Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Bombay Hook NWR

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Introduction

Tidal marshes are among the most susceptible ecosystems to climate change, especially accelerated sea level rise (SLR). The International 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 could be 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 brackish marsh (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 most Region 5 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, J.K., R.A. Park, and P.W. Mausel. 1992; Park, R.A., J.K. Lee, and D. Canning 1993; Galbraith, H., R. Jones, R.A. Park, J.S. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002; National Wildlife Federation et al., 2006; Glick, Clough, 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 width are assumed to undergo overwash during each 25-year time-step due to 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 or can be specified to respond to feedbacks such as frequency of inundation.

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 confirm the SLAMM conceptual model at each site.
- 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, Park, Fuller, 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 (CREM 2008). Site-specific factors that increase or decrease model uncertainty may be covered in the *Discussion* section of this report.

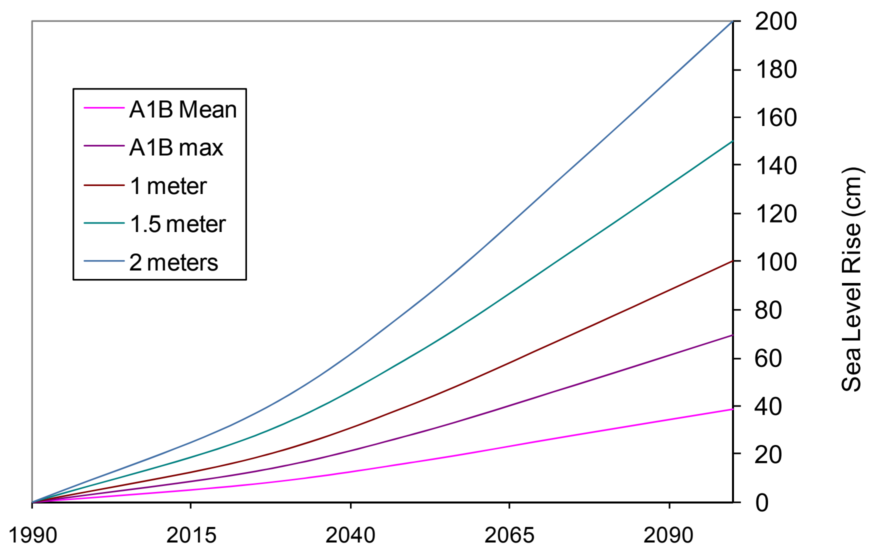
Sea Level Rise Scenarios

SLAMM 6 was run using scenario A1B from the Special Report on Emissions Scenarios (SRES) – mean and maximum estimates. The A1 scenario assumes that the future world includes very 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 (IPC, 2007) suggests a likely range of 0.21 to 0.48 meters of sea level rise 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 0.40 meters of global sea level rise 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 might be 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 meters 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 sea level rises for the end of the 21st century are too low." (US Climate Change Science Program, 2008) 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, with low probability of the rise being within Intergovernmental Panel on Climate Change (IPCC) confidence limits."

To allow for flexibility when interpreting the results, SLAMM was also run assuming 1 meter, 1½ meters, and 2 meters of eustatic sea-level rise 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



Additional information on the development of the SLAMM model is available in the technical documentation, which may be downloaded from [the SLAMM website](#) (Clough and Park, 2008).

Methods and Data Sources

The digital elevation map (DEM) used in this model simulation was derived almost entirely from 2009 Delaware Coastal Program LiDAR (Figure 1). Some contextual regions were derived with the National Elevation Dataset (NED).

Figure 1: LiDAR coverage map of Bombay Hook NWR (boundary in red). Black is NED.

The wetlands dataset for the Bombay Hook simulation is derived from 1992 Delaware ¼ acre resolution data. These wetlands data were recommended to us by David Carter of Delaware Coastal Program and are newer than the latest 1981 NWI for the area. Converting the wetlands dataset into 30 meter cells indicates that the approximately twenty one thousand acre refuge (approved acquisition boundary including water) is composed of primarily the following categories:

Regularly Flooded Marsh	57.4%
Dry Land	12.9%
Irregularly Flooded Marsh	6.9%
Estuarine Open Water	6.6%
Estuarine Beach	4.8%
Swamp	4.3%
Inland Fresh Marsh	3.2%
Inland Open Water	3.2%

The refuge has numerous impounded zones covering mostly inland open water and swamp at Bear Swamp, Raymond and Shearness, according to this State of Delaware wetland data.

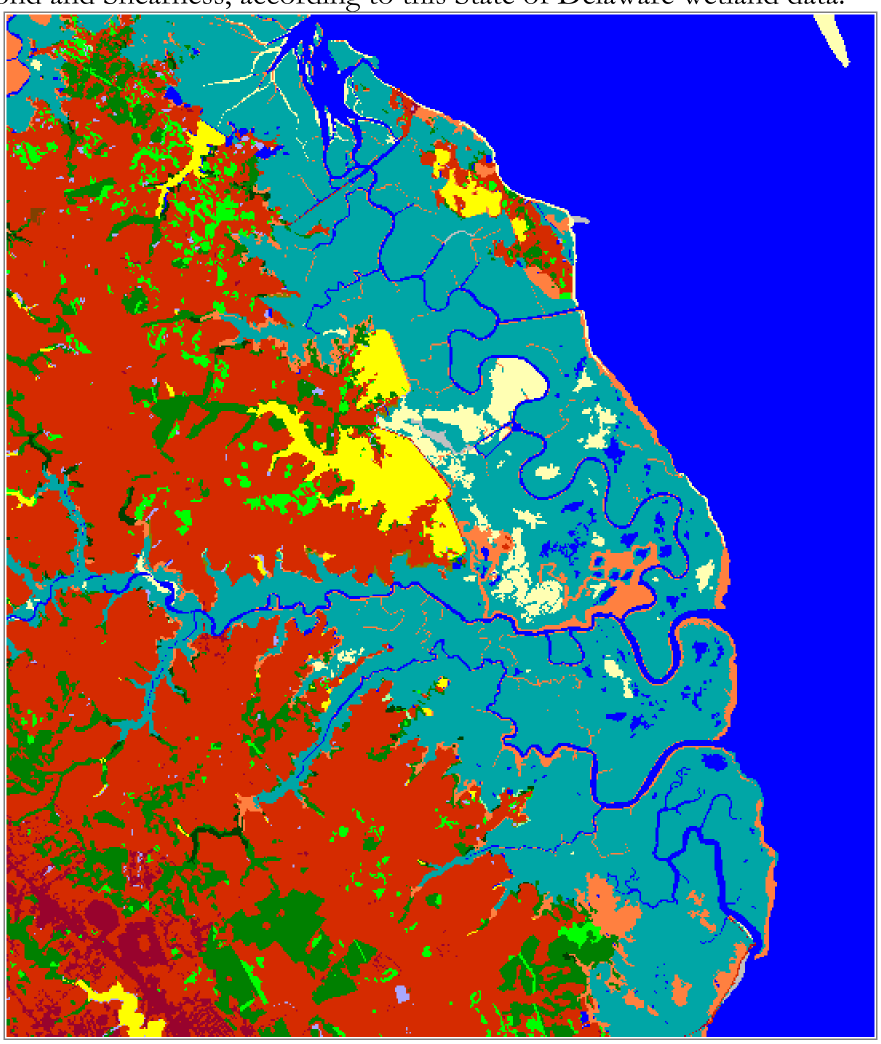


Figure 2: Diked areas in yellow.

The historic trend for sea level rise was estimated at 3.33 mm/year using the average of the two nearest NOAA gages (8551910, Reedy Point, DE; 8556380, Lewes, DE). Based on these data, it appears that the rate of sea level rise for this refuge has been higher than the global average for the last 100 years (approximately 1.7 mm/year). This differential is likely due to land subsidence. (David Carter of the Delaware Coastal Program mentioned to us that Kent County has a relatively high subsidence rate.) Within SLAMM simulations, this difference between local and global rates of SLR (1.6 mm/year) is projected forward to the year 2100.

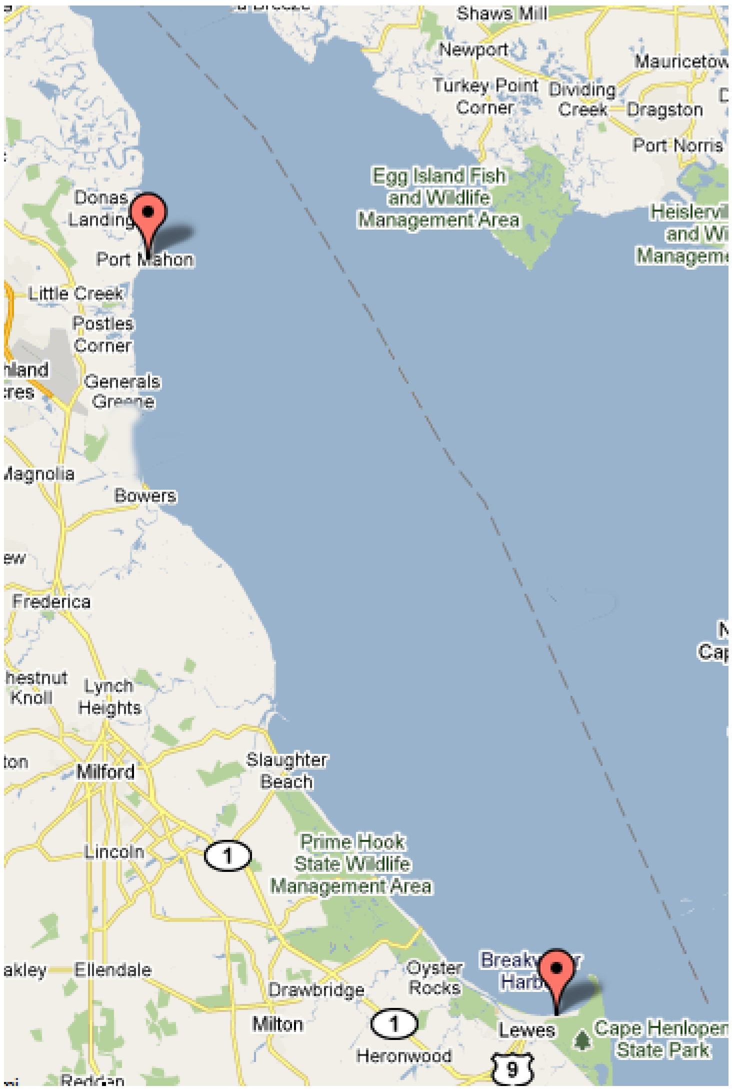


Figure 3: Two of the NOAA Gages Relevant to the Study Area.

The refuge tidal range of 1.81 meters was determined using data from the closest NOAA gage (8554299, Mahon River Entrance, DE).

For marsh accretion, a value of 3.48 mm/year was used, based on a rough average of two different calculations:

- The marsh accretion study located nearest to this study area (Port Mahon DE, Kraft, 1992) measured accretion rates as 4.06 mm/year;

- An additional accretion study performed in the Leipsic River (Nikitina, 2000) that measured accretion rates of 2.9 mm/year.

The accretion value of 3.48 mm/year closely matches the average value from a Prime Hook accretion study (State of Delaware, n = 6) of 3.44 mm/year. The value also is similar to the average Delaware salt marsh accretion value of 3.88 mm/year measured in the Delaware Bay (Reed 2008, n=9).

Marsh erosion values were set to 4.05 meters/year based on locally-derived short-term averages within a study of Delaware Bay (Kraft, 1992). Severe erosion of marsh on the southeastern shore of the refuge – around the mouth of the Mahon River – was observed by David Carter of Delaware Coastal Program. He observed a habitat loss rate of 7.78 acres/year from 1937 to 2002 along these shores. These regions are also predicted to be quickly lost in SLAMM simulations due to their elevations within the LiDAR dataset (Figure 4).

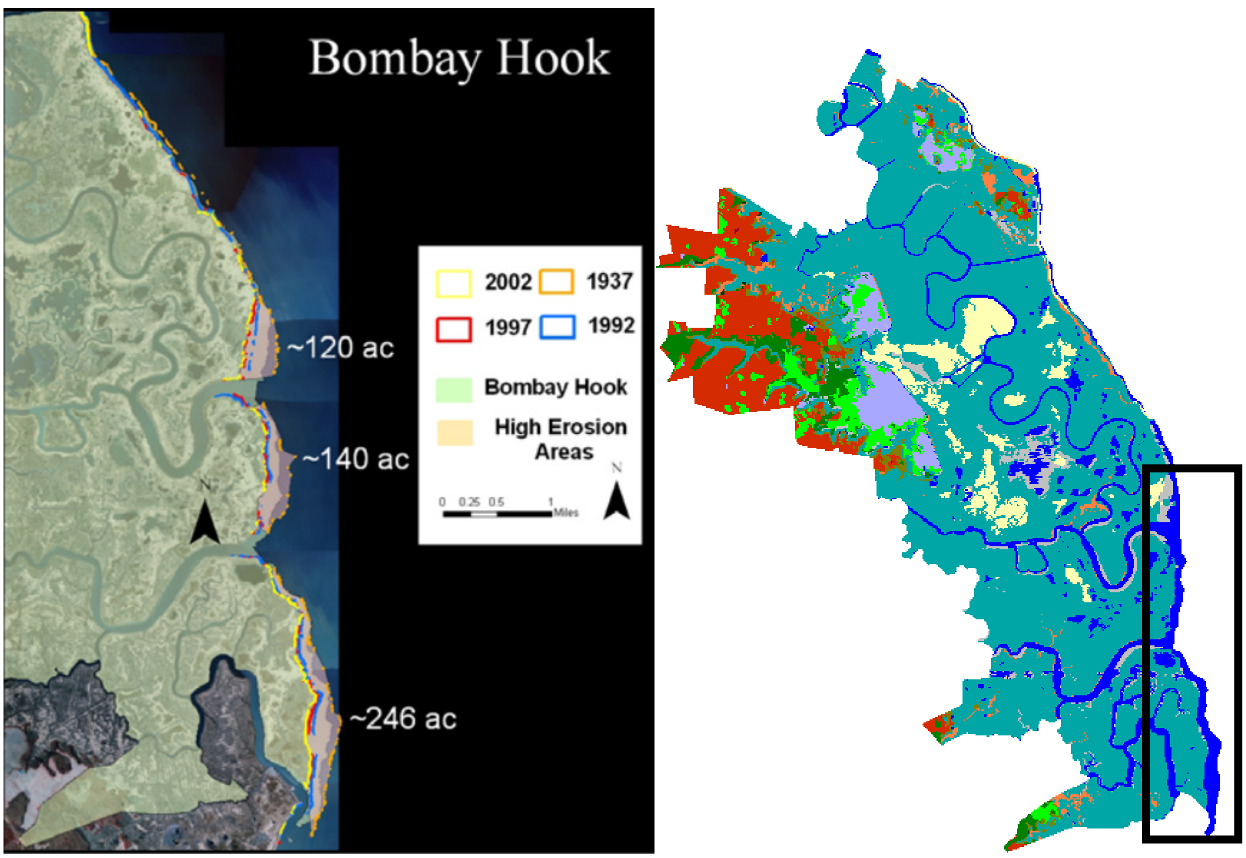


Figure 4: Wetland loss as observed by Carter (left) and as simulated in SLAMM (right, in rectangle).

The MTL to NAVD88 correction was derived using the NOAA VDATUM product. Based on the average of site-specific correction values ranging from -0.07 to -0.05, -0.06 meters was used.

Modeled U.S. Fish and Wildlife Service refuge boundaries for Delaware 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 meter by 30 meter cells. Additionally, the SLAMM model will track partial conversion of cells based on elevation and slope.

SUMMARY OF SLAMM INPUT PARAMETERS FOR BOMBAY HOOK NWR

Parameter	Global
Description	Bombay Hook
NWI Photo Date (YYYY)	1992
DEM Date (YYYY)	2009
Direction Offshore [n,s,e,w]	East
Historic Trend (mm/yr)	3.33
MTL-NAVD88 (m)	-0.06
GT Great Diurnal Tide Range (m)	1.81
Salt Elev. (m above MTL)	1.21
Marsh Erosion (horz. m /yr)	4.05
Swamp Erosion (horz. m /yr)	4.05
T.Flat Erosion (horz. m /yr)	4.05
Reg. Flood Marsh Accr (mm/yr)	3.48
Irreg. Flood Marsh Accr (mm/yr)	3.48
Tidal Fresh Marsh Accr (mm/yr)	3.48
Beach Sed. Rate (mm/yr)	0.5
Freq. Overwash (years)	25
Use Elev Pre-processor [True,False]	FALSE

Results

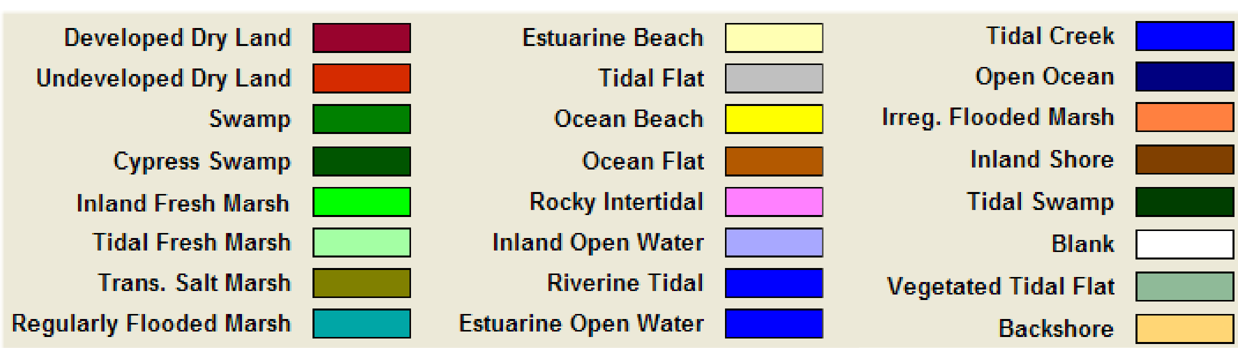
The SLAMM simulation of Bombay Hook NWR indicates a refuge susceptible to the effects of sea level rise especially at moderate-to-higher scenarios. The refuge is predicted to lose more than three quarters of its regularly flooded (salt) marsh in scenarios above 1 meter. Saltmarsh is actually predicted to increase in lower SLR scenarios due to the conversion of irregularly flooded marshes. The refuge is predicted to lose between 23% and 62% of its dry land, and between 15% and 97% of its irregularly flooded marsh across all scenarios.

Maps of model results seem to predict that the refuge is fairly resilient to rates of eustatic SLR below one meter (by 2100). There are some questions as to the accuracy of the LiDAR data covering the refuge, however, as covered in the *Discussion* section below.

SLR by 2100 (m)	0.39	0.69	1	1.5	2
Saltmarsh	-1%	-7%	-9%	84%	94%
Undeveloped Dry Land	23%	31%	38%	50%	62%
Irregularly Flooded Marsh	15%	37%	83%	95%	97%
Estuarine Beach	2%	2%	2%	3%	95%
Swamp	28%	38%	45%	54%	64%
Inland Fresh Marsh	7%	10%	13%	18%	27%

Predicted Loss Rates of Land Categories by 2100 Given Simulated Scenarios of Eustatic Sea Level Rise

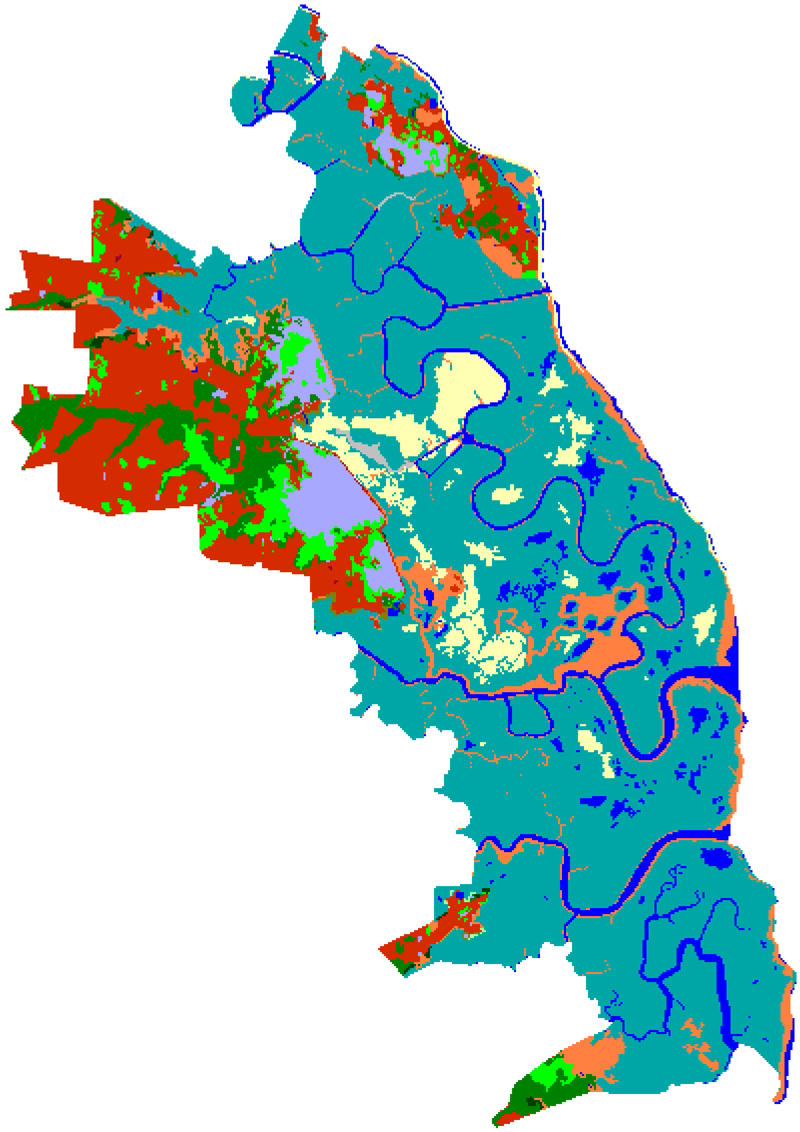
Maps of SLAMM input and output to follow will use the following legend:



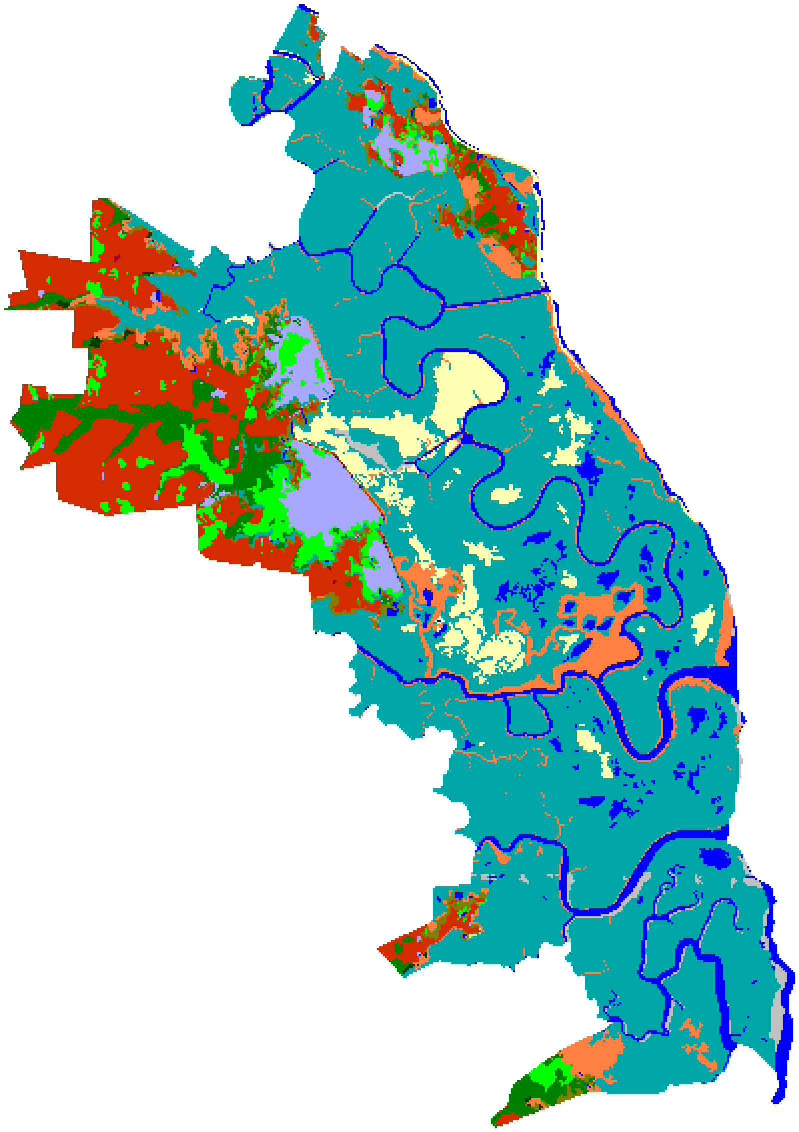
Bombay Hook NWR
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Acres

