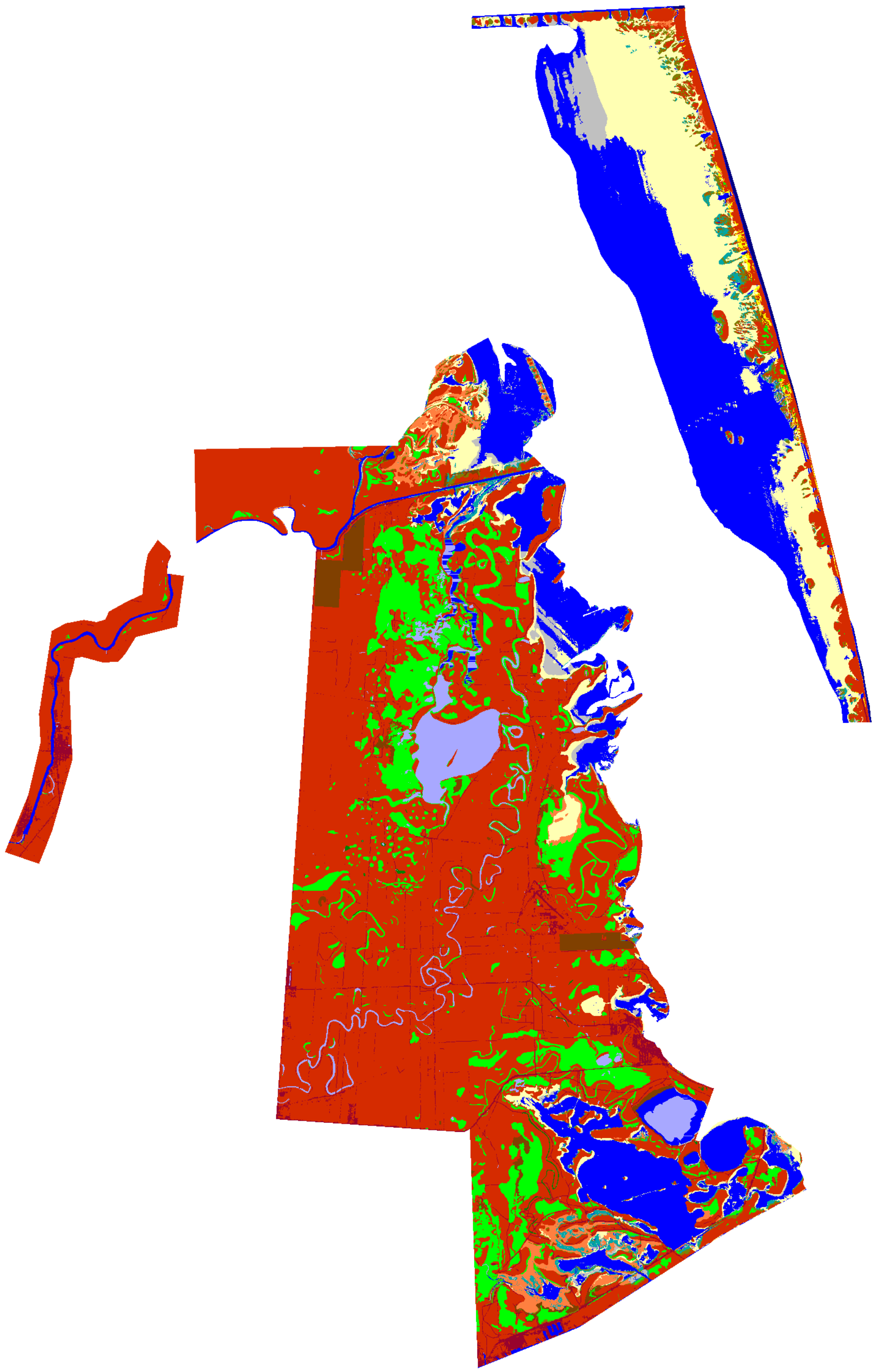
Laguna Atascosa NWR, Initial Condition



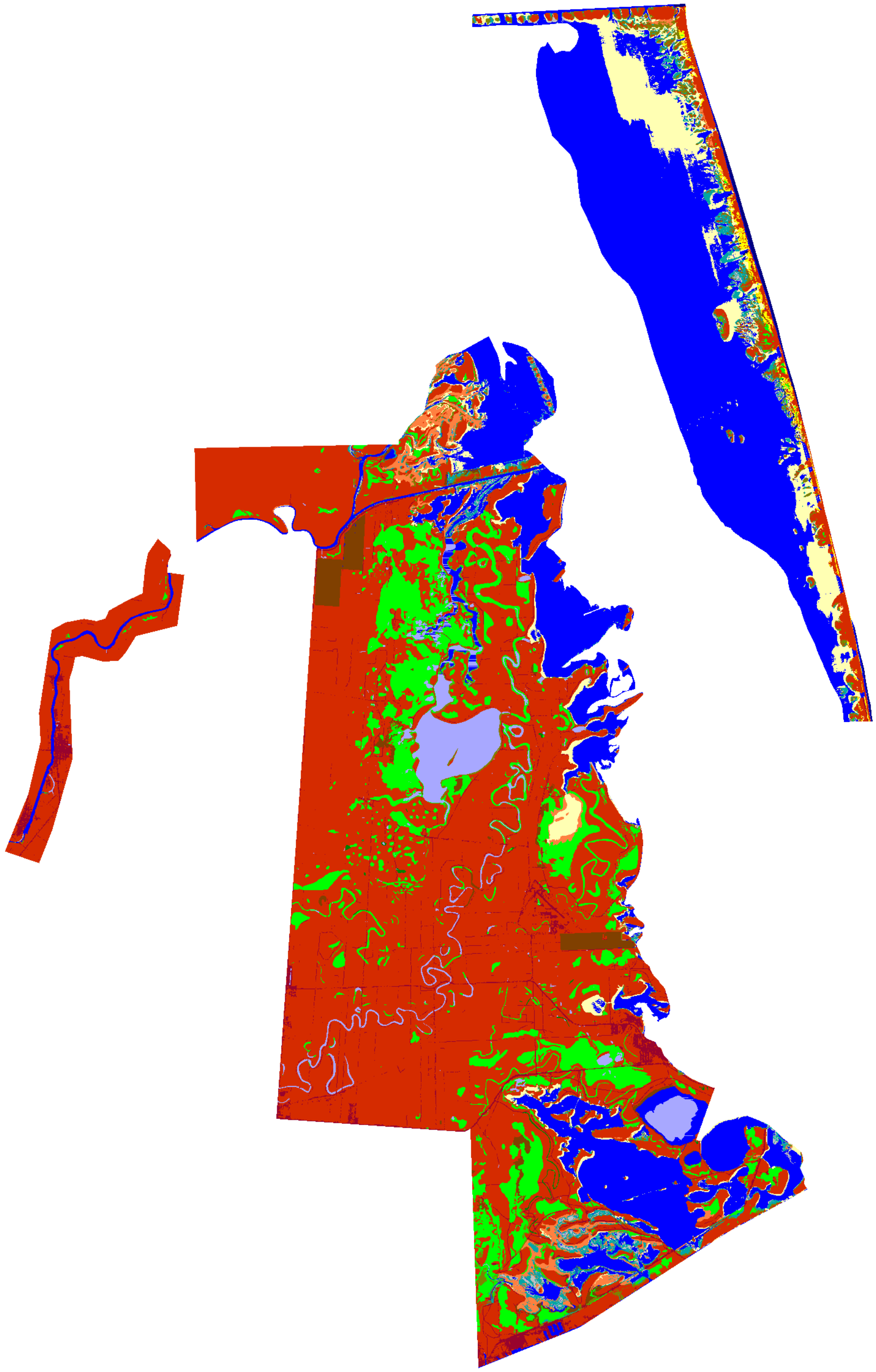
Laguna Atascosa NWR, 2025, Scenario A1B Maximum, 0.69 m SLR



Laguna Atascosa NWR, 2050, Scenario A1B Maximum, 0.69 m SLR



Laguna Atascosa NWR, 2075, Scenario A1B Maximum, 0.69 m SLR

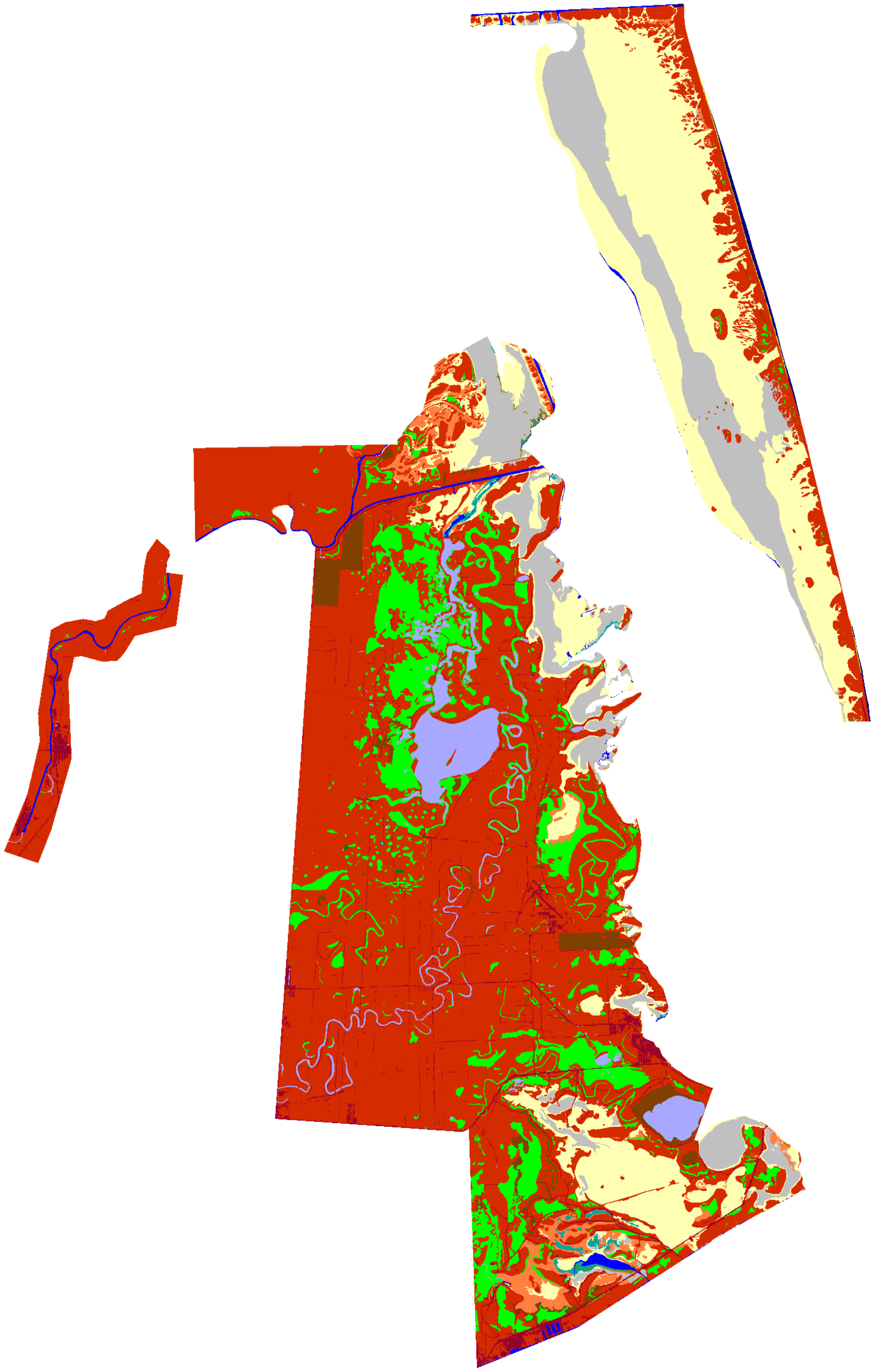


Laguna Atascosa NWR, 2100, Scenario A1B Maximum, 0.69 m SLR

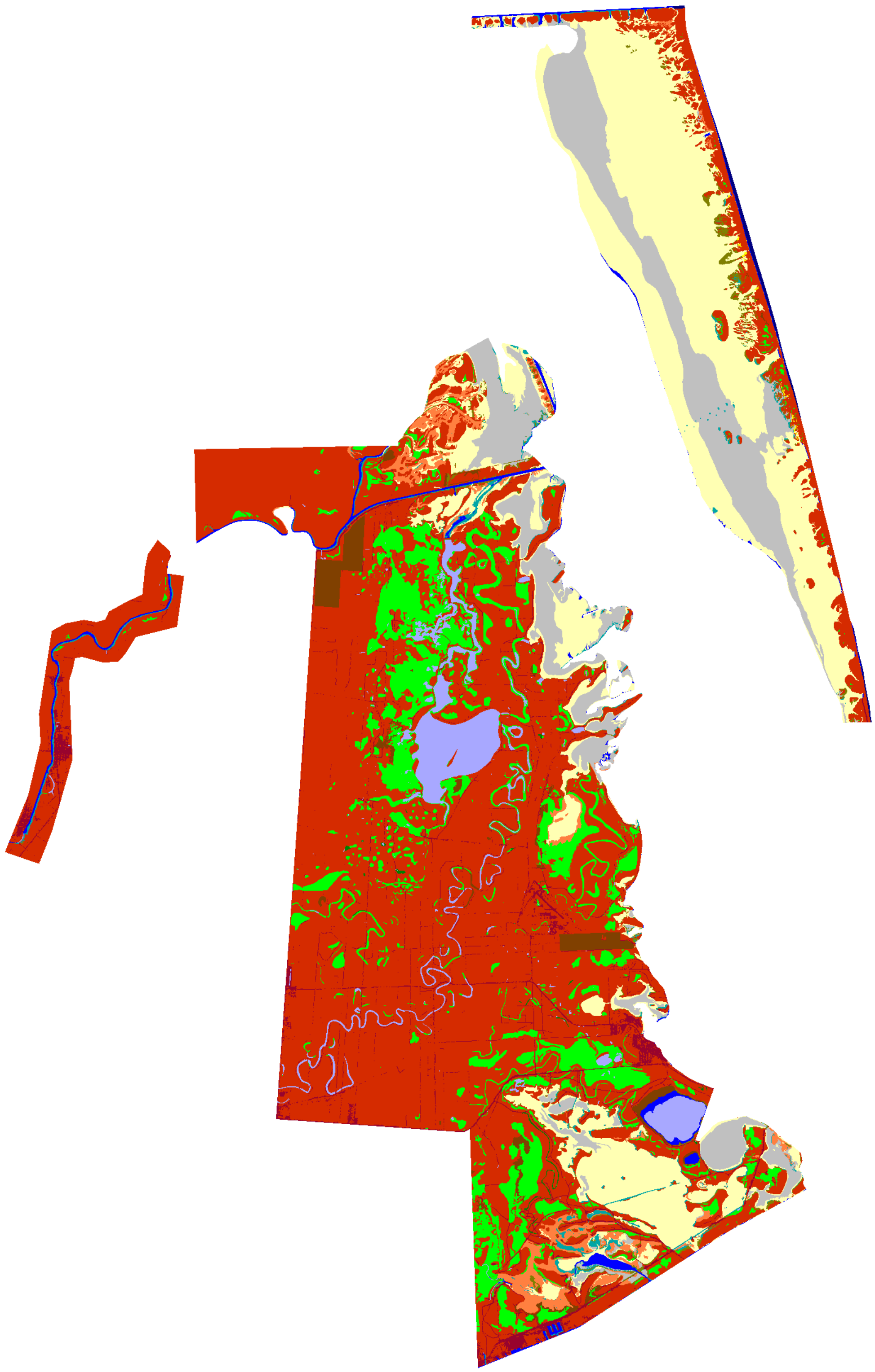
Laguna Atascosa NWR
1 m eustatic SLR by 2100

Results in Acres

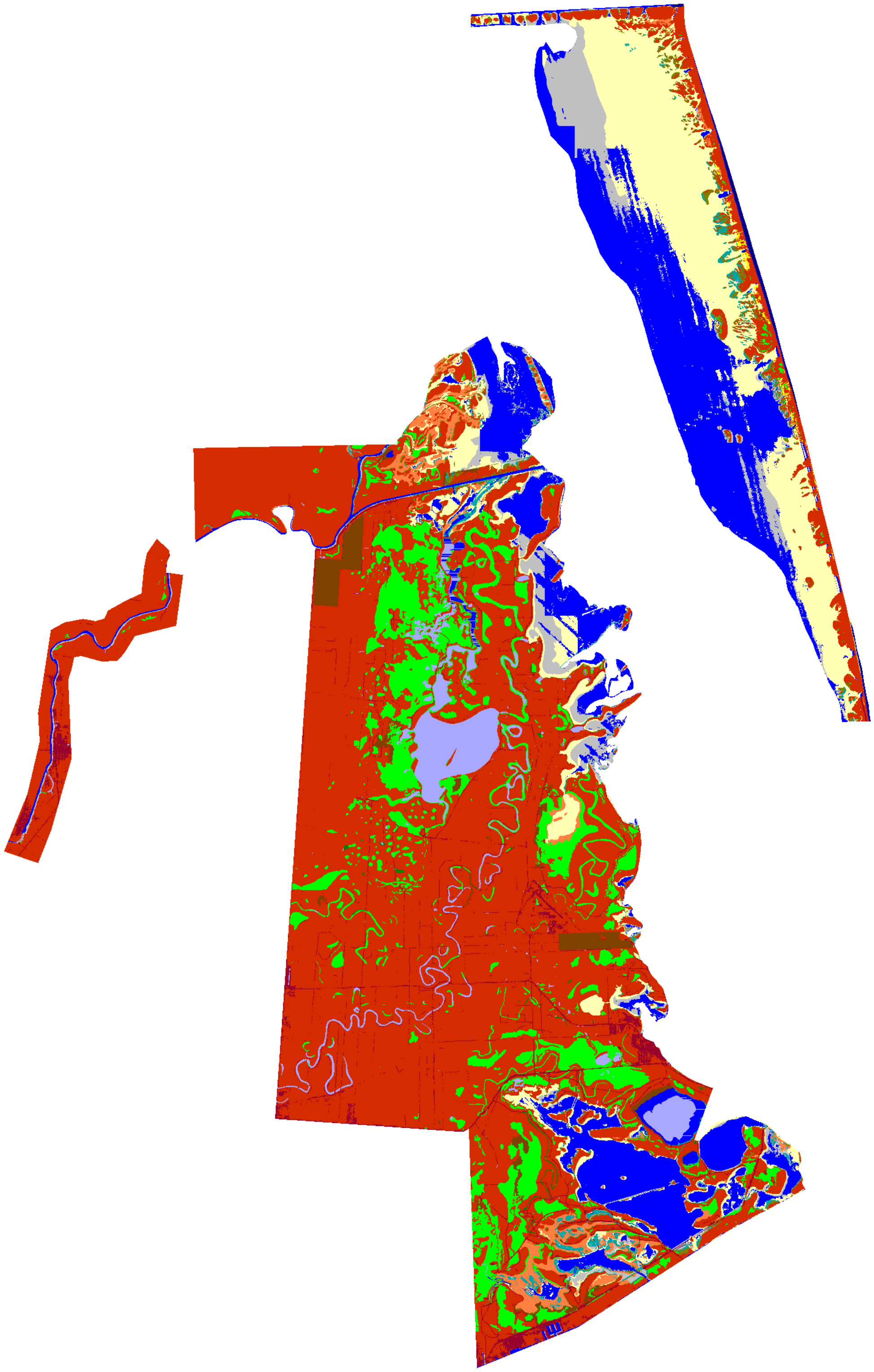
		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	118773	115710	113948	111121	107772
	Estuarine Beach	44757	44585	26435	11435	3698
	Tidal Flat	21961	22097	8772	2399	3676
	Inland Fresh Marsh	20796	20709	20628	19996	19450
	Inland Open Water	7215	7205	6734	6417	5275
	Developed Dry Land	5735	5611	5549	5445	5313
	Irregularly Flooded Marsh	4598	4417	4026	2727	1763
	Inland Shore	3542	3195	3028	2907	2676
	Estuarine Open Water	1399	2305	35725	59762	71386
	Regularly Flooded Marsh	690	1976	2354	3658	4227
	Open Ocean	497	533	581	617	824
	Riverine Tidal	419	168	165	159	154
	Swamp	193	193	193	193	191
	Transitional Salt Marsh	177	2062	2466	3362	3420
	Ocean Beach	139	126	287	694	1068
	Total (incl. water)	**230891**	**230891**	**230891**	**230891**	**230891**



