Understanding Changes in the Extent of Metcalf Marsh through Analysis of Historic Aerial Imagery

Will Behm

Staff Mentor: Keary Howley

Introduction

Tidal salt marshes are highly dynamic estuarine ecosystems that support a high level of biodiversity (Boss, 1981). Tidal salt marshes in OR, however, have been shown to be sensitive to sea level rise, as well as disturbance and land use change (Brophy, 2019). For this reason, they have great potential to indicate local effects of global climate change. Metcalf Marsh and Metcalf Islands are areas of tidal salt marsh occupying approximately 6 acres just South of Charleston, OR, near the mouth of the South Slough estuary. South Slough National Estuarine Research Reserve (SSNERR), has an archive of historic aerial imagery from various areas within the Reserve (including Metcalf Marsh and Islands), that have not yet been utilized to understand trends in land cover change. In this analysis, my goal was to initiate a framework for future study of historic land cover using SSNERR's archive, as well as understand historic trends and drivers of change in tidal salt marsh extent within Metcalf Marsh and Islands. I am hopeful that analyzing historic imagery can become a useful guide in restoration efforts within South Slough, as it holds potential to inform concepts of structure and function in desired restoration outcomes, as well as potential rates of change after disturbance.

Methods

Study Site

Metcalf Marsh and Metcalf Islands are regions of tidal salt marsh at the mouth of the South Slough Estuary, just South of Charleston, OR. Metcalf Islands are small islands comprised entirely of marsh, protruding from a mudflat, that are regularly inundated by the tide (Figure 1). At high tide, they are surrounded by water on all sides, and at low tide they are surrounded by exposed mudflat. Metcalf marsh is separated from the mudflat/estuary by a dike, built by digging out a channel (which still exists today) that was used to temporarily store/float logs for the timber industry. Metcalf Marsh's connection to South Slough is via a small channel at the end of the dike, where it receives regular tidal inundation from the estuary (Figure 1). Metcalf Marsh's inland boundary is forest, with some gradient of shrubs and grasses (Figure 1). In Figure 1, the section of visible road leads directly to the intersection of Roosevelt Rd and Cape Arago Highway, just South of the Oregon Institute of Marine Biology.

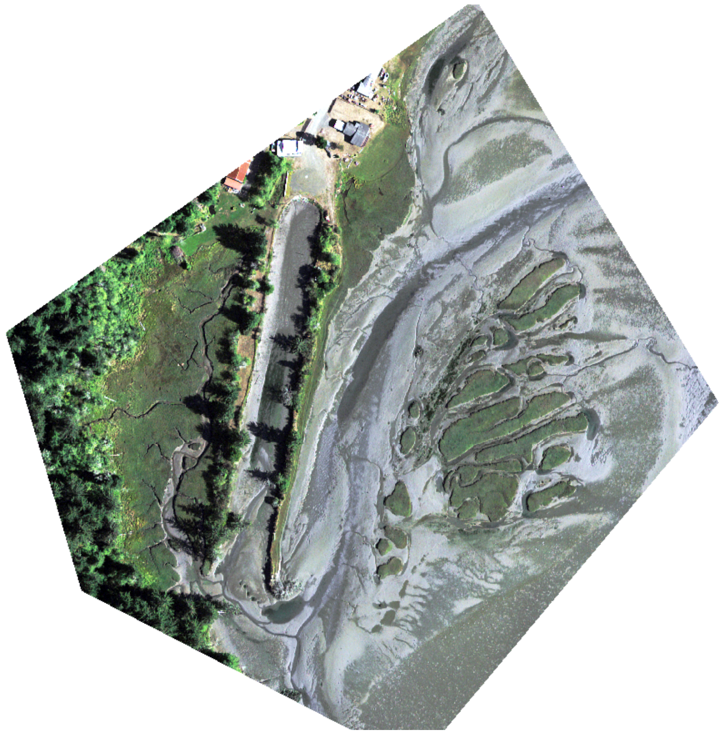


Figure 1. Metcalf Marsh (Left) and Metcalf Islands (Right). Imagery shows exposed mudflat at low tide, as well as the dike containing a log-floating inlet.

Georeferencing

Historic aerial images for this analysis were found in South Slough's image archive, from a variety of sources. The reference imagery (2018), was produced the Oregon Statewide Imagery Program (OSIP, 2018). 2005 imagery was produced by the United States EPA (EPA, 2005). All other images (1989, 1978, 1964, 1959, 1939) were produced by the U.S. Army Corps of Engineers (USACE).

In order to analyze the historic aerial imagery, most of which were scanned versions of physical photographs, each image needed to be georeferenced (save for those from 2005 and 2018, which were orthoimages already with associated geographic data). All analyses in this report were completed in ArcGIS Pro (ArcGIS 2021). After each scanned image was imported (in .tif format), it was projected into a NAD 1983 Oregon Statewide Lambert coordinate system (2011, Intl feet). Images were then fit to the map display over a bookmarked area including Metcalf Marsh and Islands (Figure 2.1). The 2018 OSIP Imagery served as the background for this display, as well as the reference layer for all steps of georeferencing. Once fitted to the map display, images were matched to the reference layer using the move, scale and rotate tools in the georeferencing tab, as well as the swipe tool under the appearance tab in the ribbon.

Once the preliminary registration of the images was complete, ground control points (GCP's) were added and a first-order transformation was applied to complete the georeferencing of the image. Ground control points were chosen from physical structures unlikely to have changed much over the time period of analysis, as well as other notable points surrounding Metcalf marsh that were easily identifiable. Some natural features were used, in order to surround the Area of Interest (AOI) with GCP's and ensure an accurate local (while likely sacrificing the accuracy of the global) registration. Forward Residuals of RMS error, (the average distance between a GCP in the reference layer and the target georeferenced image in map units) were recorded as each image's georeferencing was completed. After being georeferenced, the Extract By Mask tool was used on the images (using a polygon layer of the AOI as the mask), as well as the Raster to other Format tool (Outputting ERDAS Imagine Files [.img]).This was done in order to accommodate 999999 errors encountered with tools in the segmentation and image classification steps of the analysis, and to simplify the images to only display the AOI. The processing extent and clip for all layers was also set to the AOI polygon in the map properties and the global environment. All files and outputs after Georeferencing was completed were saved to the project file geodatabase.