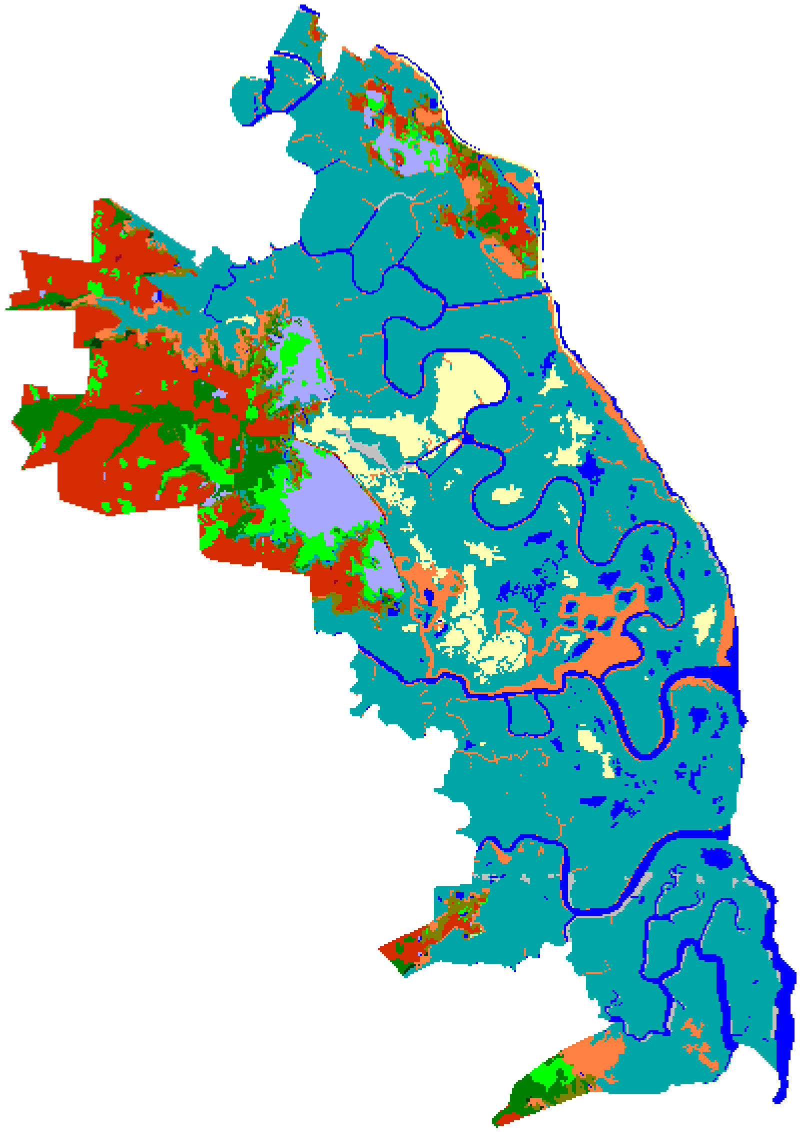
	Initial	2025	2050	2075	2100
Saltmarsh	12145.2	12174.8	12186.7	12215.5	12267.0
Undeveloped Dry Land	2737.2	2435.5	2333.9	2219.5	2111.1
Irregularly Flooded Marsh	1470.7	1323.5	1306.9	1286.3	1252.0
Estuarine Open Water	1407.5	1540.7	1607.3	1647.0	1686.9
Estuarine Beach	1012.8	999.4	997.2	996.5	994.1
Swamp	919.6	807.2	762.0	720.4	658.8
Inland Fresh Marsh	680.7	646.4	643.4	639.5	634.9
Inland Open Water	670.5	655.4	652.7	650.3	647.8
Tidal Flat	42.0	191.9	158.4	160.6	158.5
Tidal Swamp	37.4	23.2	21.1	17.4	15.0
Trans. Salt Marsh	35.1	368.7	498.8	616.6	744.5
Dev. Dry Land	9.3	6.1	4.9	4.2	3.8
Tidal Fresh Marsh	6.7	1.8	1.4	0.9	0.4
Total (incl. water)	**21174.8**	**21174.8**	**21174.8**	**21174.8**	**21174.8**



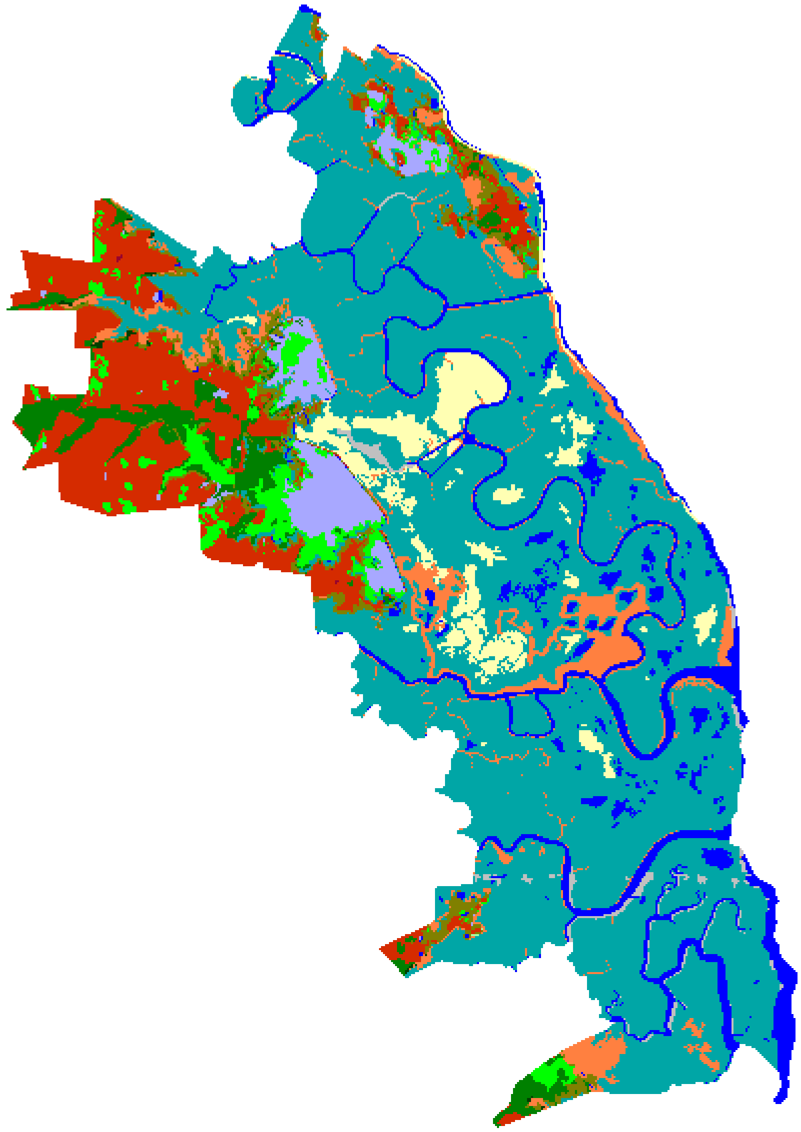
Bombay Hook NWR, Initial Condition



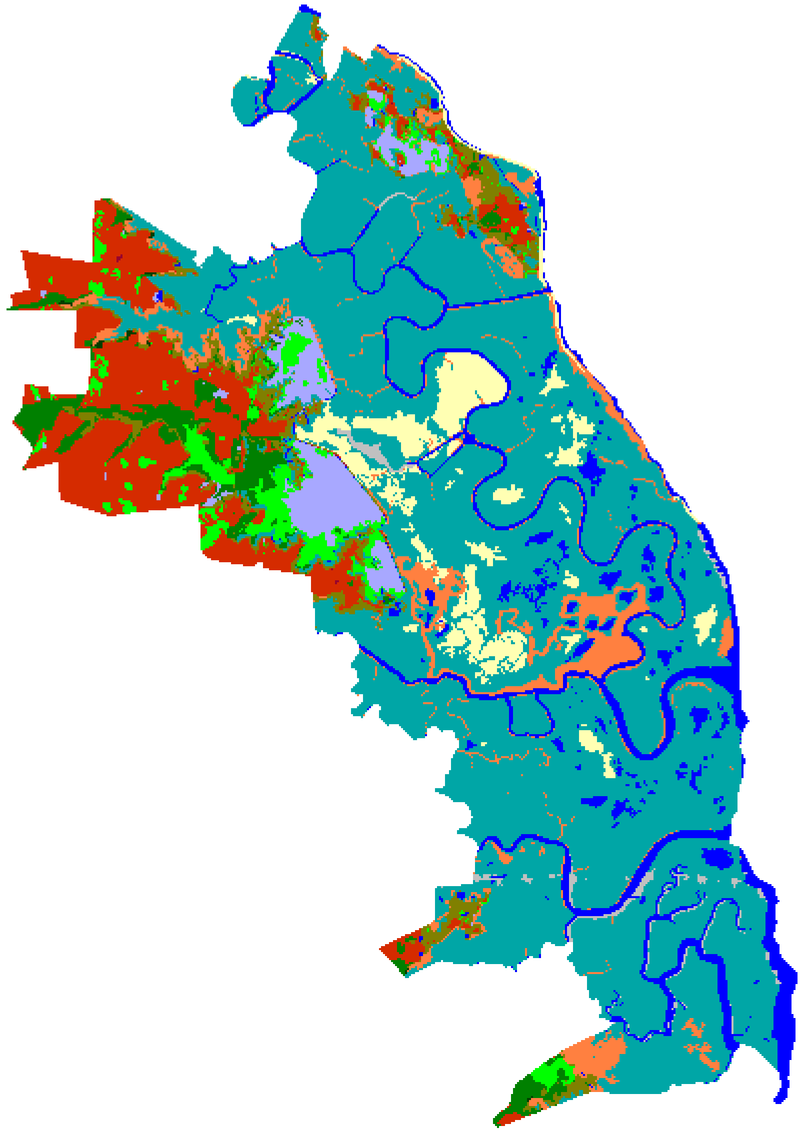
Bombay Hook NWR, 2025, Scenario A1B Mean



Bombay Hook NWR, 2050, Scenario A1B Mean



Bombay Hook NWR, 2075, Scenario A1B Mean

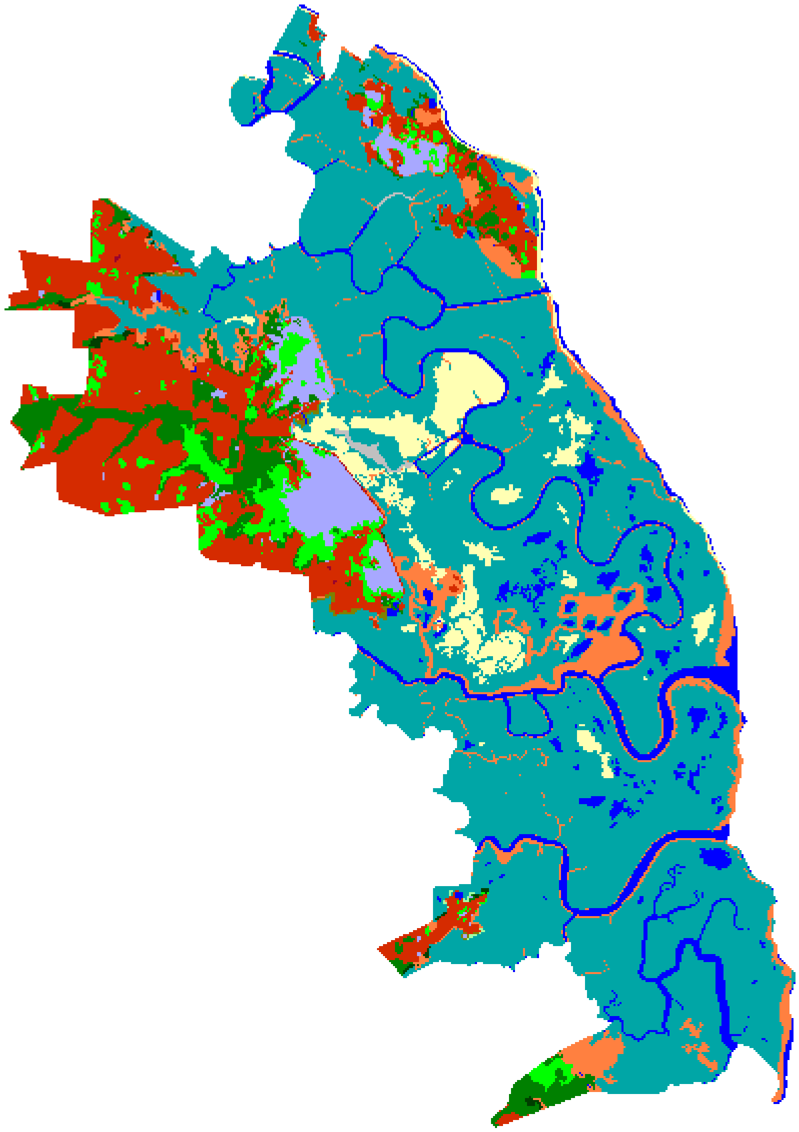


Bombay Hook NWR, 2100, Scenario A1B Mean

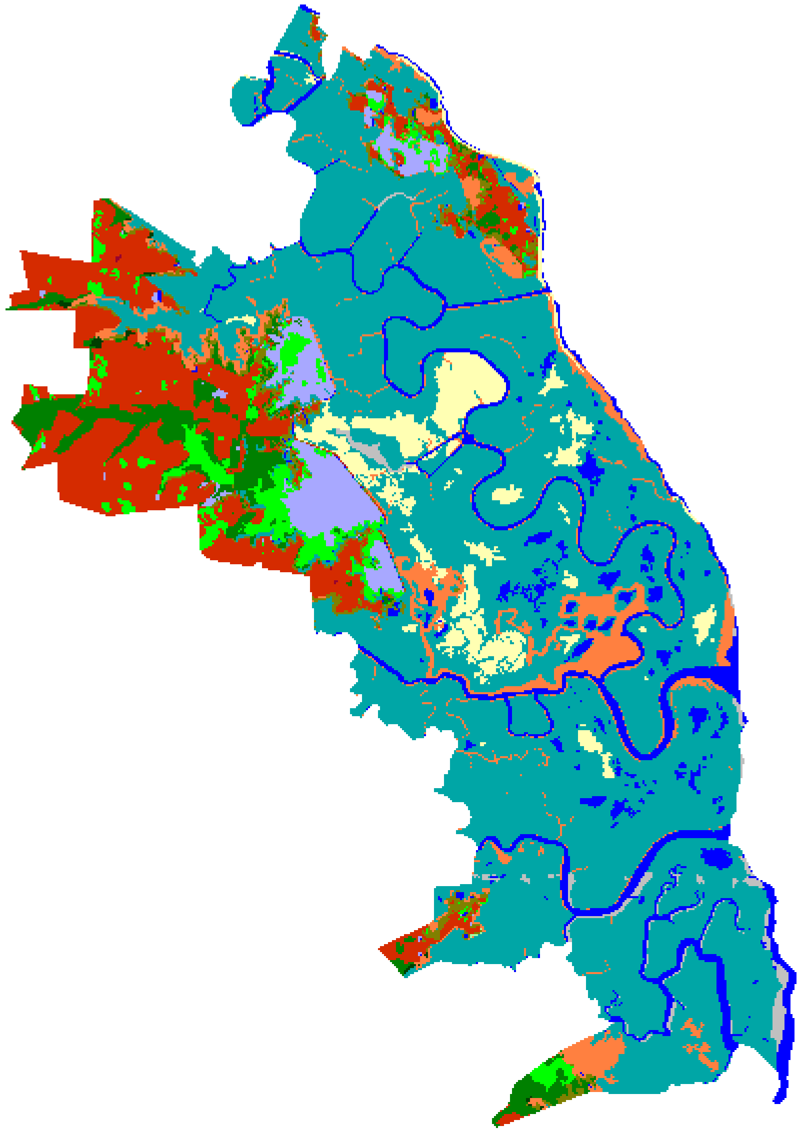
Bombay Hook NWR
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Acres

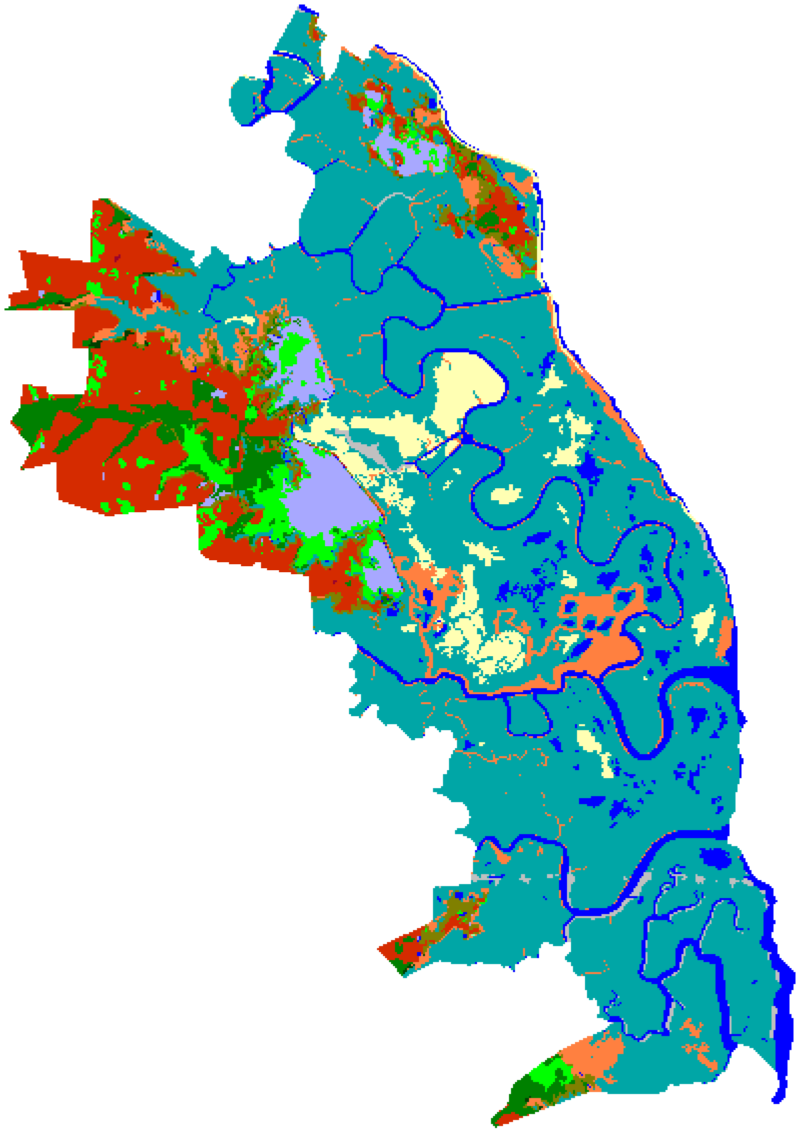
	Initial	2025	2050	2075	2100
Saltmarsh	12145.2	12205.6	12295.0	12535.8	12954.7
Undeveloped Dry Land	2737.2	2397.0	2248.0	2073.0	1894.9
Irregularly Flooded Marsh	1470.7	1307.5	1258.5	1178.3	931.4
Estuarine Open Water	1407.5	1544.3	1615.4	1683.3	1816.1
Estuarine Beach	1012.8	999.4	997.2	996.5	994.1
Swamp	919.6	785.6	729.8	634.0	568.1
Inland Fresh Marsh	680.7	644.3	637.1	626.1	613.2
Inland Open Water	670.5	654.1	650.9	647.4	644.5
Tidal Flat	42.0	198.8	175.6	210.4	229.4
Tidal Swamp	37.4	22.4	17.8	13.8	11.9
Trans. Salt Marsh	35.1	408.7	544.6	572.7	513.6
Dev. Dry Land	9.3	5.8	4.3	3.6	2.9
Tidal Fresh Marsh	6.7	1.4	0.5	0.0	0.0
Total (incl. water)	**21174.8**	**21174.8**	**21174.8**	**21174.8**	**21174.8**



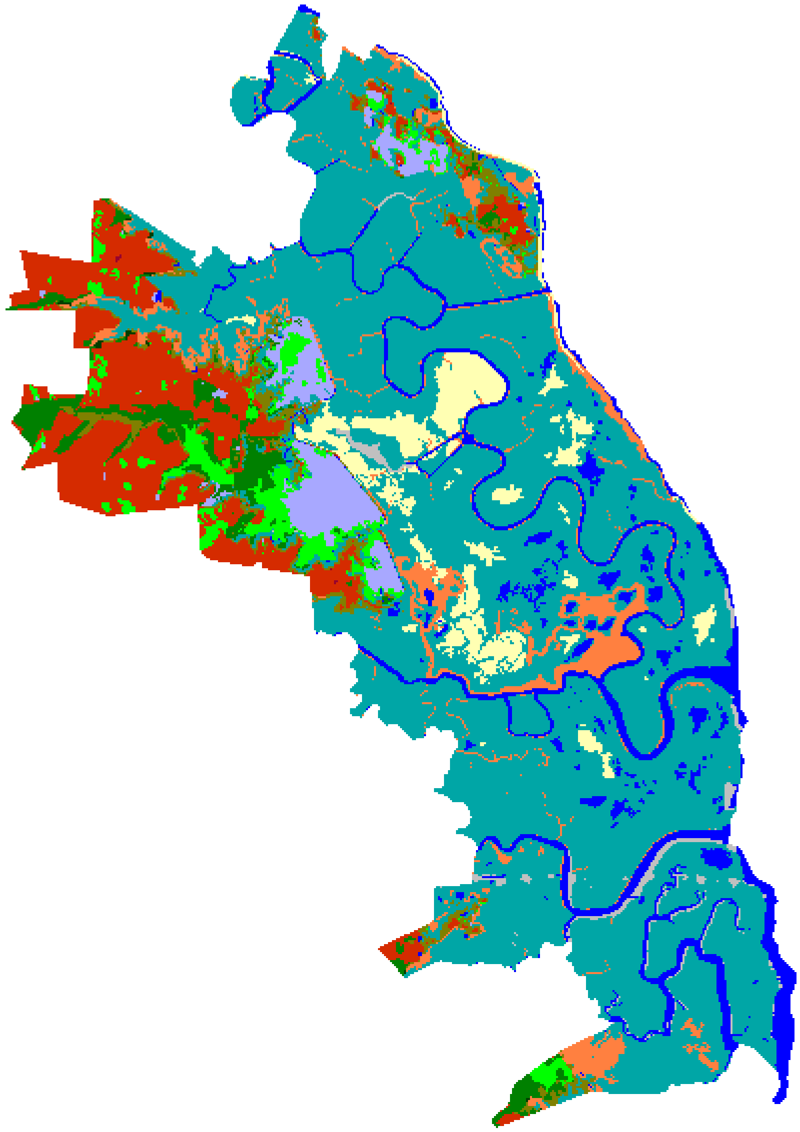
Bombay Hook NWR, Initial Condition



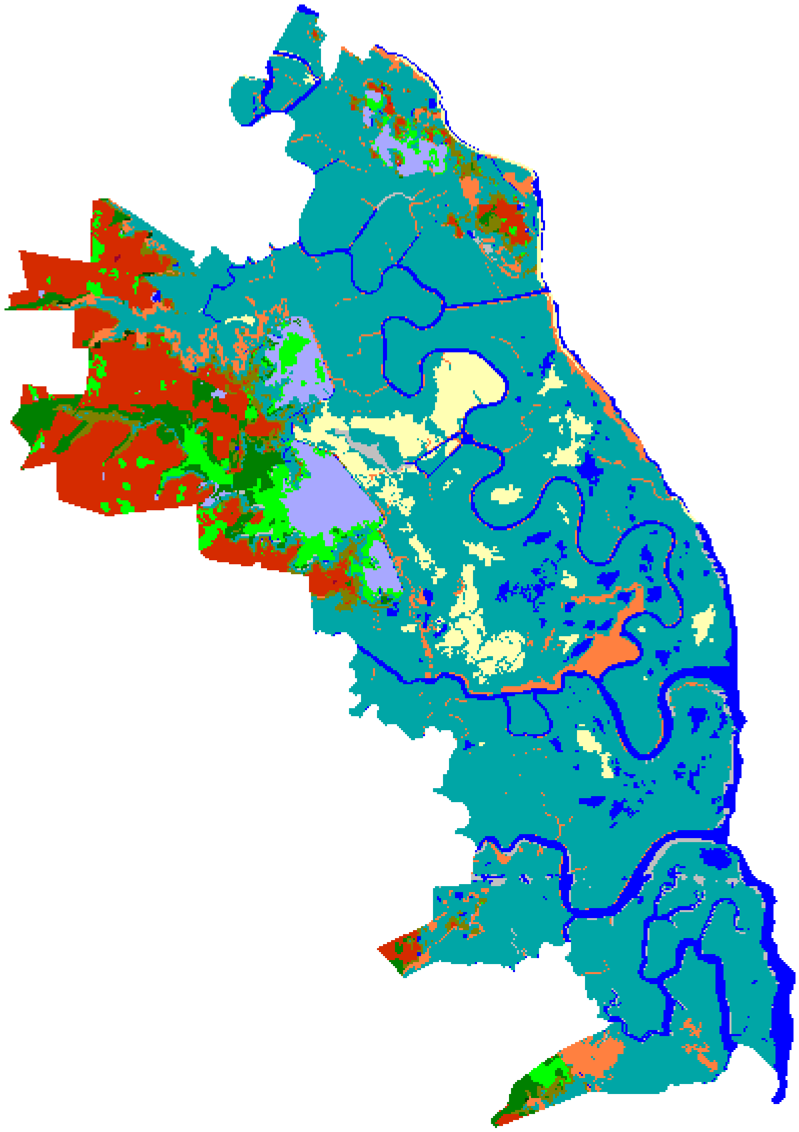
Bombay Hook NWR, 2025, Scenario A1B Maximum