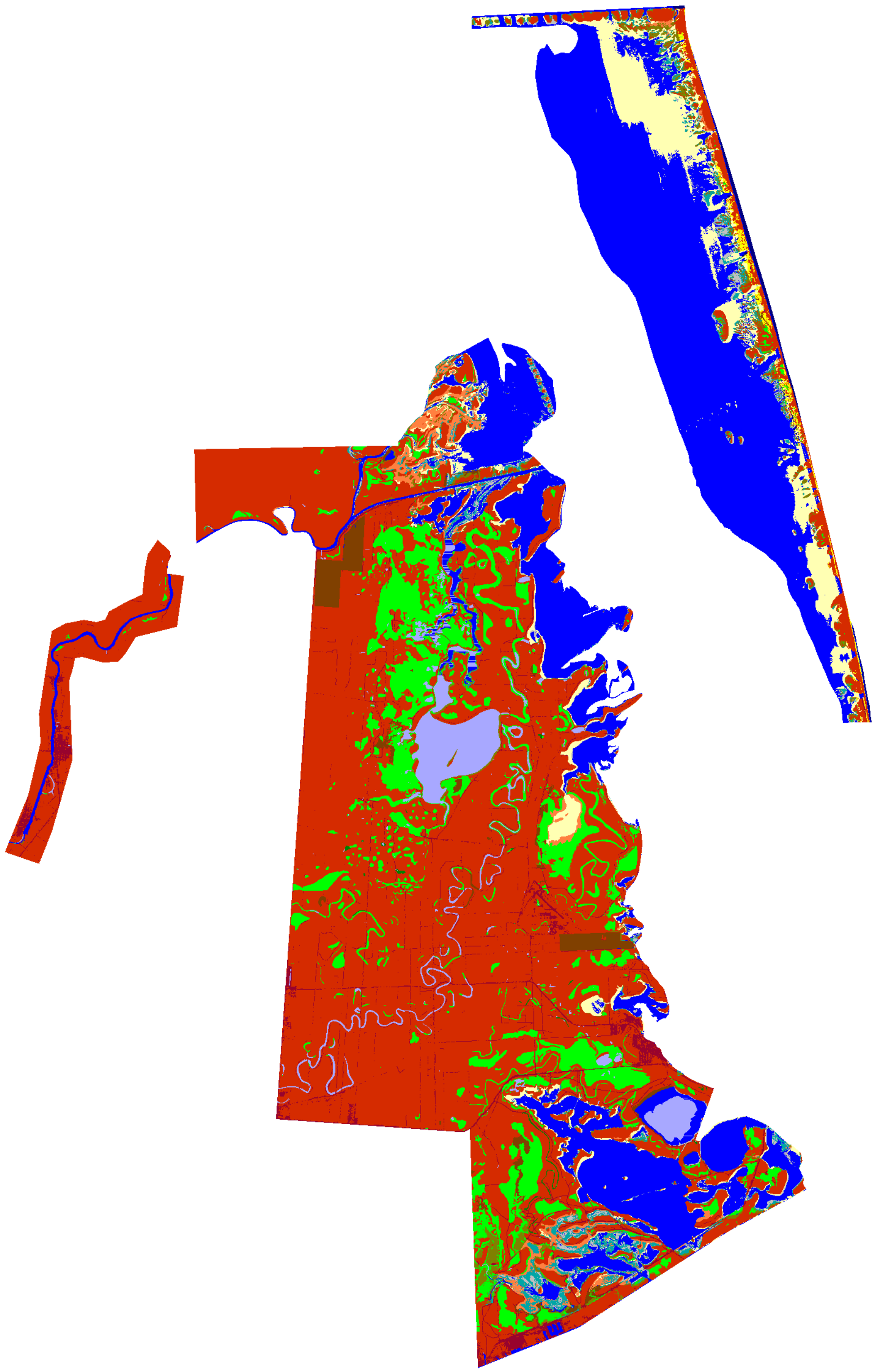
Laguna Atascosa NWR, Initial Condition



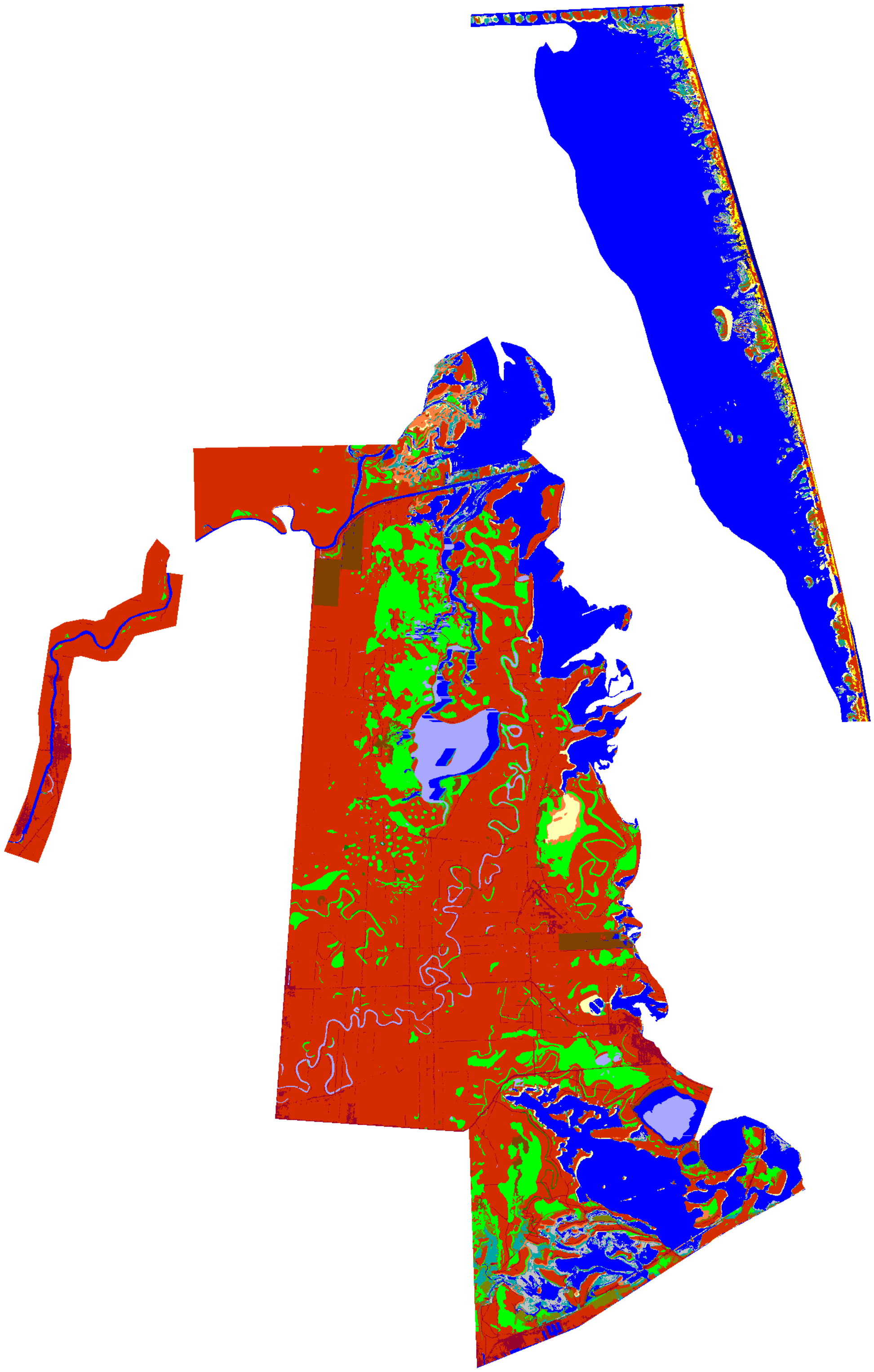
Laguna Atascosa NWR, 2025, 1 m SLR



Laguna Atascosa NWR, 2050, 1 m SLR



Laguna Atascosa NWR, 2075, 1 m SLR

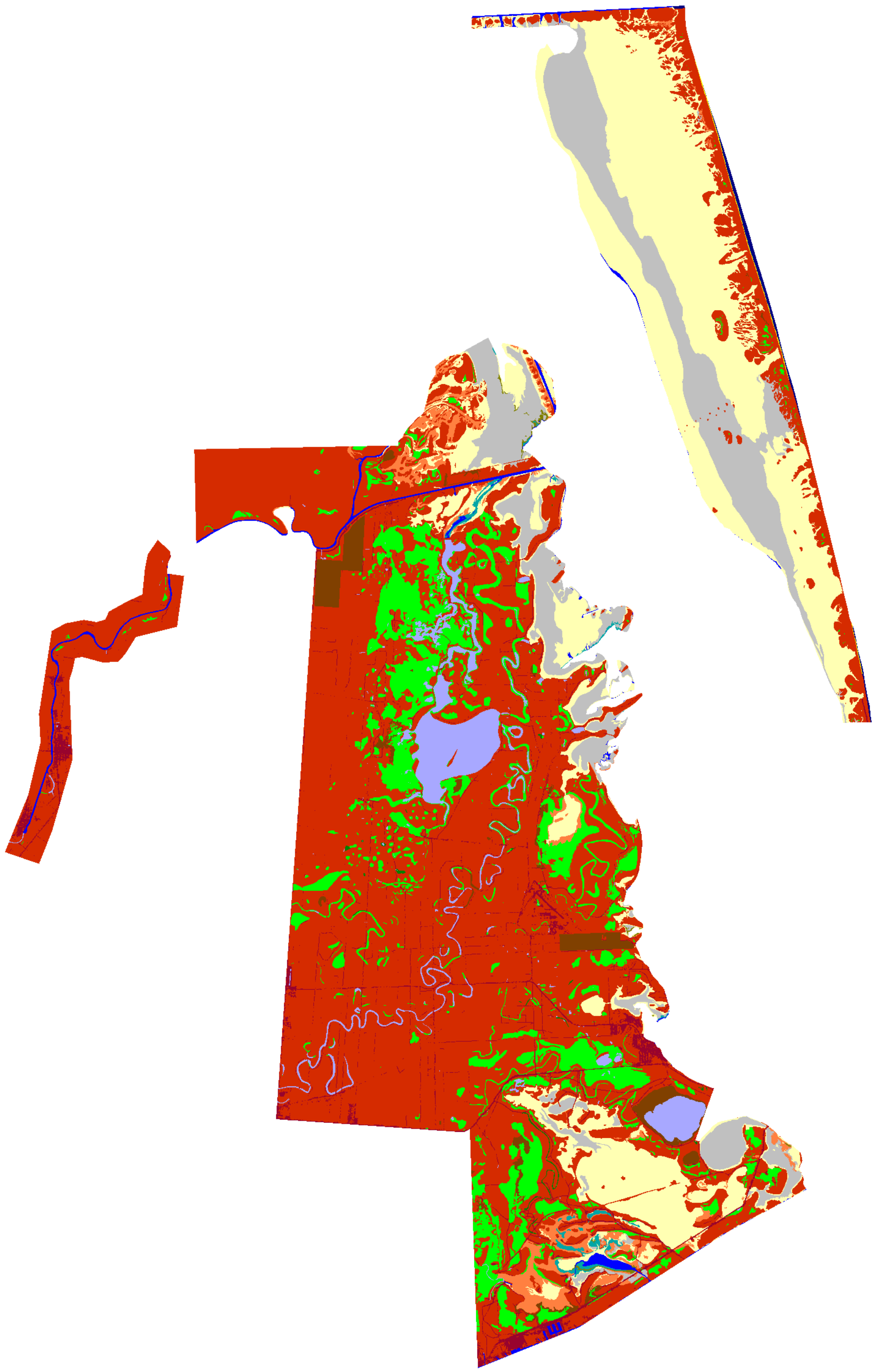


Laguna Atascosa NWR, 2100, 1 m SLR

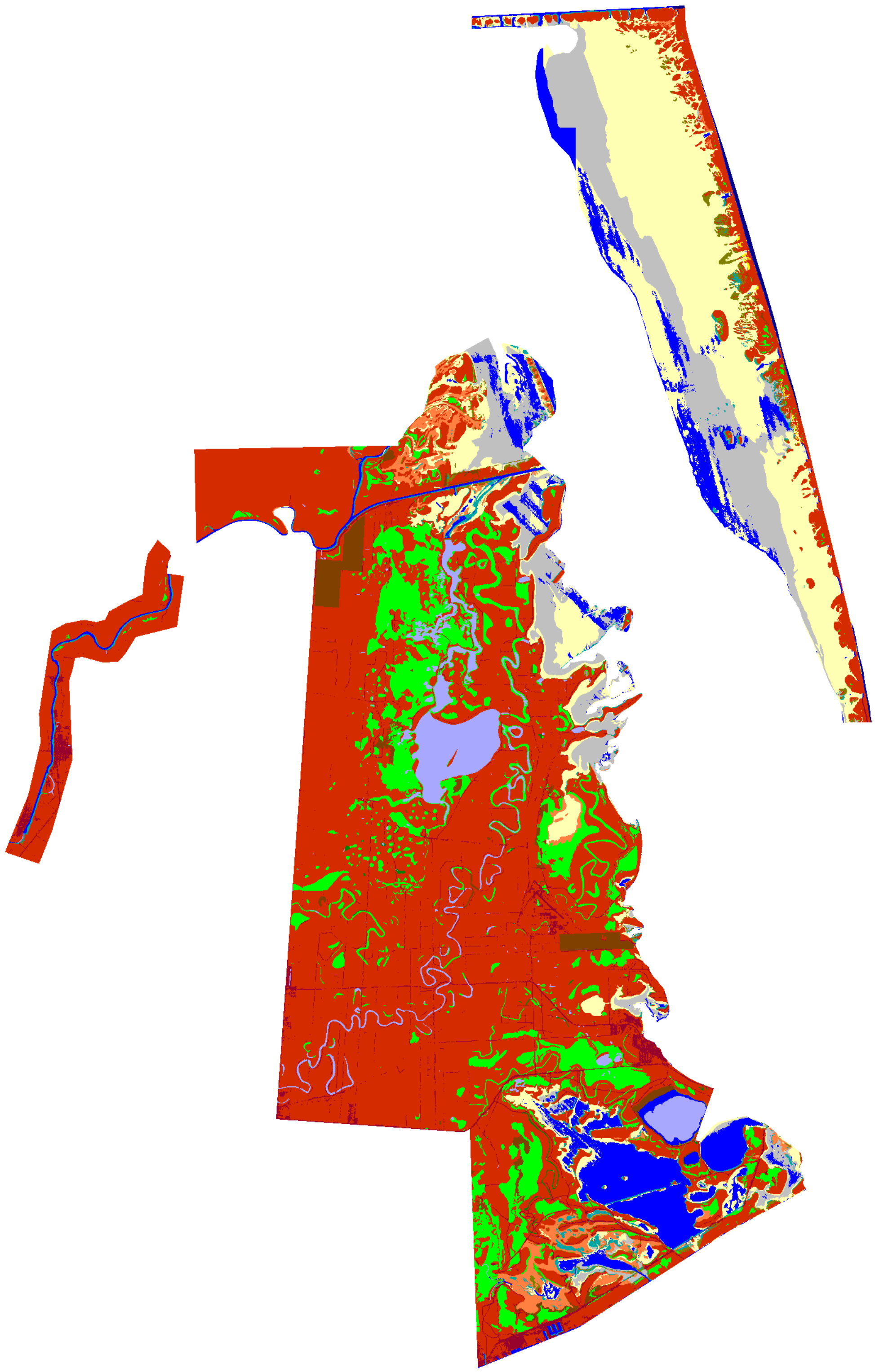
Laguna Atascosa NWR
1.5 m eustatic SLR by 2100

Results in Acres

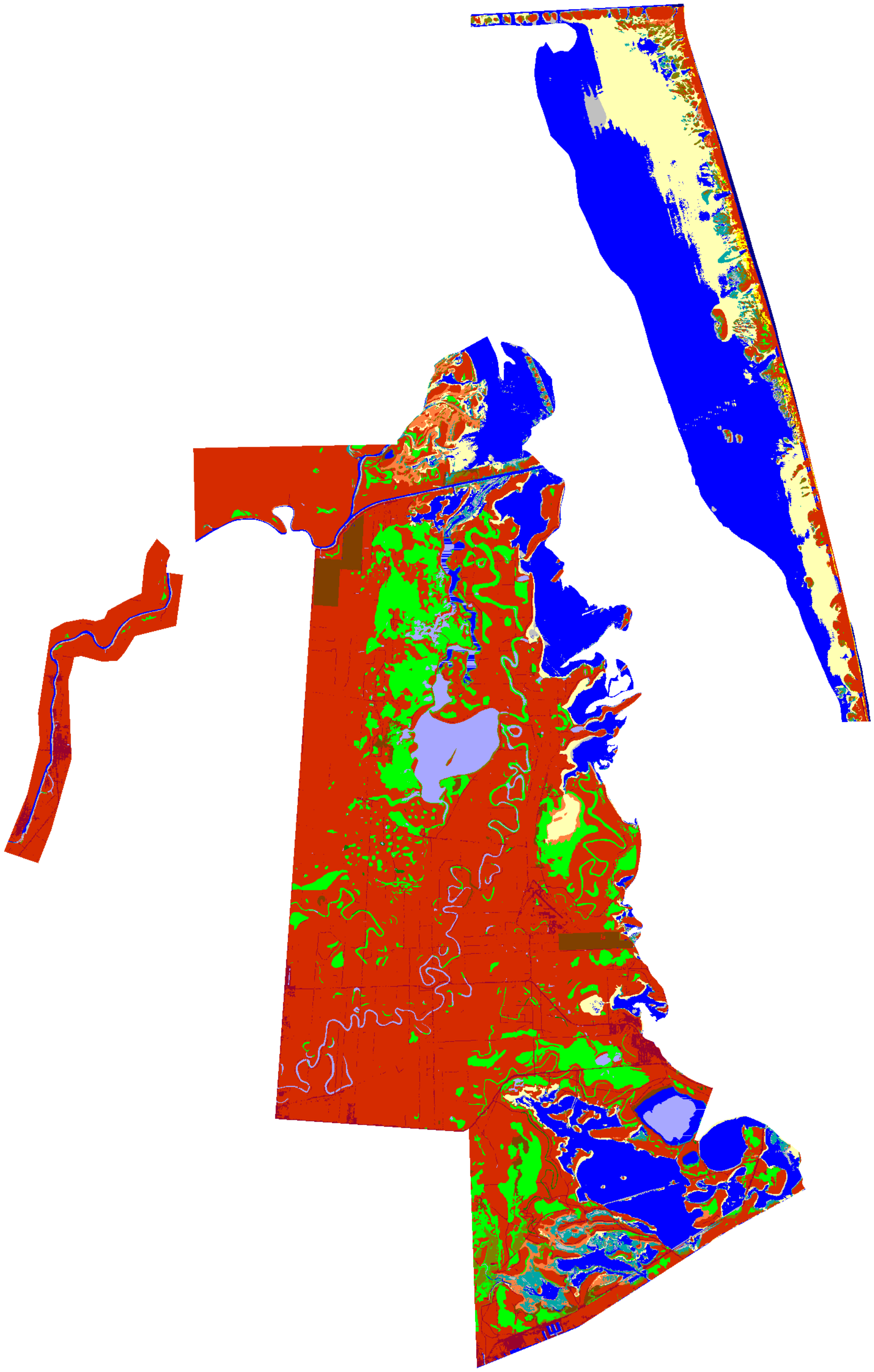
		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	118773	115179	112096	107617	99657
	Estuarine Beach	44757	35592	17522	3659	2081
	Tidal Flat	21961	18300	3079	4053	4716
	Inland Fresh Marsh	20796	20657	19938	19058	17630
	Inland Open Water	7215	7204	6565	5310	5028
	Developed Dry Land	5735	5595	5483	5306	4907
	Irregularly Flooded Marsh	4598	4247	2807	1438	889
	Inland Shore	3542	3115	2958	2669	2332
	Estuarine Open Water	1399	15321	51594	70316	76870
	Regularly Flooded Marsh	690	2332	3964	4768	5038
	Open Ocean	497	553	601	844	1520
	Riverine Tidal	419	167	161	154	148
	Swamp	193	193	193	190	179
	Transitional Salt Marsh	177	2290	3393	4500	9158
	Ocean Beach	139	146	537	1008	739
	Total (incl. water)	**230891**	**230891**	**230891**	**230891**	**230891**