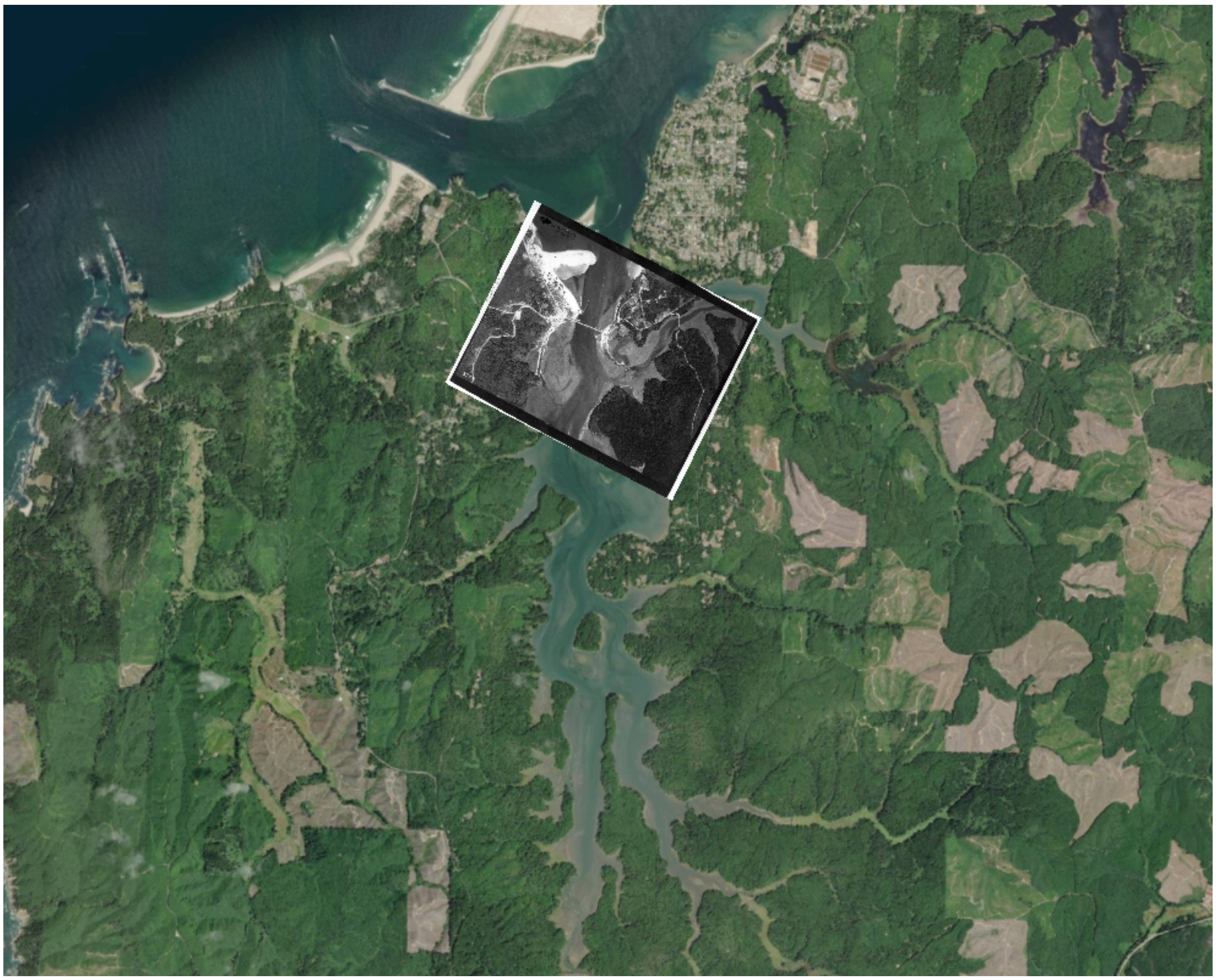


Figure 2.1 Example Georeferencing of 1939 aerial imagery

Image Segmentation

Many of the images used in the analysis varied in quality, and in older greyscale images some objects were not well defined. In order to control for these factors, aid the accuracy of classification, and begin to simplify the images, all images were segmented using the Segment Mean Shift tool. In order to determine appropriate Spectral Detail, Spatial Detail, and Minimum Segment Size parameters, the Segment Mean Shift tool under Raster Functions was used. These parameters were varied in the function chain until the resulting image appeared simplified, but edges and land cover classes of interest (namely marsh, forest, and water) were still visible. With appropriate parameters chosen, each image was then input to the Segment Mean Shift tool in the Geoprocessing toolbox.

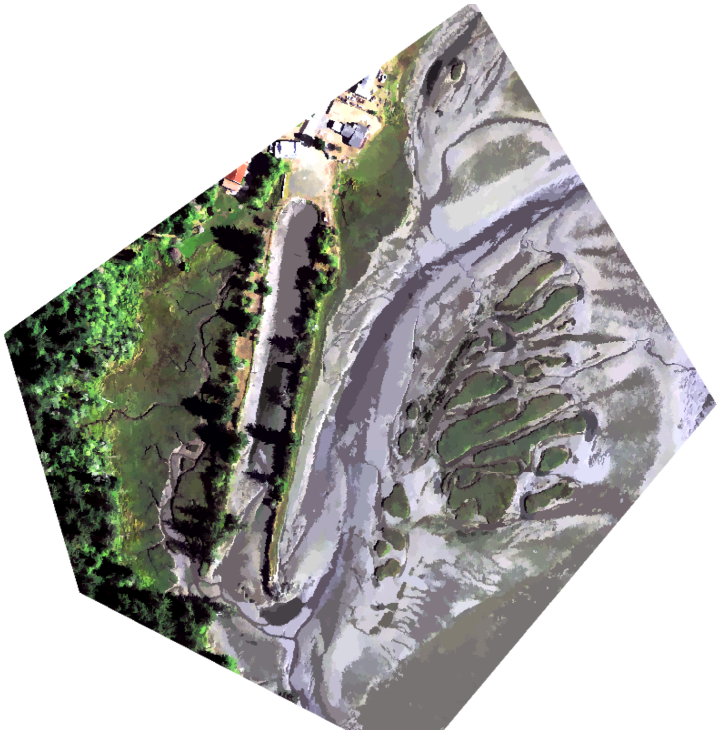


Figure 2.2 Segmented version of 2018 OSIP imagery (Compare to Figure 1)

Supervised, Object-based Image Classification

To fully simplify the images into landcover classes, each was run through the Image Classification Wizard to perform a supervised, object-based classification. In preparation for this step, a classification schema and training samples were created for each image in the Training Samples Manager. The classification schema was created with 7 land cover classes for this analysis: Marsh, Water, Mud (as a subclass of water), Forest (assumed to include shrubs), Developed, Bare Ground (assumed to include short grass), and Shadow (used for areas obscured from classification by shadows). In the 1959 and 1939 images, shadow was not used in order to prevent excess class confusion in the low resolution, greyscale images. Training samples for each image were then created by drawing polygons within areas of known land cover type. For each image, at least ten training samples were created within each class, or as many training samples as were easily identifiable for poorer quality images.

With training samples created, the image Classification Wizard was opened with the pre-segmentation image selected. In the Configure step, the method and type of classification were selected as Supervised and Object-Based, respectively. The previously created classification schema, segmented image, and training samples were also selected in this step. In the Training samples step, training samples were visually reevaluated, and only edited if an error was found. The classifier was then trained in the next step, with all output attributes except rectangularity selected. If the result of the train classifier step appeared to have excess class confusion, then training samples were reevaluated or redrawn, or the segmentation parameters were reevaluated. Once the output of the train classifier step appeared to have minimized class confusion, the image was classified in the Classify step. In the merge classes step, the mud class was merged with water (its parent class) in order to account for variation in tides across images. Finally, in the Reclassify step, any obvious remaining class confusions were manually reclassified by drawing polygon regions. For example, if any section of Metcalf Islands, which have clearly remained undeveloped throughout all the images, were classified as developed, it would be reclassified as marsh, the island's primary land cover type (visible in the original image). In images where class confusion was high (as was the case in most of the older images), reclassification was focused only on class confusions that were obvious and accessible (for example, open water reclassifying as forest) or directly relevant to marsh extent (ex. development in marsh where there clearly was none). In some instances, such as for the area of Metcalf Islands in 1939, no reclassification was performed despite potential class confusions, because the land cover types were not well defined in the original image.