Bombay Hook NWR, 2050, Scenario A1B Maximum



Bombay Hook NWR, 2075, Scenario A1B Maximum

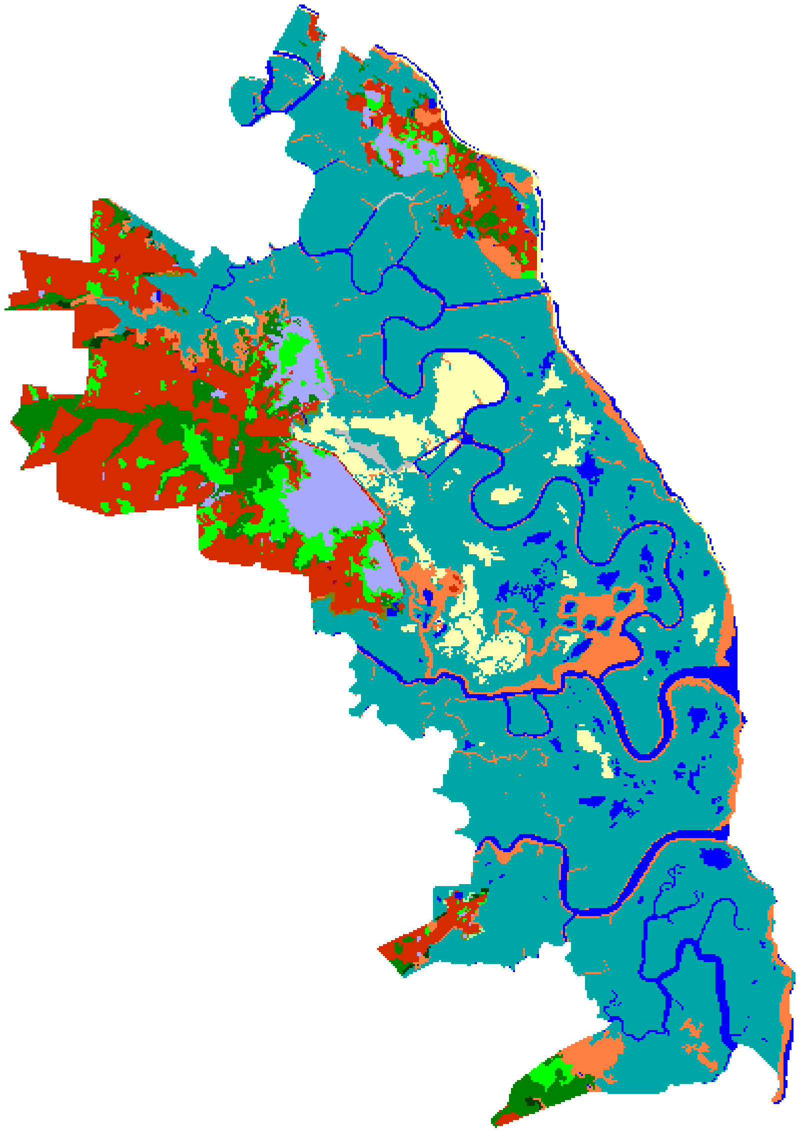


Bombay Hook NWR, 2100, Scenario A1B Maximum

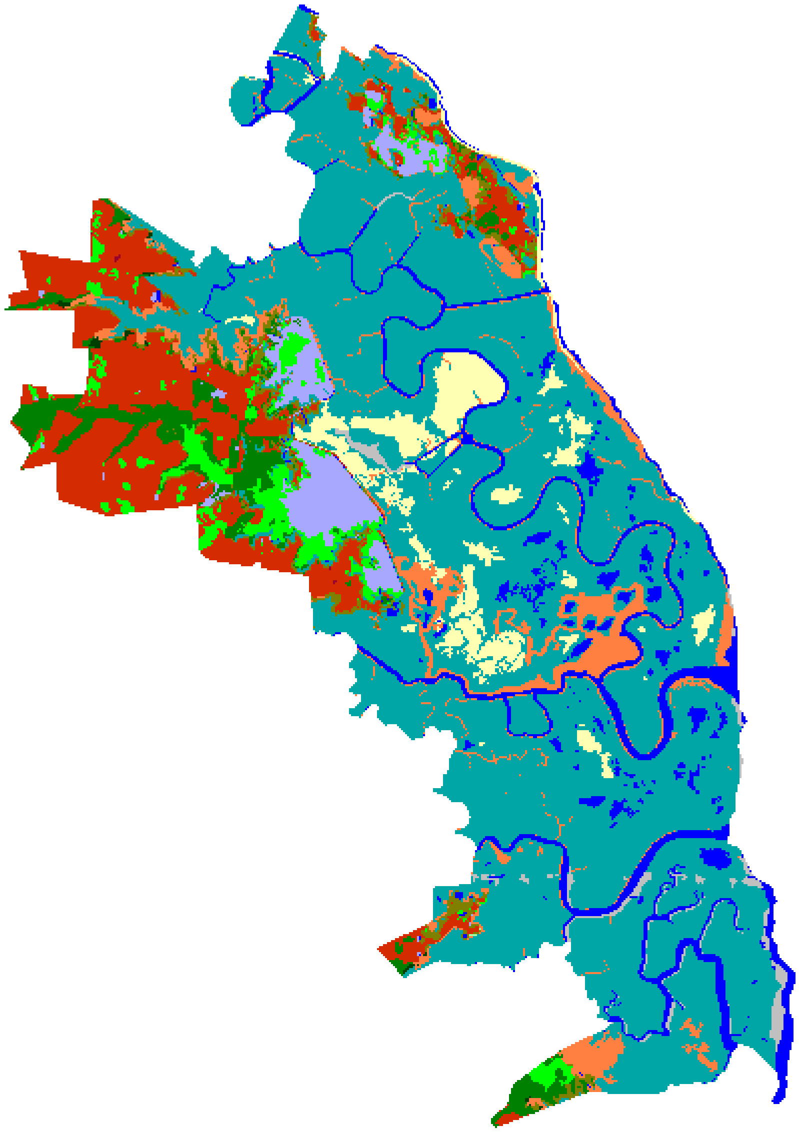
Bombay Hook NWR
1 Meter Eustatic SLR by 2100

Results in Acres

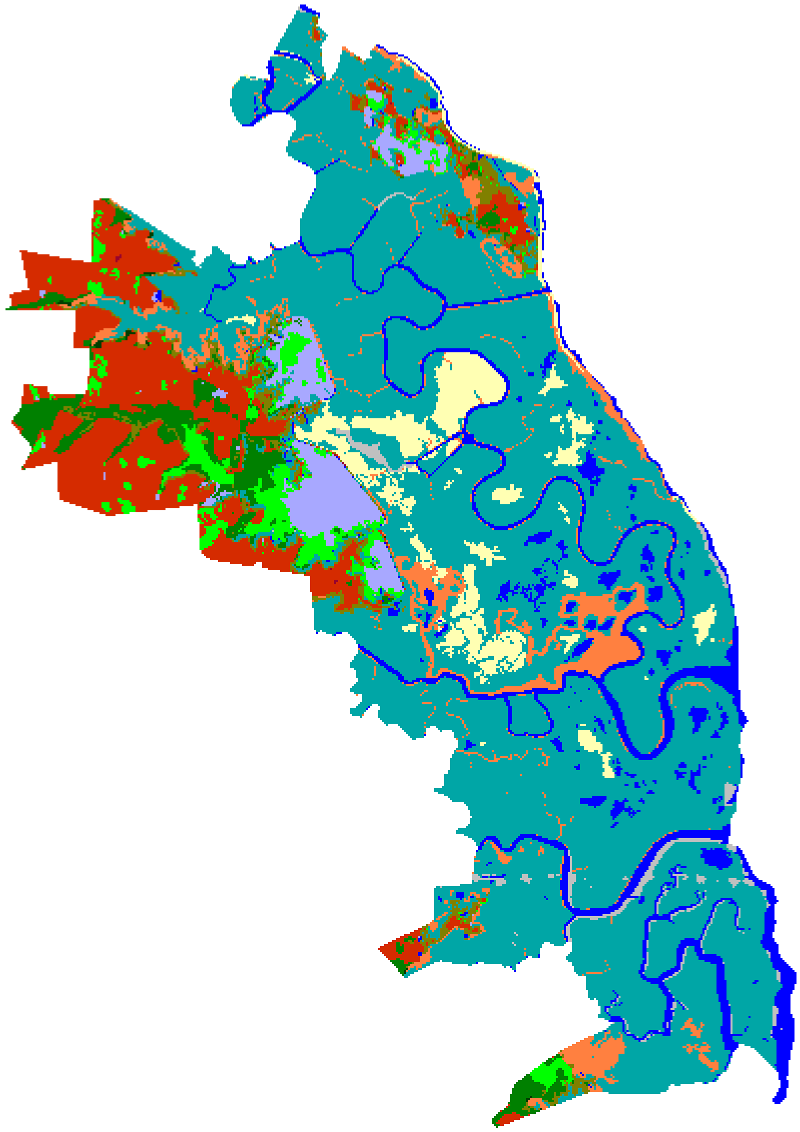
	Initial	2025	2050	2075	2100
Saltmarsh	12145.2	12243.4	12465.3	13043.4	13283.5
Undeveloped Dry Land	2737.2	2357.2	2157.3	1922.4	1701.4
Irregularly Flooded Marsh	1470.7	1295.3	1195.1	827.9	254.0
Estuarine Open Water	1407.5	1546.6	1641.3	1800.6	2021.0
Estuarine Beach	1012.8	999.4	997.2	996.5	994.0
Swamp	919.6	767.3	681.7	575.2	509.8
Inland Fresh Marsh	680.7	641.5	629.0	610.5	592.1
Inland Open Water	670.5	653.2	648.9	644.7	640.3
Tidal Flat	42.0	208.1	217.8	261.7	794.0
Tidal Swamp	37.4	21.2	15.1	12.0	9.1
Trans. Salt Marsh	35.1	435.3	522.1	476.8	372.9
Dev. Dry Land	9.3	5.2	3.9	3.0	2.7
Tidal Fresh Marsh	6.7	0.9	0.0	0.0	0.0
Total (incl. water)	**21174.8**	**21174.8**	**21174.8**	**21174.8**	**21174.8**



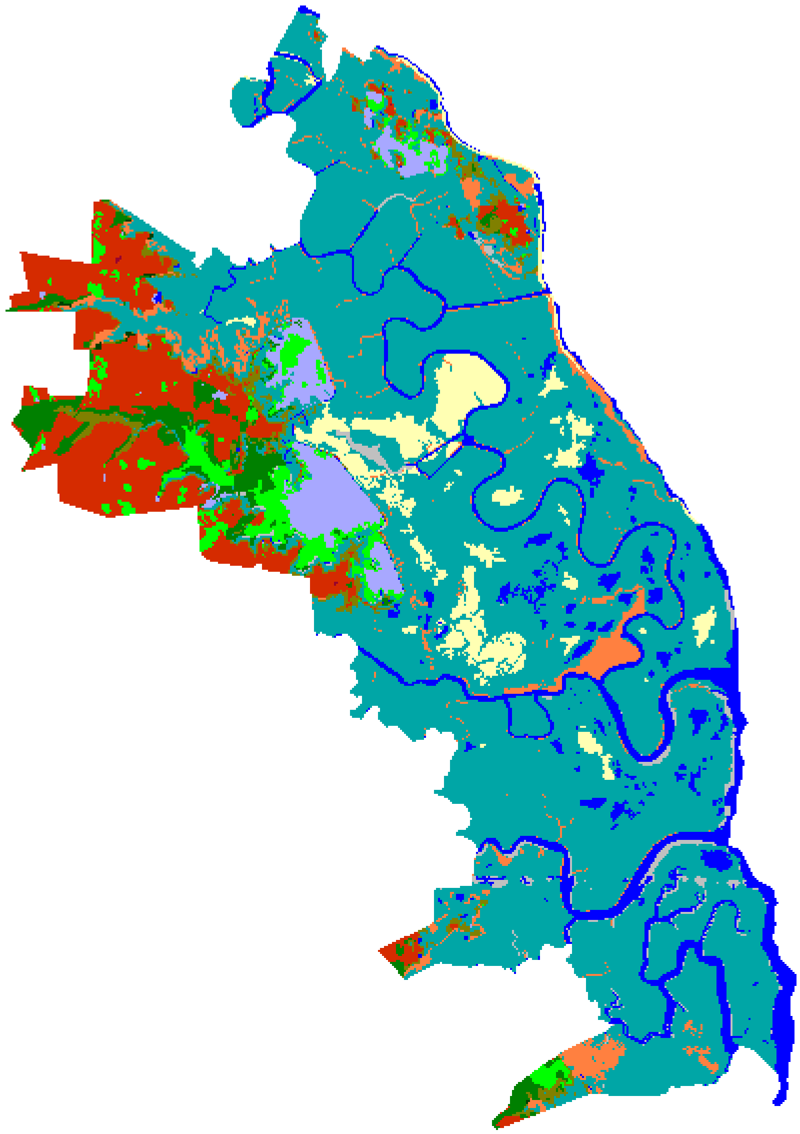
Bombay Hook NWR, Initial Condition



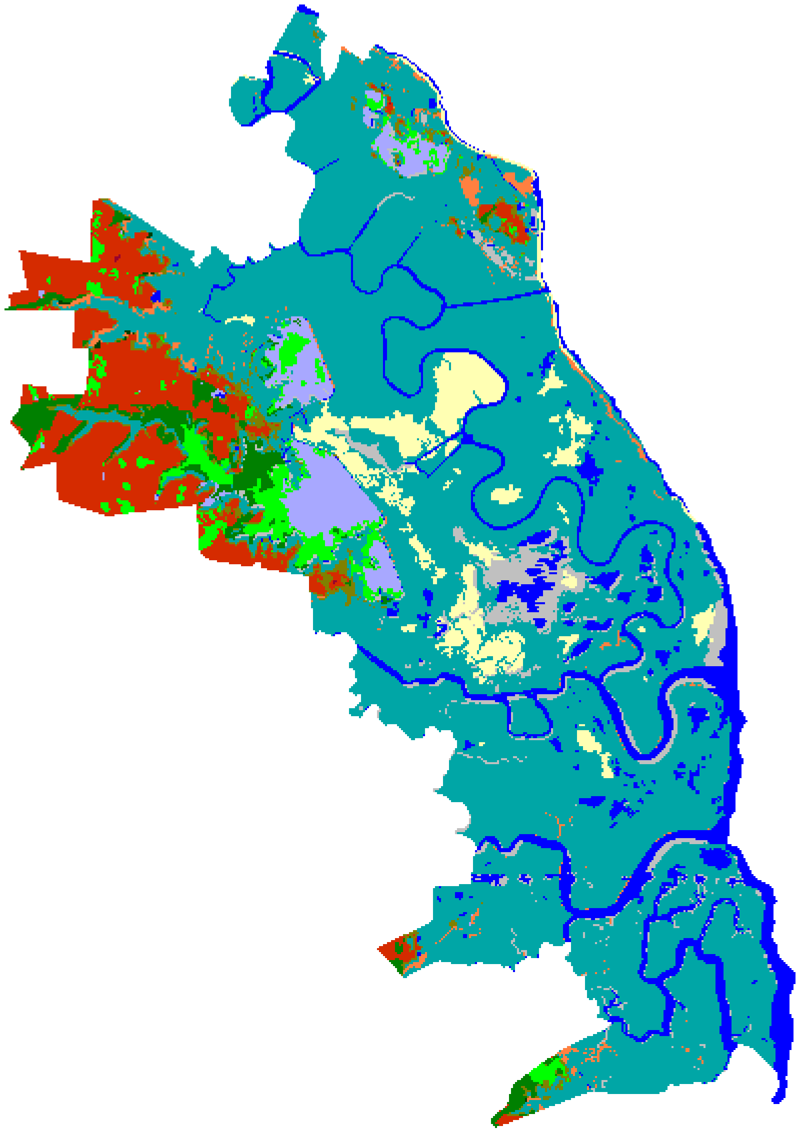
Bombay Hook NWR, 2025, 1 meter



Bombay Hook NWR, 2050, 1 meter



Bombay Hook NWR, 2075, 1 meter

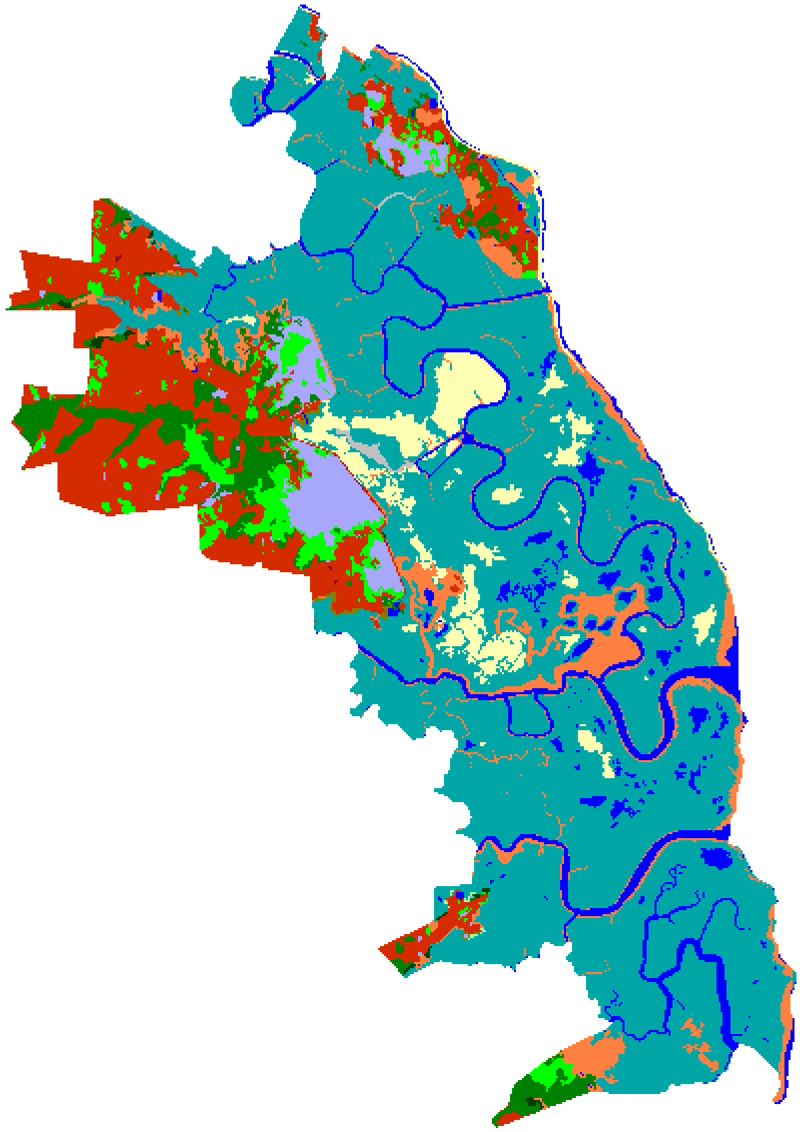


Bombay Hook NWR, 2100, 1 meter

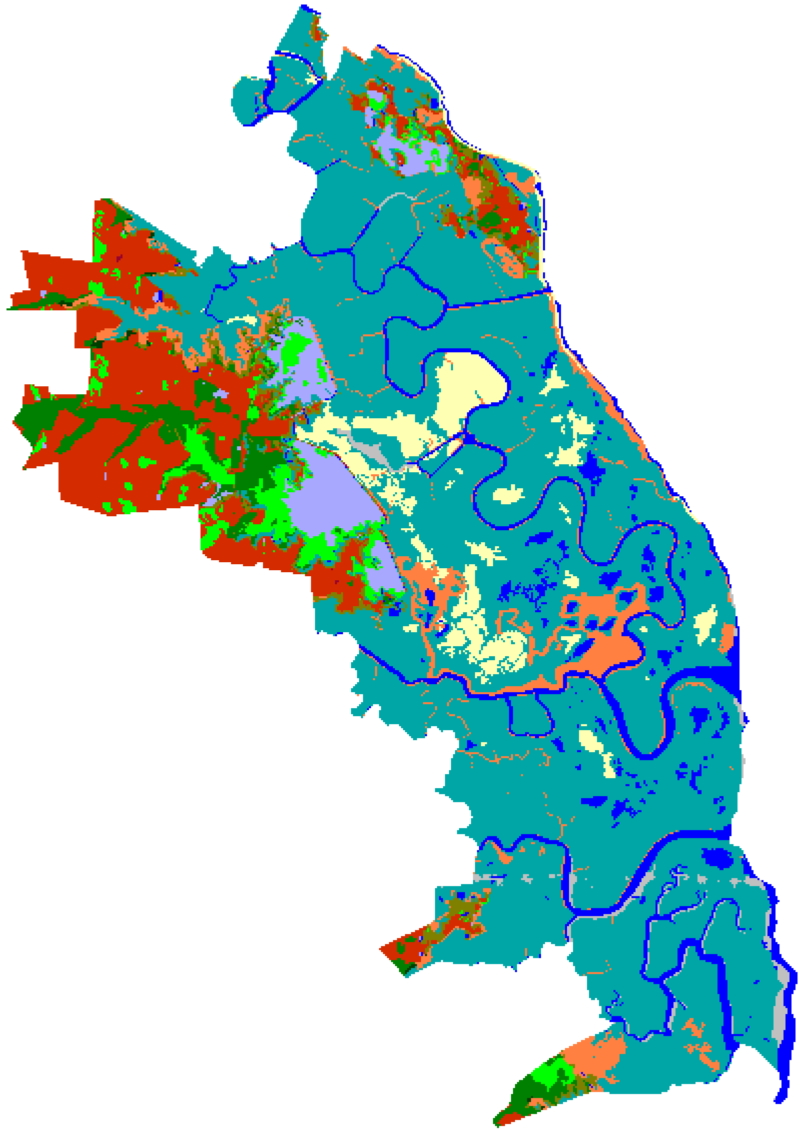
Bombay Hook NWR
1.5 Meters Eustatic SLR by 2100

Results in Acres

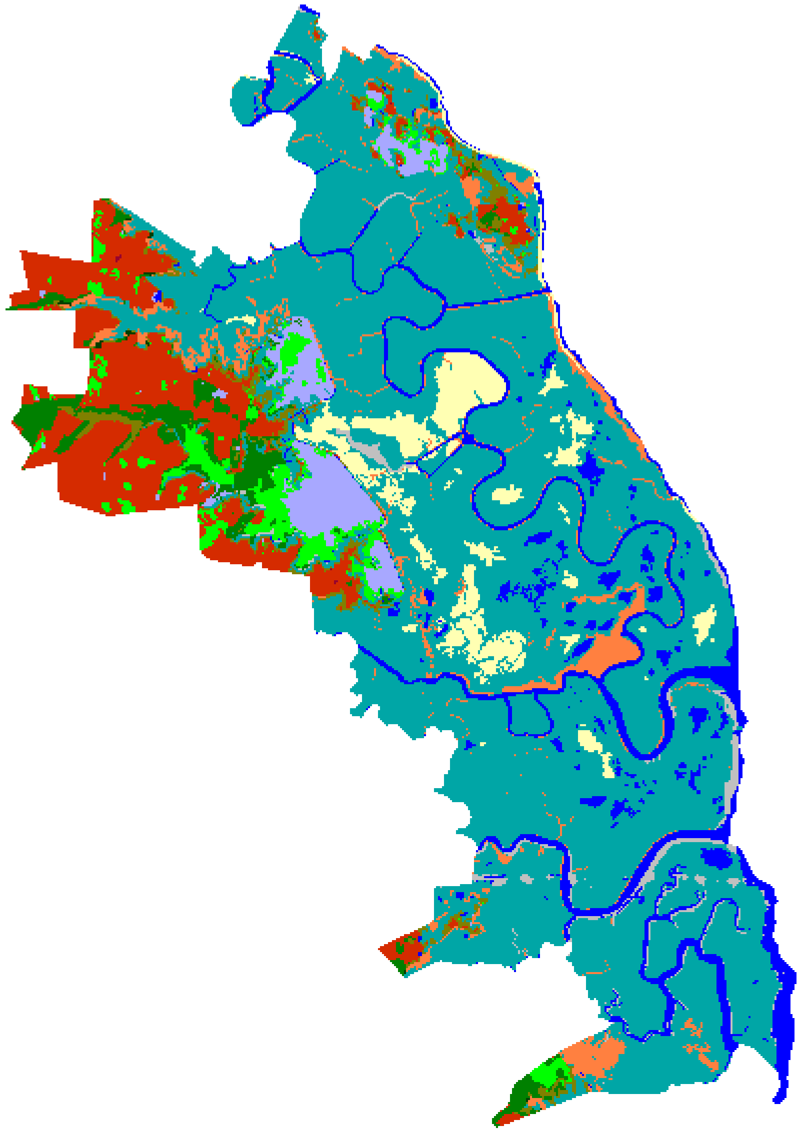
	Initial	2025	2050	2075	2100
Saltmarsh	12145.2	12343.3	12872.2	12539.7	1941.7
Undeveloped Dry Land	2737.2	2292.1	2017.4	1701.0	1369.4
Irregularly Flooded Marsh	1470.7	1245.2	923.1	174.5	71.2
Estuarine Open Water	1407.5	1556.4	1709.1	2060.8	3462.9
Estuarine Beach	1012.8	999.4	997.2	996.1	983.9
Swamp	919.6	741.3	606.4	507.8	418.6
Inland Fresh Marsh	680.7	635.9	613.8	585.0	555.0
Inland Open Water	670.5	652.5	646.5	640.3	638.3
Tidal Flat	42.0	218.6	301.9	1509.9	11273.9
Tidal Swamp	37.4	18.8	12.8	8.8	5.5
Trans. Salt Marsh	35.1	466.4	471.2	448.2	452.5
Dev. Dry Land	9.3	4.6	3.3	2.7	2.0
Tidal Fresh Marsh	6.7	0.4	0.0	0.0	0.0
Total (incl. water)	**21174.8**	**21174.8**	**21174.8**	**21174.8**	**21174.8**