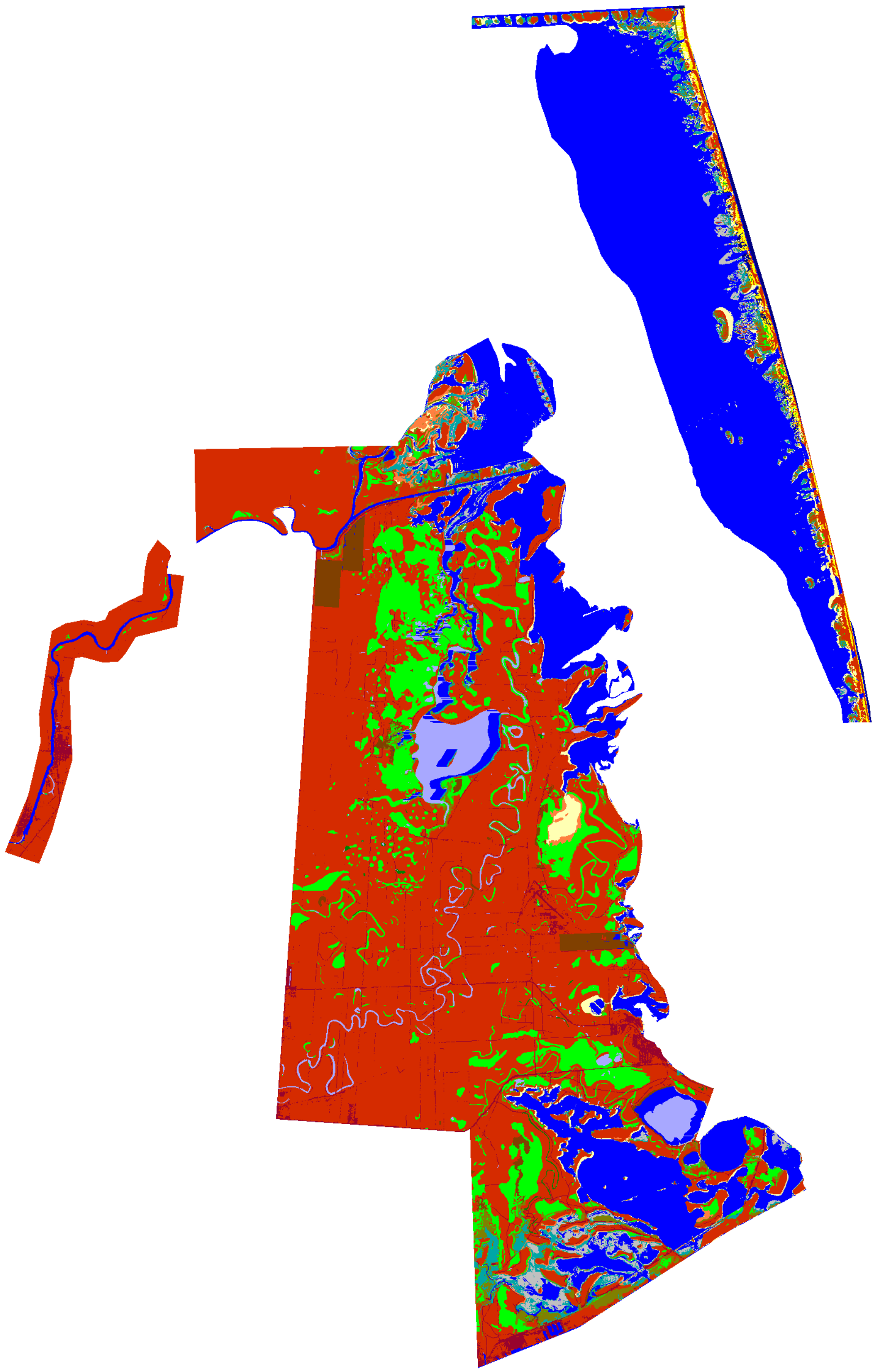
Laguna Atascosa NWR, Initial Condition



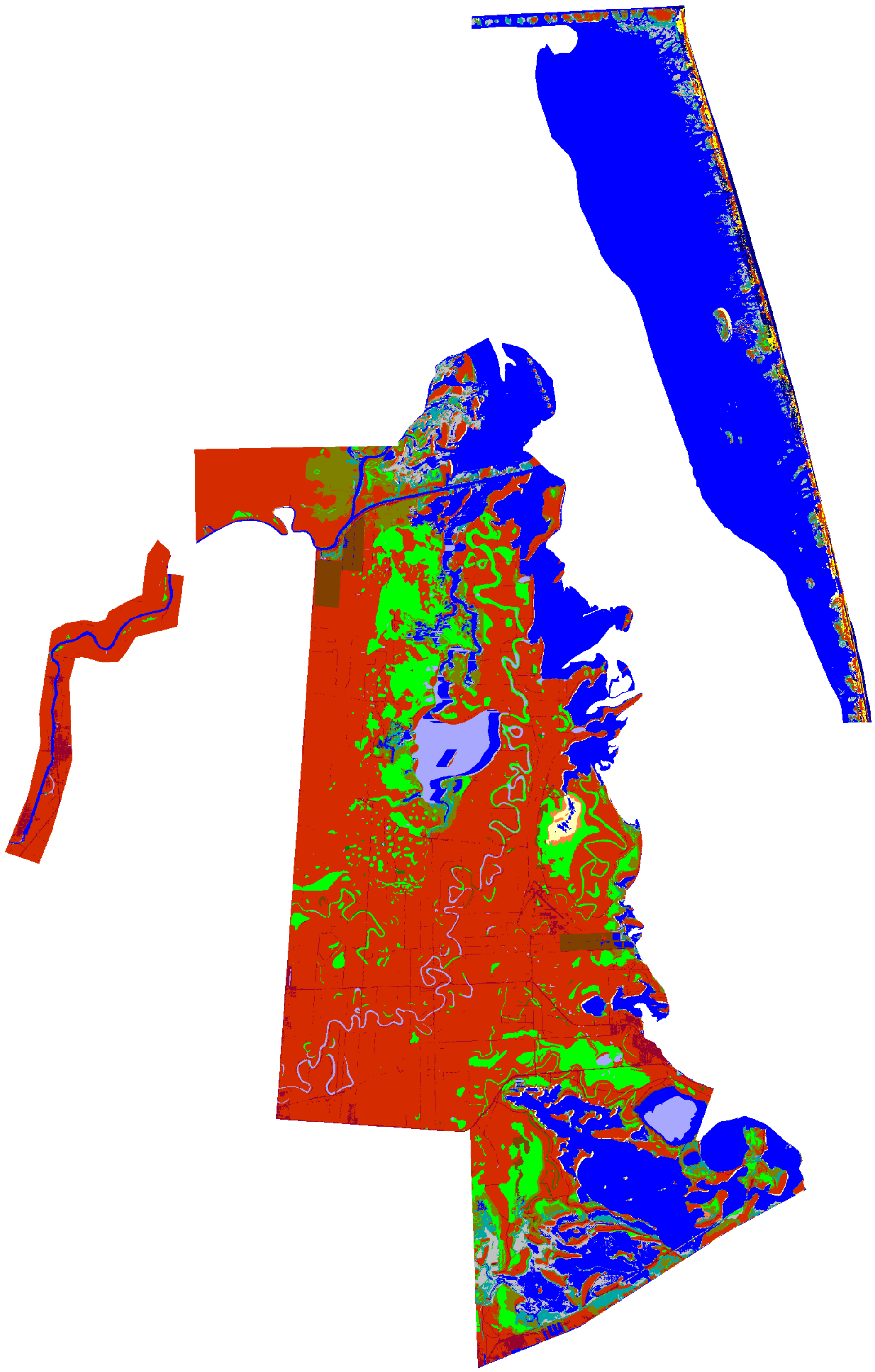
Laguna Atascosa NWR, 2025, 1.5 m SLR



Laguna Atascosa NWR, 2050, 1.5 m SLR



Laguna Atascosa NWR, 2075, 1.5 m SLR

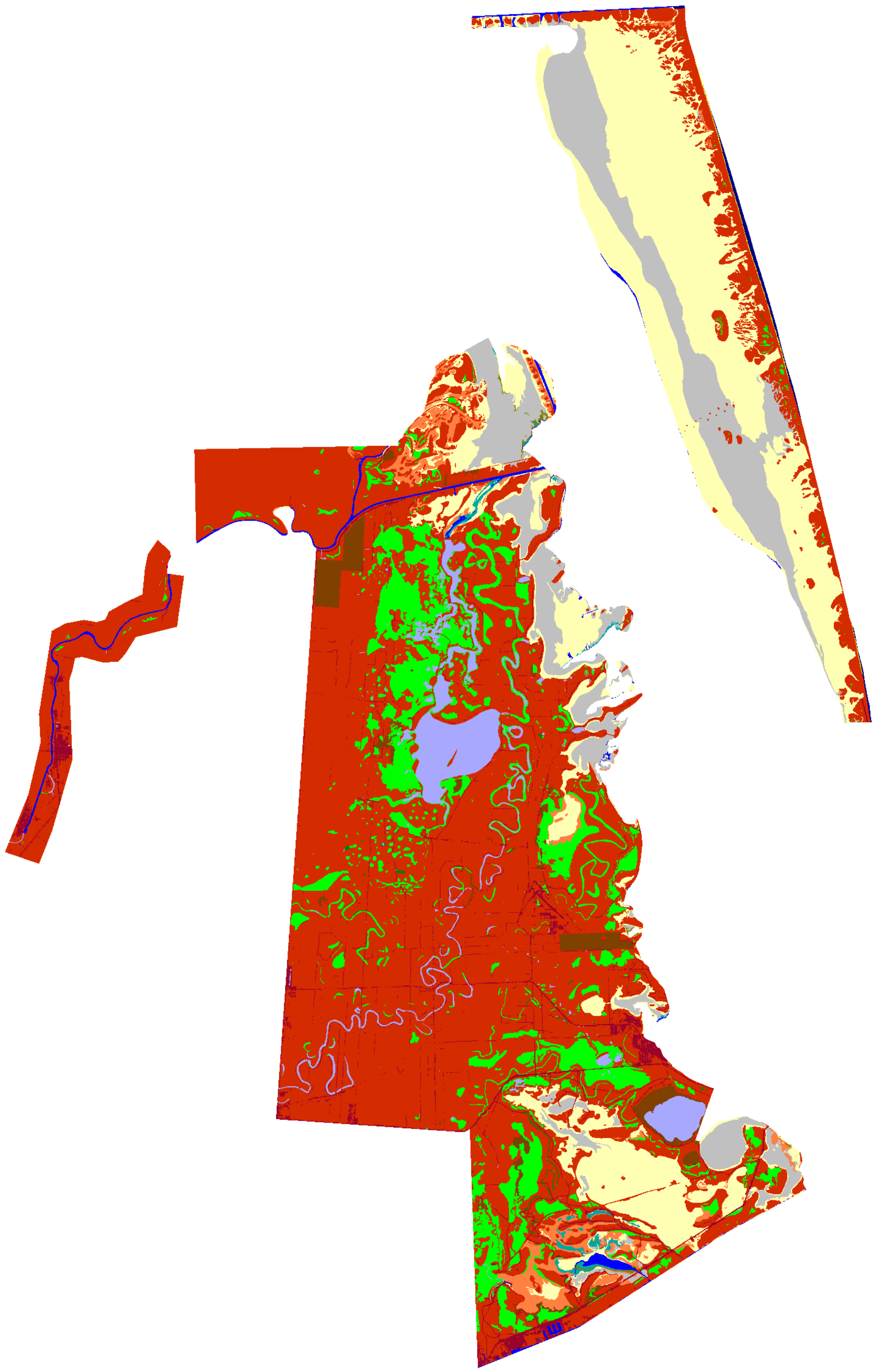


Laguna Atascosa NWR, 2100, 1.5 m SLR

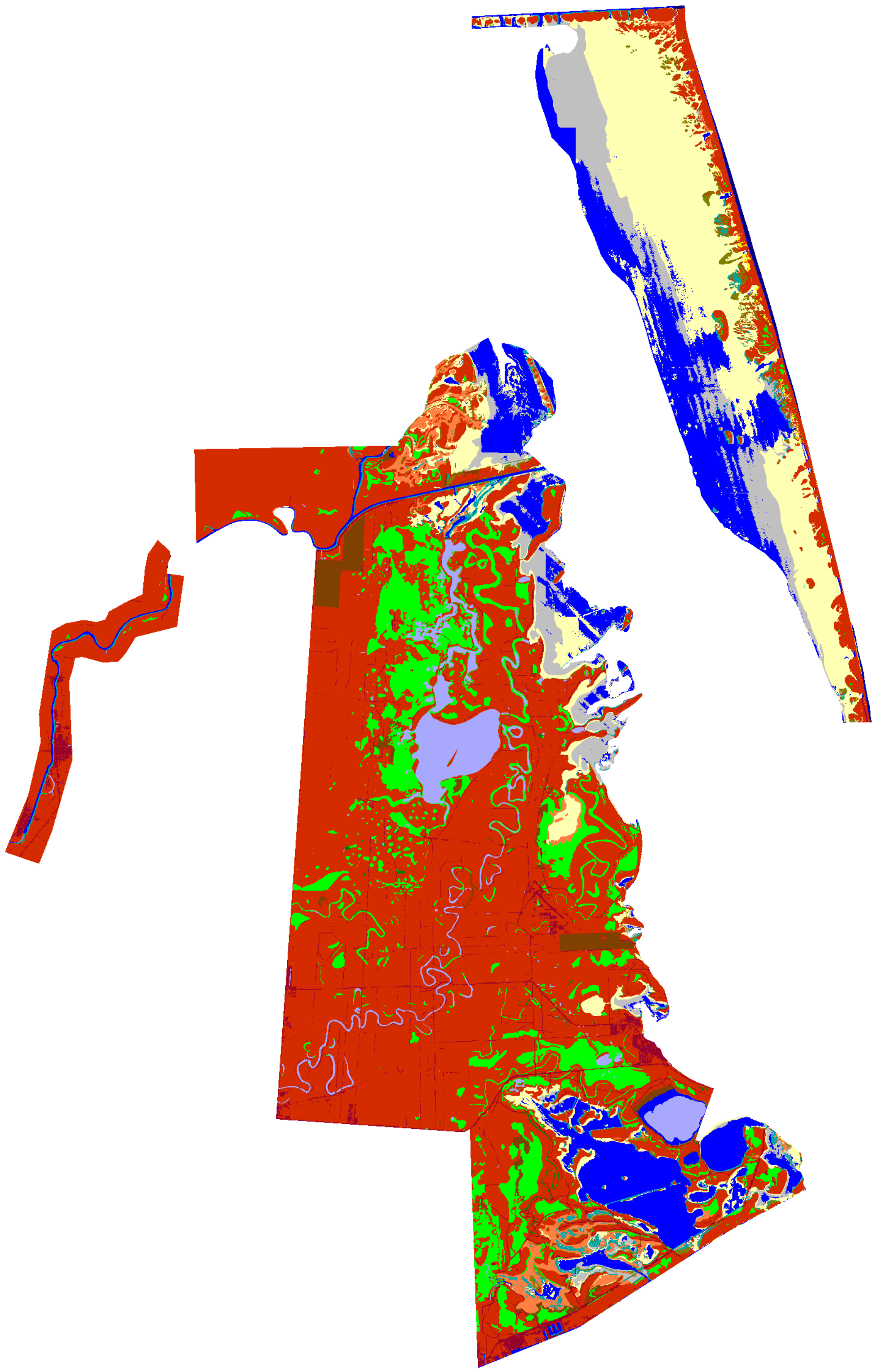
Laguna Atascosa NWR
2 m eustatic SLR by 2100

Results in Acres

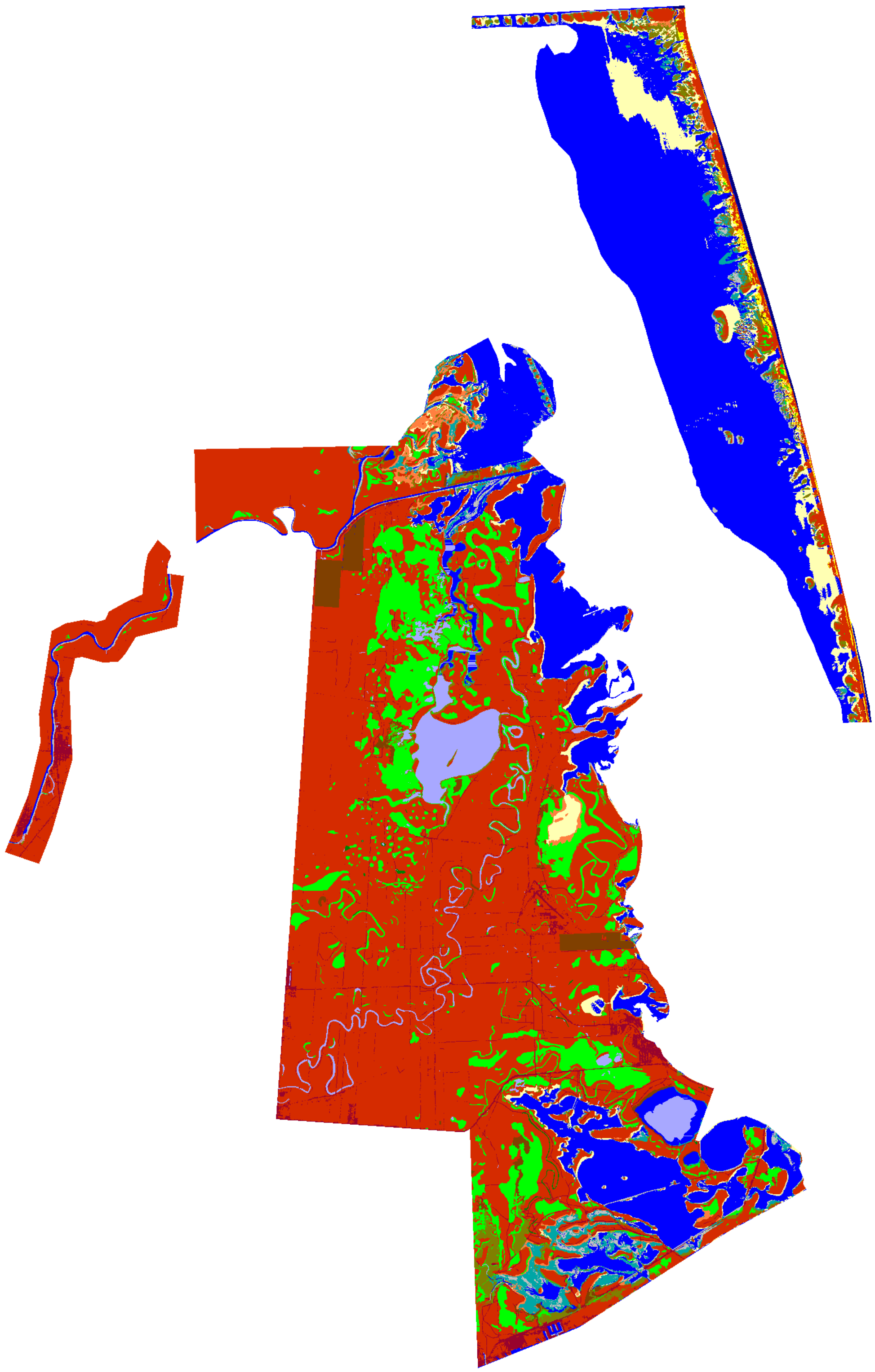
		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	118773	114607	110378	102566	89653
	Estuarine Beach	44757	30733	8158	2470	1103
	Tidal Flat	21961	12567	3120	4593	5510
	Inland Fresh Marsh	20796	20583	19385	17657	11103
	Inland Open Water	7215	7202	6431	5150	4900
	Developed Dry Land	5735	5577	5421	5054	4397
	Irregularly Flooded Marsh	4598	3918	1888	936	393
	Inland Shore	3542	3068	2866	2419	1933
	Estuarine Open Water	1399	26055	62218	73147	80272
	Regularly Flooded Marsh	690	2944	4592	5646	9346
	Open Ocean	497	574	643	1233	2031
	Riverine Tidal	419	167	158	150	137
	Swamp	193	193	193	184	151
	Transitional Salt Marsh	177	2513	4702	8824	19600
	Ocean Beach	139	191	738	864	362
	Total (incl. water)	**230891**	**230891**	**230891**	**230891**	**230891**