To gauge the accuracy of each image's classification, 100 Accuracy Assessment points were created within each image using the Create Accuracy Assessment Points tool, and a confusion matrix was created to determine Cohen's Kappa Statistic. The target field was set to classified, and a stratified random sampling strategy was used. Once the point layer was created, the ground truth values (coding for land cover type) were manually entered into the attribute table (with classified values hidden) for each point. This was done by visually evaluating the landcover type of the accuracy points over a pre-classification version of the image. After evaluating the ground truth attributes, a confusion matrix was created from each set of accuracy assessment points using the compute confusion matrix tool. Each confusion matrix (containing the Cohen's Kappa Statistic values) was then exported to an excel file for reformatting.

Categorical Change Detection

Changes in marsh extent across the classified images were evaluated through a categorical change detection using the Change Detection Wizard. Two change detections were performed for each classified image, both of which used the classified image itself as the "From" raster, and the classified image from 2018 as the "To" raster. One of the analyses for each image was set to quantify the amount of forest and water that changed to marsh (The "To Marsh" change detections), while the other quantified the amount of marsh that changed to forest and water (The "From Marsh" change detection). Water and marsh were chosen as the land cover types of interest because the land cover surrounding Metcalf Marsh and Islands is dominated by forest and water. After the change detections were complete, the "To Marsh" output layer was visualized over the "From" image, and the "From Marsh" output layer was visualized over the "To" layer (2018) both for analysis of the trends of march extent change in Metcalf Marsh and Islands, but also to qualify error from differences in registration in the georeferencing step.

Results

Year	Forward Residual (feet)	Transformation	#GCP's
1989	8.041533	first order	8

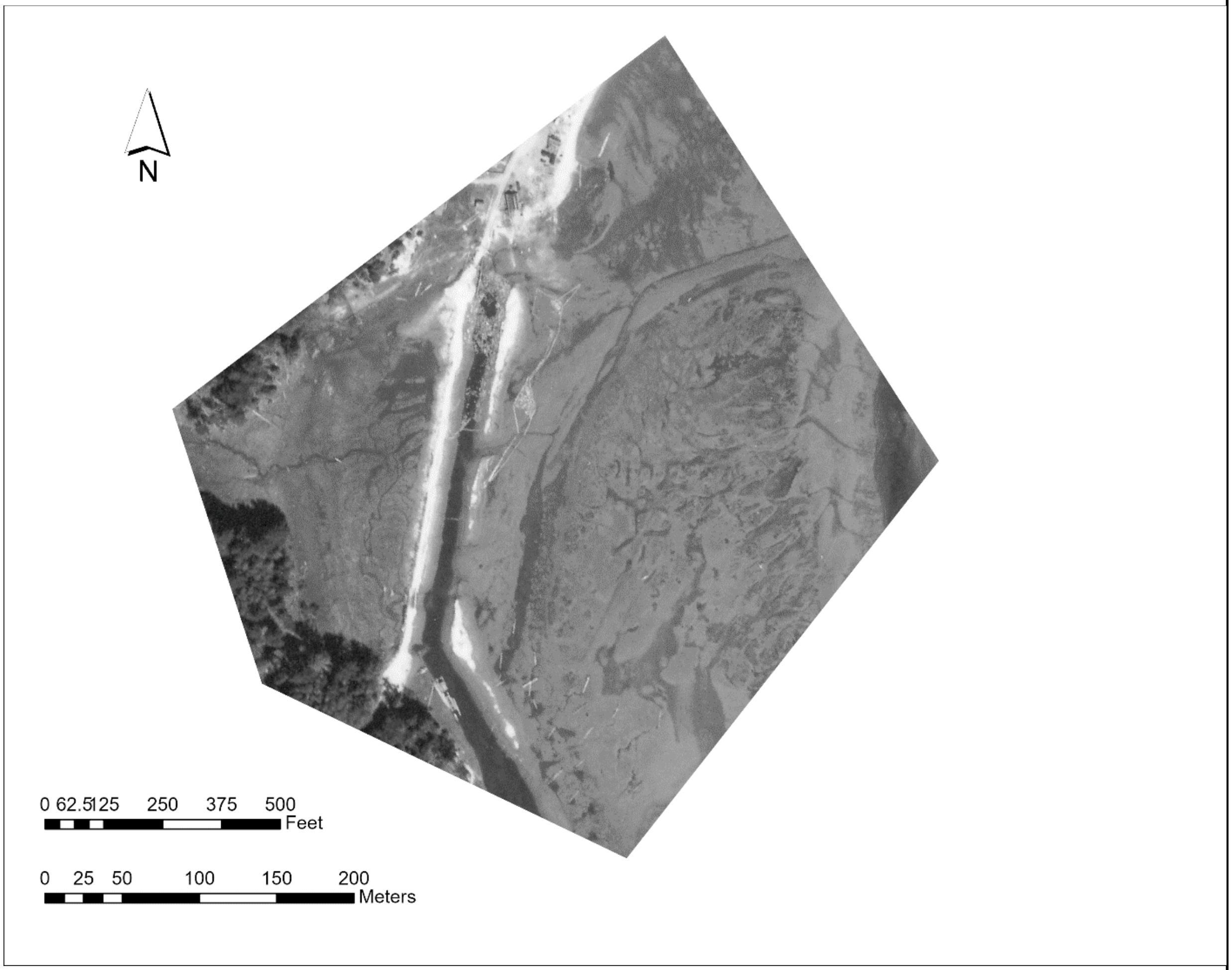
1978	7.490653	first order	8
1964	9.916447	first order	8
1959	10.08533	first order	7
1944	7.187652	first order	7
1939	9.467679	first order	6

Table 1. Forward Residuals, transformation type, and number of Ground Control Points (GCP's) from the georeferencing of historic images of Metcalf Marsh and Islands.