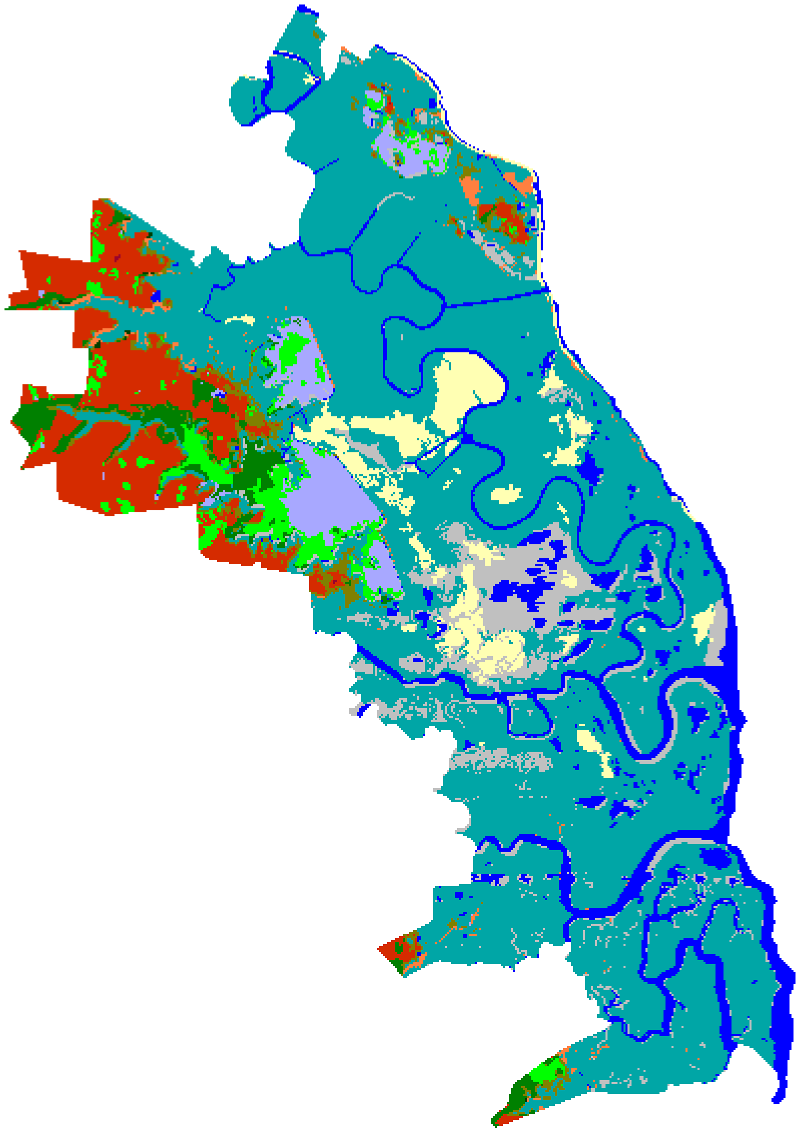
Bombay Hook NWR, Initial Condition



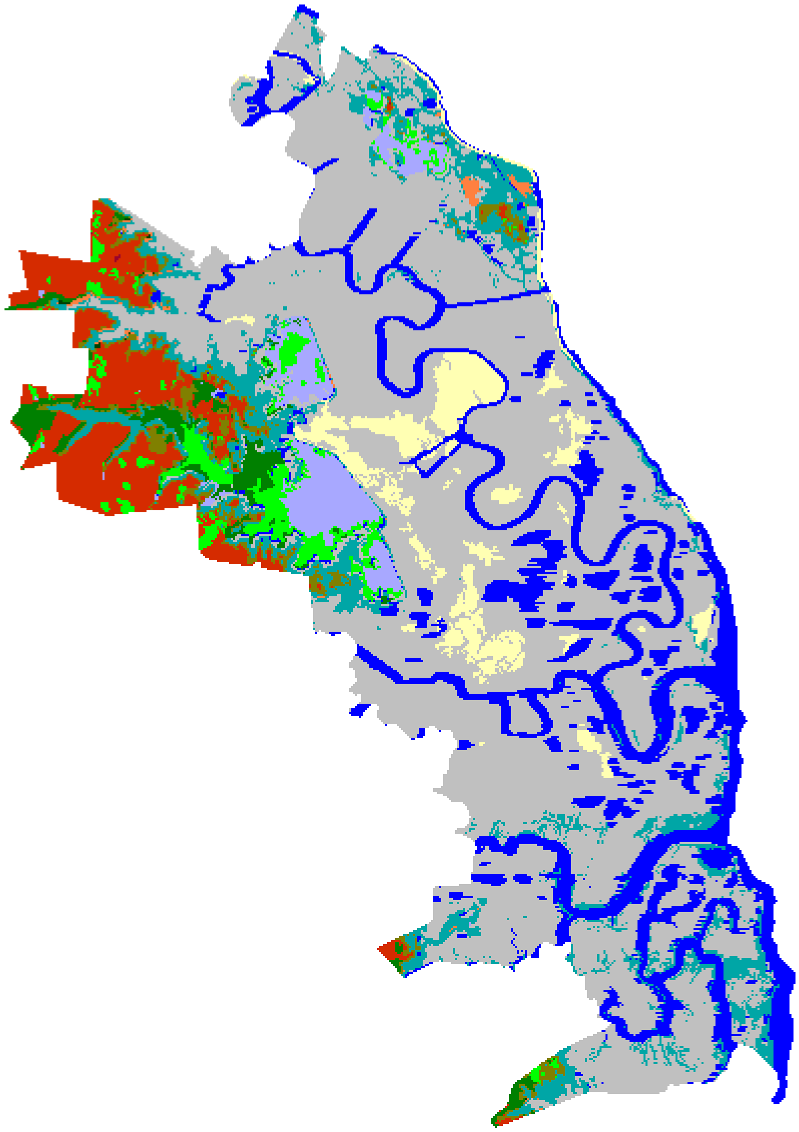
Bombay Hook NWR, 2025, 1.5 meter



Bombay Hook NWR, 2050, 1.5 meter



Bombay Hook NWR, 2075, 1.5 meter

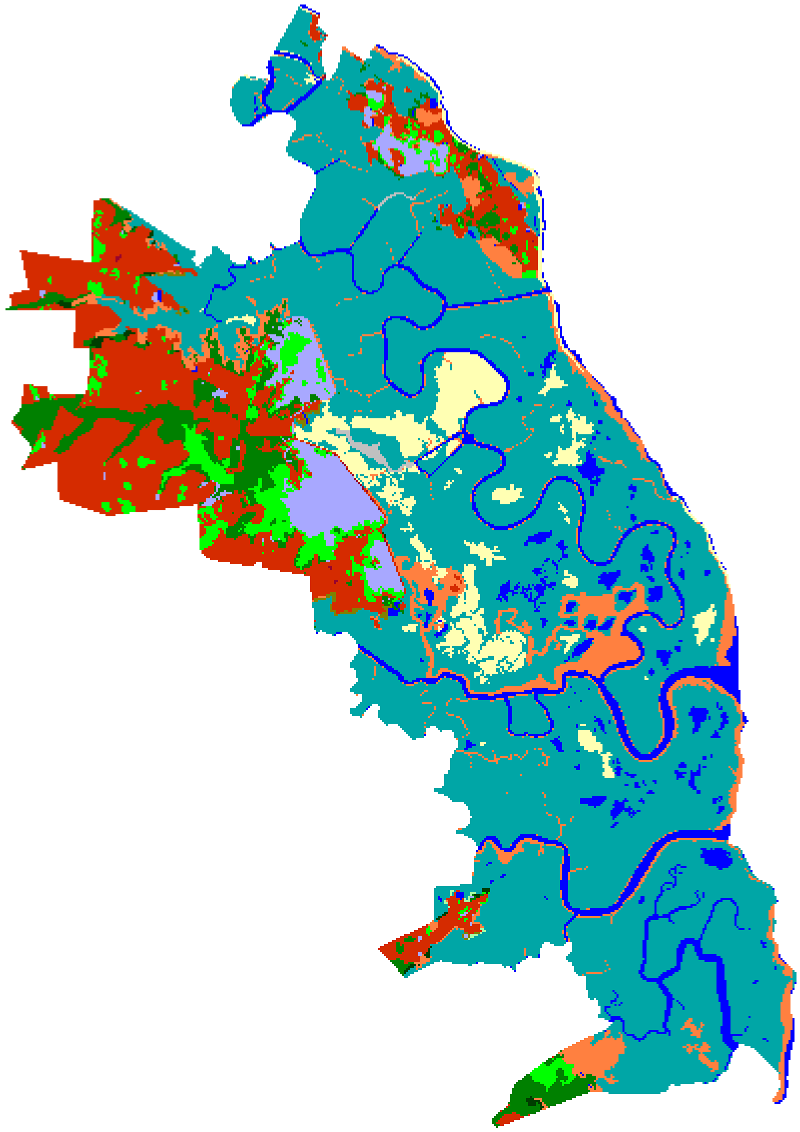


Bombay Hook NWR, 2100, 1.5 meter

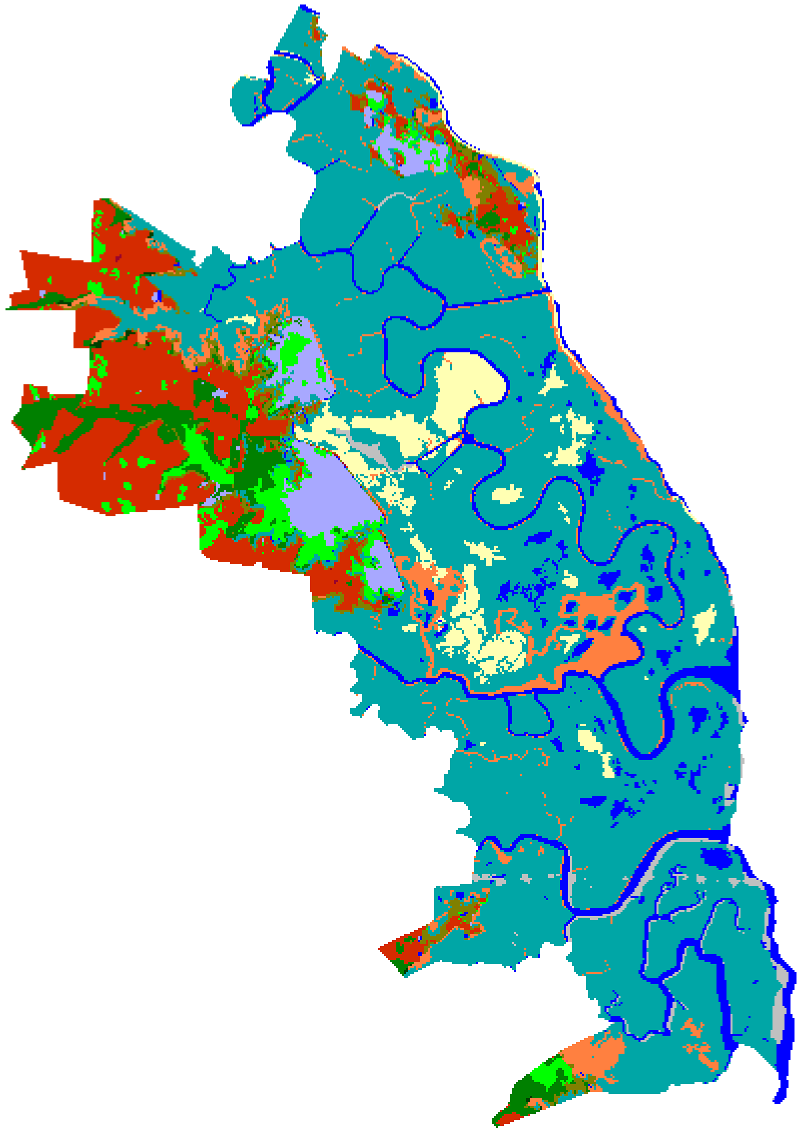
Bombay Hook NWR
2 Meters Eustatic SLR by 2100

Results in Acres

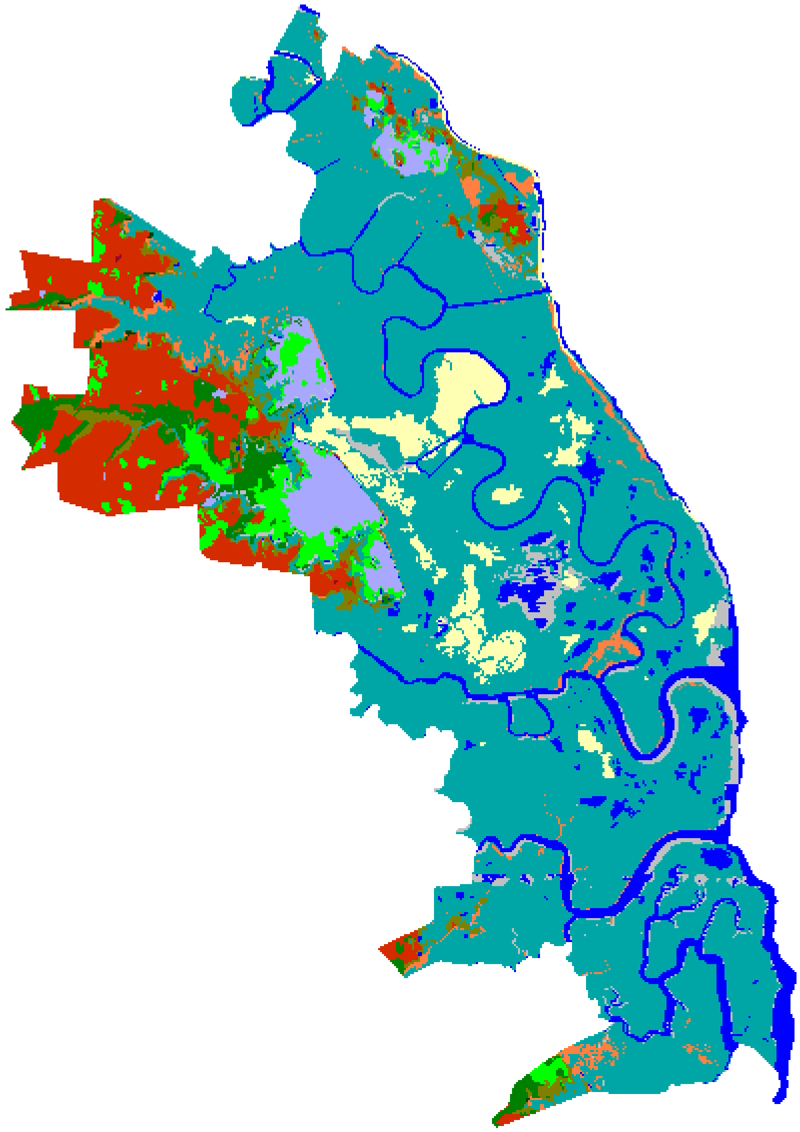
	Initial	2025	2050	2075	2100
Saltmarsh	12145.2	12418.8	13083.0	2754.5	767.4
Undeveloped Dry Land	2737.2	2227.7	1876.8	1472.5	1034.9
Irregularly Flooded Marsh	1470.7	1199.2	435.0	78.9	39.4
Estuarine Open Water	1407.5	1577.4	1851.3	3077.0	7871.9
Estuarine Beach	1012.8	999.4	997.0	990.6	49.4
Swamp	919.6	715.8	558.3	443.4	335.4
Inland Fresh Marsh	680.7	629.9	600.7	558.9	499.2
Inland Open Water	670.5	650.9	644.7	638.5	634.5
Tidal Flat	42.0	249.6	566.9	10589.2	9360.4
Tidal Swamp	37.4	16.0	11.2	6.3	2.5
Trans. Salt Marsh	35.1	485.8	546.9	563.1	578.8
Dev. Dry Land	9.3	4.2	2.9	2.0	1.0
Tidal Fresh Marsh	6.7	0.0	0.0	0.0	0.0
Total (incl. water)	**21174.8**	**21174.8**	**21174.8**	**21174.8**	**21174.8**



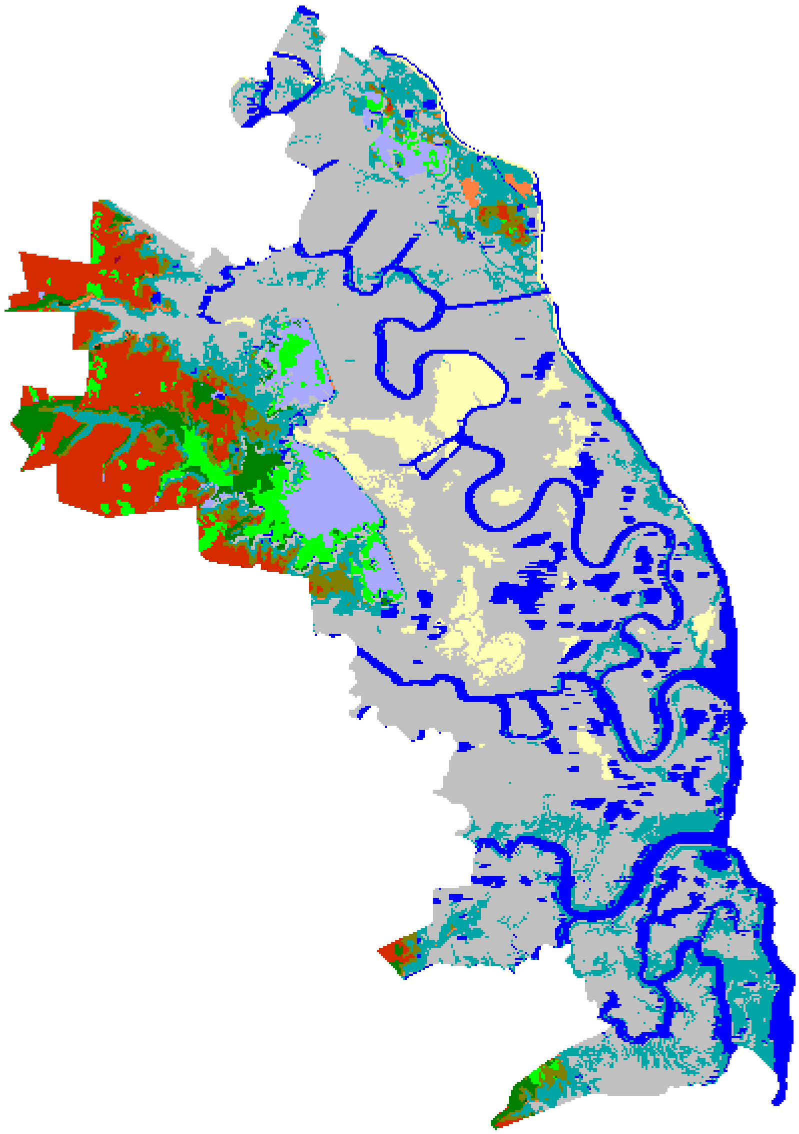
Bombay Hook NWR, Initial Condition



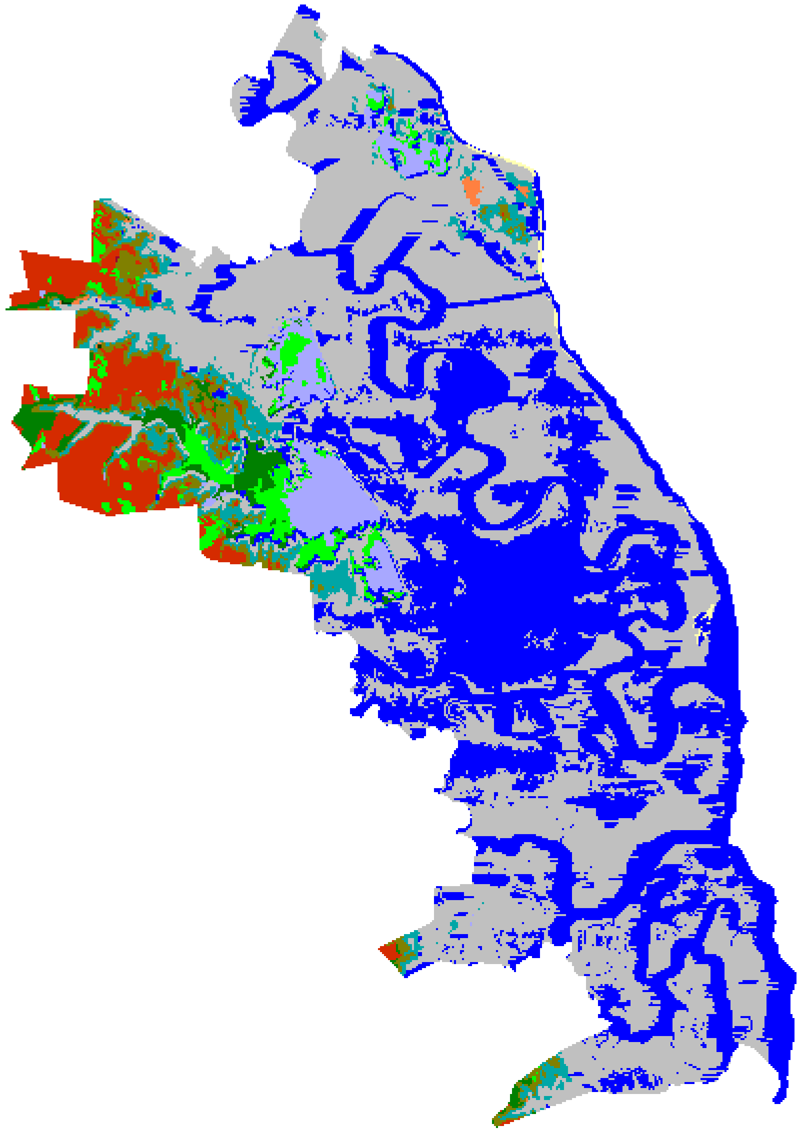
Bombay Hook NWR, 2025, 2 meters



Bombay Hook NWR, 2050, 2 meters



Bombay Hook NWR, 2075, 2 meters



Bombay Hook NWR, 2100, 2 meters

Discussion

Model simulations indicate that there is a tipping point for this refuge right at right around one meter of eustatic sea level rise (SLR) by 2100. Simulations with rates of SLR above this threshold predict dramatic losses of wetlands.

According to personal communication with David Carter, the LiDAR data for Delaware wetlands may be of questionable quality. Carter noted that the "basis for our determination that the LiDAR data in wetlands has problems is a series of RTK corrected survey grade elevation transects we have done in numerous wetland areas along the coast" (D. Carter, personal communication, 1/4/10). Our examination of wetlands elevation ranges for this site also suggested that regions designated as "low marsh" had surprisingly high initial-condition elevations. If these wetlands should, in fact, be assigned lower elevations, then the "tipping point" referenced above may come at a lower rate of eustatic SLR.

Another source of model uncertainty is the potential for feedbacks between rates of wetland accretion and rates of sea level rise. This model assumed constant accretion rates over the course of the simulation based on historical measurements. While SLAMM 6.0 has the capability to model feedbacks between cell inundation frequency and accretion rates, insufficient data were available at this site to define this relationship. Future model runs for this site can potentially evaluate the importance of this potential feedback as part of a model sensitivity or uncertainty analysis.

In addition to the 1992 wetland data utilized, an NWI layer from 1981 was initially considered for use. The 1981 layer is composed primarily of irregularly flooded marsh (Figure 5), whereas the 1992 layer regularly flooded marsh. Although the 1981 NWI matched more closely with model-to-wetland-elevation expectations, Harold Laskowski, the biologist working at the refuge, indicated that the refuge has long been composed primarily of low marsh. This suggests that the "questionable" elevation data may be the source of this off-set rather than the wetland data.

Contact was also made with Susan Guiteras the Wildlife Biologist for Bombay Hook NWR. She sent a more recent land cover map based on the National Vegetation Classification System (NVCS) derived from 2002 and 2007 imagery. This map shows some larger areas of open water which are classified as estuarine beach in our analysis (Figure 6). The LiDAR data that we have for this site indicate that these areas have elevations compatible with estuarine beach or tidal flats, but as noted above there are questions as to whether these data are providing elevations that are too high. We do not have a NVCS to SLAMM-category linkage, so the 1992 Delaware data were used to represent this site's initial condition. Susan Guiteras also noted that a newer NWI map is under production but it was not available for this analysis.

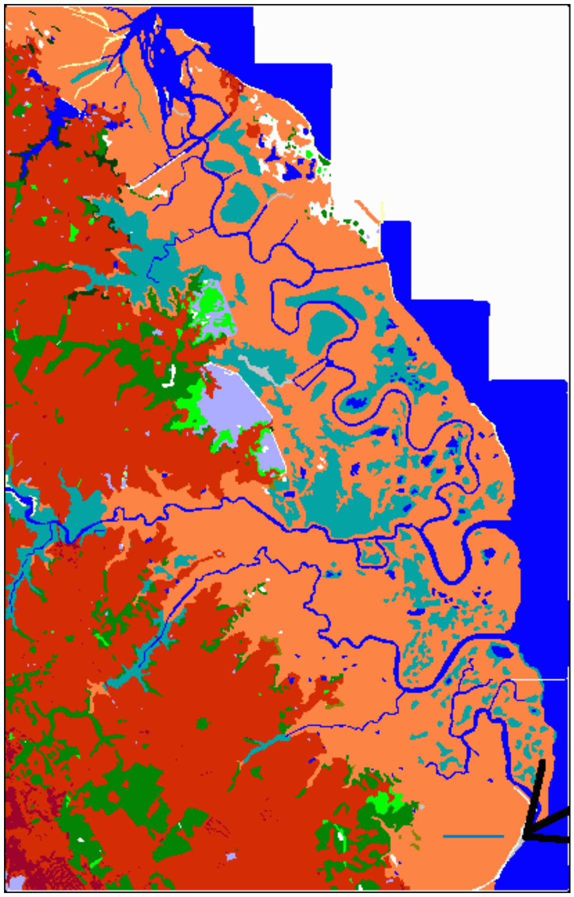


Figure 5: NWI layer from 1981.