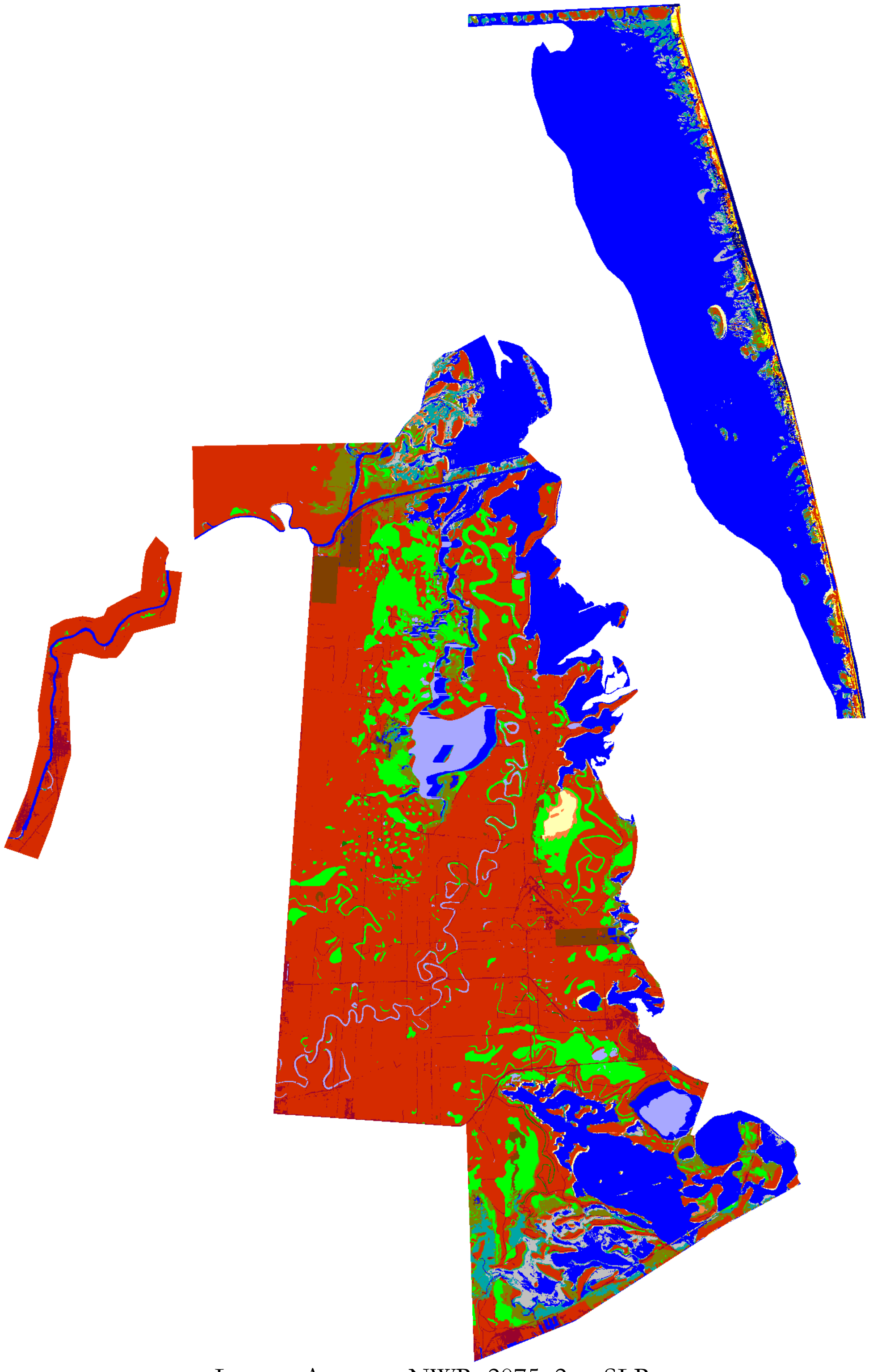
Laguna Atascosa NWR, Initial Condition



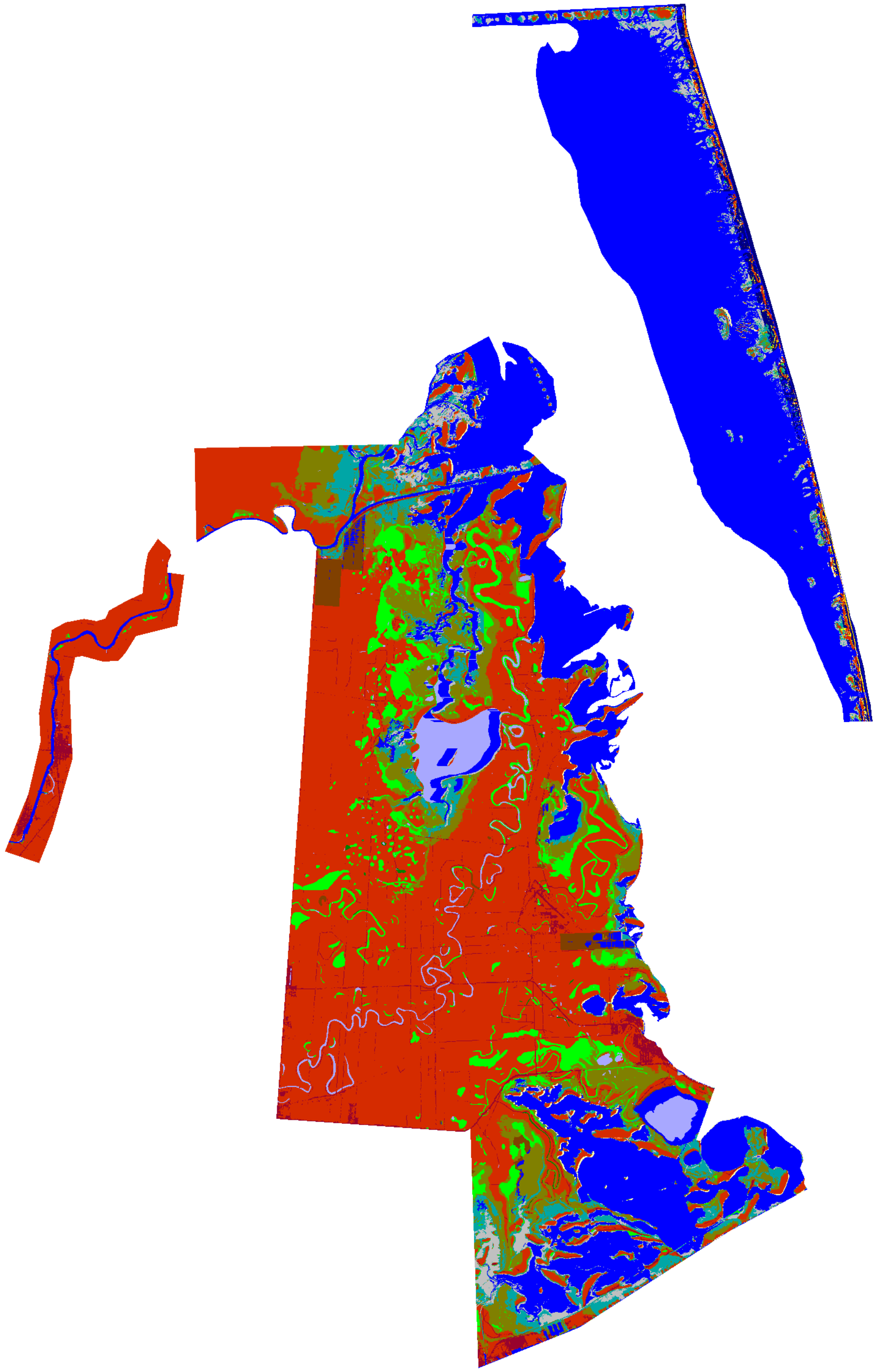
Laguna Atascosa NWR, 2025, 2 m SLR



Laguna Atascosa NWR, 2050, 2 m SLR



Laguna Atascosa NWR, 2075, 2 m SLR



Laguna Atascosa NWR, 2100, 2 m SLR

Discussion

For Laguna Atascosa NWR, the areas predicted to be most heavily affected by SLR are the coastal boundaries. By 2100, a large portion of these lands may be inundated under each SLR scenario examined. The beaches on the Intracoastal Waterway are predicted to be significantly affected, with losses ranging from 43% to 98%.

Other wetland types are also predicted to undergo large changes. A considerable portion of the irregularly-flooded marshes will be lost and converted to regularly-flooded marshes for SLR above 1 m. Inland-fresh marshes and swamps are predicted to be resilient due to high elevations and higher dry-lands located between these wetlands and the ocean.

In addition to the land-cover changes cited above, model predictions under higher rates of SLR suggest that the protective functions of the barrier islands will be largely compromised.

The refuge approved acquisition boundary was covered by high-vertical-resolution LiDAR data which reduces model uncertainty.

Regional accretion data were available from the scientific literature and applied on the entire study area. However, more specific measurements of accretion rates within the refuge could provide better predictions of marsh losses in the future.

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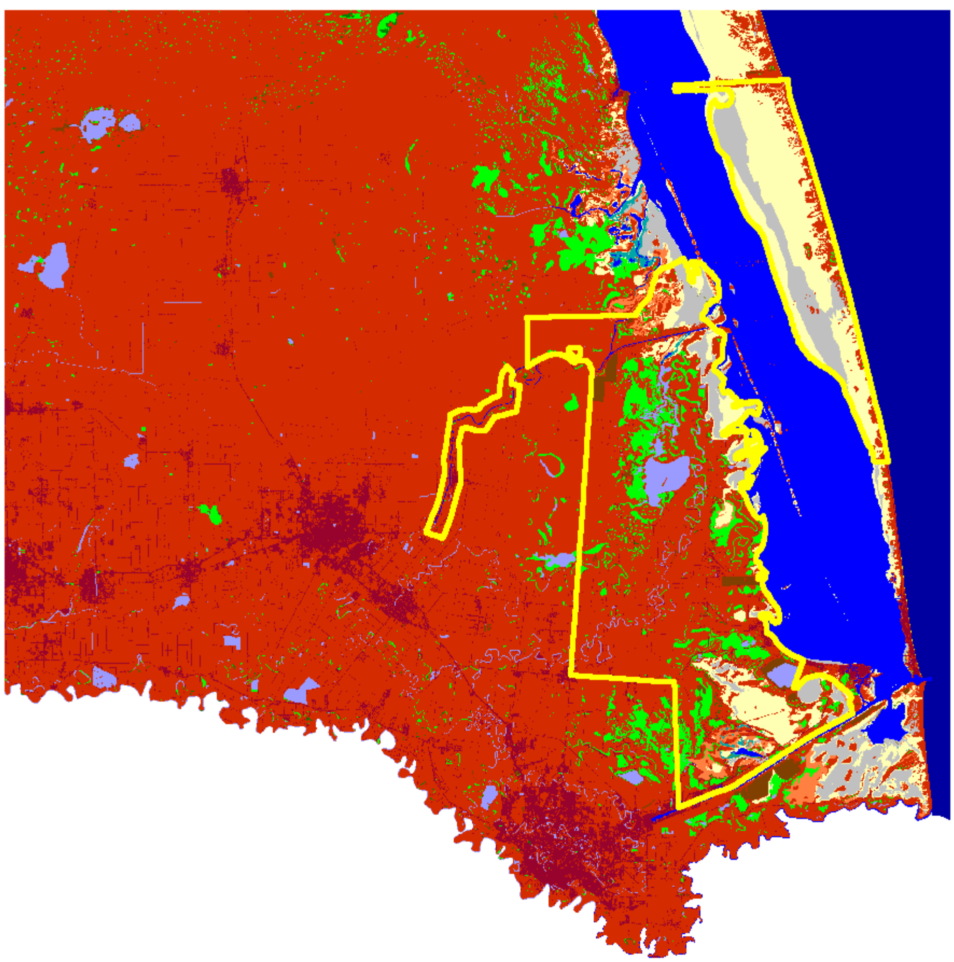
Appendix A: Contextual Results

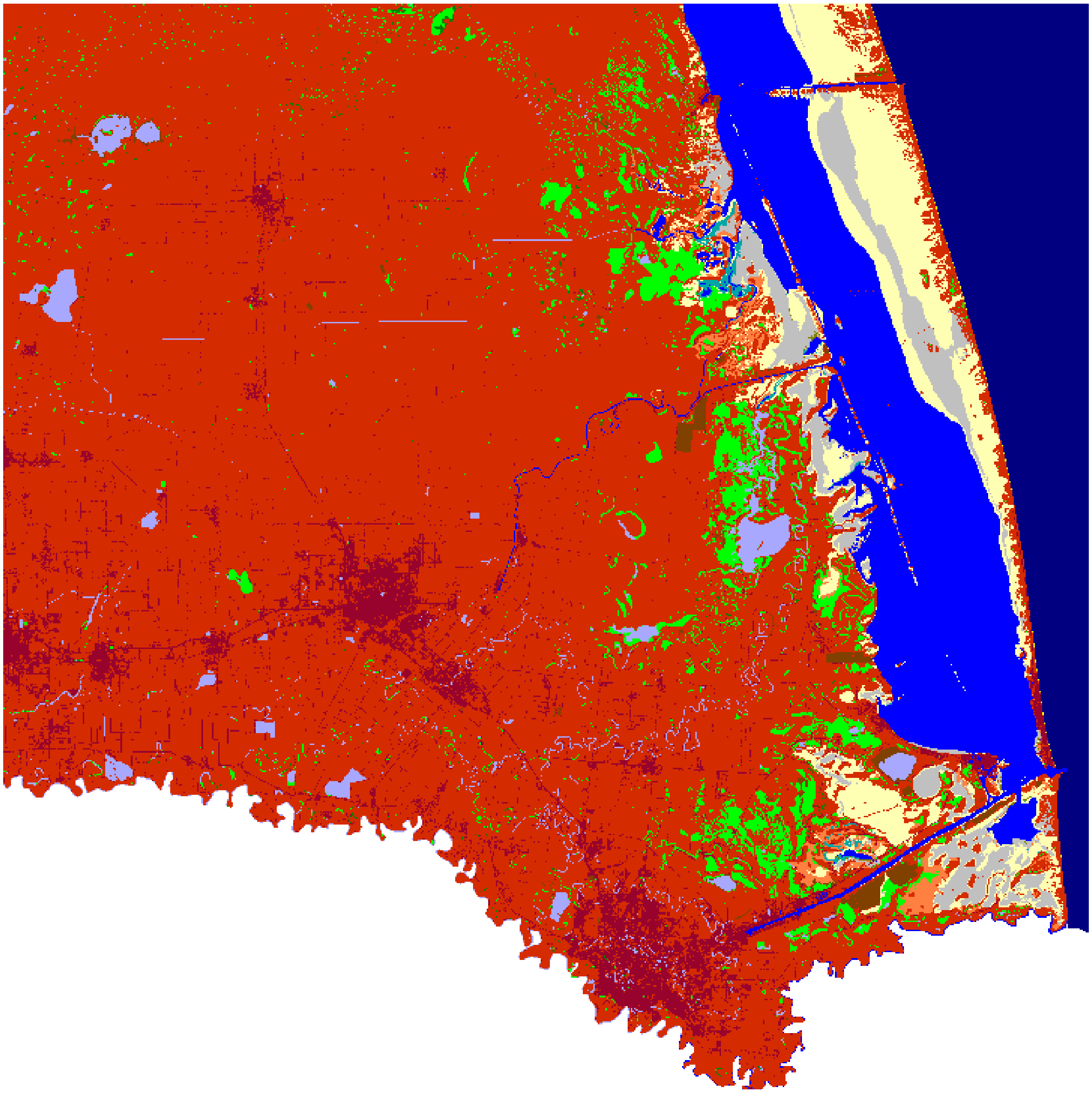
The SLAMM model does take into account the context of the surrounding lands or open water when calculating effects. For example, erosion rates are calculated based on the maximum fetch (wave action) which is estimated by assessing contiguous open water to a given marsh cell. Another example is that inundated dry lands will convert to marshes or ocean beach depending on their proximity to open ocean.

For this reason, an area larger than the boundaries of the USFWS refuge was modeled. Maps of these results are presented here with the following caveats:

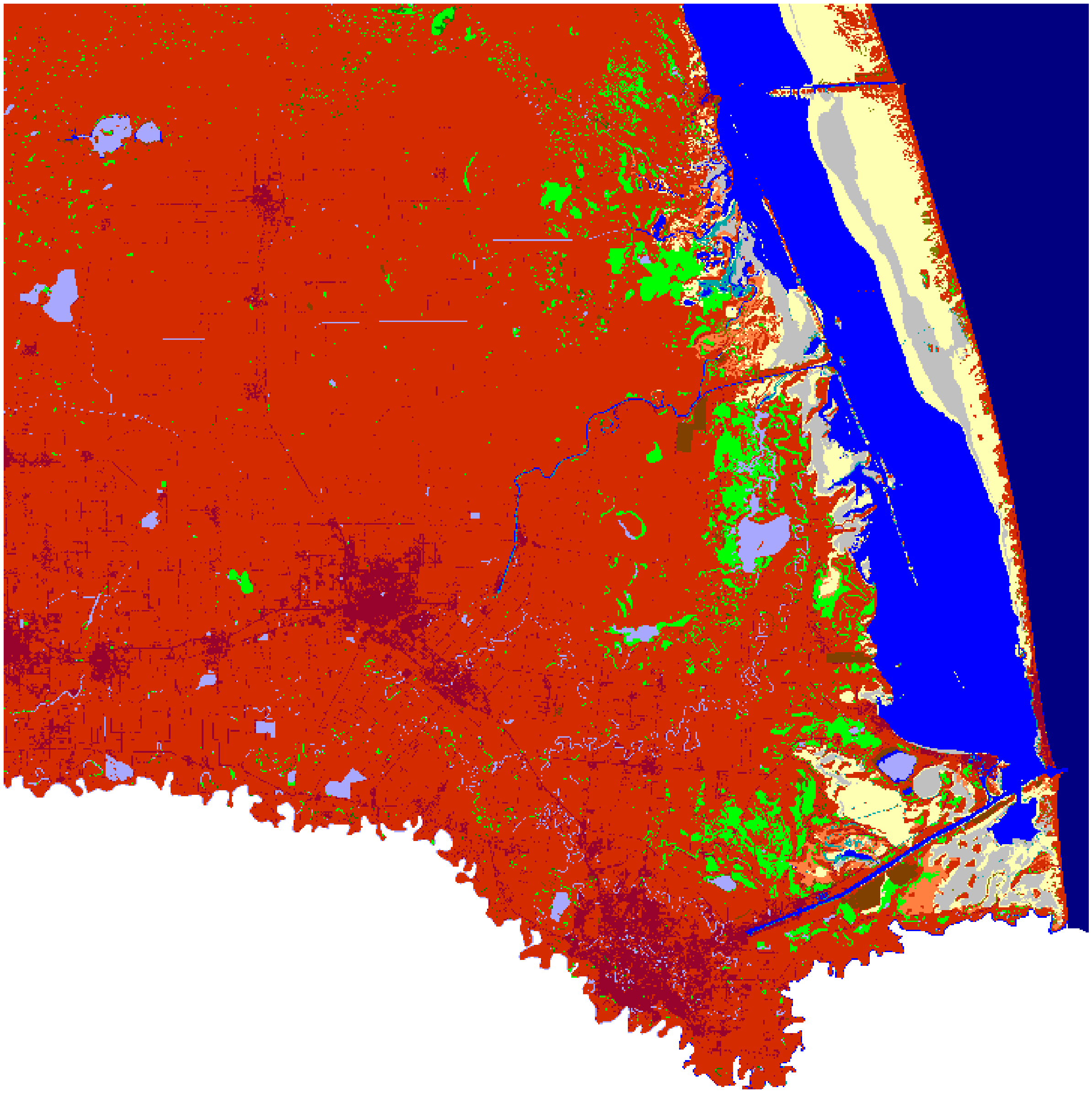
- Results were closely examined (quality assurance) within USFWS refuges but not closely examined for the larger region.
- Site-specific parameters for the model were derived for USFWS refuges whenever possible and may not be regionally applicable.
- Especially in areas where dikes are present, an effort was made to assess the probable location and effects of dikes for USFWS refuges, but this effort was not made for surrounding areas.



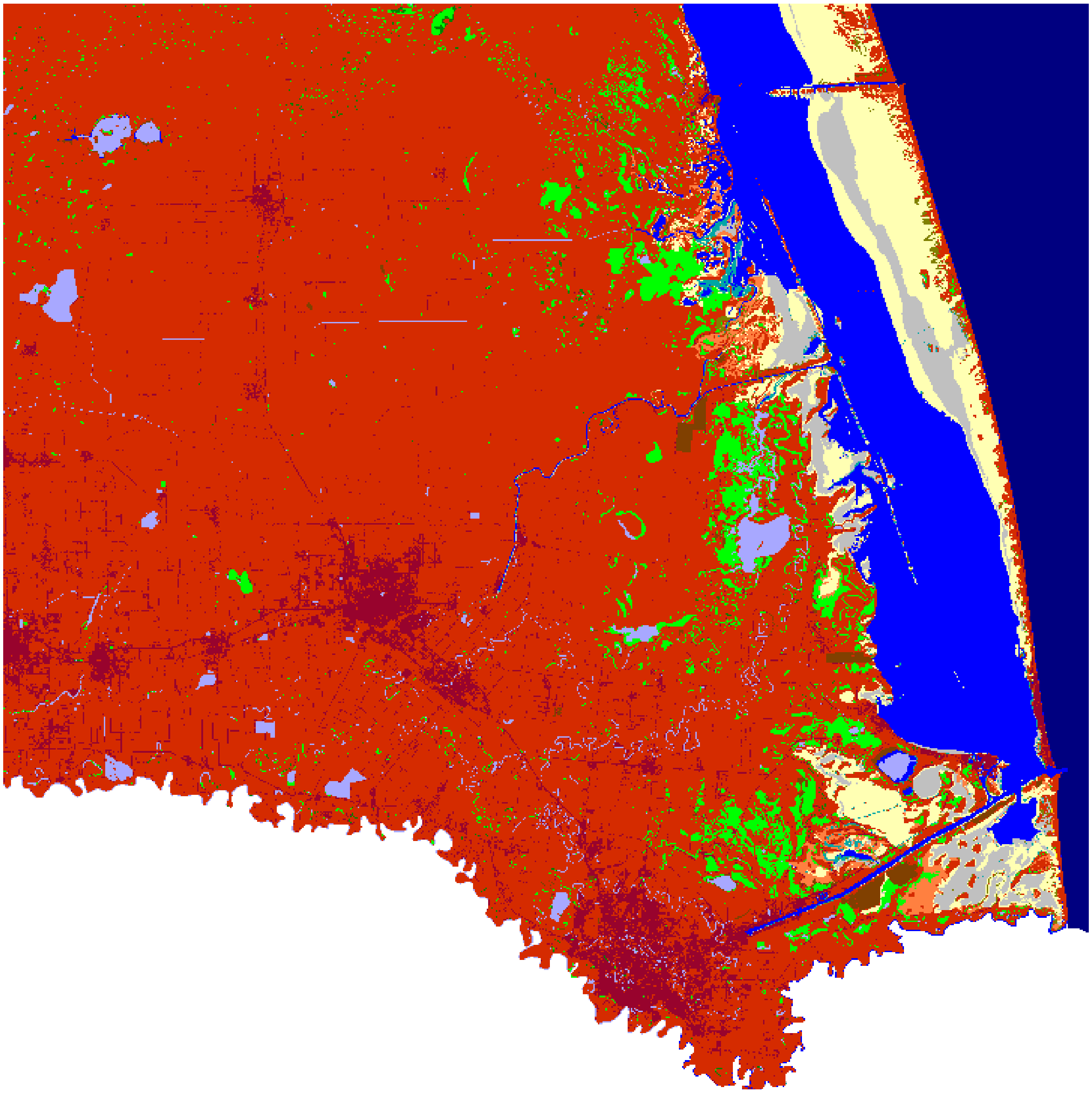
Laguna Atascosa NWR within simulation context (white).