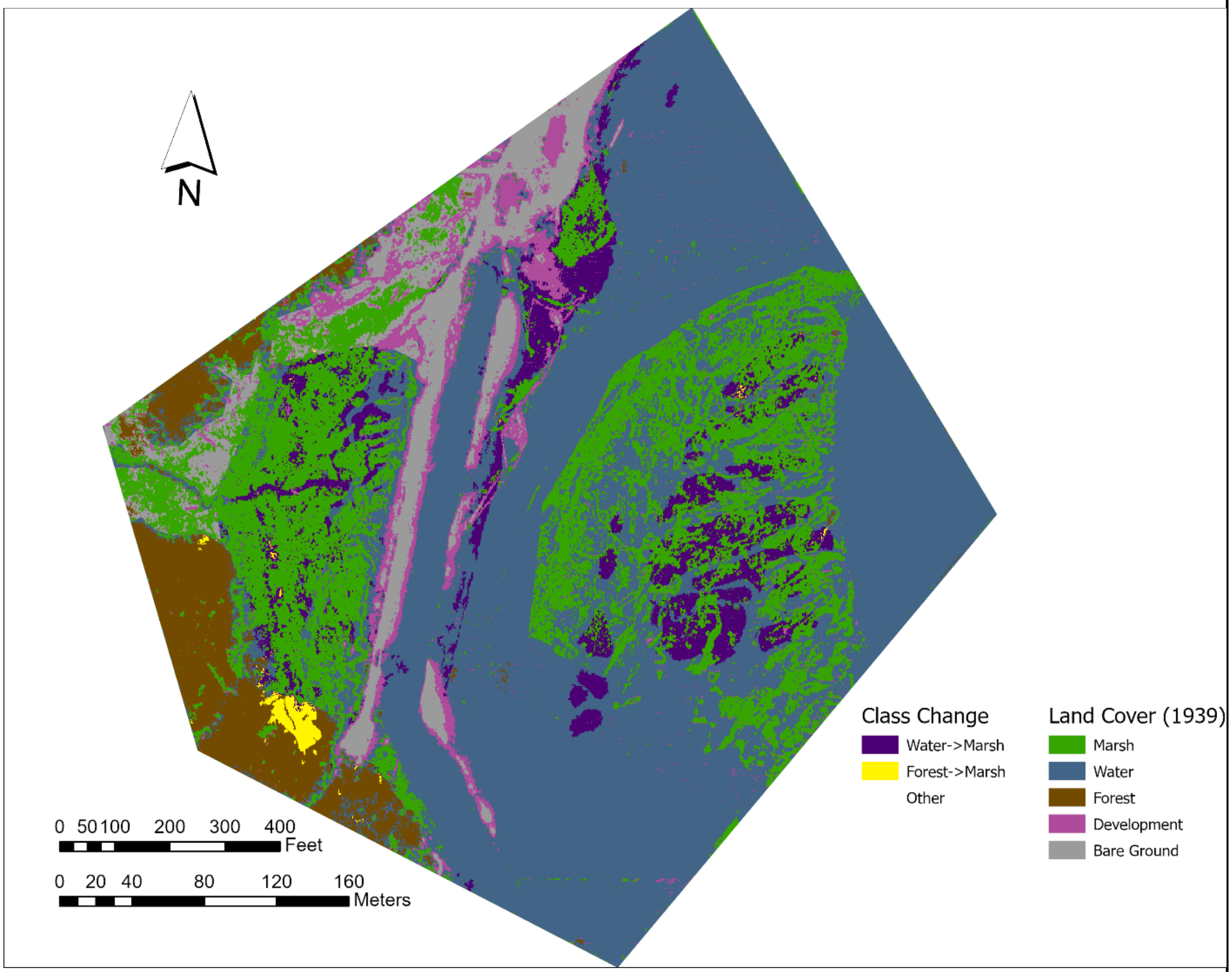
Year	**K-Value**
2018	0.80113 9
2005	0.56597 8
1989	0.46645
1978	0.46645
1964	0.50423 3
1959	0.61403 5
1939	0.62249 5

Table 2. Cohen's Kappa values for each classified image of Metcalf Marsh and Islands near Charleston, OR. Values were produced from computed confusion matrices of a 100-point accuracy points layer.

A.



B.


N
0 50 100 200 300 400
Feet
0 20 40 80 120 160
Meters
Class Change
Water->Marsh
Forest->Marsh
Other
Land Cover (1939)
Marsh
Water
Forest
Development
Bare Ground

C.

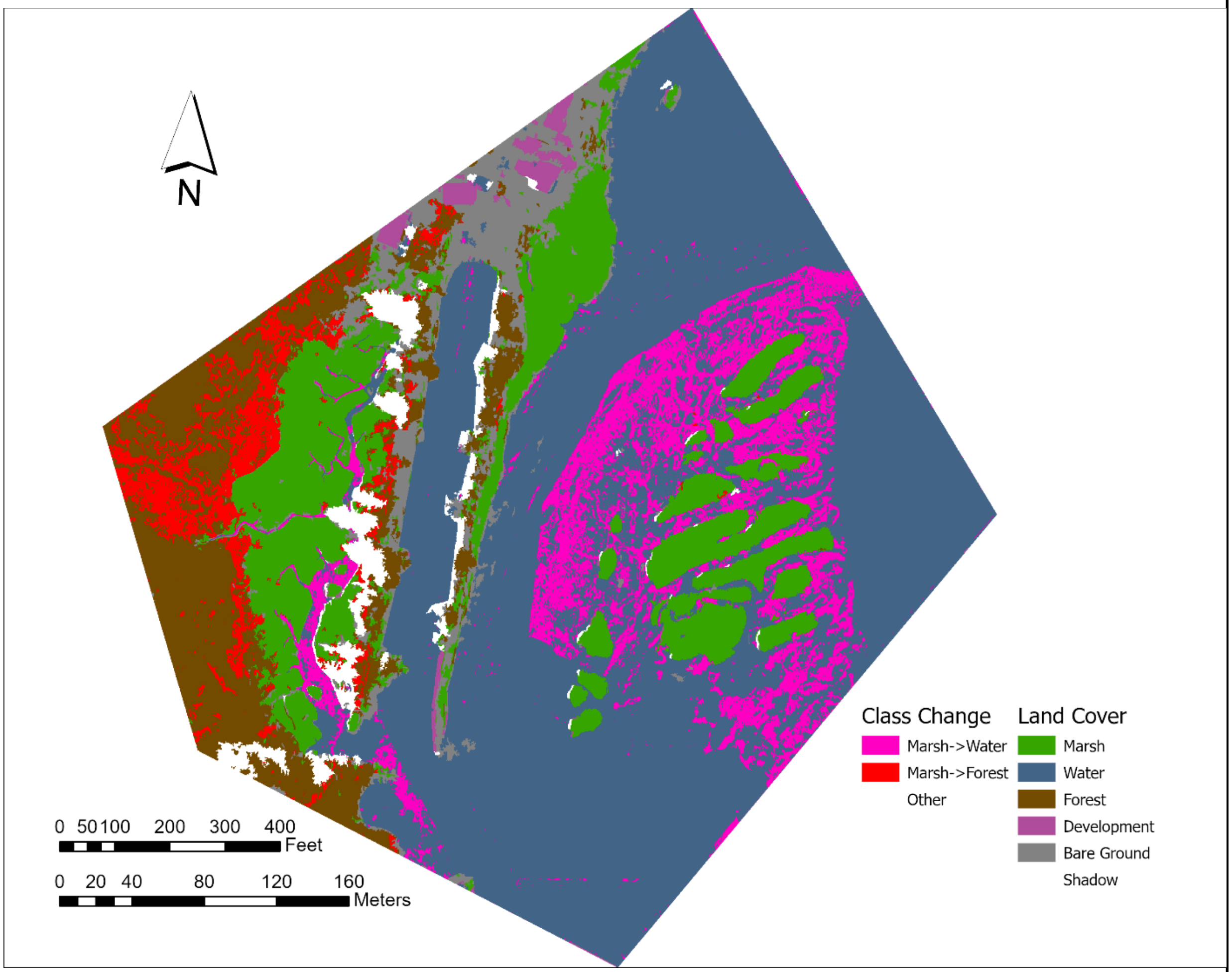


Figure 3. Map layouts of Metcalf Marsh and Islands near Charleston, OR. A.) Historic aerial image of Metcalf Marsh and Islands from 1939. B.) Classified land cover raster of Metcalf Marsh and Islands from the 1939 image with land cover class change layer (Purple and yellow) of forest and water classes that changed to marsh between 1939 and 2018. C.) Classified land cover raster of Metcalf Marsh and Islands from 2018 imagery with land cover class change layer (Pink and Red) of marsh class that changed to forest or water land cover classes between 1939 and 2018.