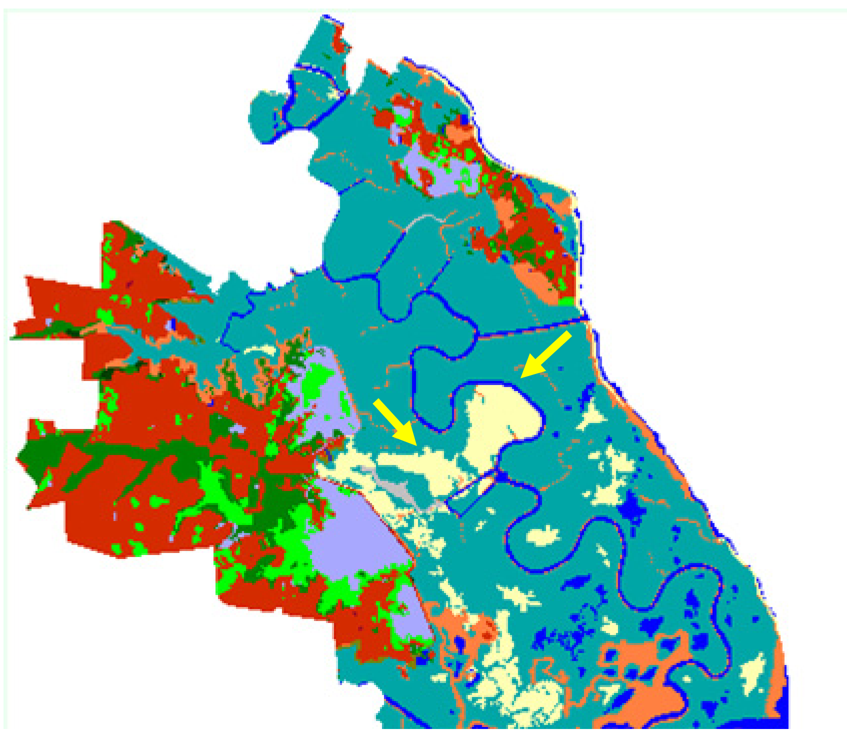


Figure 6: Areas Classified as Estuarine Beach/Tidal Flats that may be Open-Water based on NVCS data

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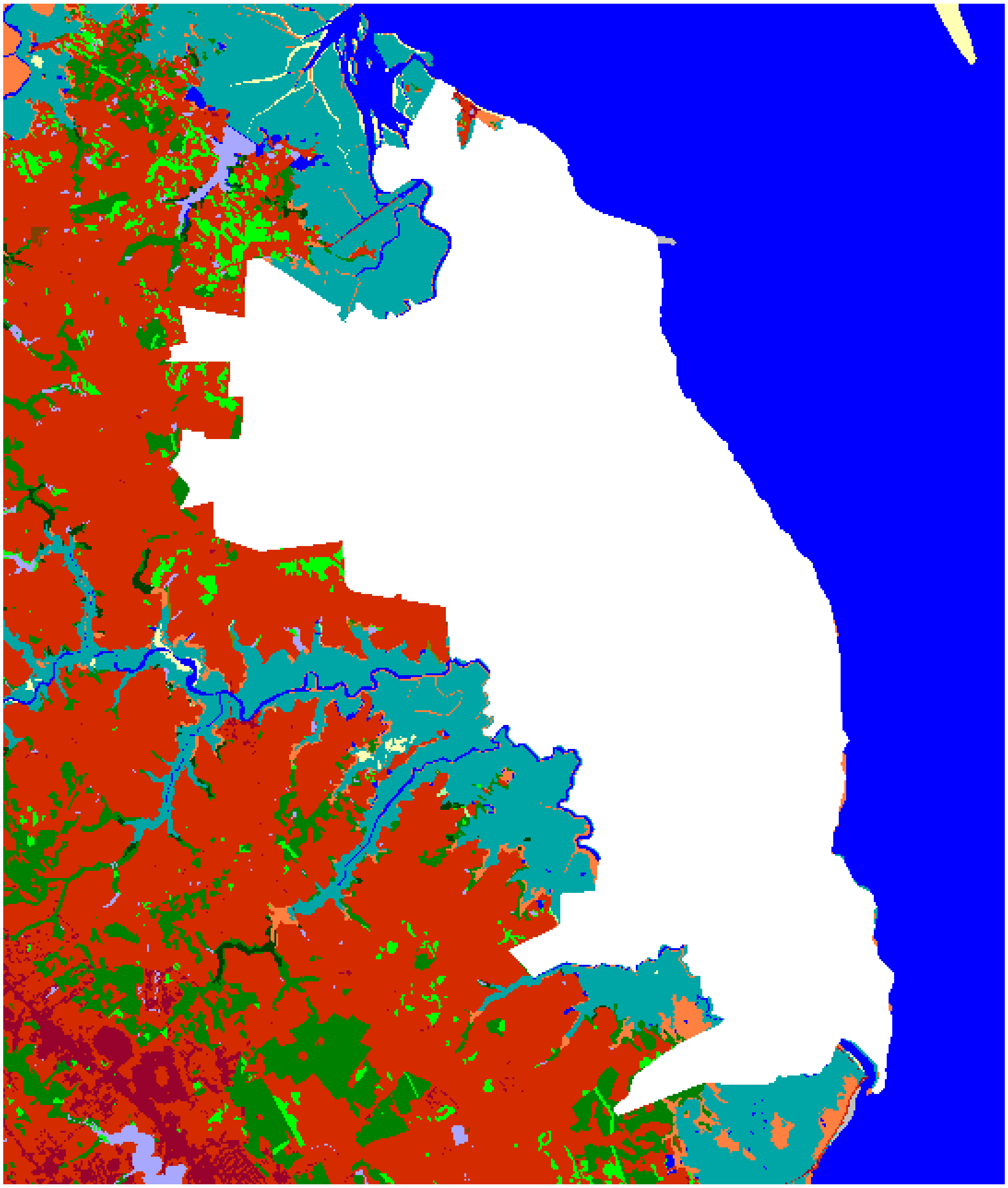
Appendix A: Contextual Results

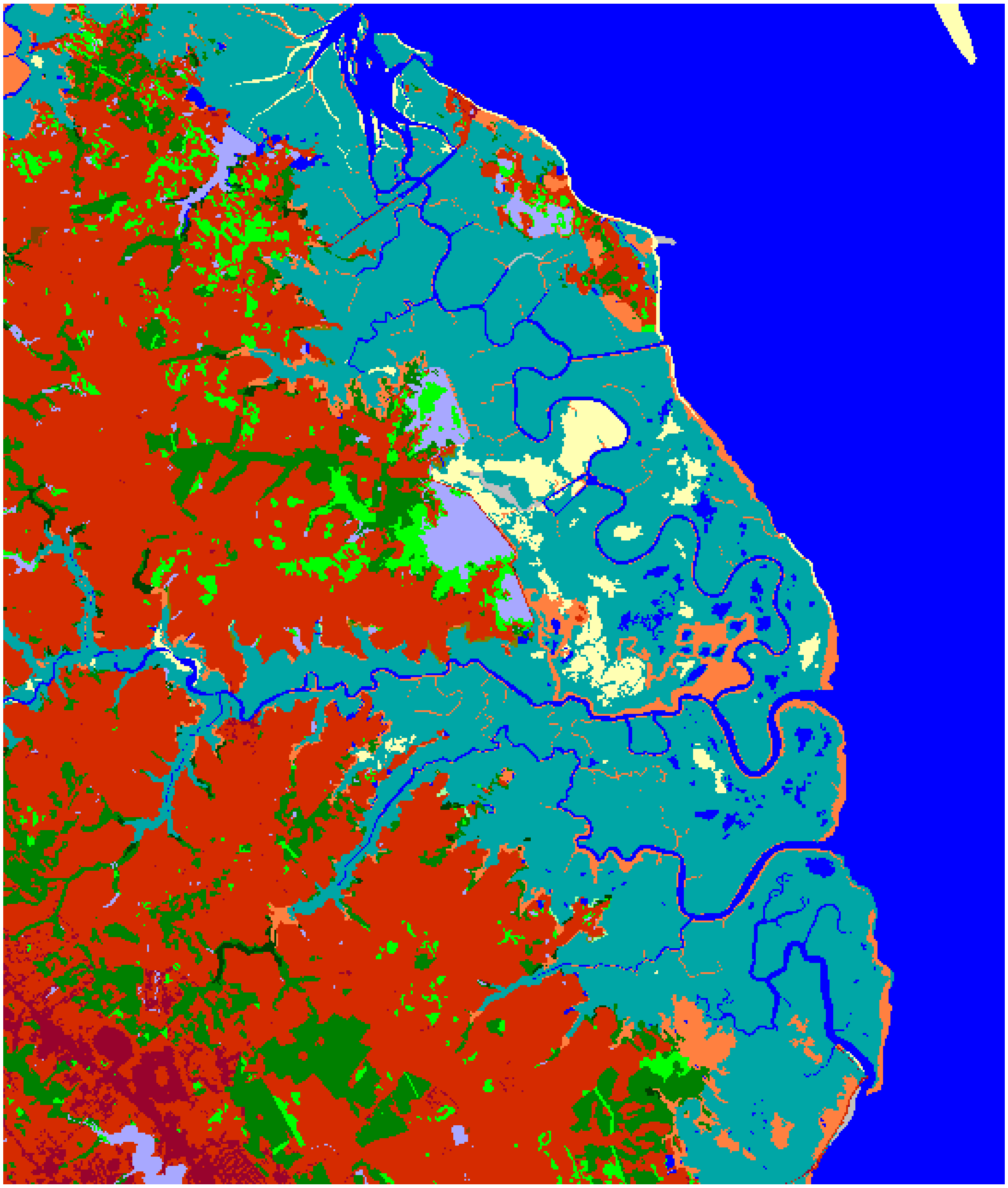
The SLAMM model does take into account the context of the surrounding lands or open water when calculating effects. For example, erosion rates are calculated based on the maximum fetch (wave action) which is estimated by assessing contiguous open water to a given marsh cell. Another example is that inundated 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. These results maps are presented here with the following caveats:

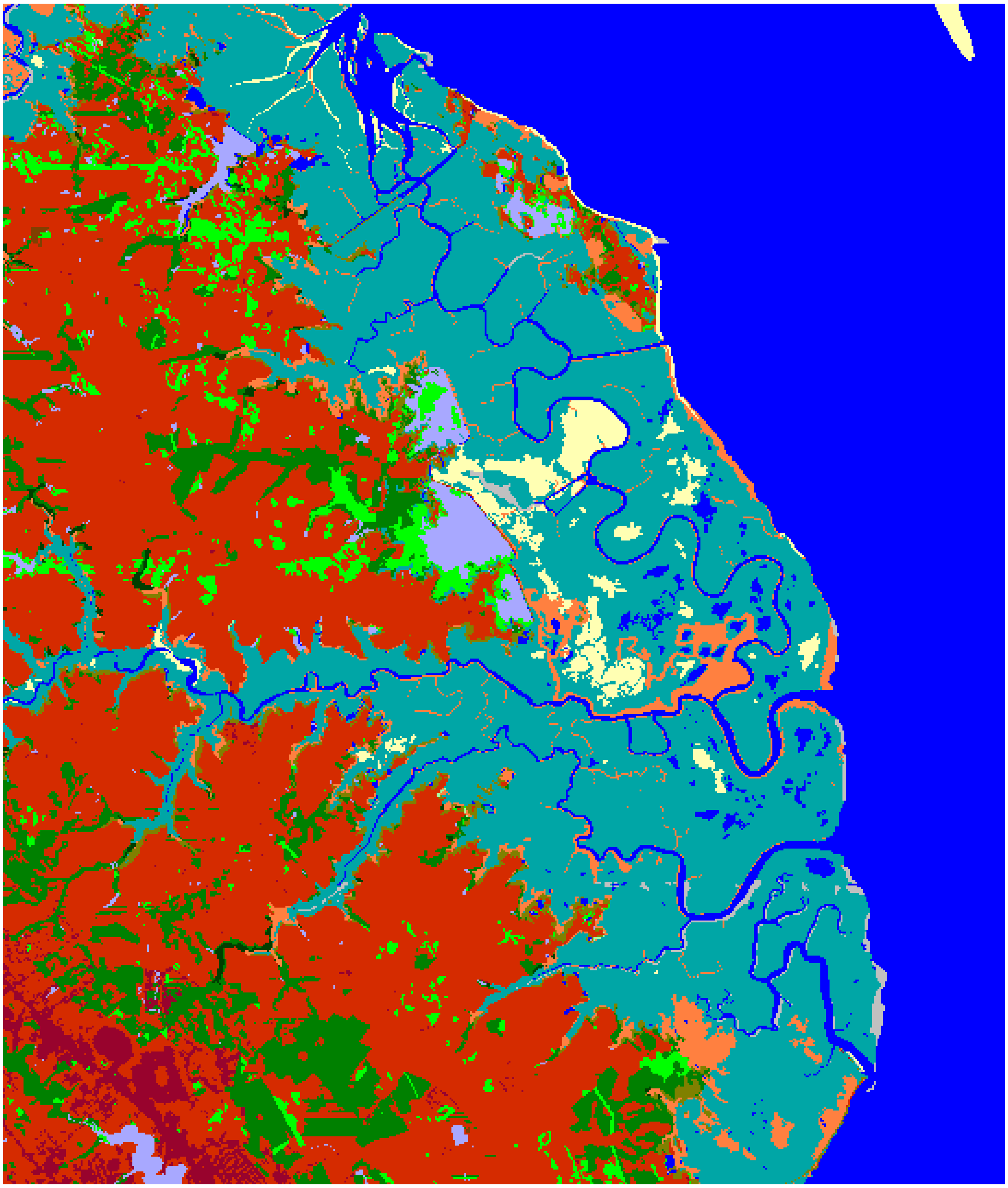
- Results were closely examined (quality assurance) within USFWS refuges but not closely examined for the larger region.
- Site-specific parameters for the model were derived for USFWS refuges whenever possible and may not be regionally applicable.
- Especially in areas where dikes are present, an effort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



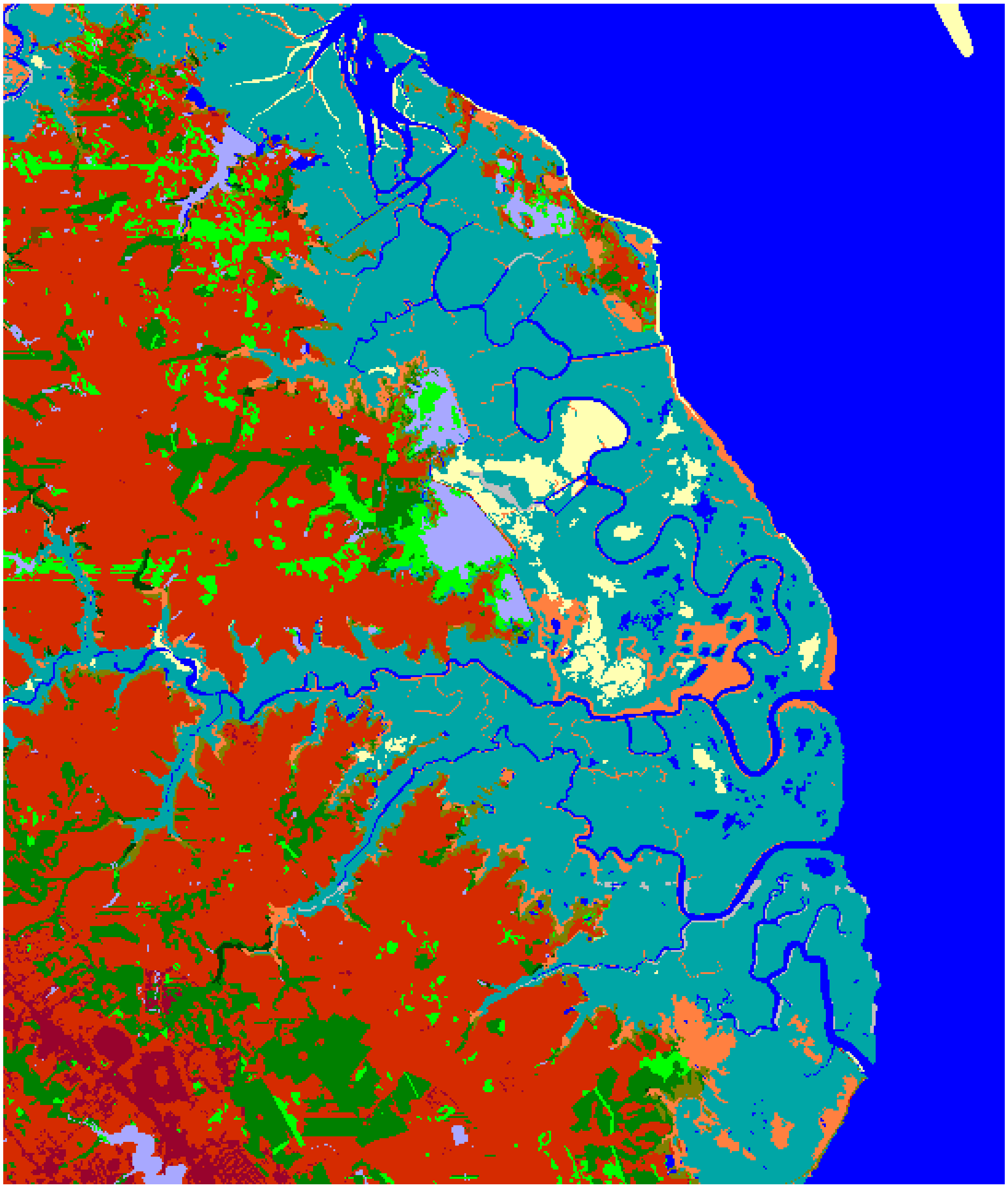
Location of Bombay Hook National Wildlife Refuge (white) within simulation context



Bombay Hook NWR, Initial Condition



Bombay Hook NWR, 2025, Scenario A1B Mean



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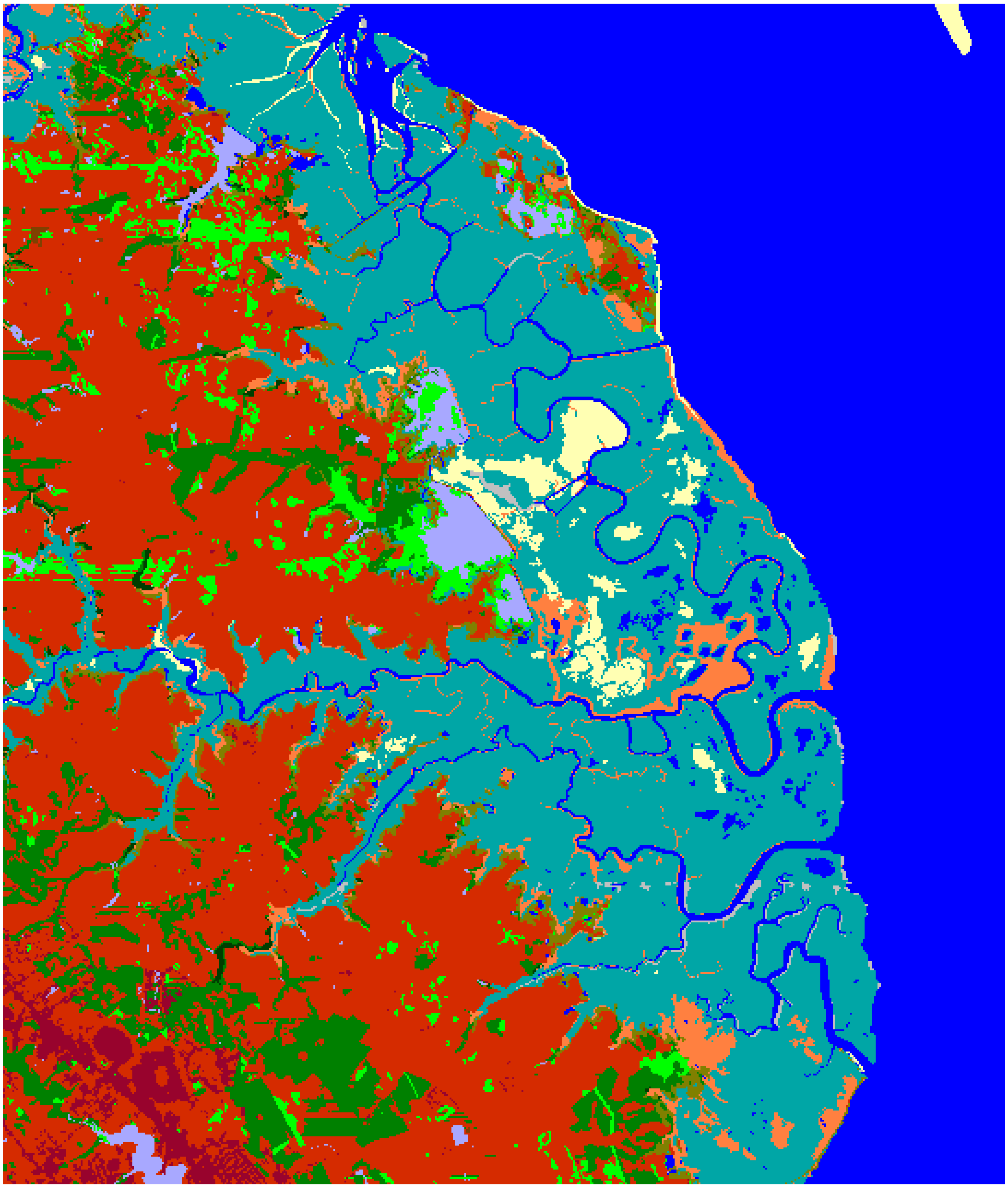