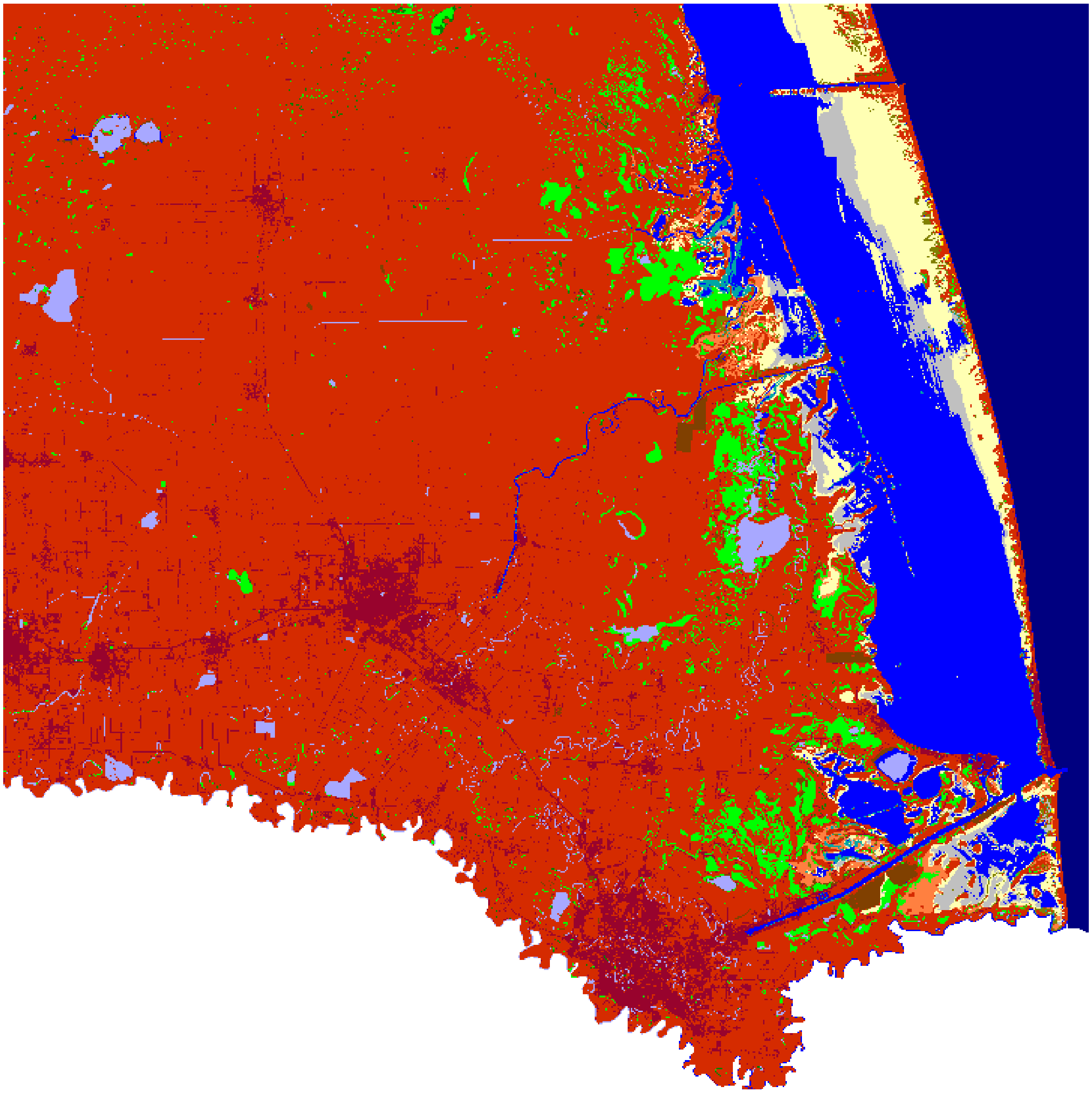
Laguna Atascosa NWR, Initial Condition



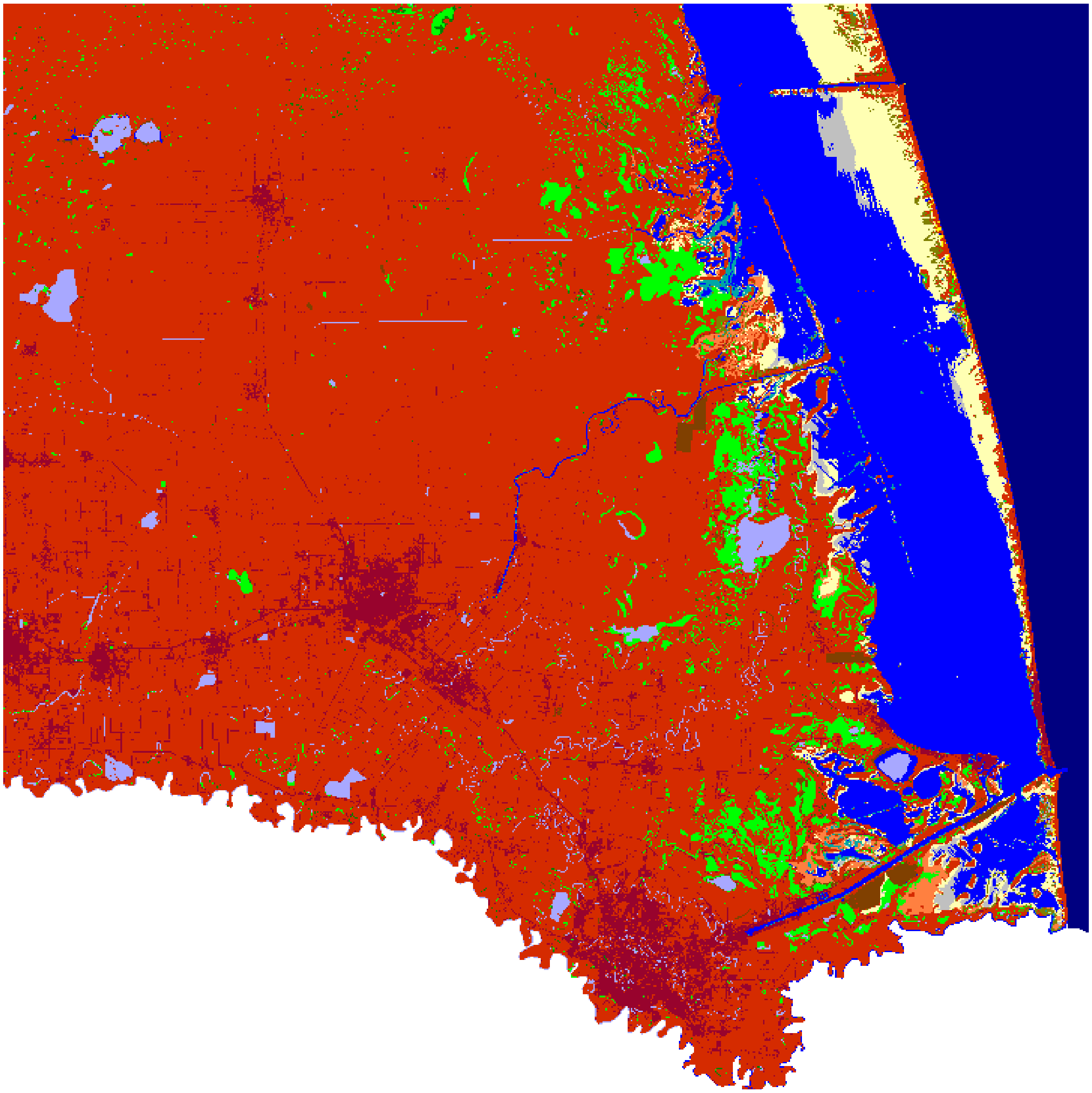
Laguna Atascosa NWR, 2025, Scenario A1B Mean, 0.39 m SLR



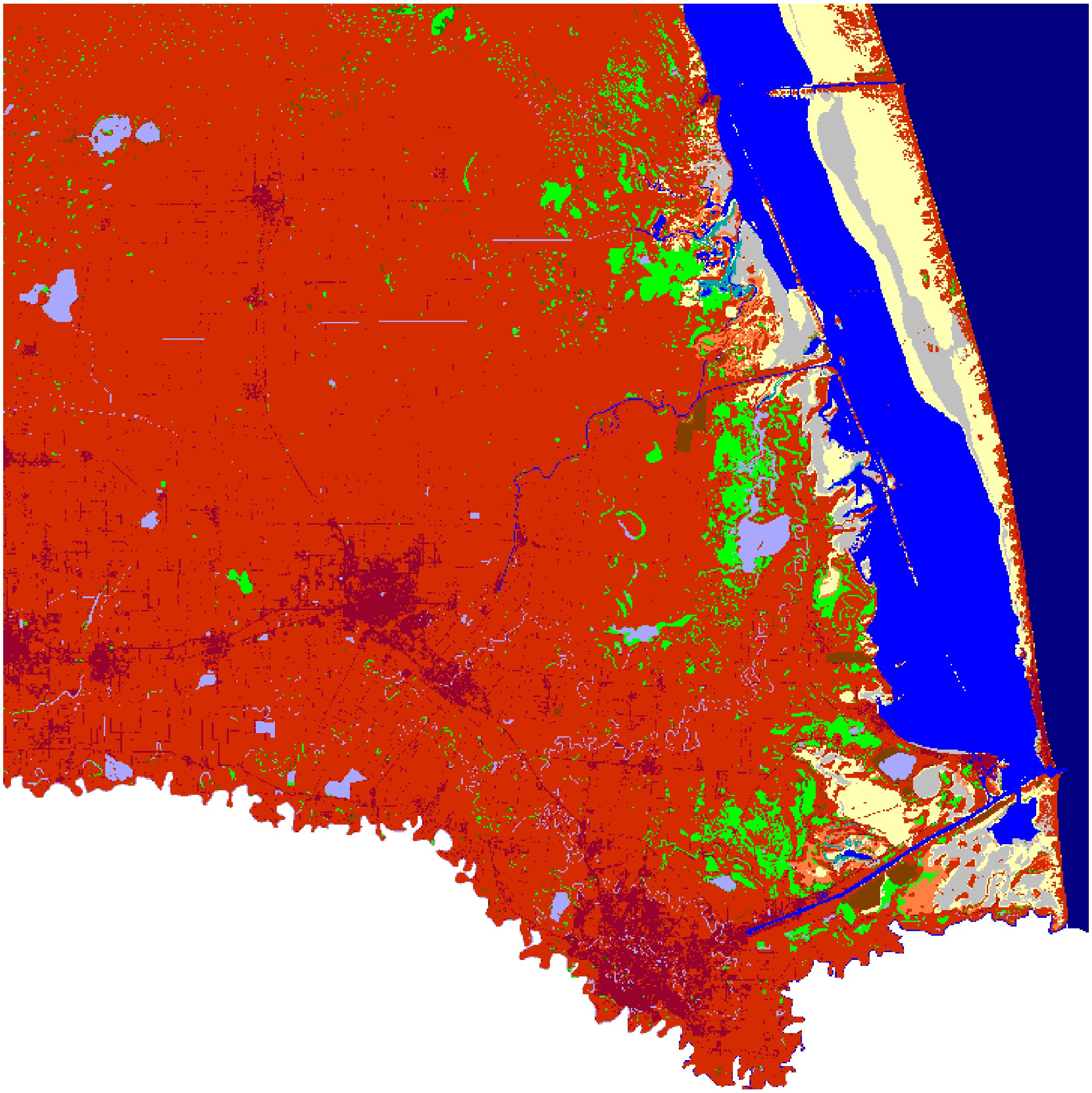
Laguna Atascosa NWR, 2050, Scenario A1B Mean, 0.39 m SLR



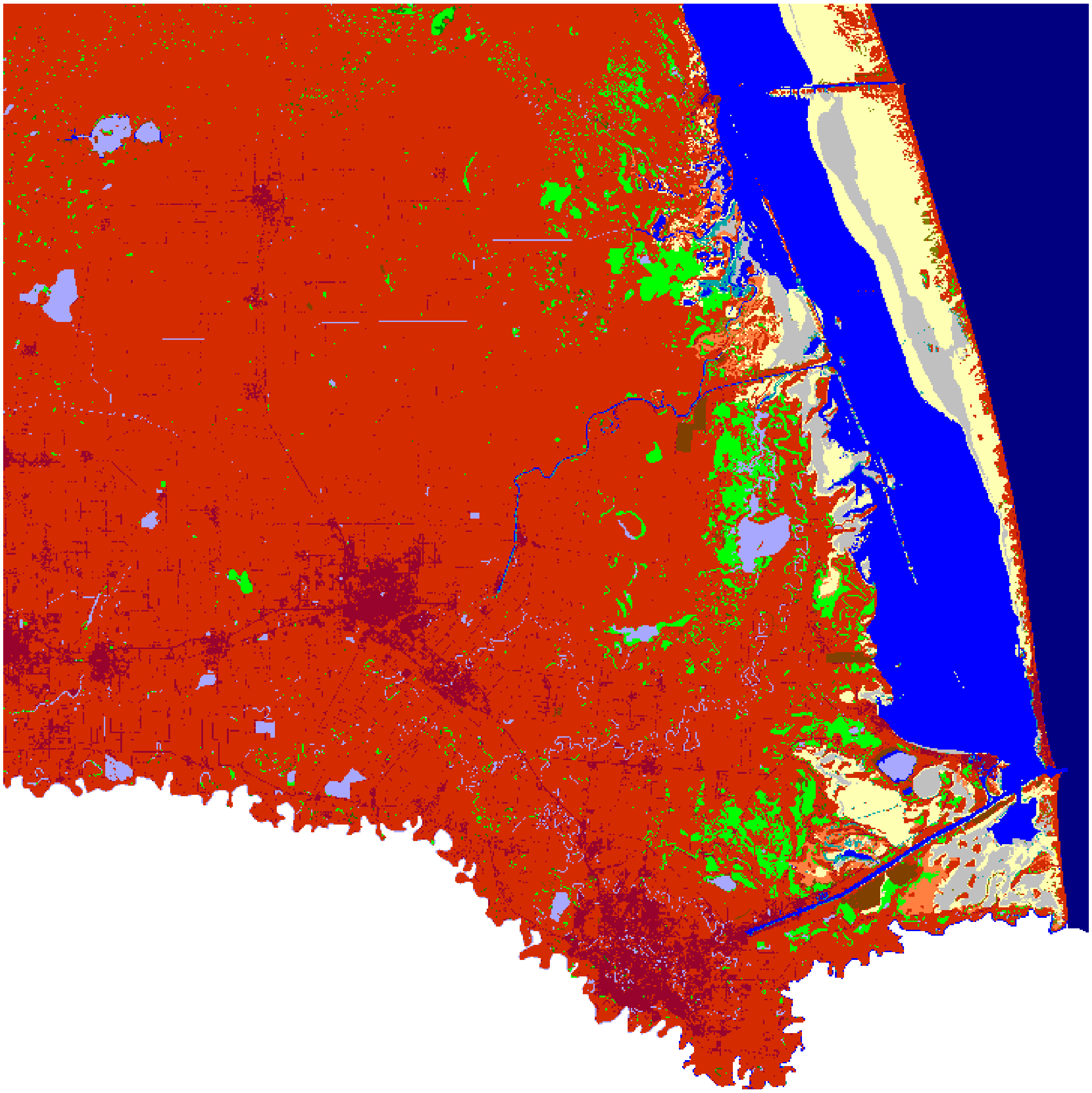
Laguna Atascosa NWR, 2075, Scenario A1B Mean, 0.39 m SLR



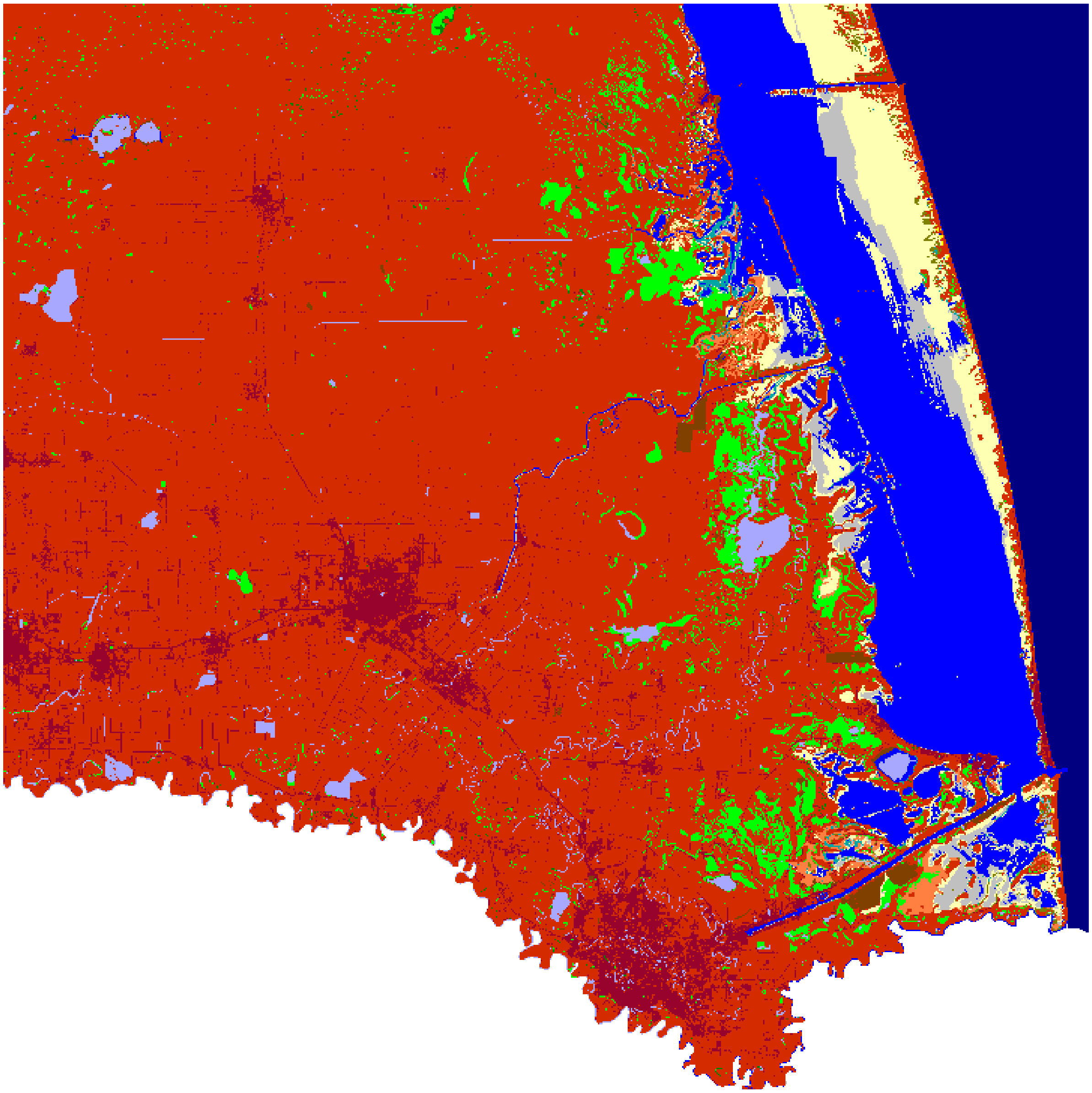
Laguna Atascosa NWR, 2100, Scenario A1B Mean, 0.39 m SLR