Each of the historic images that needed georeferenced yielded a forward residual between 7 and 10 feet (Table 1). The Cohen's Kappa statistic for the 2005, 1989, 1978, and 1964 image classifications were within the "rule of thumb" standard of "moderate" agreement (0.4-0.6), the 1959 and 1939 classifications were within the standard of "good" agreement, and the 1989 classification was the only image that fell within the standard for "Very good" agreement. These Kappa values do not, however, appear to describe the accuracy of the classified images consistently. For example, the land cover classes appear to be very accurate in the 1978 and 1989 images (When compared to the original image), which both yielded a lower Kappa value than the 1959 and 1939 classifications, which appear to have higher amounts of class confusion when compared to the original aerial images (See Appendix for all classifications and change detections).

The extent of change in marsh to and from forest produced by the Categorical Change Detection analyses varied widely. Most notably, a large section of marsh on the eastern side of the 1939 classification appears to have changed to marsh in the 2018 classification. Metcalf Islands appear to have changed in nearly their entirety between 1939 and 2018, which is likely indicative of classification error, given the uncertainty of the marsh's location in the original image (see discussion).

Discussion

Given the registration error present in most of the photos, when the change detection was performed, any displacement between the two images showed up as "change" that was not actually present. For example, if one of the Metcalf Islands was completely unchanged between two images, registration error of one of the images would cause the change detection to show change in marsh that was not actually present. Thus, it is likely that the data and visualizations associated with the categorical change detection in this analysis contain some degree of unquantified error. This error is particularly confounding around Metcalf Islands, where high rates of change in marsh extent were expected but cannot be distinguished from registration error. There also appears to be more error in the classifications than indicated by the Cohen's Kappa statistic values. That is, there is a great deal of evident class confusion in some of the images, such as the broad span of marsh around Metcalf Islands in the 1939 classification (which was not reclassified due to uncertainty of the actual location of the islands in the image). This class confusion does not appear to be reflected in the "good" agreement of the Kappa statistic. This is likely due to the sampling strategy used in creating the accuracy assessment points. Because a stratified random sampling strategy was used on an image that was mostly water and marsh, with only 100 points used, it is likely that a large portion of the class confusion in the images went unsampled. A larger number of points (500) was not feasible for this analysis but would likely yield a much more accurate assessment of the image classifications. Therefore, the use of these results to accurately describe quantitative changes in area and highly specific changes in land cover over time is not recommended.

Despite the errors present in this analysis, it still appeared to identify broad trends in the extent of Metcalf Marsh and Islands. More specifically, large changes in marsh extent appear to have occurred along the Marsh-forest boundary. Between 1939 and 2018 (as in Figure 3B), the forest to marsh change appears to have been focused on the eastern side of Metcalf marsh, where one of the main drainage channels enters the forest. In 1939, much of the area was marsh, but by 2018 the entire area appears to be forested, and the forest overall appears to have encroached upon the marsh (although the rate seems to slow over time, see appendix). This trend is evident even considering potential error along the marsh-forest boundary, where shrubs or non-marsh grasses (which would ideally classify as forest), may have classified as marsh. Further research would be required to determine the true driver of these trends, but land-use change appears to be the most plausible explanation. The dike and log inlet on the estuary side of Metcalf marsh seems to be in heaviest use, or possibly new, in the 1939 image. This is evidenced by the large amount of bare ground along the dike, and the fact that the dike extends across the channel through which saltwater enters Metcalf marsh in all the other images. If this image had been taken recently after the construction of the dike, then it is plausible that forest encroachment on the inland boundary of the marsh would have increased in the following years with reduced tidal inundation. It is also possible, however, that the dike had been in existence for a longer period before the 1939 image was taken. If this were the case, then other trends in land use may better explain the change in forest boundary. There also appears to be a large amount of bare ground along the forest boundary of the 1939 image, so there is potential that there was some form of disturbance (such as logging, or access to the far side of the dike) that could have been the driver for land cover change. Regardless, more historical background and a more in-depth analysis of the marsh-forest boundary, as well as change detections and a more focused classification of bare ground would be required to elucidate the patterns observed above. Perhaps most notably, the results of this analysis highlight the need for a greater understanding of Metcalf Marsh and Islands' extent before the construction of the dike. Effects of sea-level rise were not evident in this analysis, but it is likely that the analysis was not sensitive enough, or that sea level changes were not evident due to registration and classification error.

Broadly, this type of image analysis could provide very valuable insights into historic conditions of ecosystems within South Slough if it were to be carried out on other locations of interest for which historic aerial imagery is available. As this analysis has shown, even with a dearth of sound quantitative results, important questions for further research can be identified from historic imagery. There are, however, some recommendations for future analyses that should be noted. Before any analysis, the imagery used should be heavily scrutinized. Images with the highest quality and resolution, as well as the best contrast and fewest shadows/obscurities, should be used. For older historic imagery, all possible image enhancement should be considered. For georeferencing, local accuracy of the AOI should be prioritized, and GCP's that are within or immediately surrounding the AOI should be used if possible. A major difficulty within South Slough is that there are few unchanging physical/developed features present due to the dynamic nature of estuarine ecosystems. Thus, when local accuracy is maximized, it may not be reflected in the forward residuals. Current GPS field data for GCPs should also be collected to maximize accuracy of the reference layer.

There are also recommendations for the Segmentation and classification steps of the analysis that should be considered. In image segmentation, spatial detail, spectral detail, and minimum segment size should be modified until the output is as simplified as possible without sacrificing any clarity of prospective land cover class boundaries. Doing so will enhance the ability of the classifier to distinguish between land cover classes, and ultimately decrease the amount of reclassification necessary later in the analysis. In image classification, it seems beneficial to have higher numbers of small training samples within each class, rather than fewer, larger samples. Save for large, homogenous expanses of area that can accurately be represented by a single sample, samples covering large areas should be broken up into smaller samples that still represent the spectral variety of objects within the land cover class. Land cover classes themselves should also be broken up into parent classes and subclasses where feasible (just as mud and water were in this analysis), as it is often easier to merge classes into one parent class and simplify an image than it is to reclassify detailed sections of an image. This tactic can also help account for periodic differences between images, as it did for tidal variation in this analysis. Considering the above recommendations to produce more quantitatively accurate future analyses could be invaluable to restoration efforts within South Slough. Not only would the analyses suggest historic drivers of ecological change within the Slough; an accurate understanding of the rate of change could be gained. Identifying patterns in historic land use can elucidate our concept and affect our selection of desired restoration outcomes, or what structure and function we would like to restore. This, along with understanding rates of change and quantifying ecosystem structural variation through time, serves an understanding of how our own restoration efforts may progress, and ultimately become more successful.

Acknowledgements

I would like to thank Keary Howley for his mentorship and guidance in all aspects of this analysis, as well as the staff of South Slough NERR for making this summer research opportunity possible!

References

ArcGIS Pro. Version 2.8.2. 2021. Esri inc. Copyright 2021, all rights reserved.

Brophy, L.S. 2019. Comparing historical losses of forested, scrub-shrub, and emergent tidal wetlands on the Oregon coast, USA: A paradigm shift for estuary restoration and conservation. Prepared for the Pacific States Marine Fisheries Commission and the Pacific Marine and Estuarine Fish Habitat Partnership. Estuary Technical Group, Institute for Applied Ecology, Corvallis, Oregon, USA.