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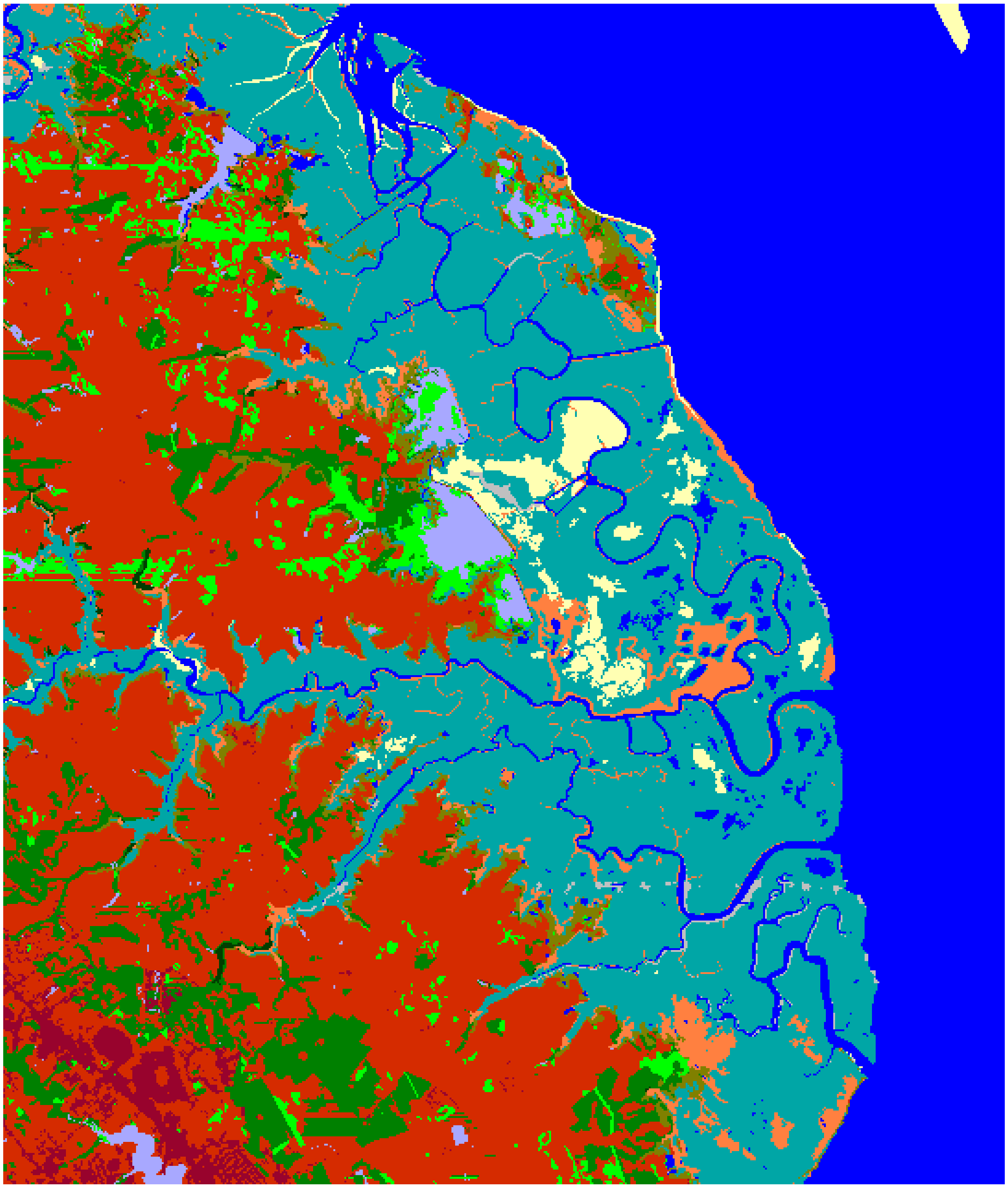
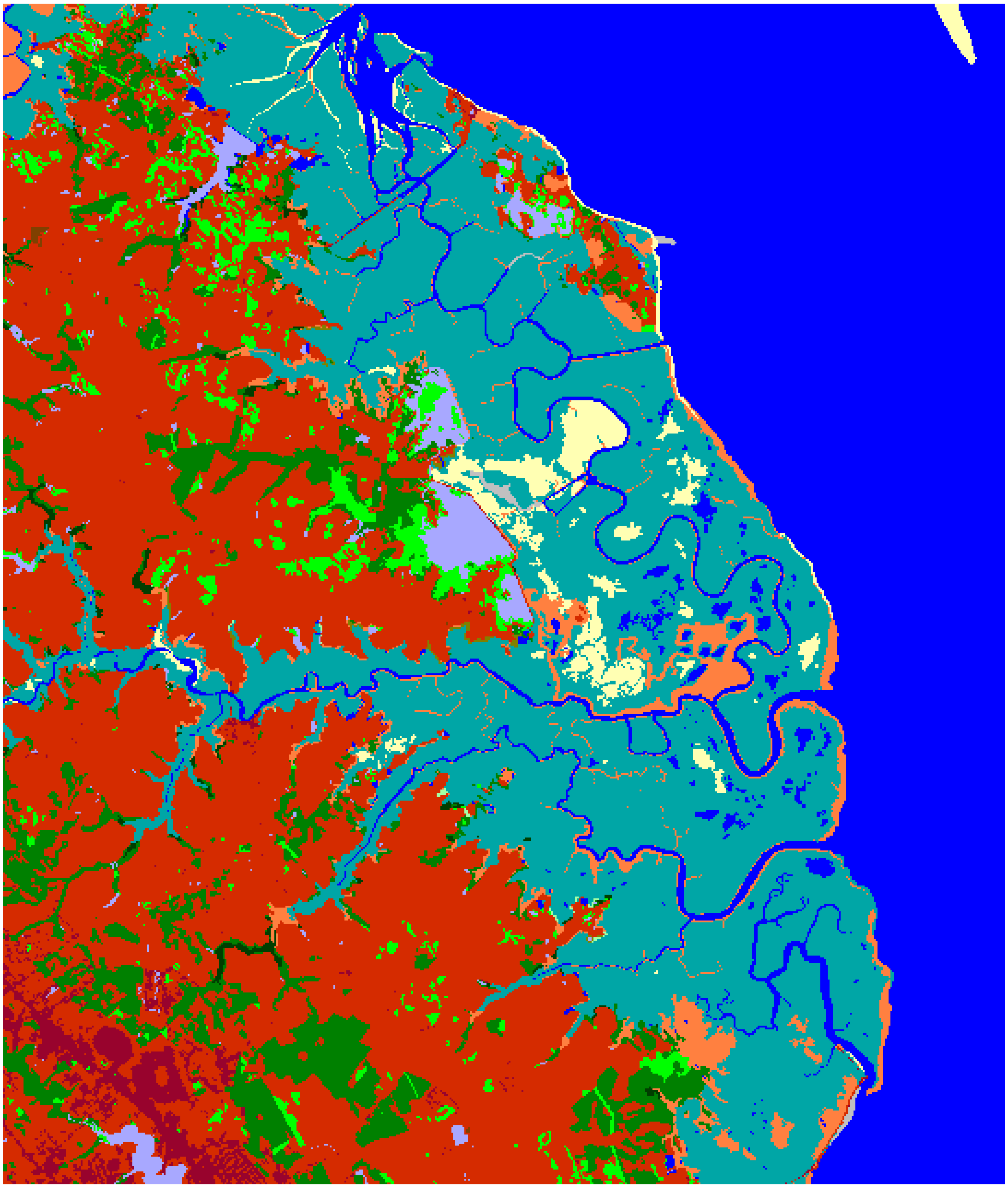
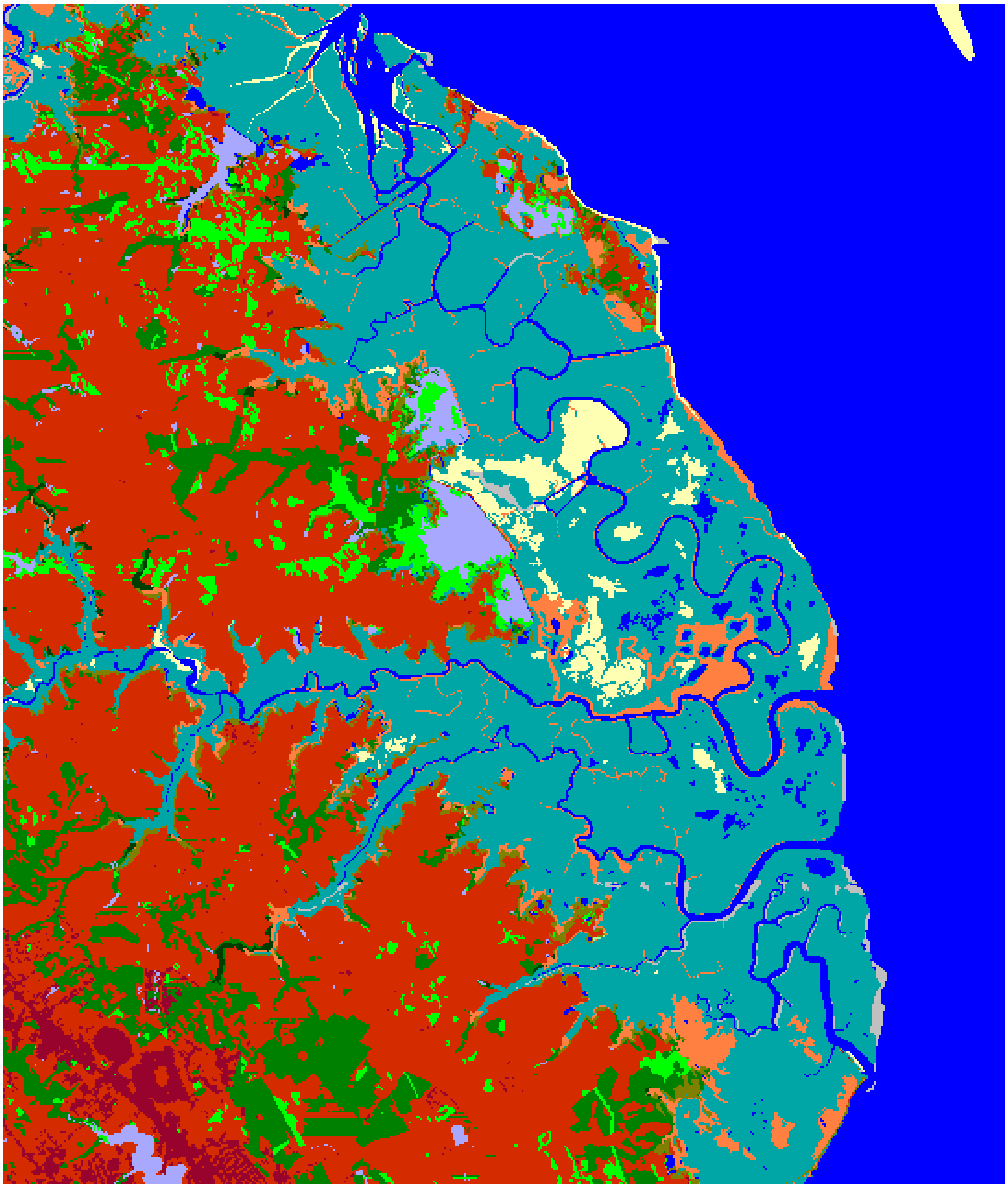


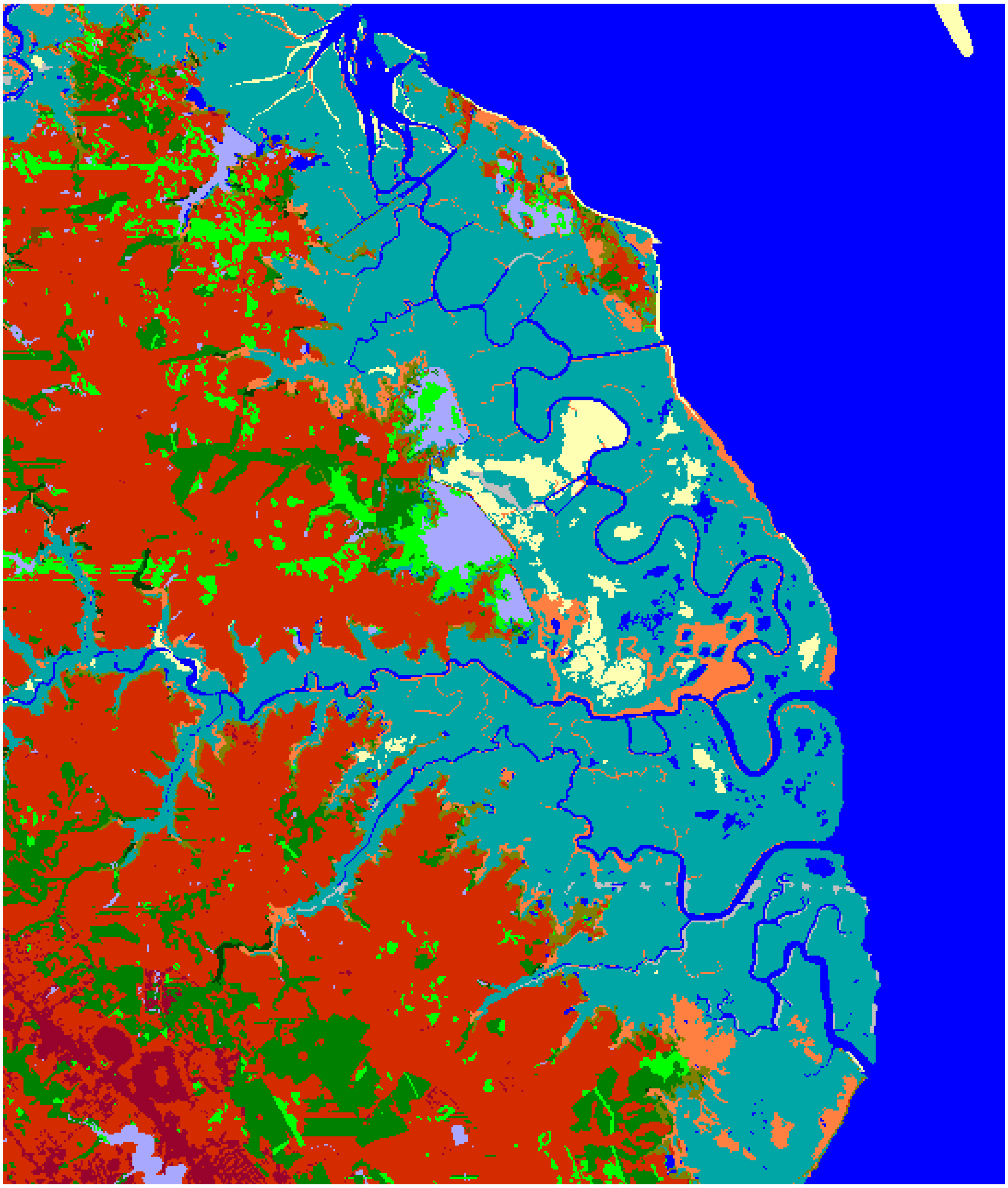
Bombay Hook NWR, 2100, Scenario A1B Mean



Bombay Hook NWR, Initial Condition



Bombay Hook NWR, 2025, Scenario A1B Maximum



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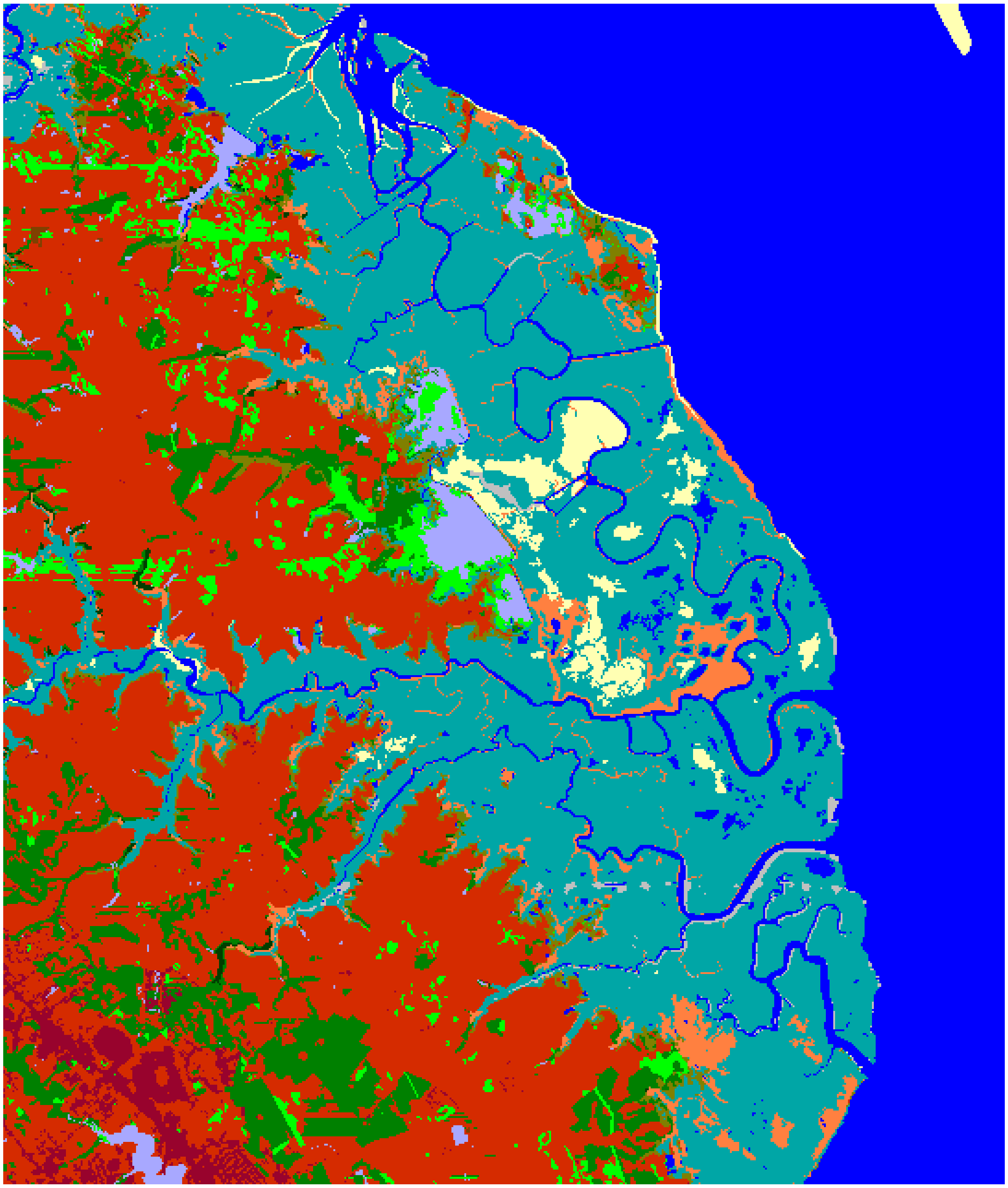

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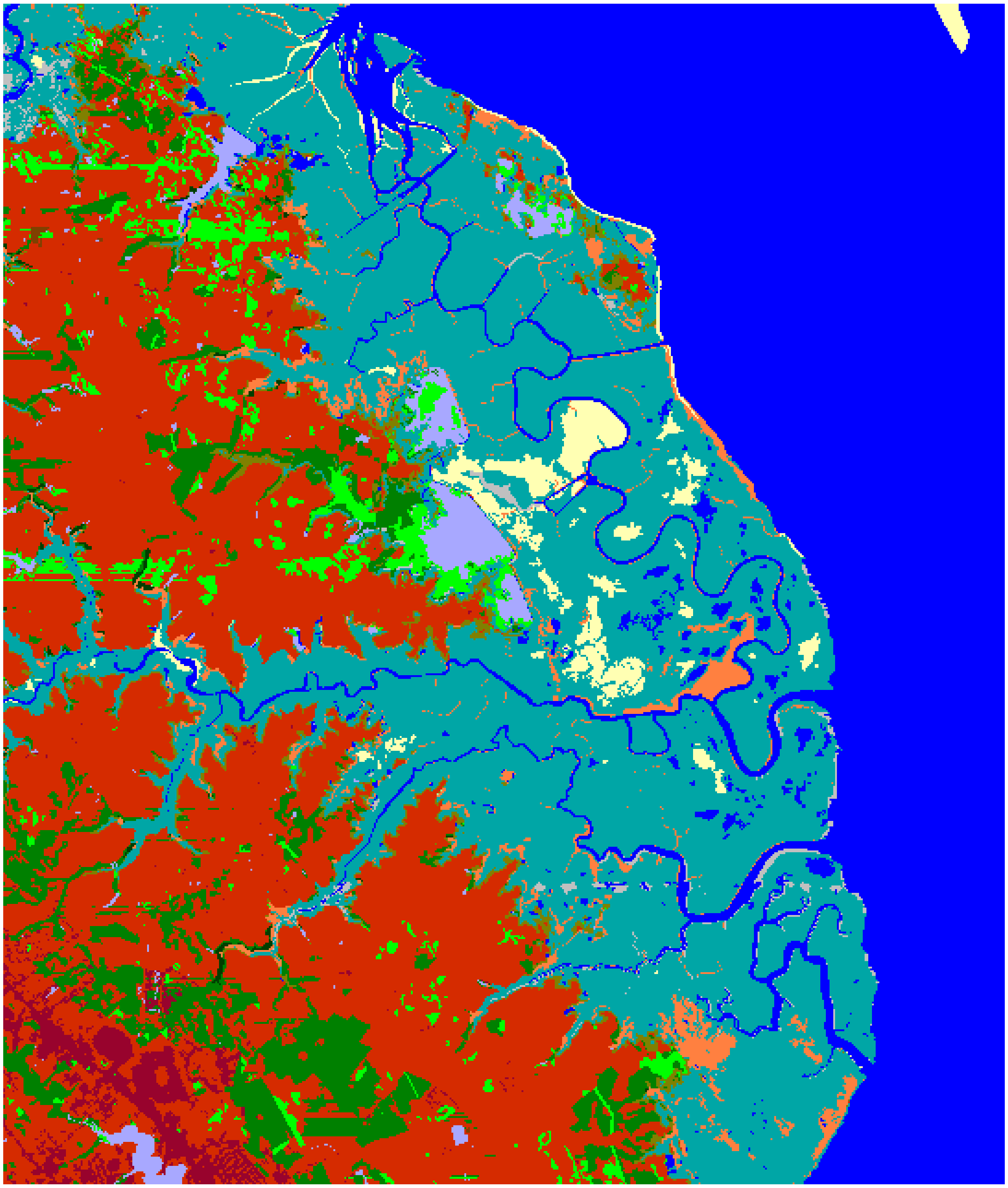

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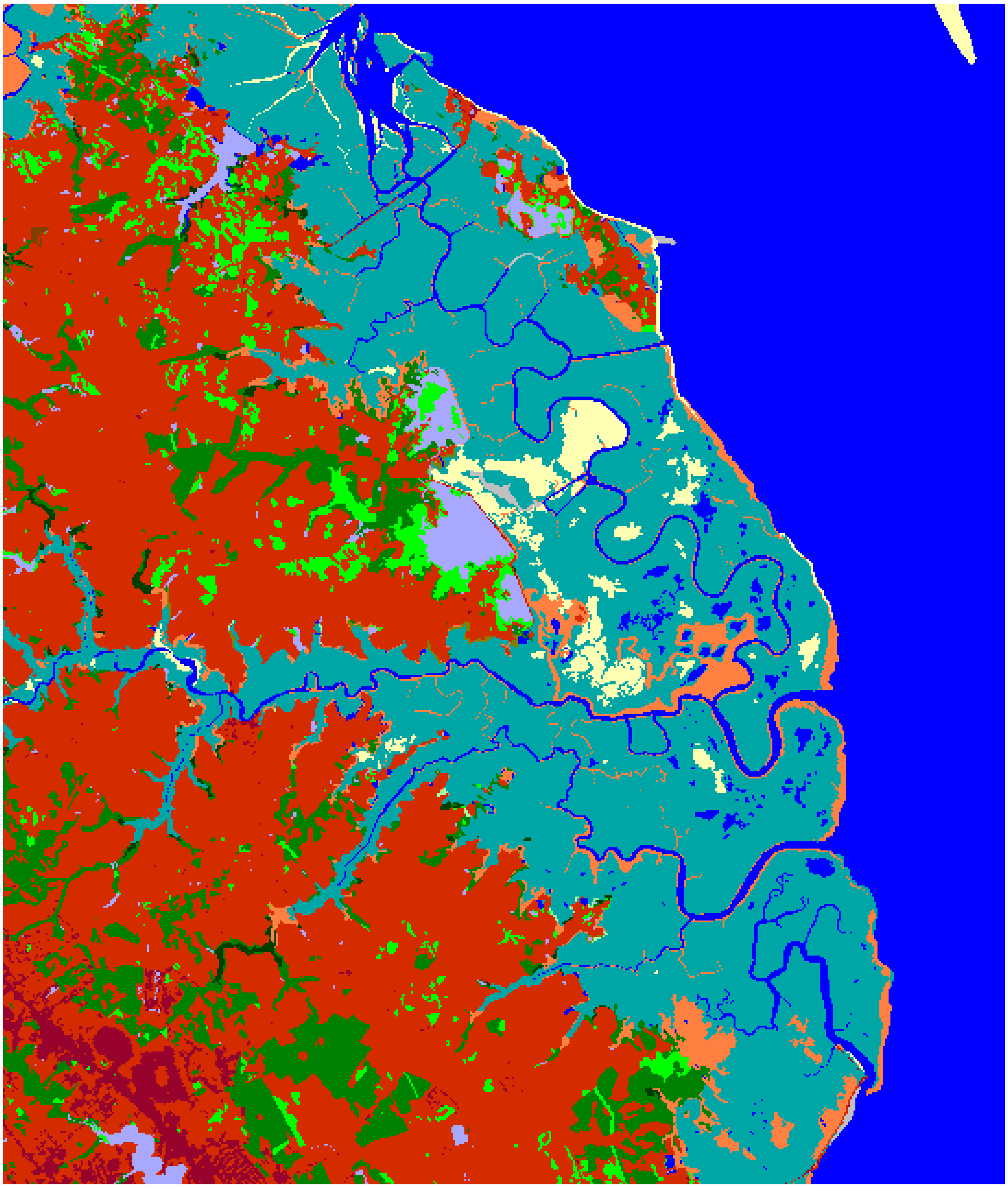
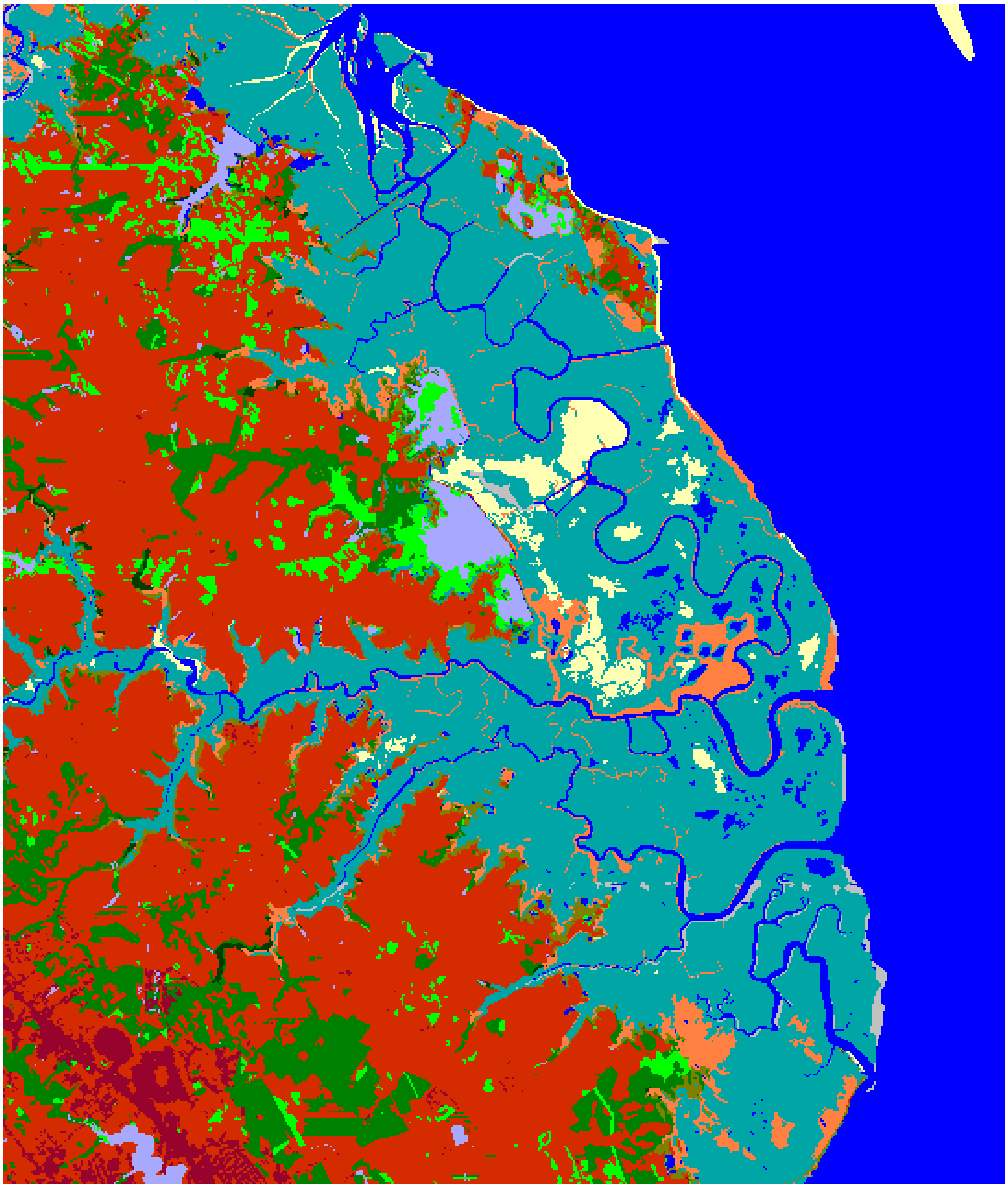
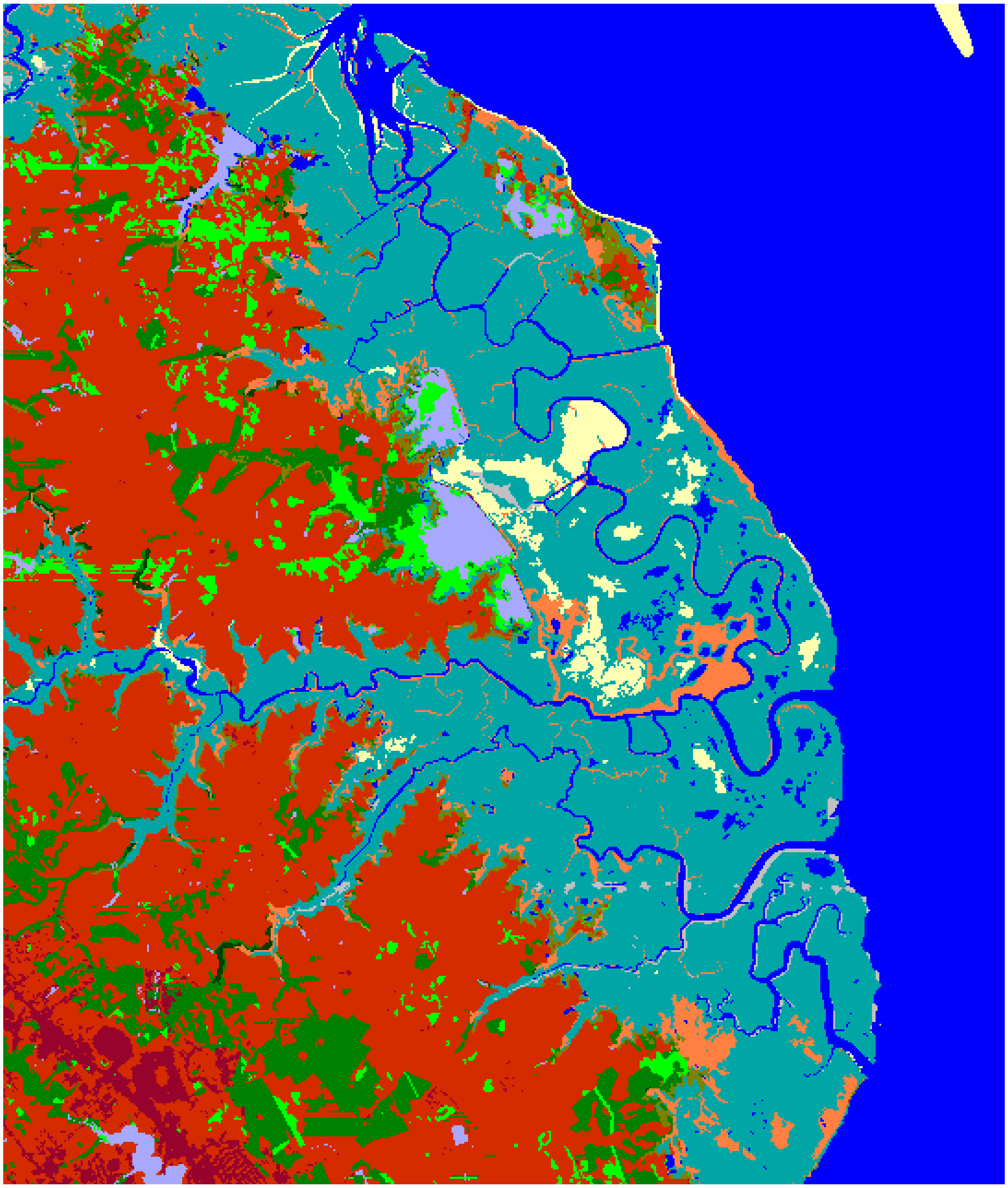