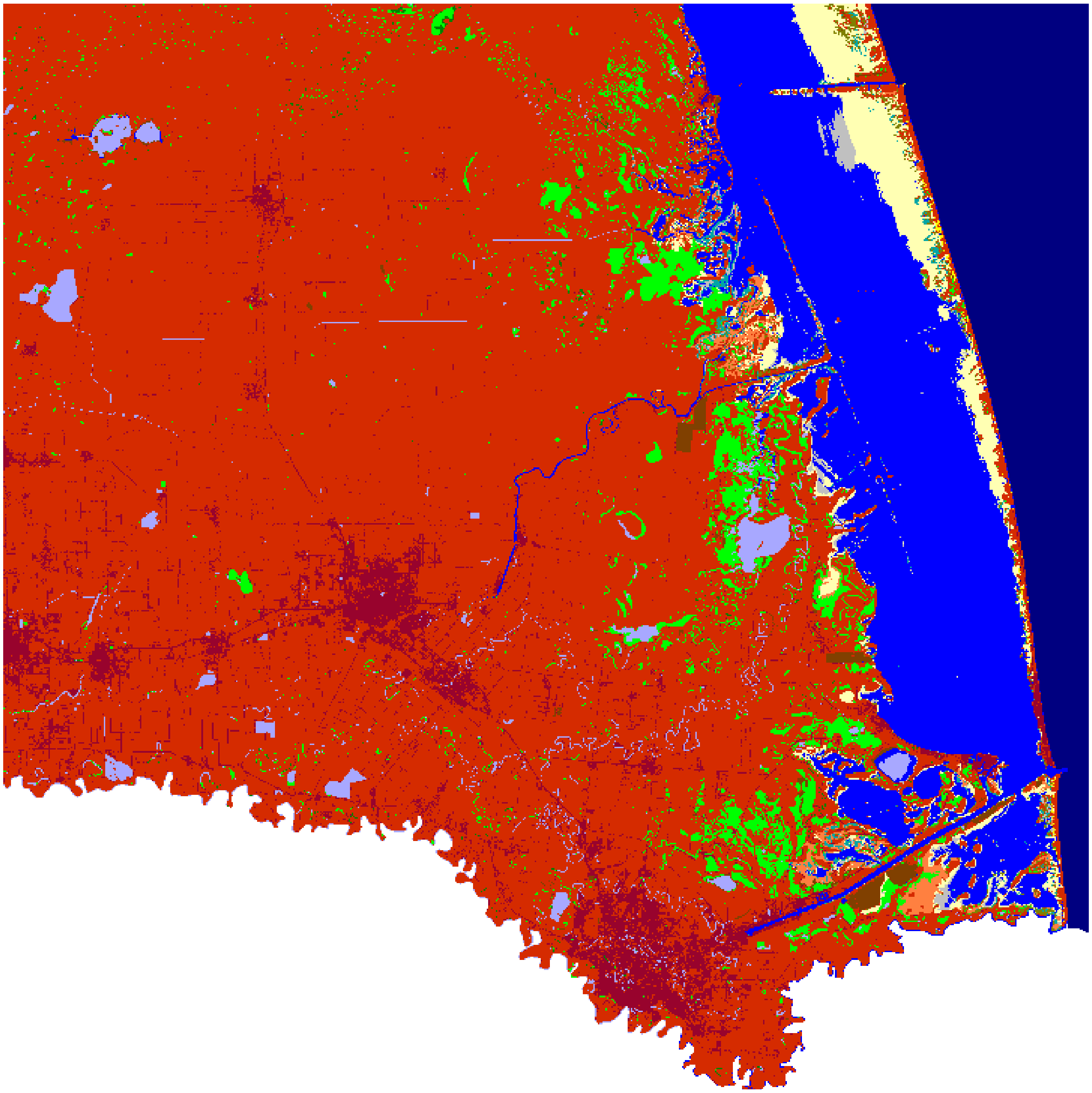
Laguna Atascosa NWR, Initial Condition



Laguna Atascosa NWR, 2025, Scenario A1B Maximum, 0.69 m SLR



Laguna Atascosa NWR, 2050, Scenario A1B Maximum, 0.69 m SLR



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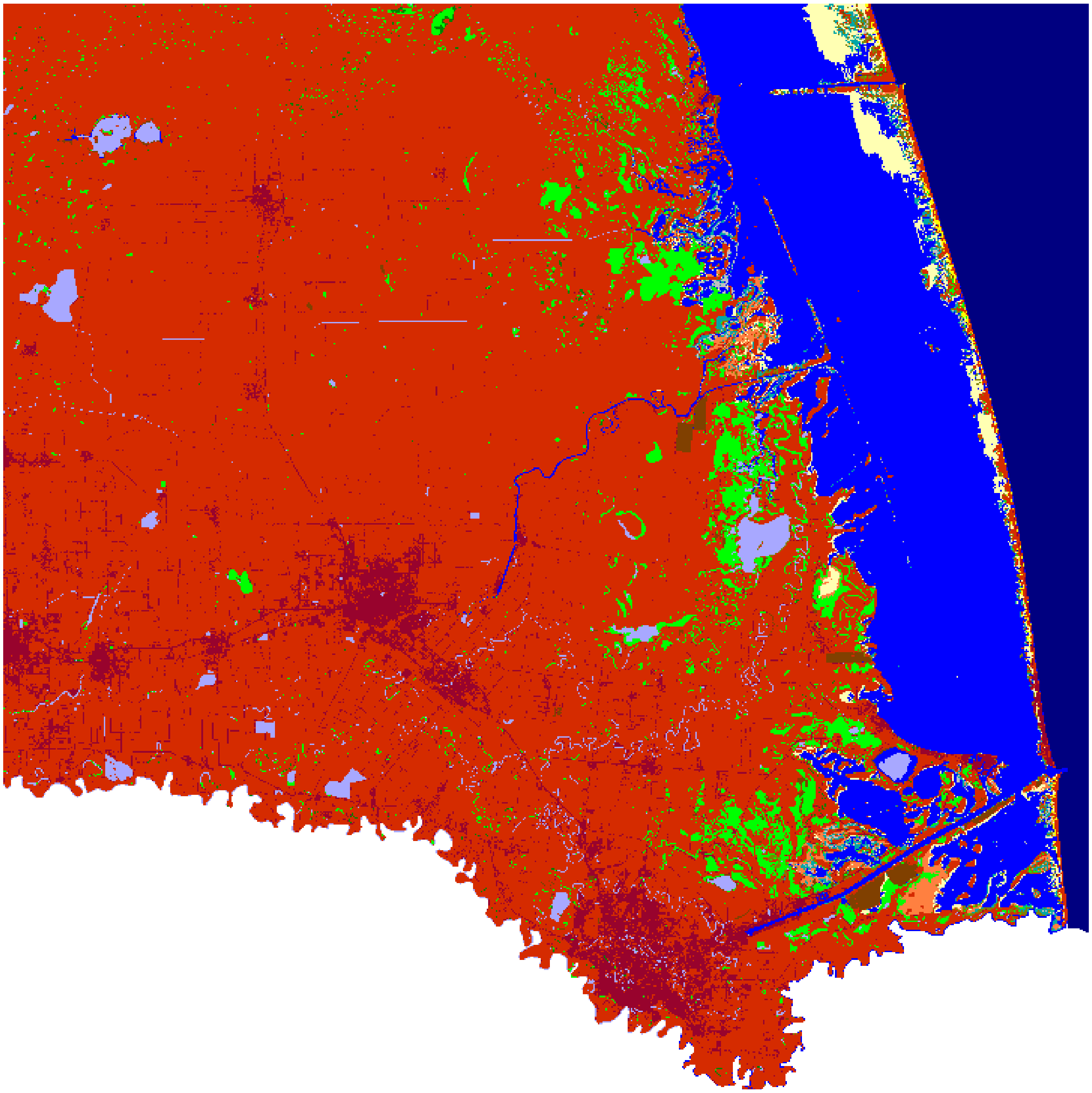
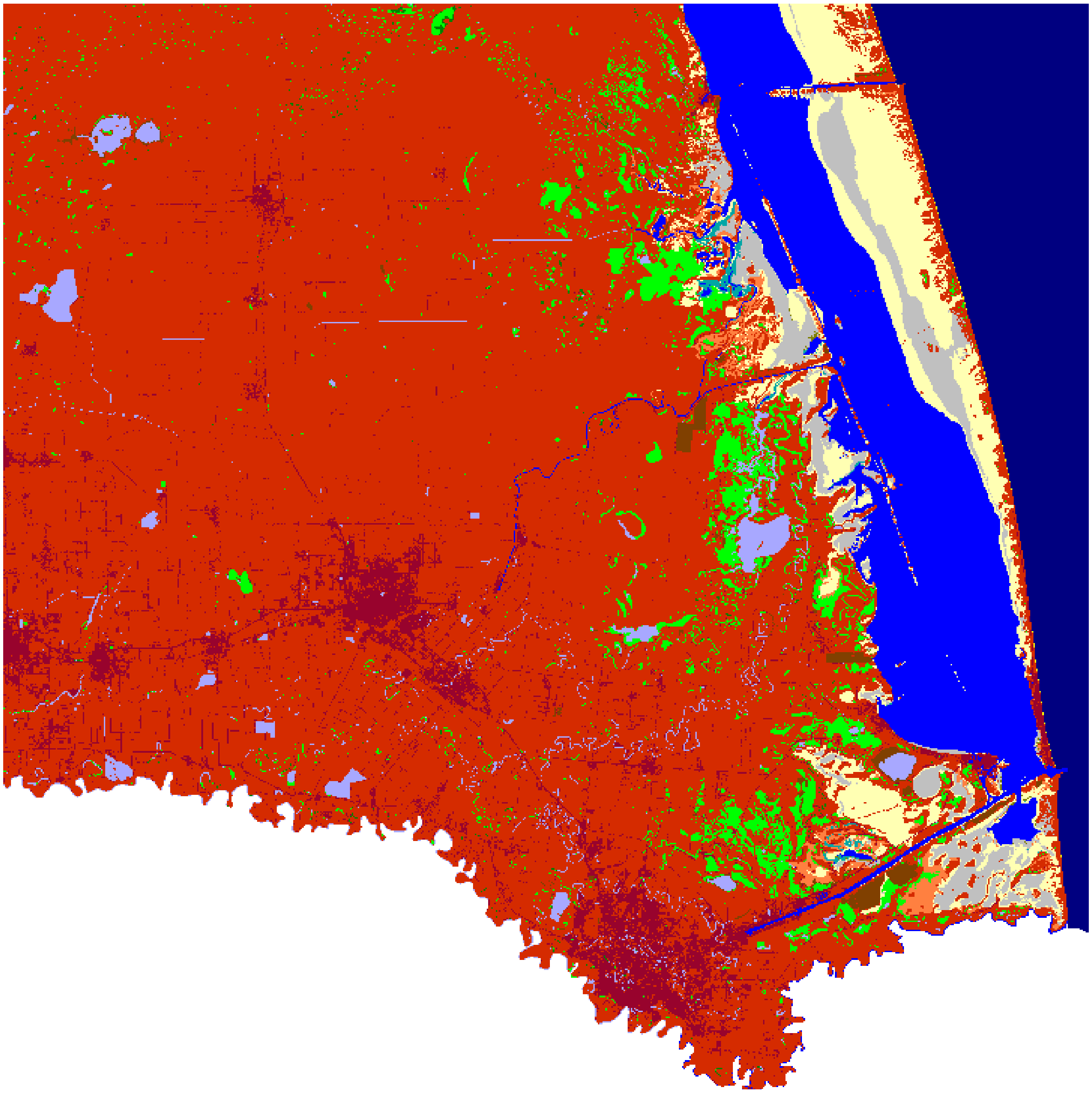
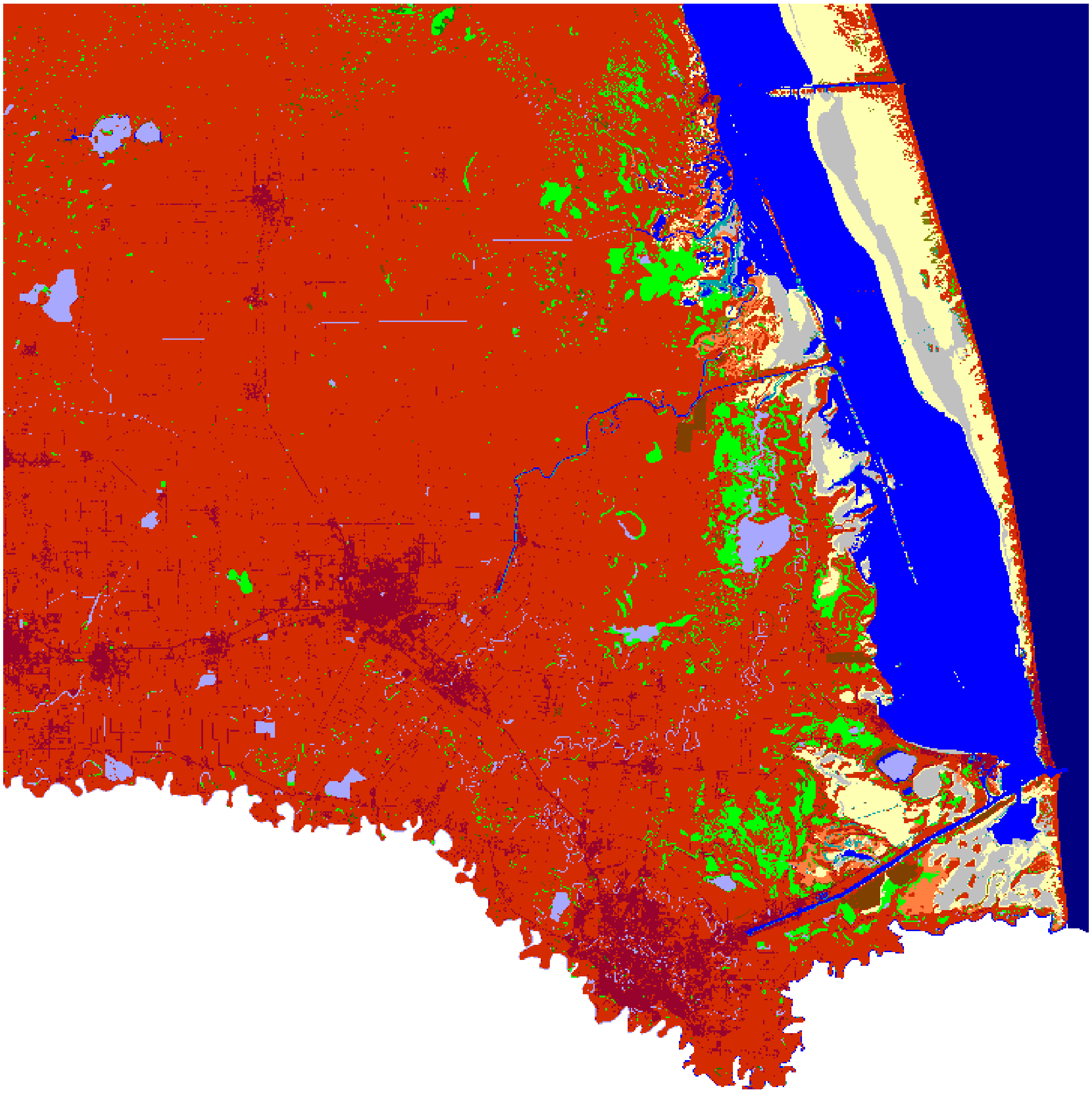


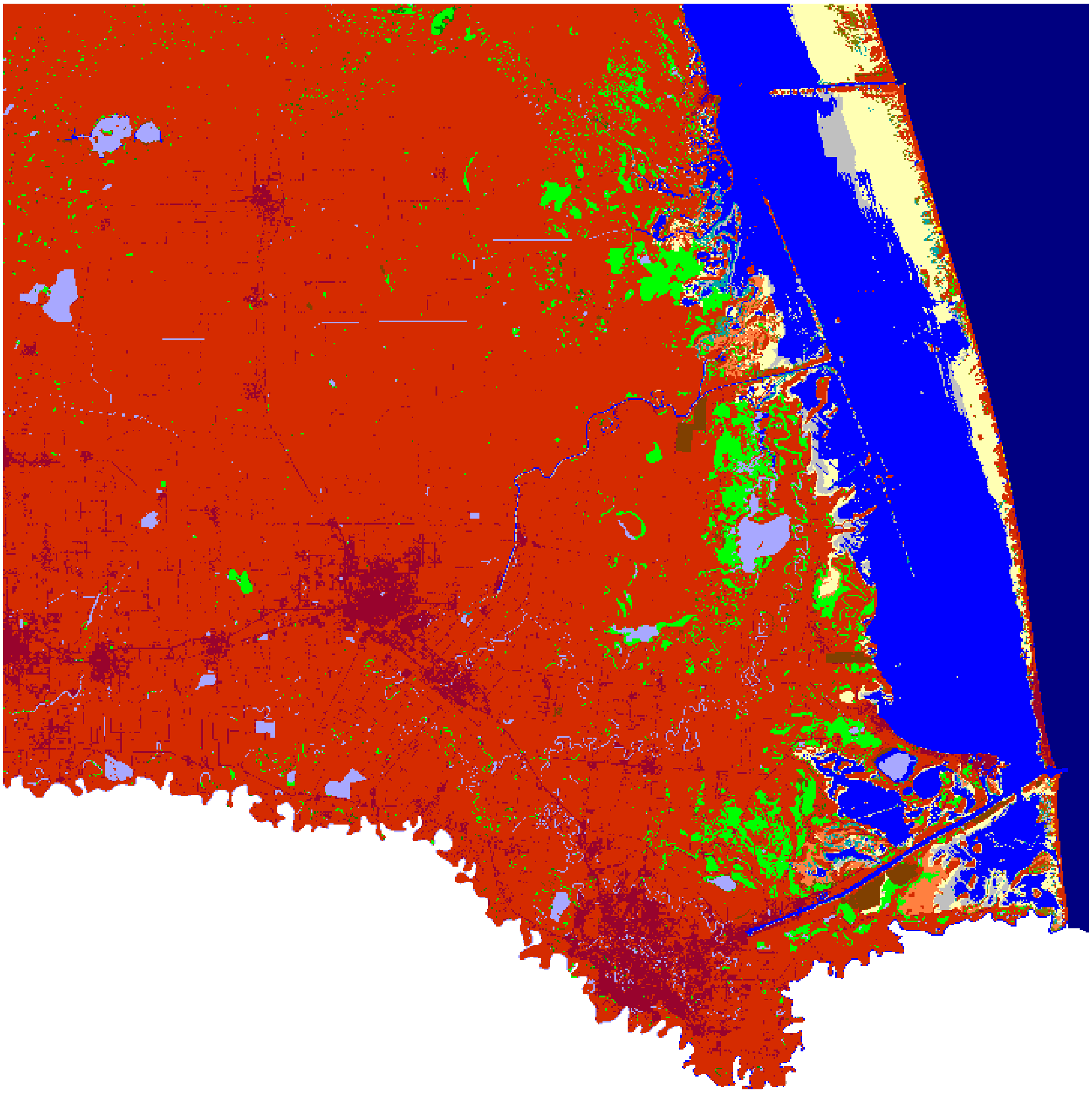
Laguna Atascosa NWR, 2100, Scenario A1B Maximum, 0.69 m SLR