Oregon Statewide Imagery Program (OSIP). 2018. Geospatial Enterprise Office, 530 Airport Rd SE, Salem, OR 97301.

Boss, T.R. January, 1981. Intertidal salt marshes of Oregon. Department of Geography, Oregon State University, prepared for the Marine Advisory Program through the Oregon State University Extension Service. Corvallis, Oregon, USA.

U.S. Army Corps. of Engineers (USACE), Portland District. 1939-1989. Portland, OR 97208-2946

U.S. Environmental Protection Agency (EPA). 2005.

Appendix

Note: Images here are for visualization purposes only. Actual image files/layers can be found in the ArcGIS Pro Project where this analysis was completed:

MetcalfImageAnalysis\MetcalfImageAnalysis.aprx

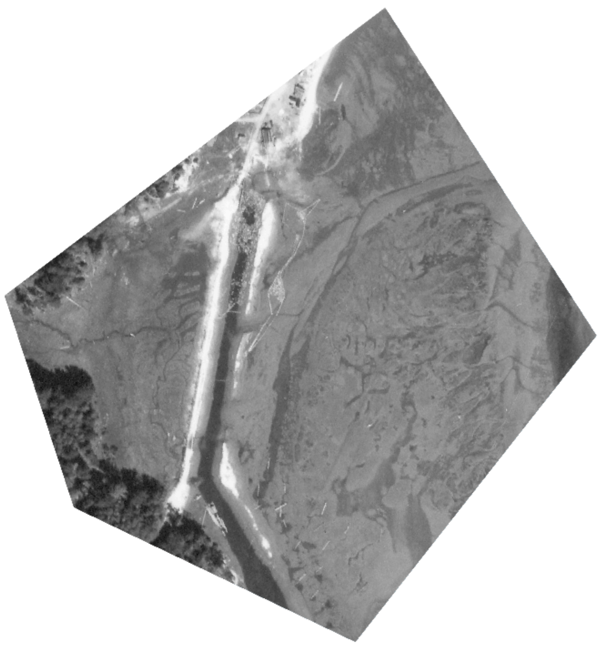
All metadata and other deliverables associated with this project can be found here:

..\DELIVERABLES

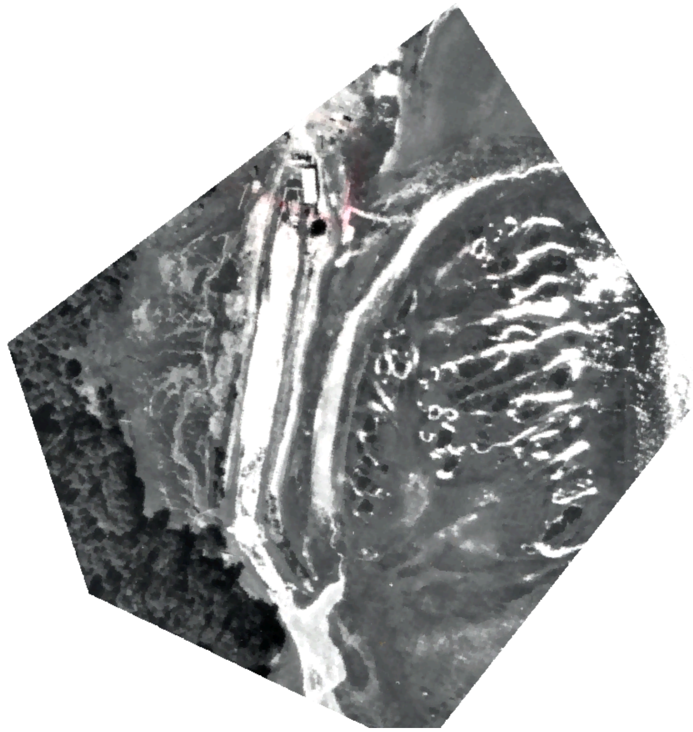
GCP Locations
Center of Charleston Bridge
Intersection of Cape Arago Highway and Roosevelt Rd
Intersection of Cape Arago Highway and 7 Devils Rd
First right-angle curve in 7 Devils Rd
Intersection of 7 Devils Rd and Walker Ln
Collver Point
Southern bank at the Mouth of Joe Ney Slough (Across from boatyard)
Port dock benchmark

Appendix Figure 1. Locations of Ground Control Points (GCP's) used to georeference the historic images used in this analysis

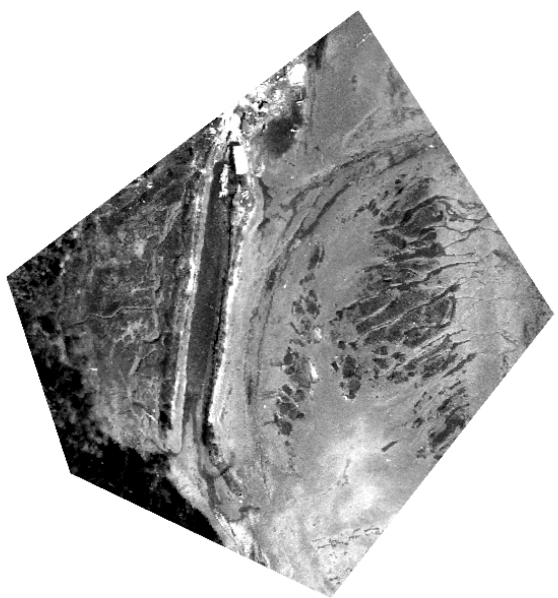
A.



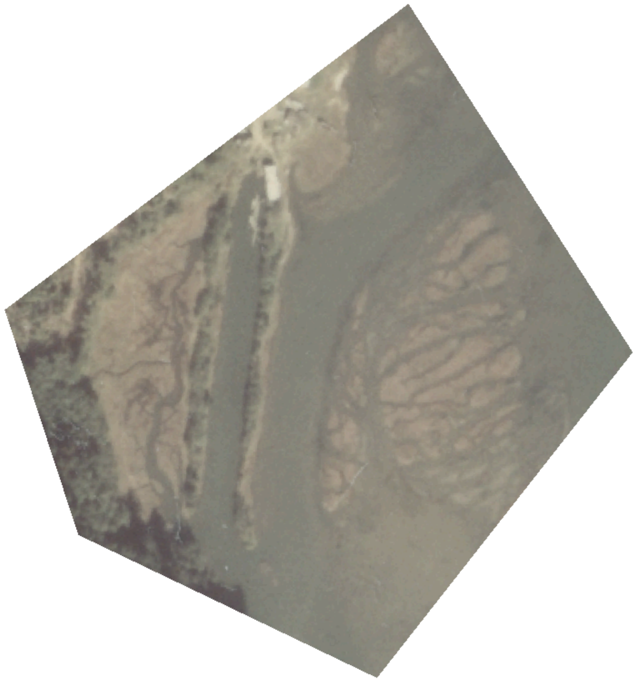
B.