Bombay Hook NWR, Initial Condition



Bombay Hook NWR, 2025, 1 meter



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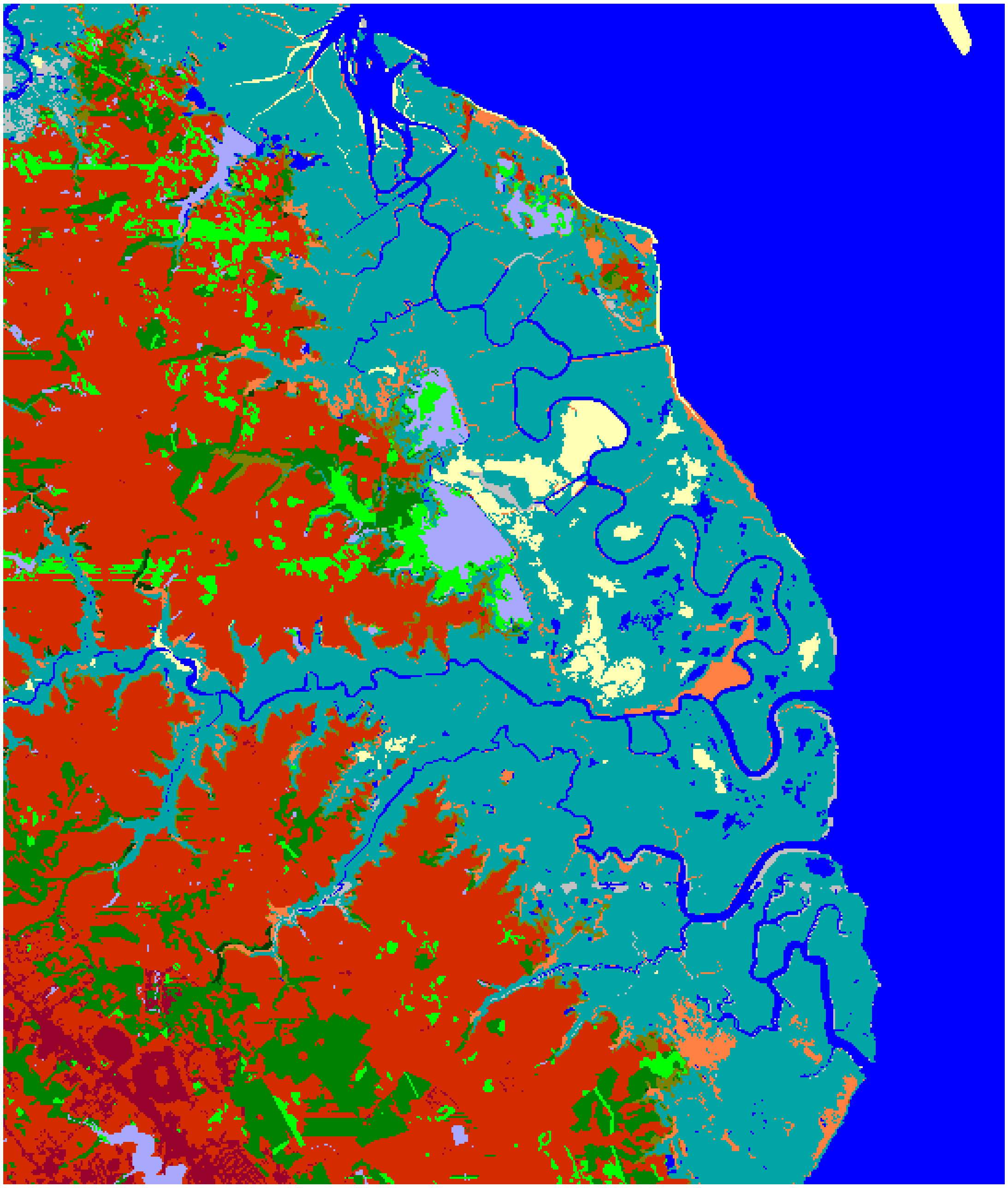

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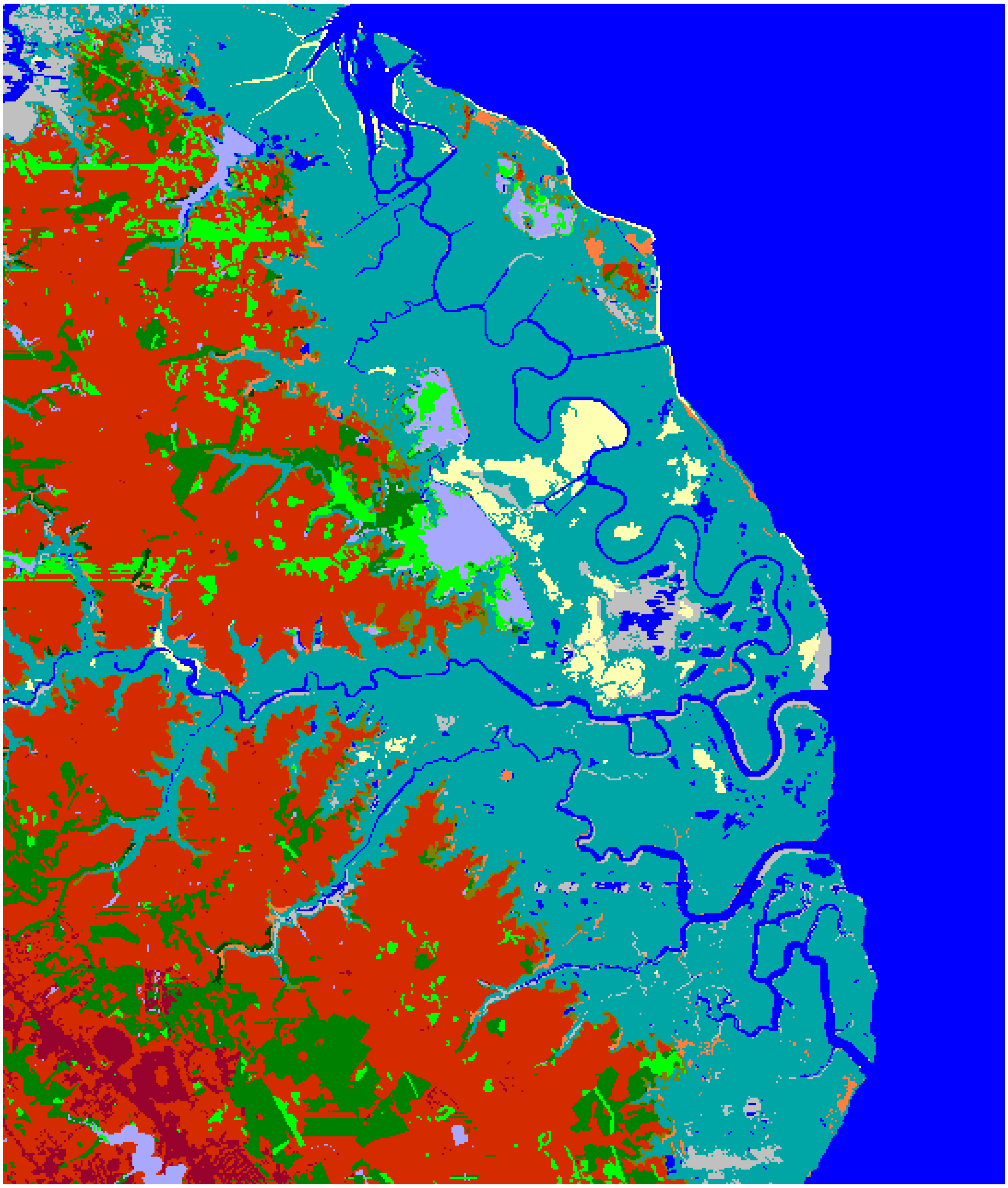

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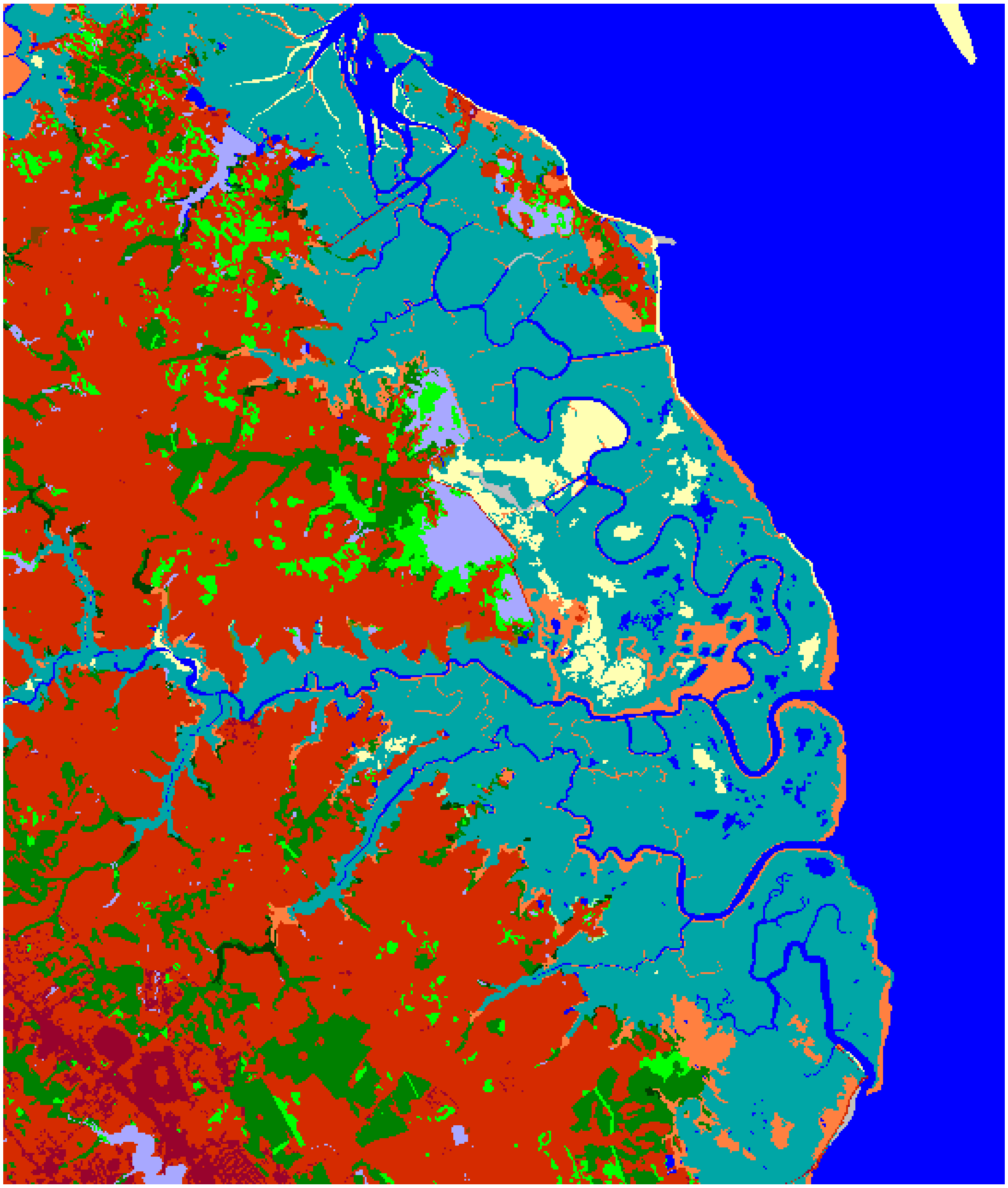

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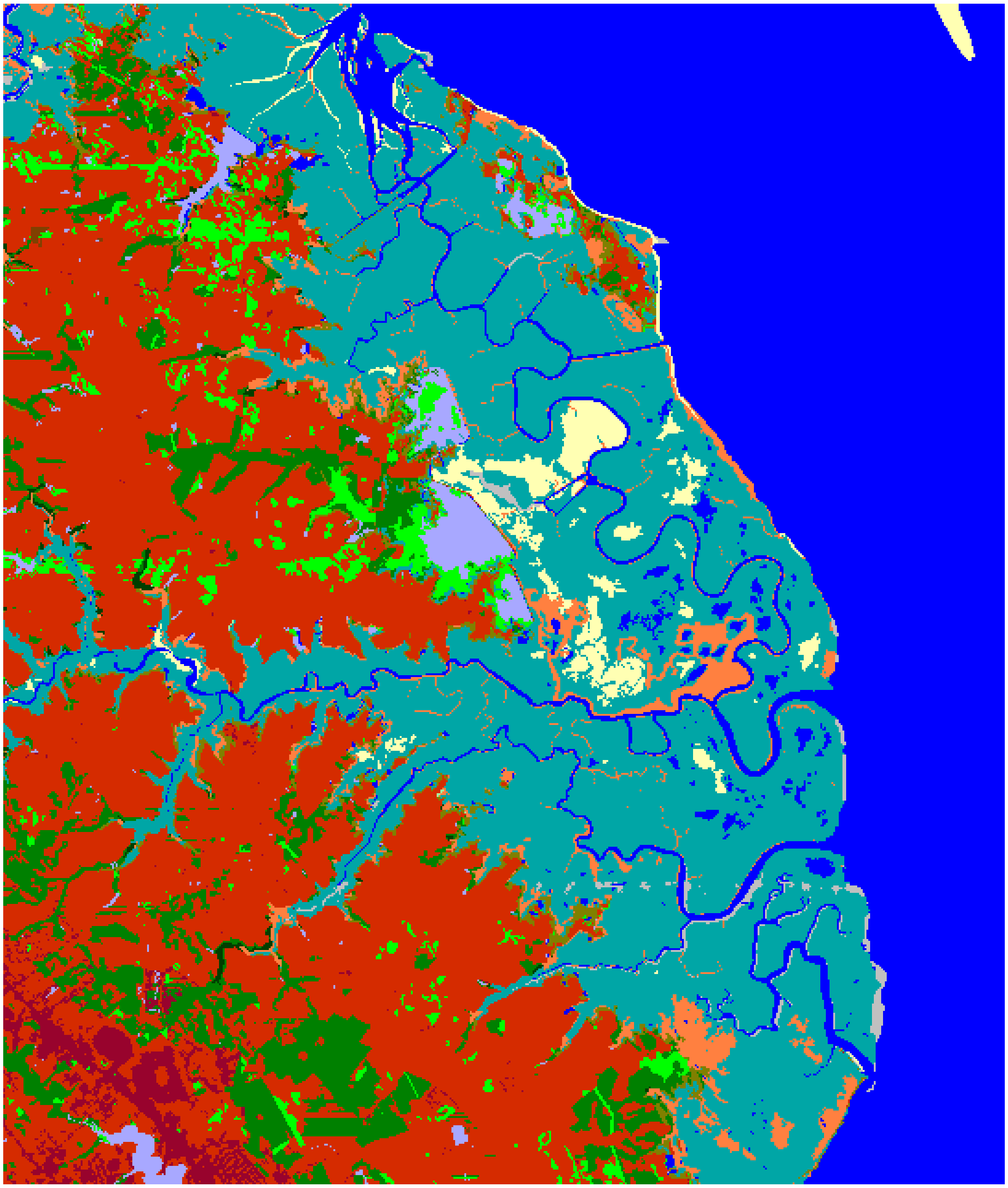
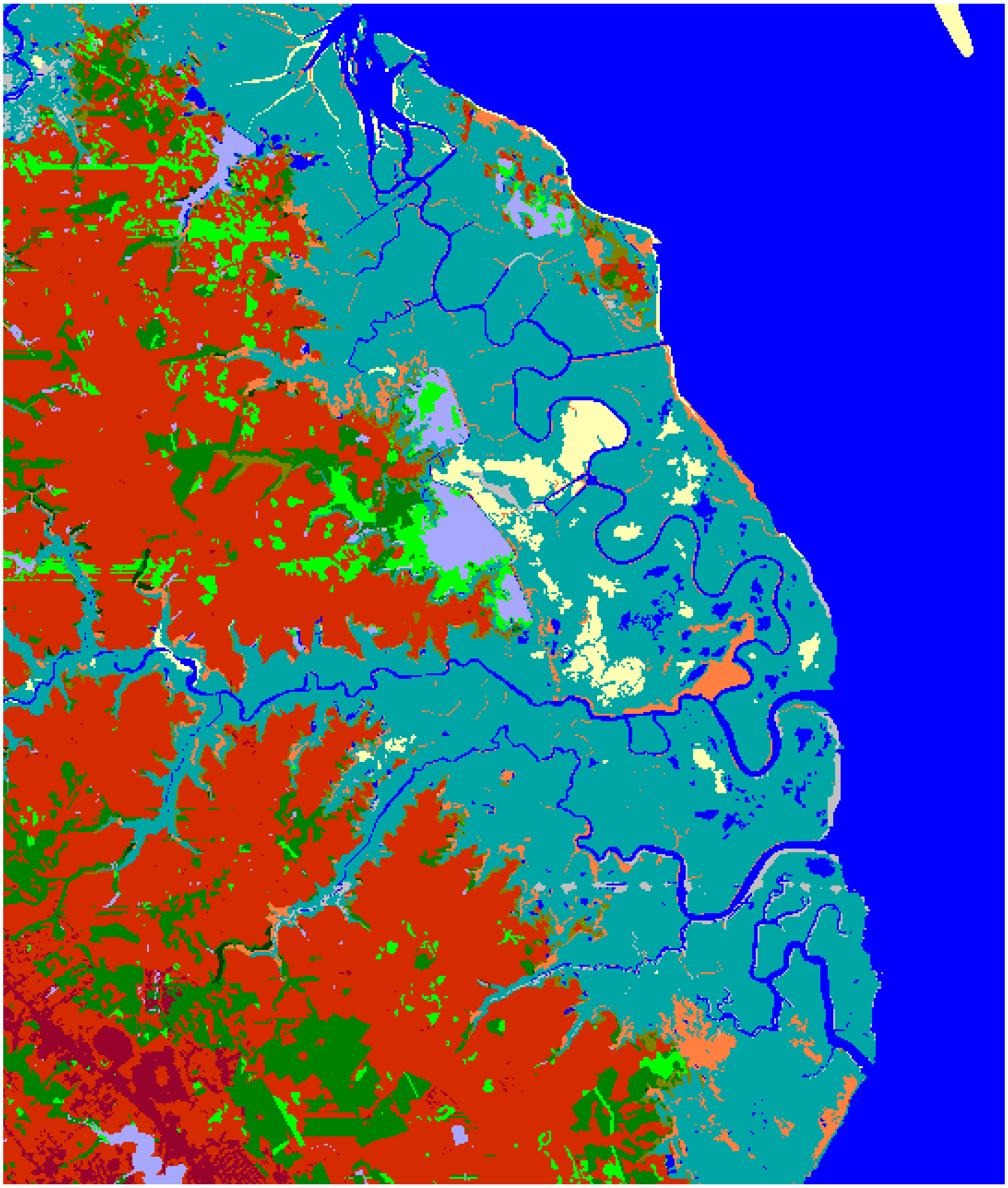