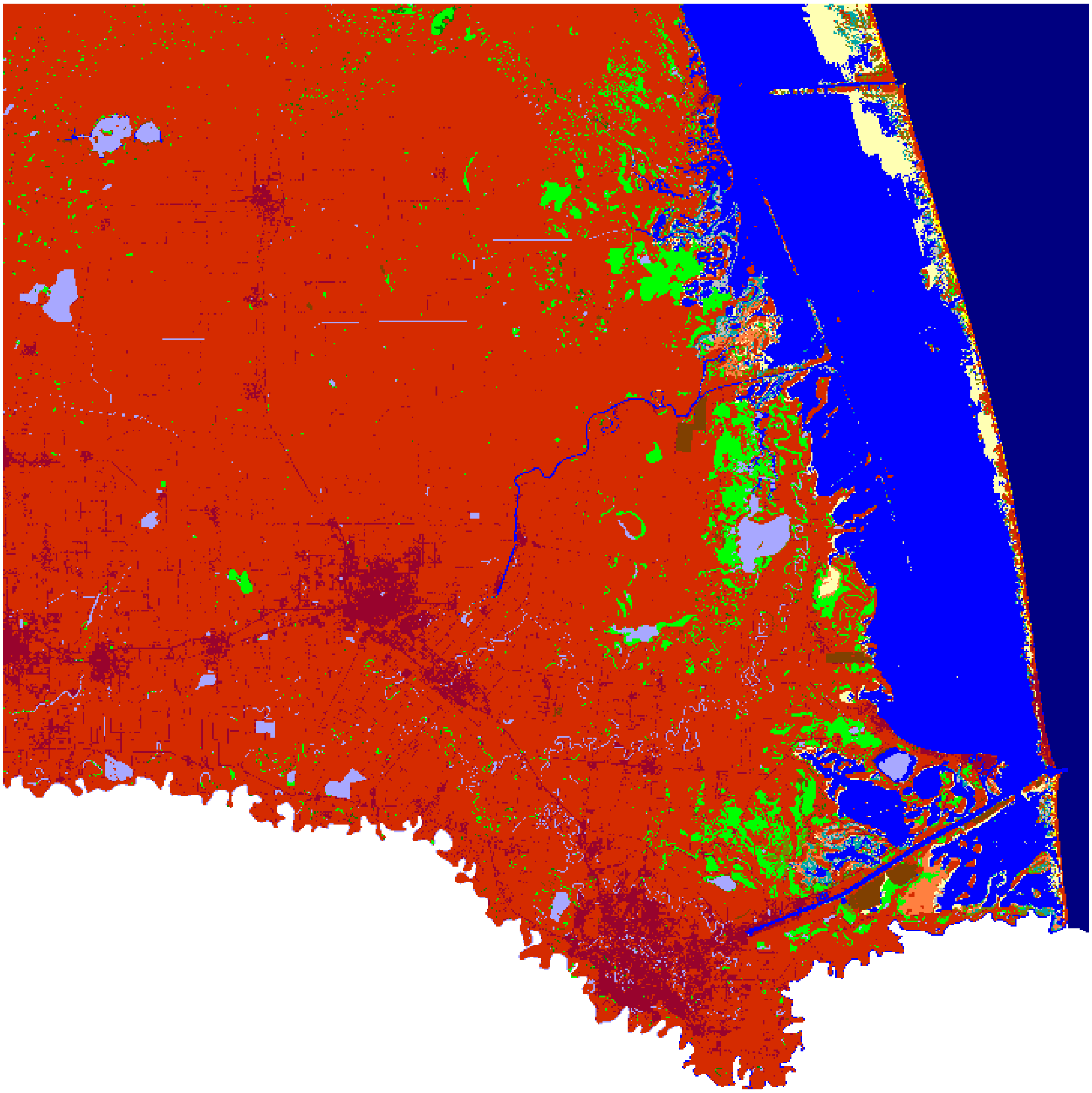
Laguna Atascosa NWR, Initial Condition



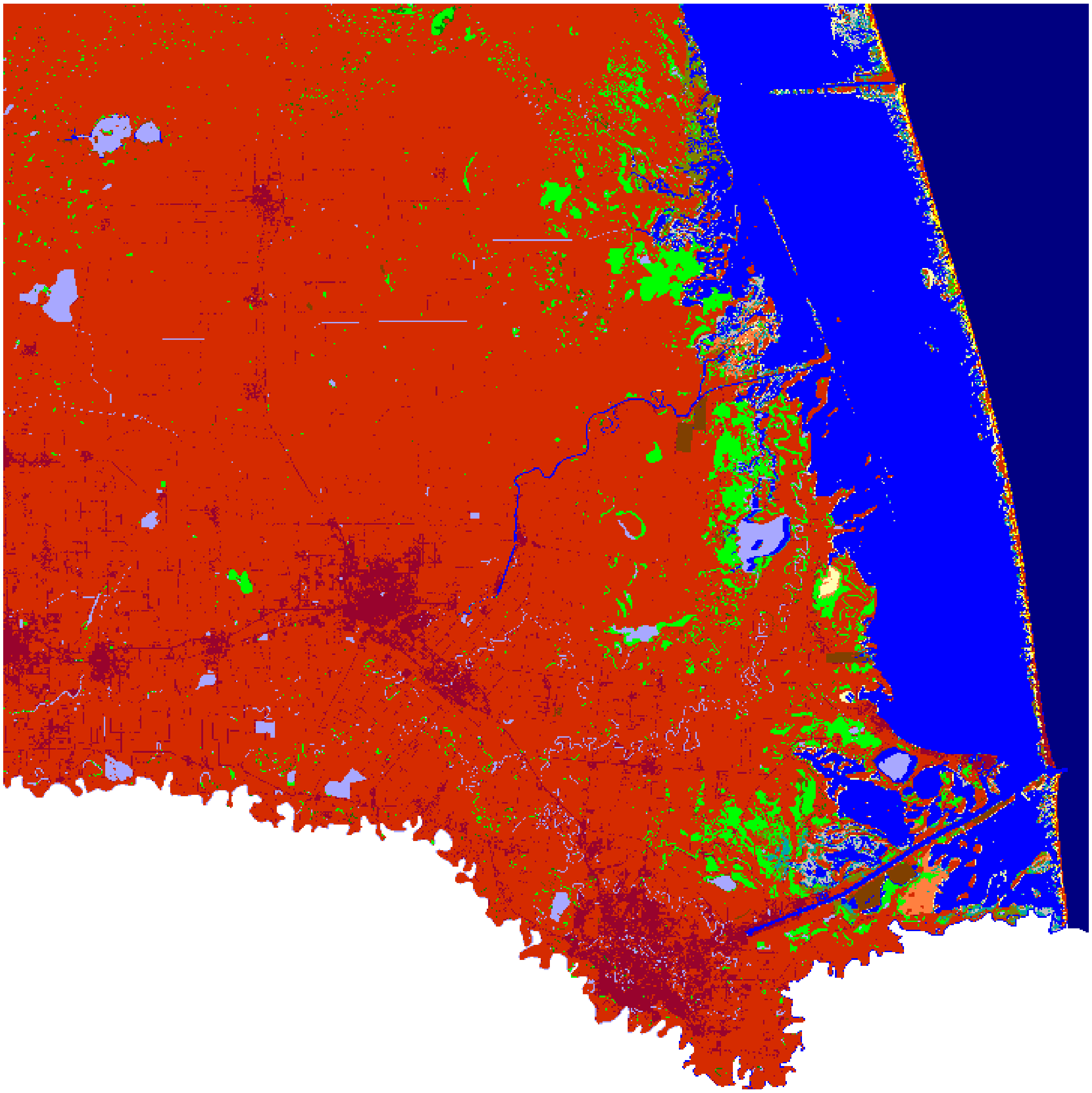
Laguna Atascosa NWR, 2025, 1 m SLR



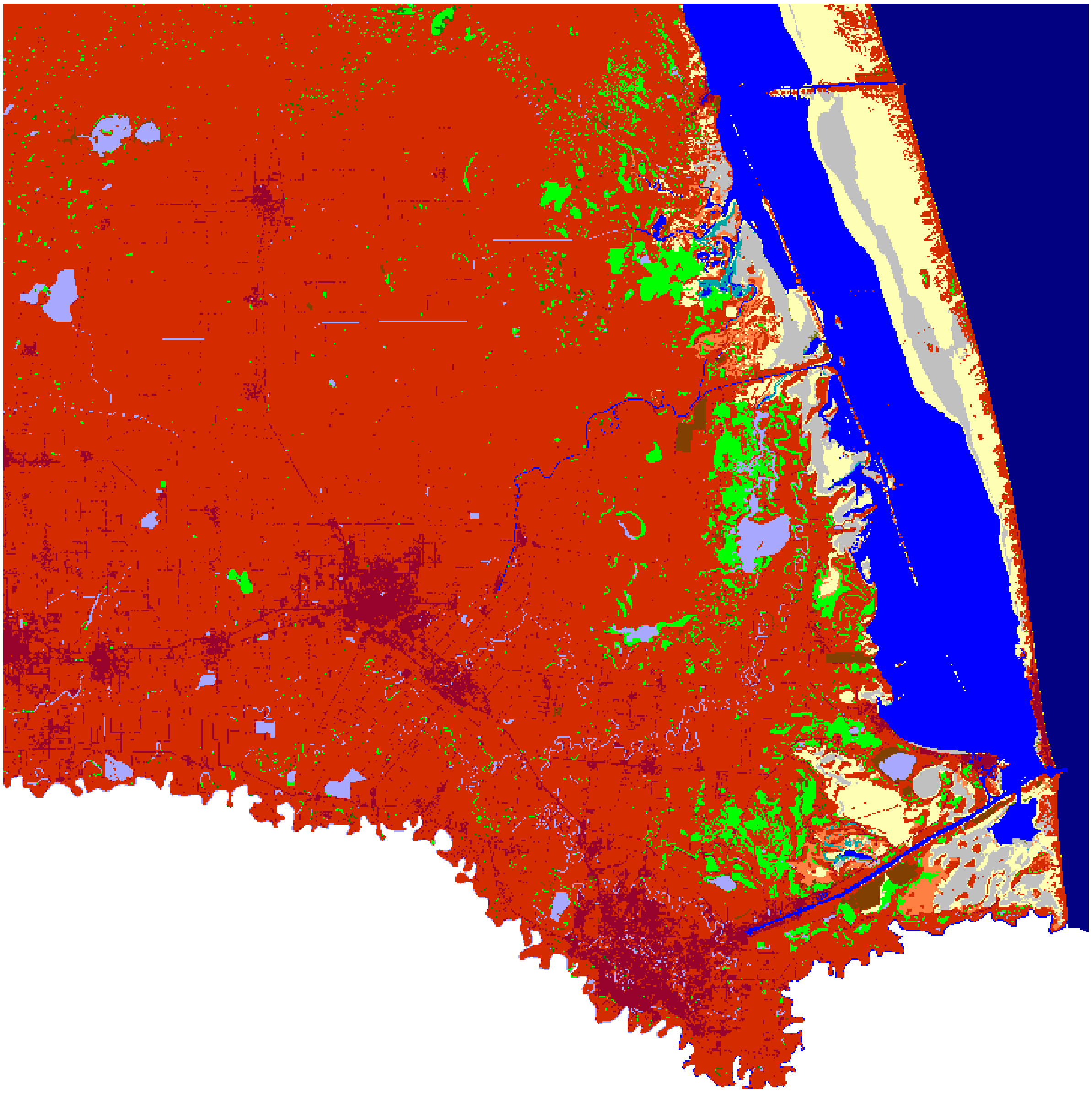
Laguna Atascosa NWR, 2050, 1 m SLR



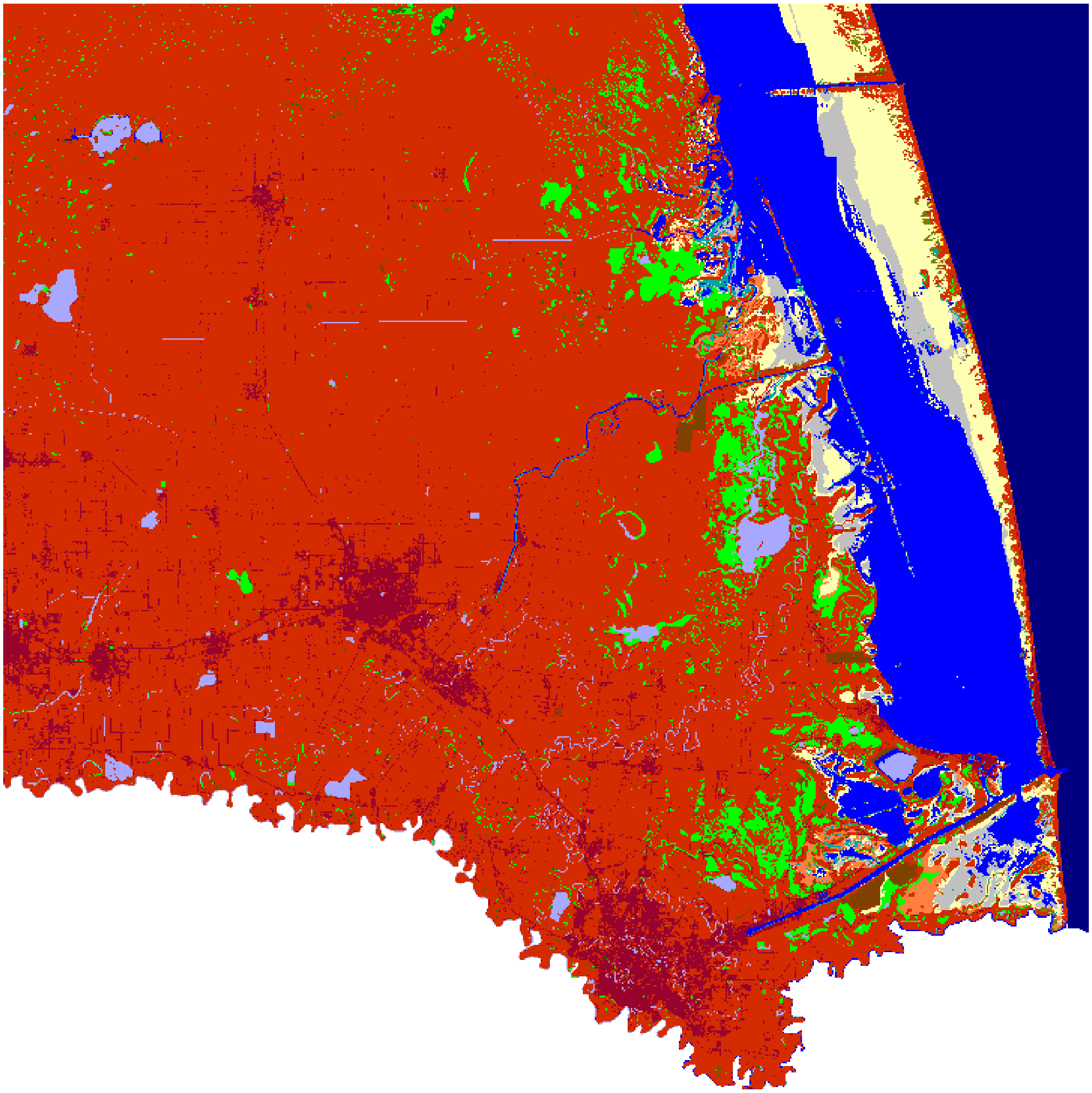
Laguna Atascosa NWR, 2075, 1 meter



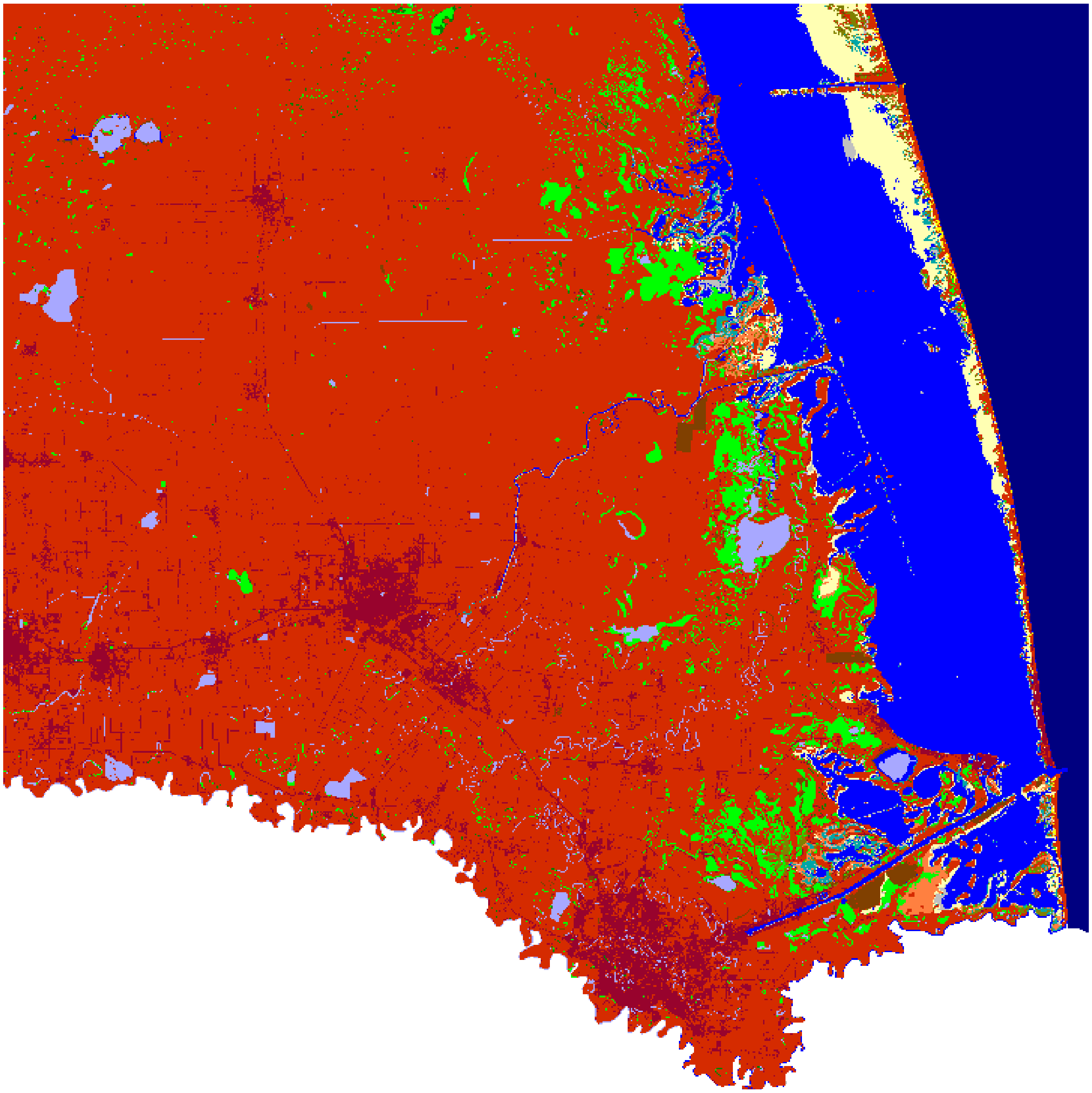
Laguna Atascosa NWR, 2100, 1 m SLR



Laguna Atascosa NWR, Initial Condition



Laguna Atascosa NWR, 2025, 1.5 m SLR



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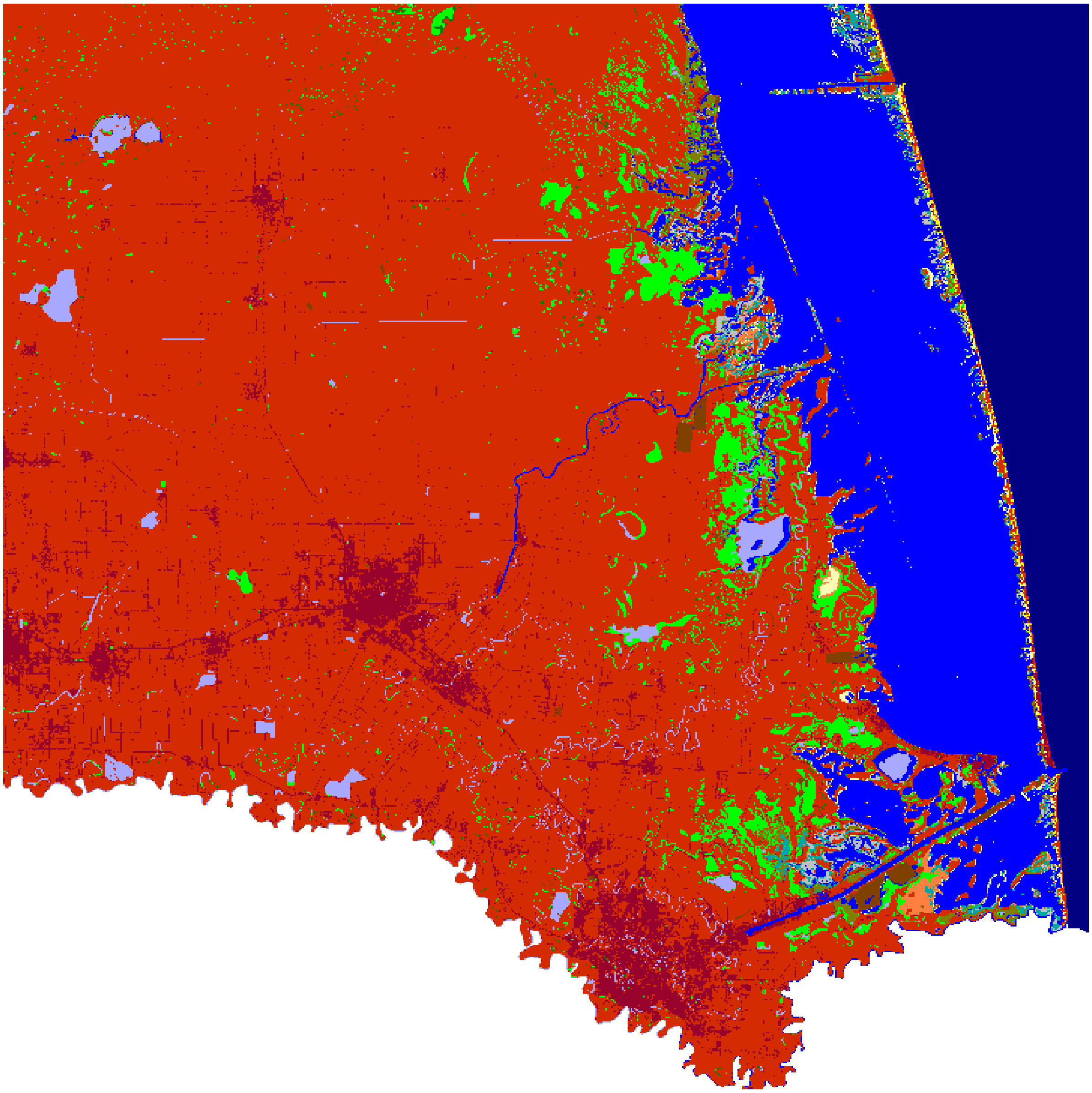