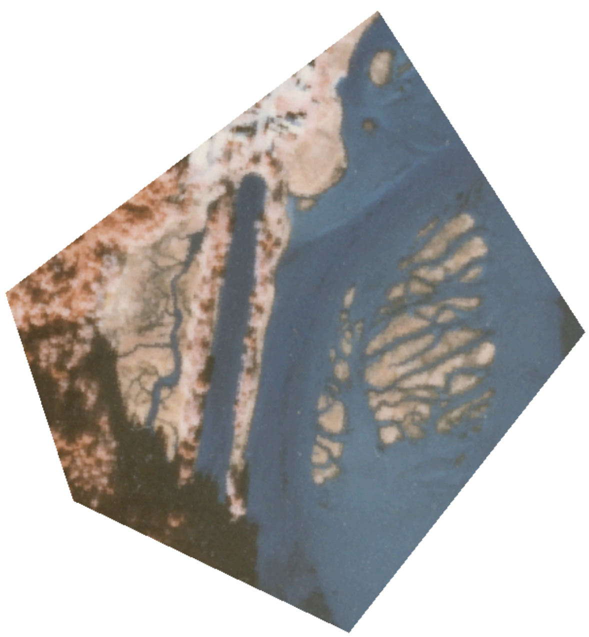
C.



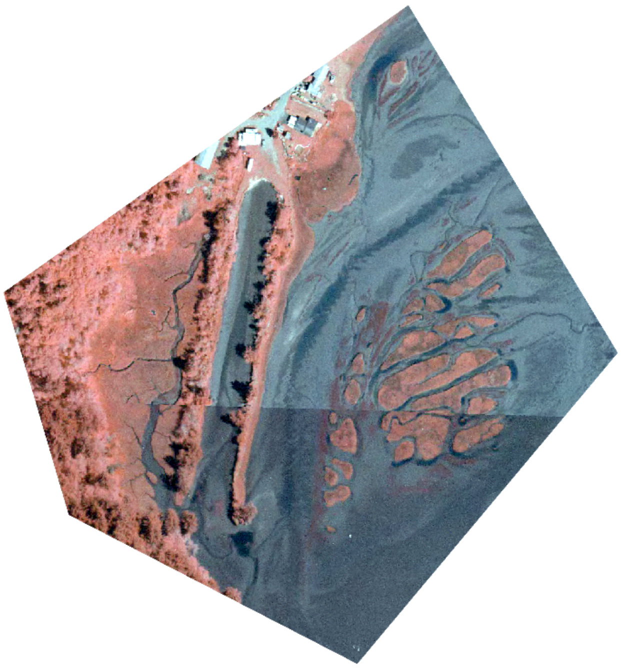
D.



E.



F.



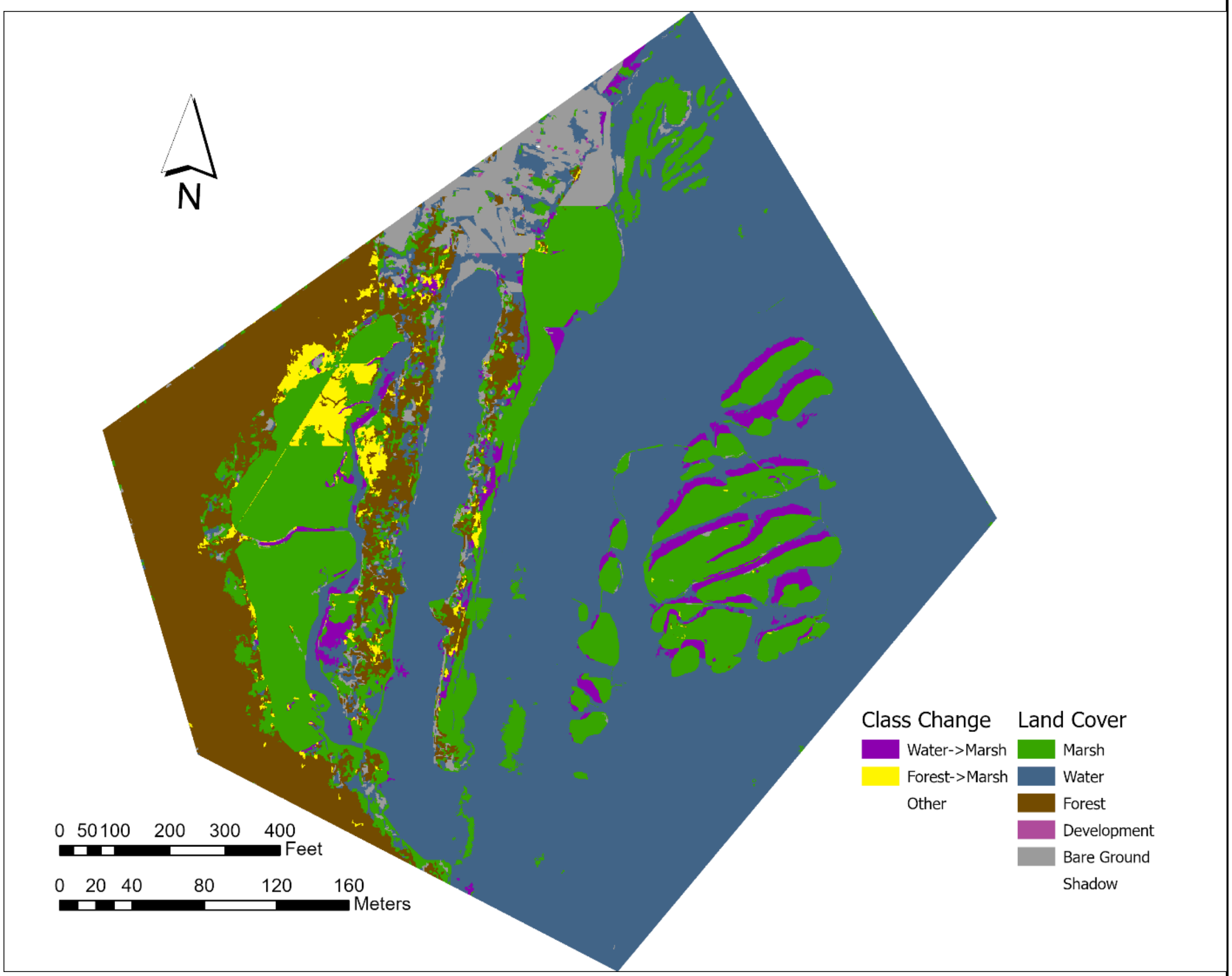
G.

Appendix Figure 2. Images used in the analysis before any image processing was performed. A. 1939, B. 1959, C. 1964, D. 1978, E. 1989, F. 2005, G. 2018.