Bombay Hook NWR, 2025, 1.5 meter



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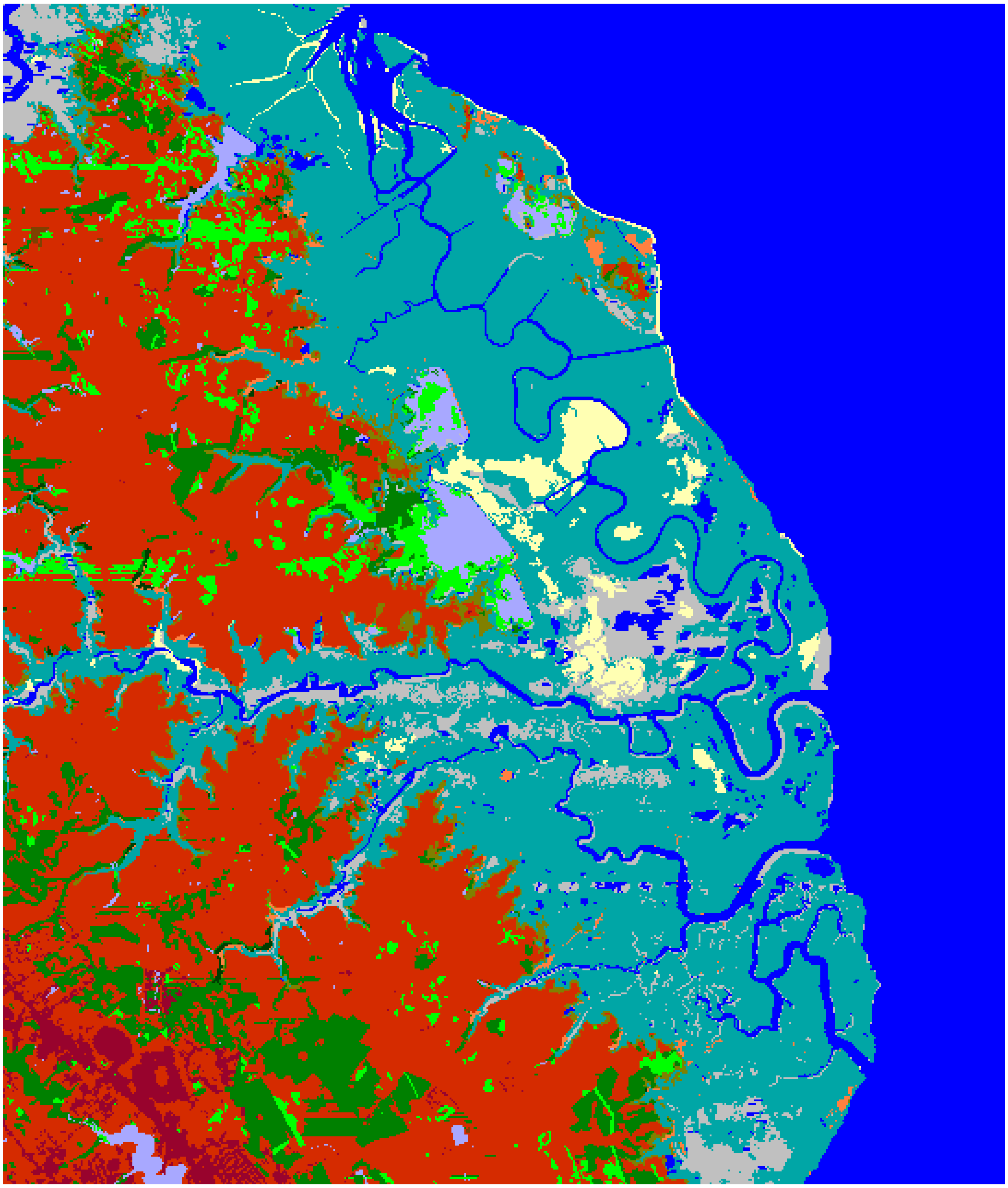
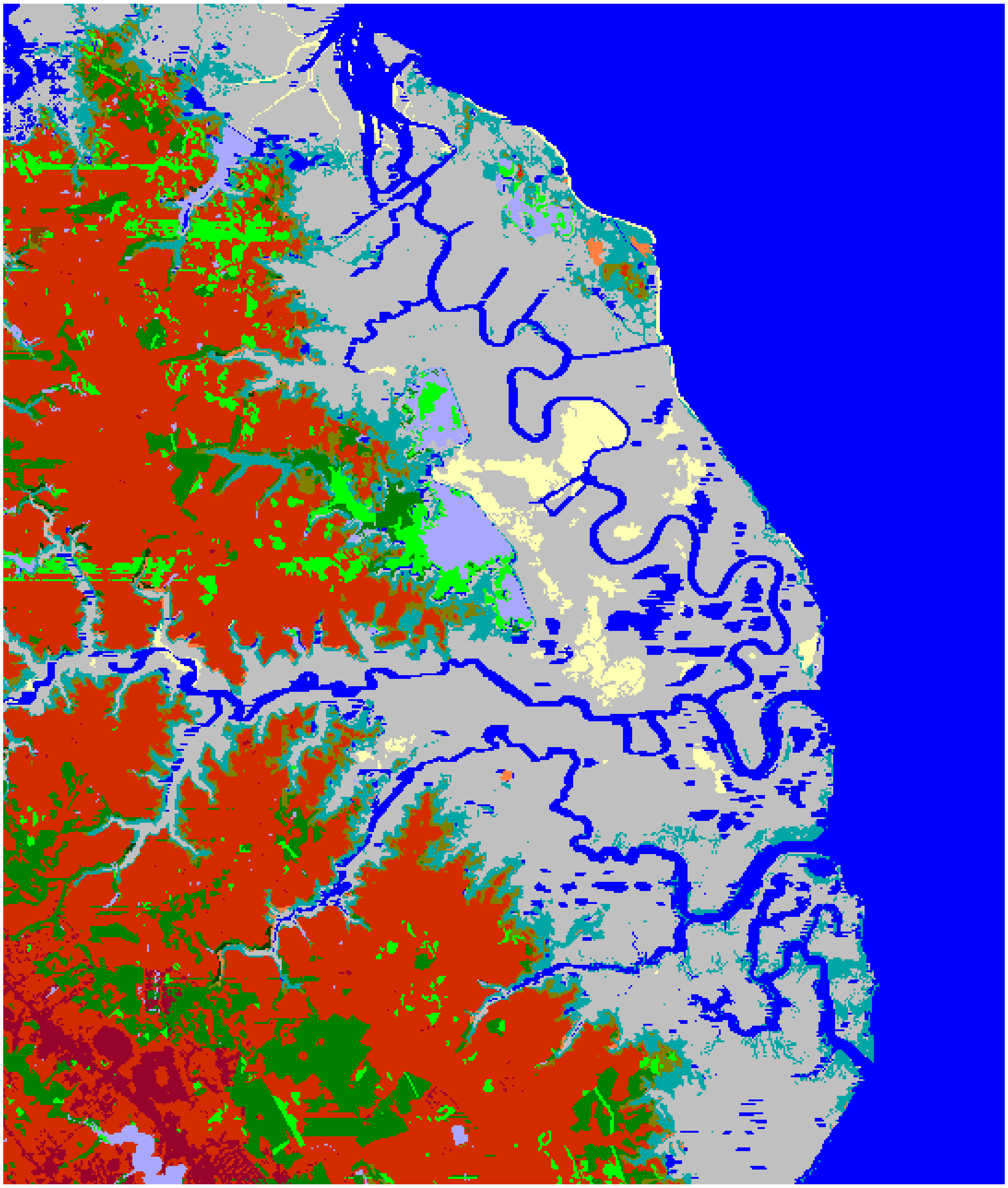
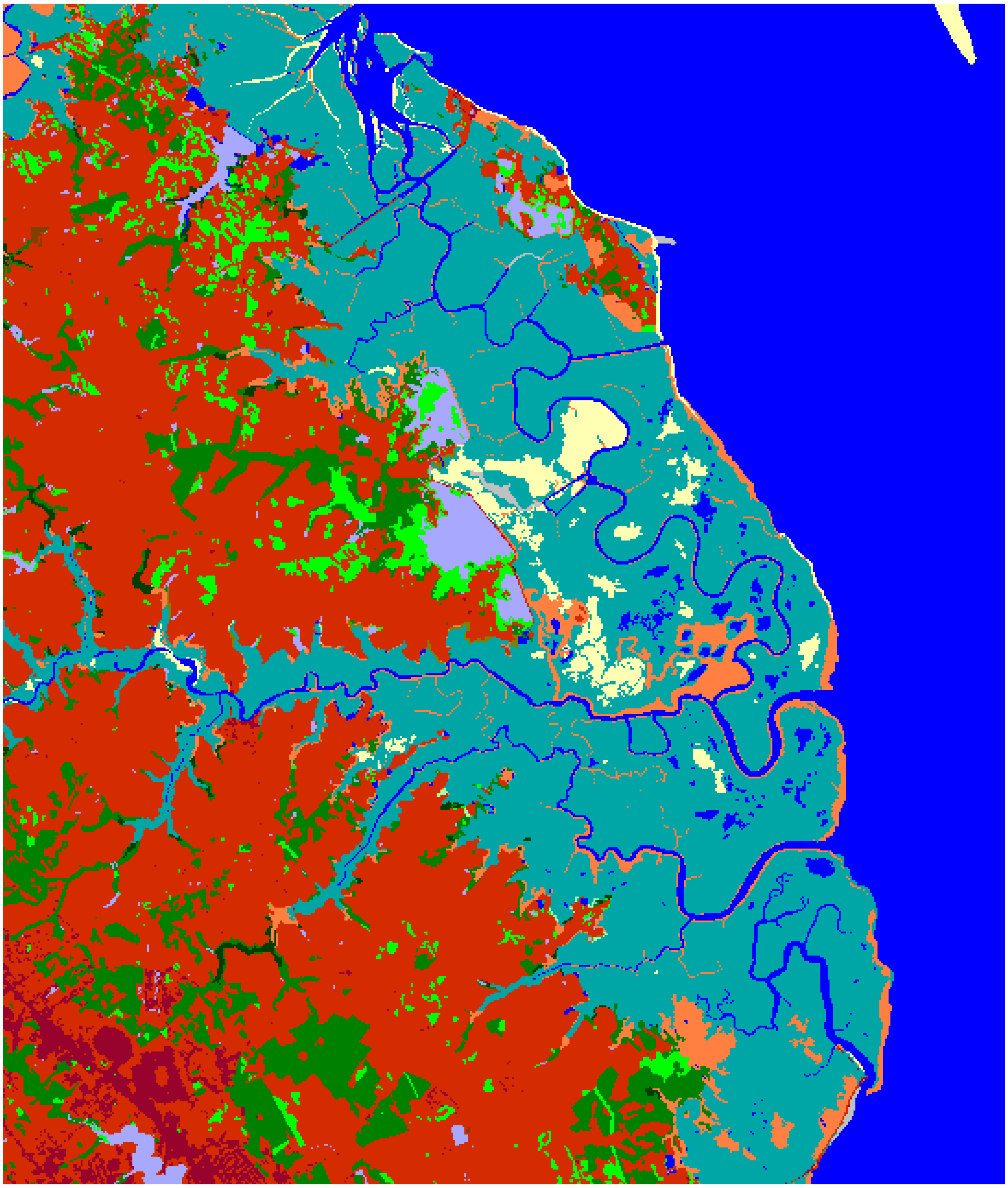


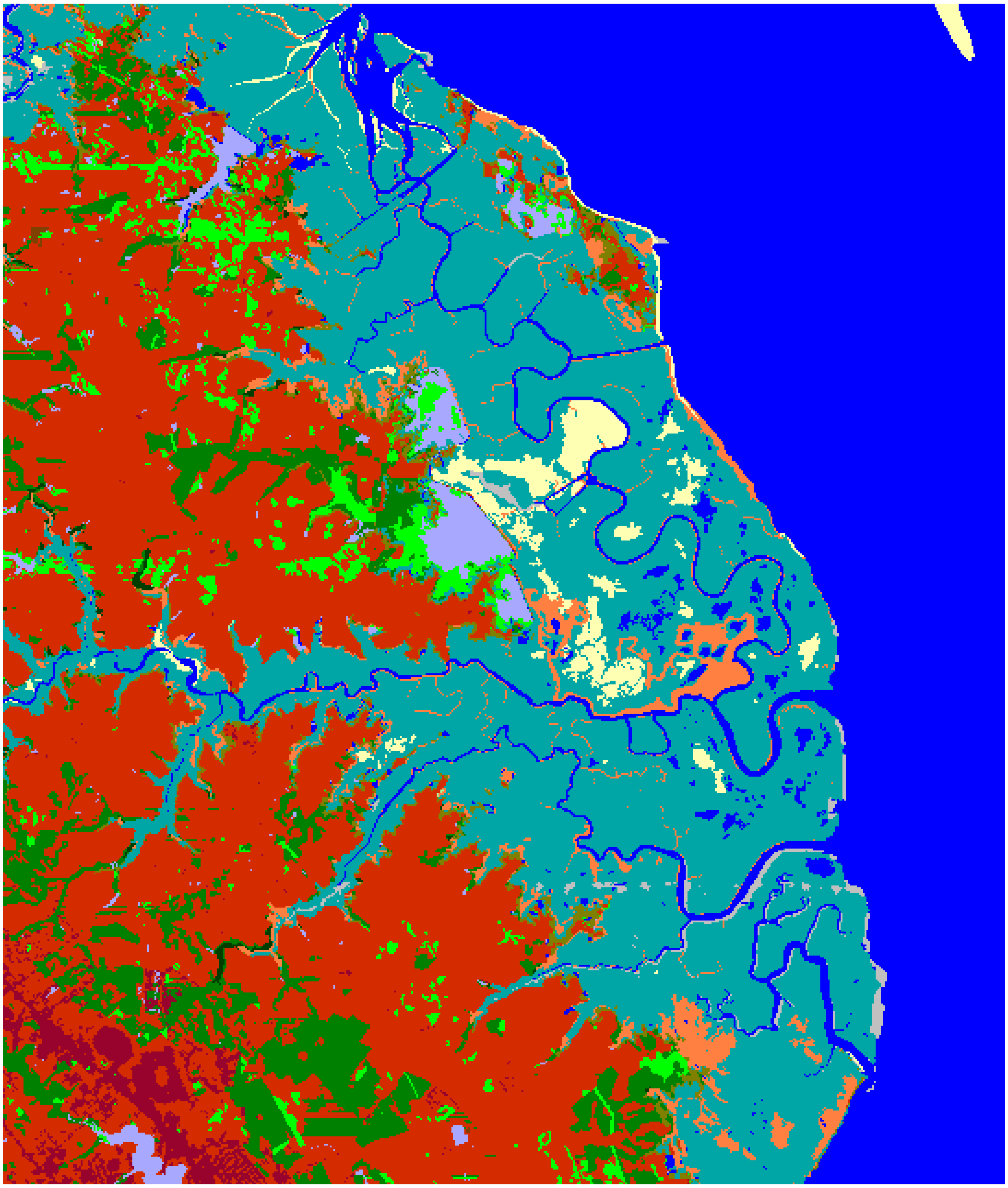
Bombay Hook NWR, 2075, 1.5 meter



Bombay Hook NWR, 2100, 1.5 meter



Bombay Hook NWR, Initial Condition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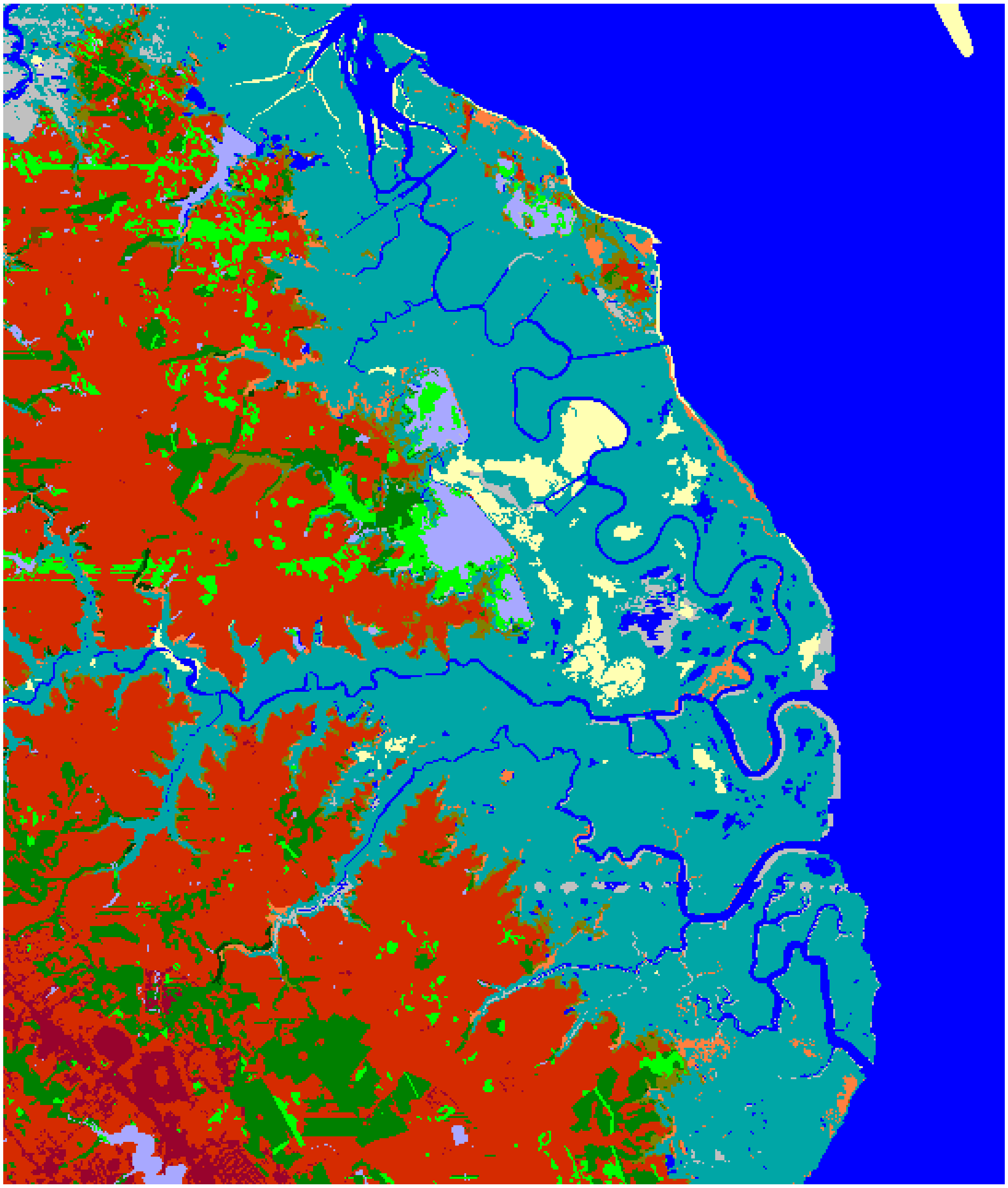
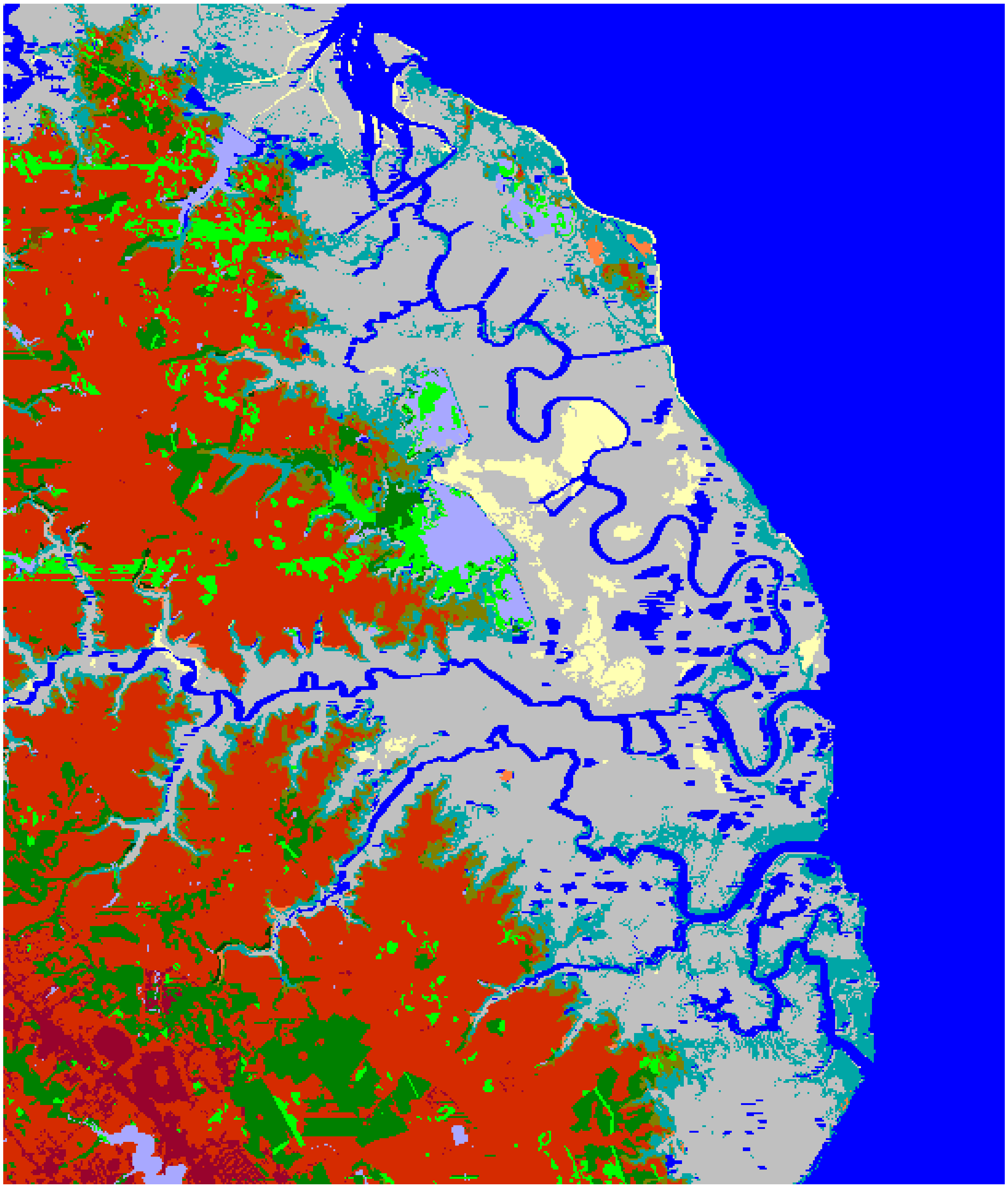
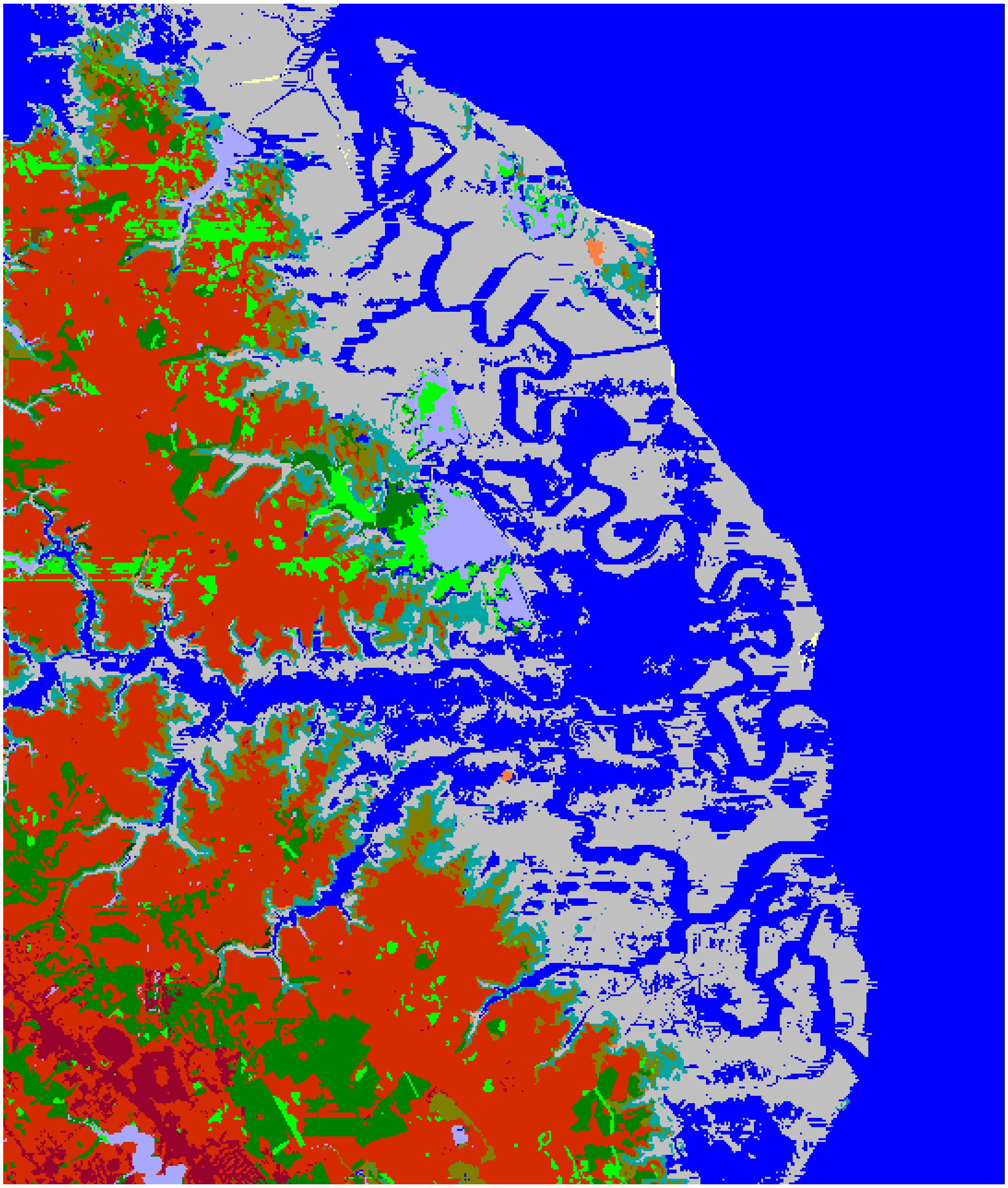


Bombay Hook NWR, 2050, 2 meter



Bombay Hook NWR, 2075, 2 meter



Bombay Hook NWR, 2100, 2 meter