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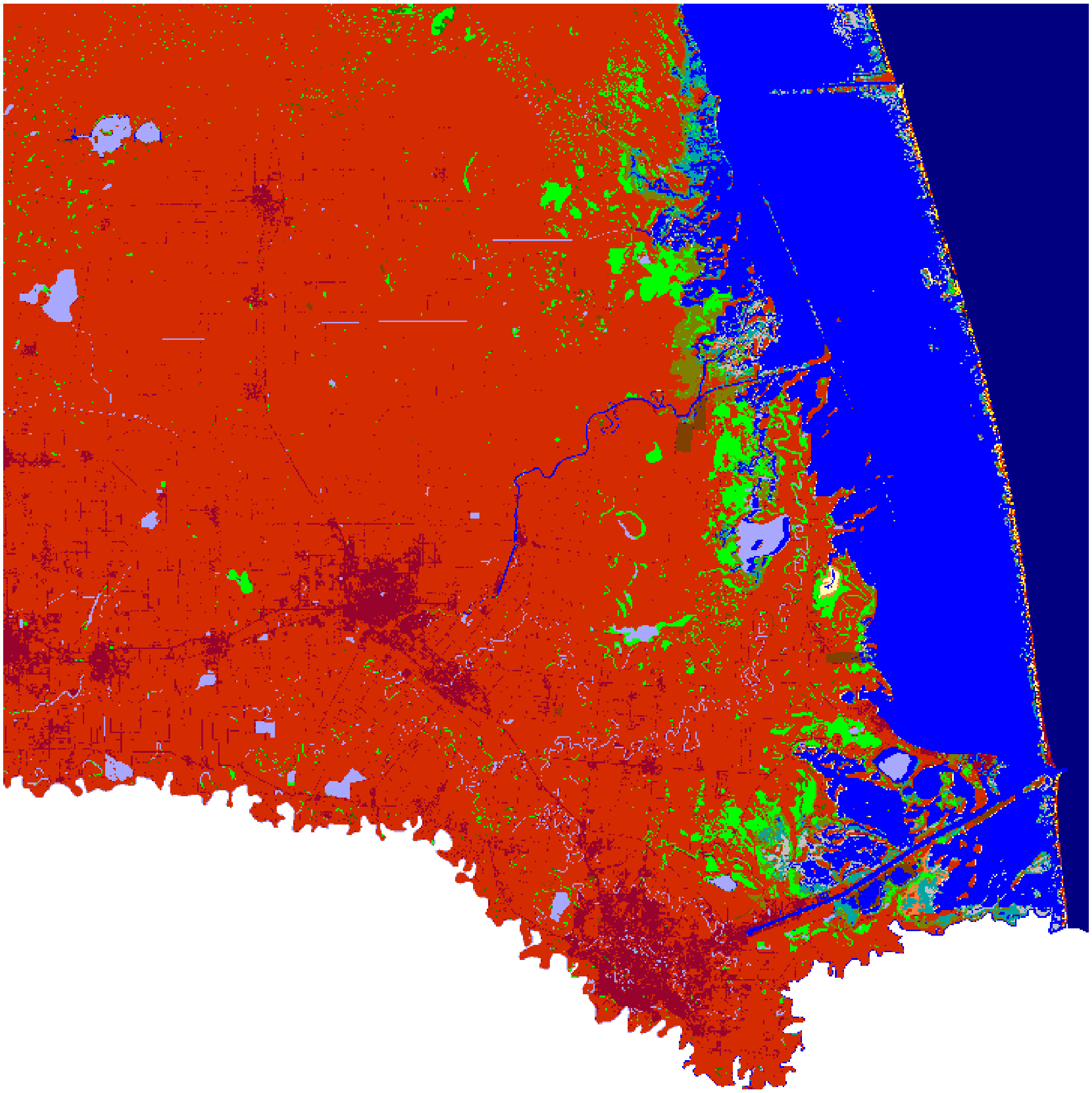
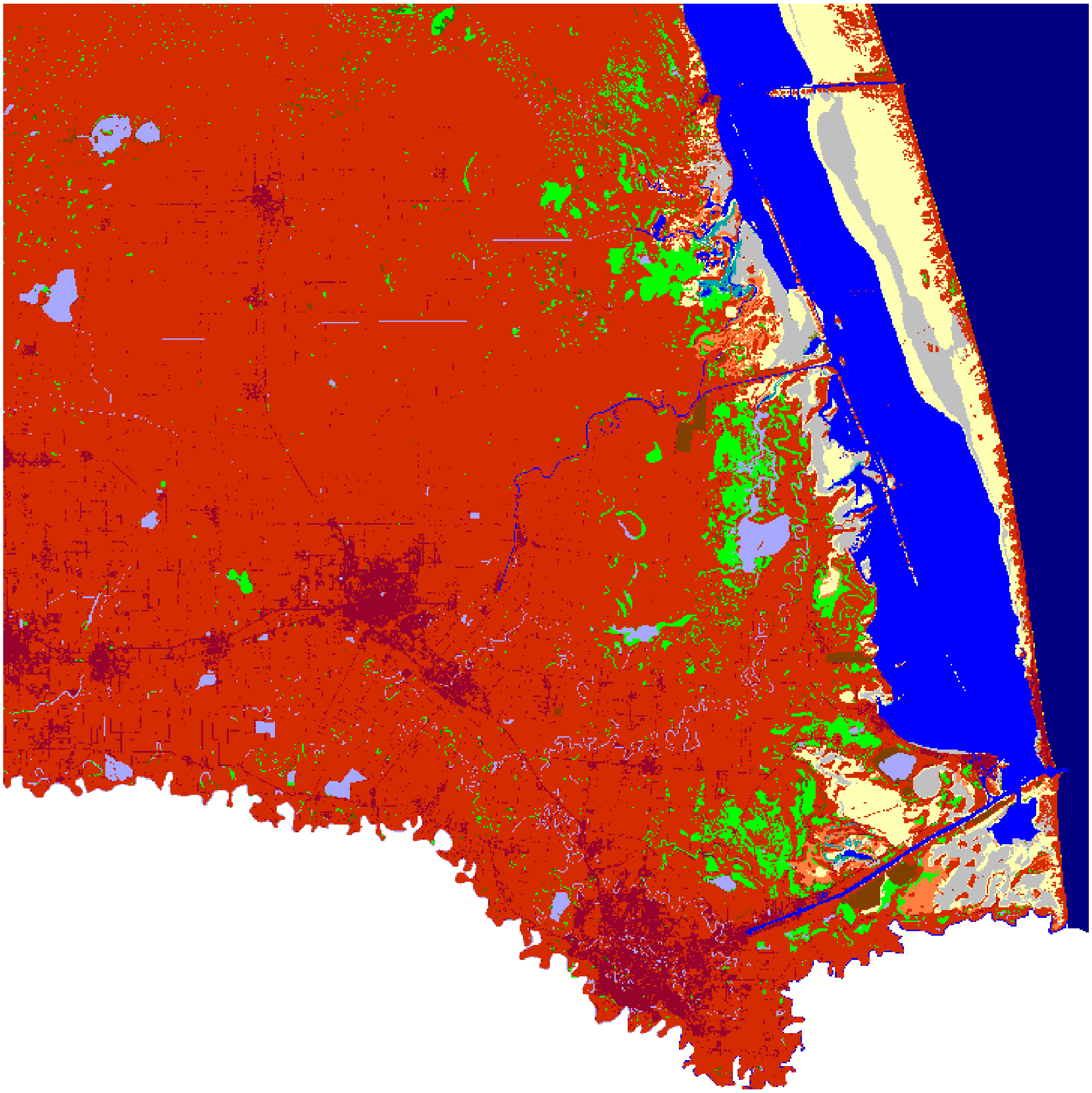
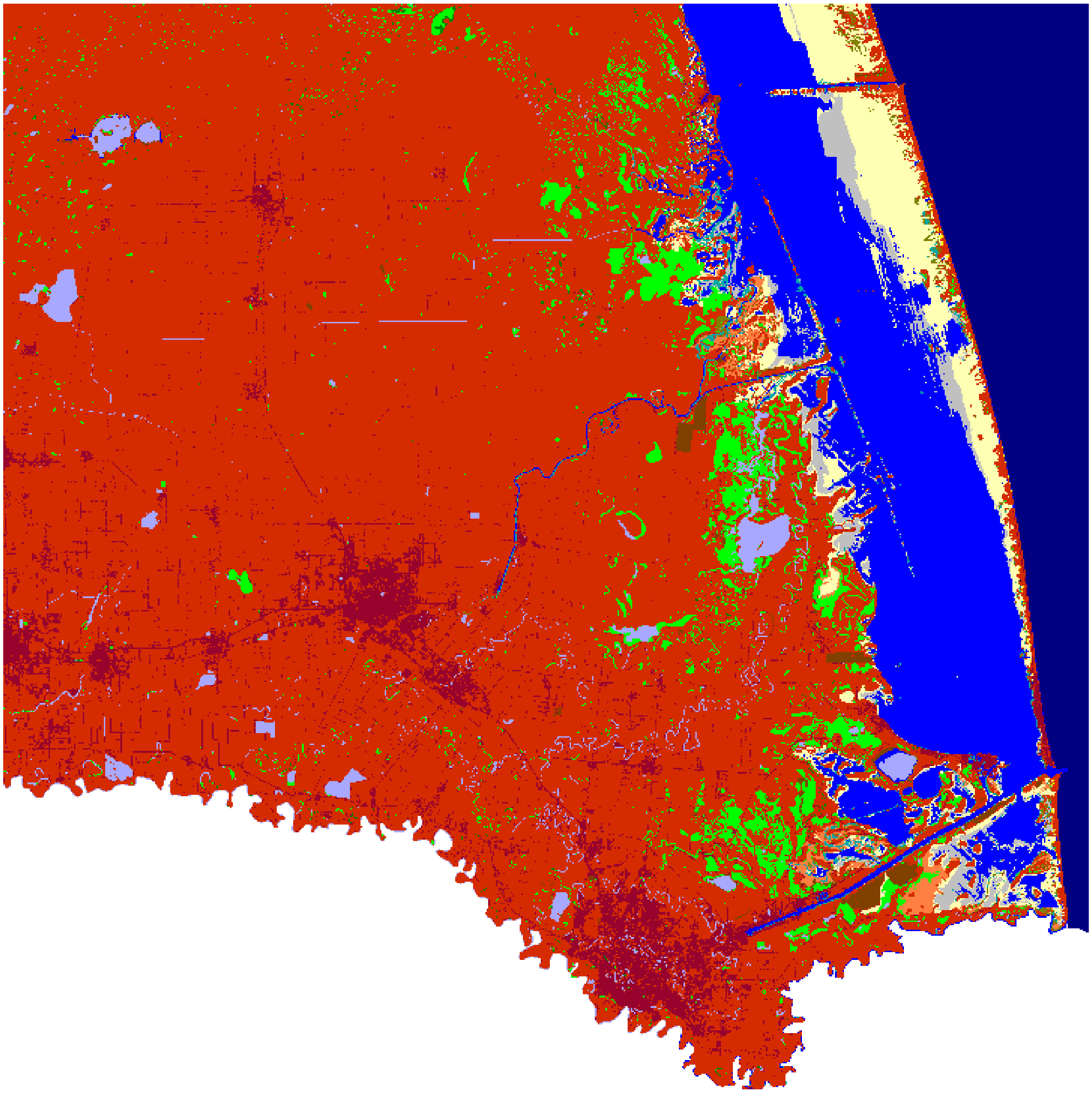


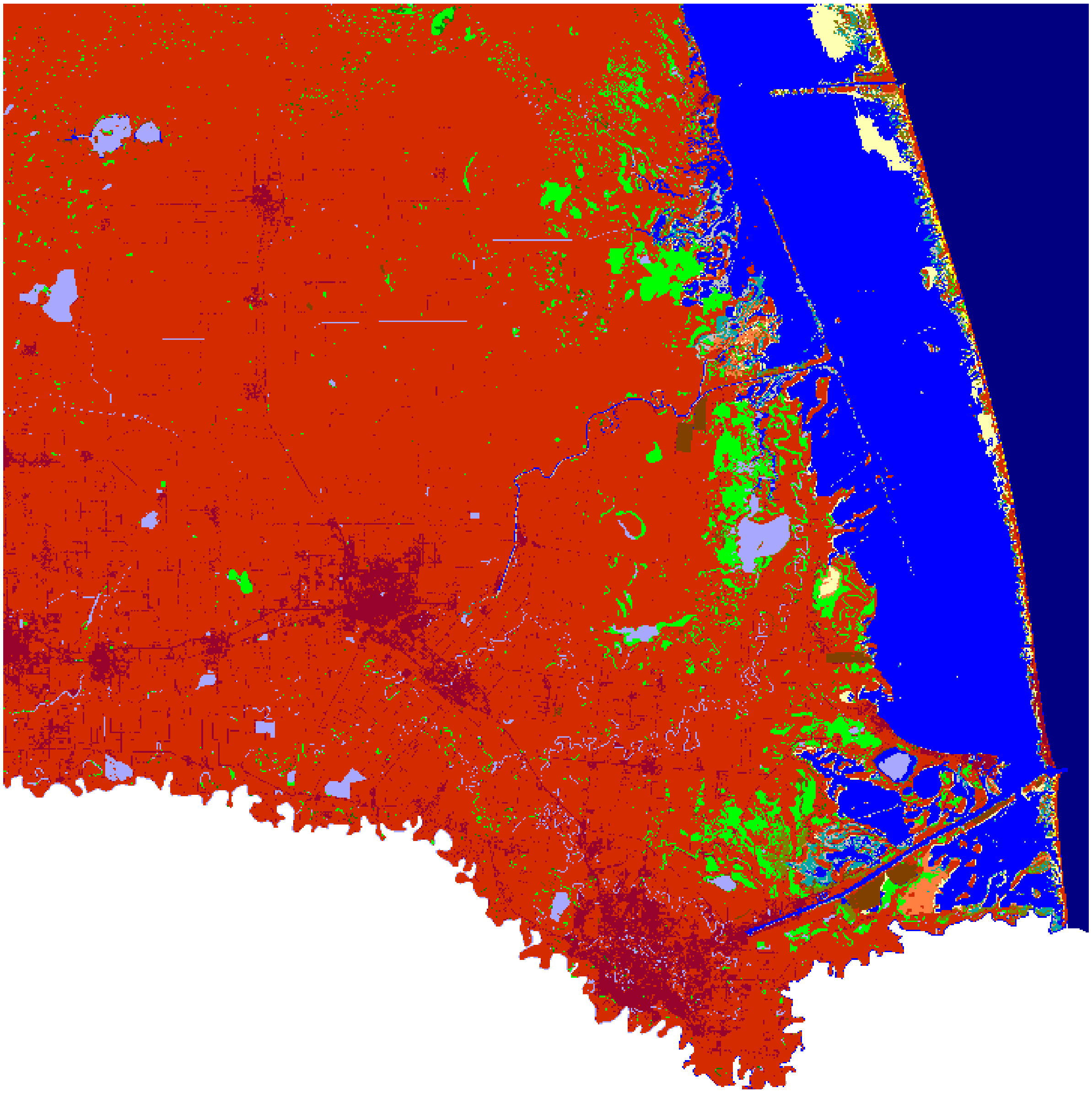
Laguna Atascosa NWR, 2100, 1.5 m SLR



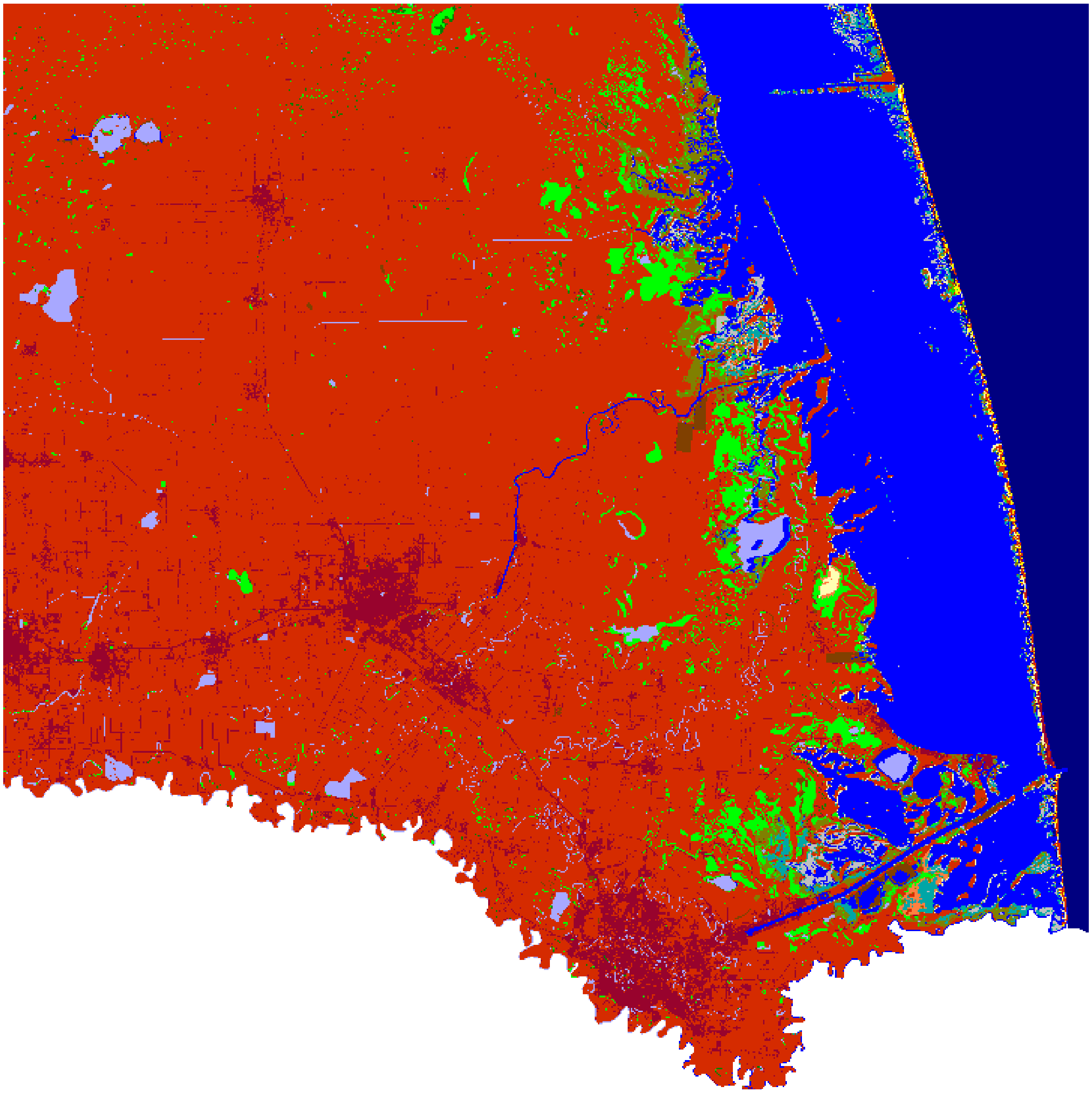
Laguna Atascosa NWR, Initial Condition



Laguna Atascosa NWR, 2025, 2 m SLR



Laguna Atascosa NWR, 2050, 2 m SLR



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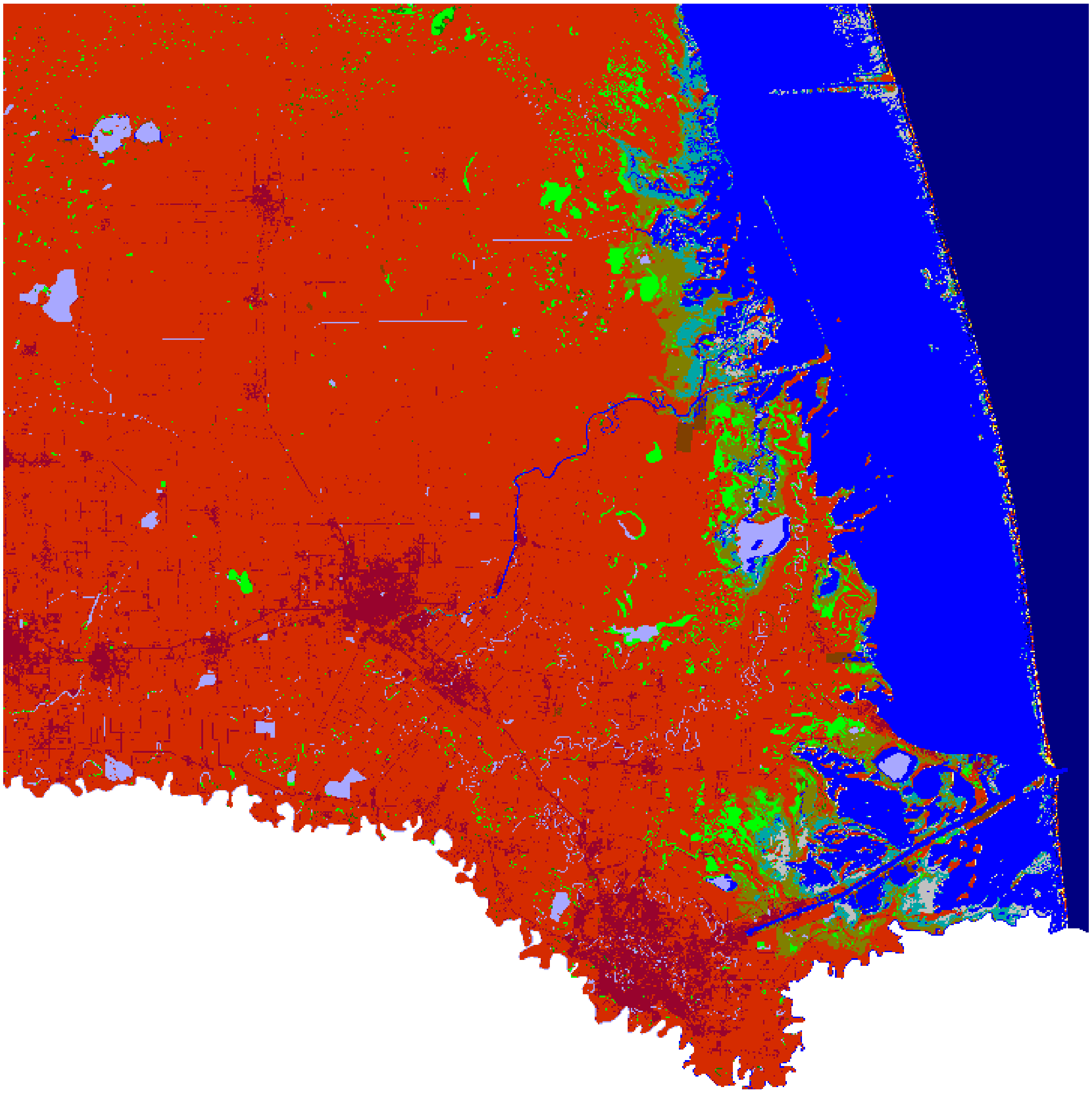

Laguna Atascosa NWR, 2100, 2 m SLR