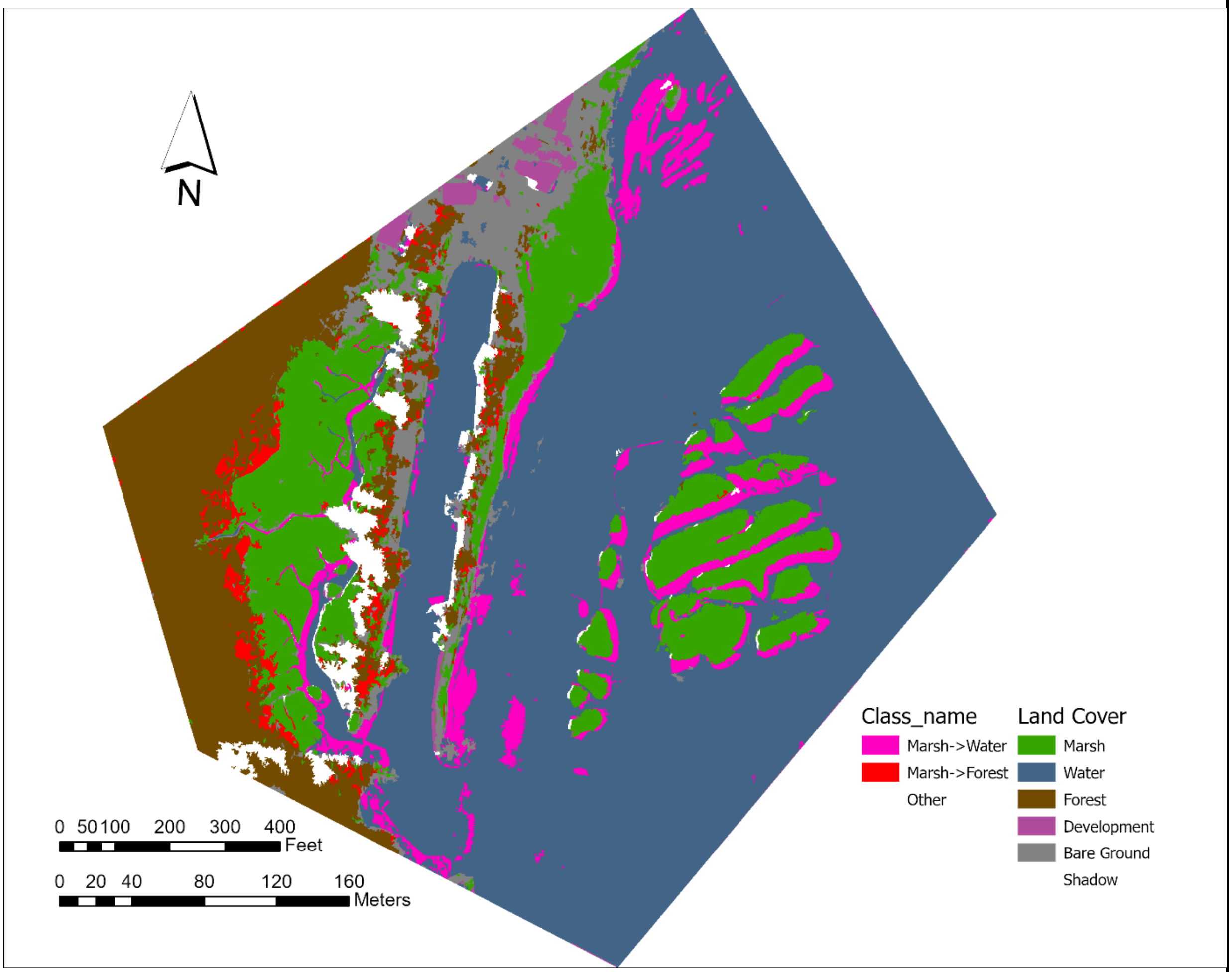
Year	Total Marsh Area (Acres)	Total Marsh Area (Hectares)
2018	5.7	2.306708165
2005	7.4	2.994673758
1989	5.7	2.306708165
1978	5.5	2.225771037
1964	6	2.428113858
1959	4.1	1.659211136
1939	8.6	3.48029653

Appendix Figure 3. Total area covered by marsh in each of the classified images of Metcalf Marsh (Charleston, OR). Area represented in Acres and Hectares.

A.

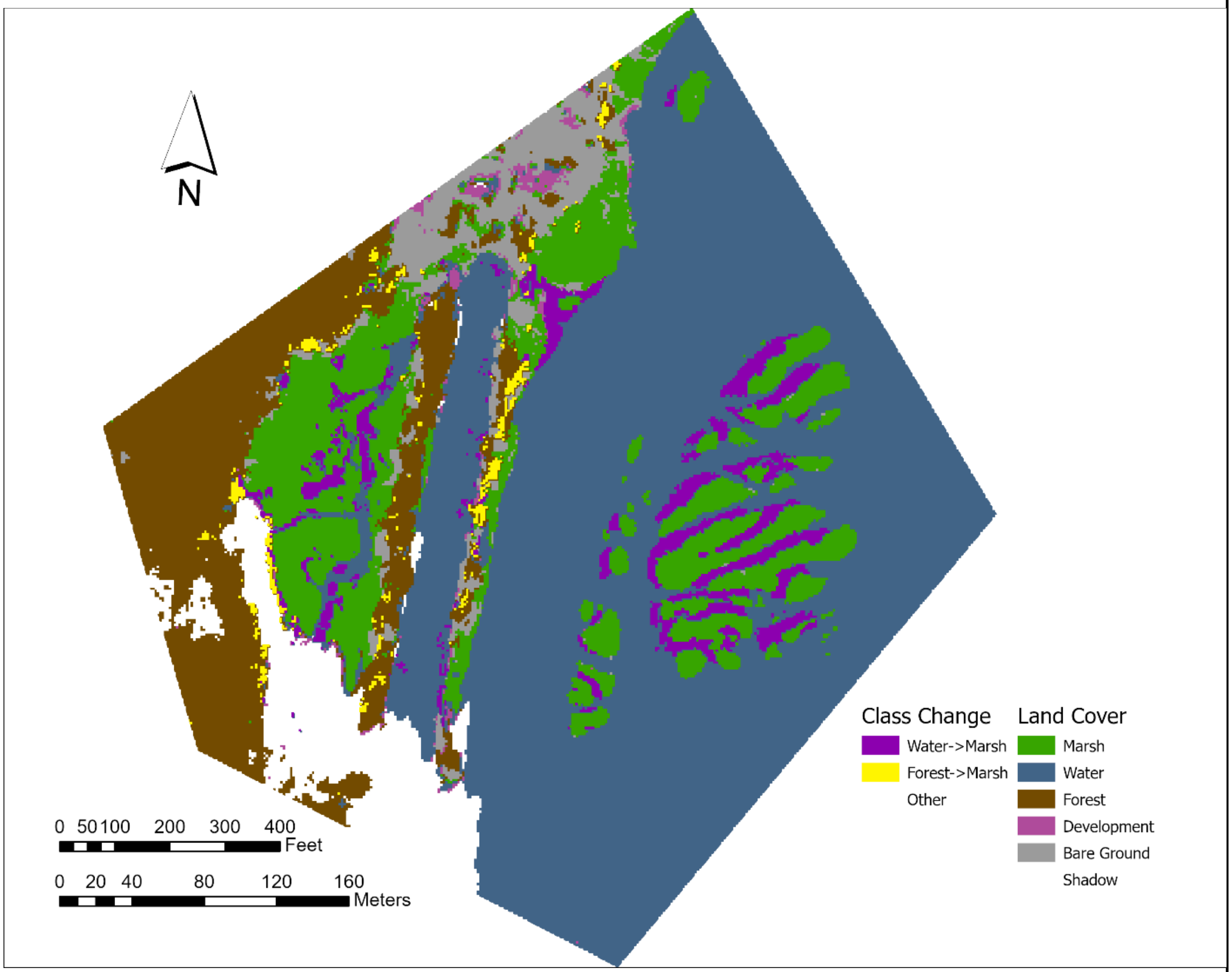


B.

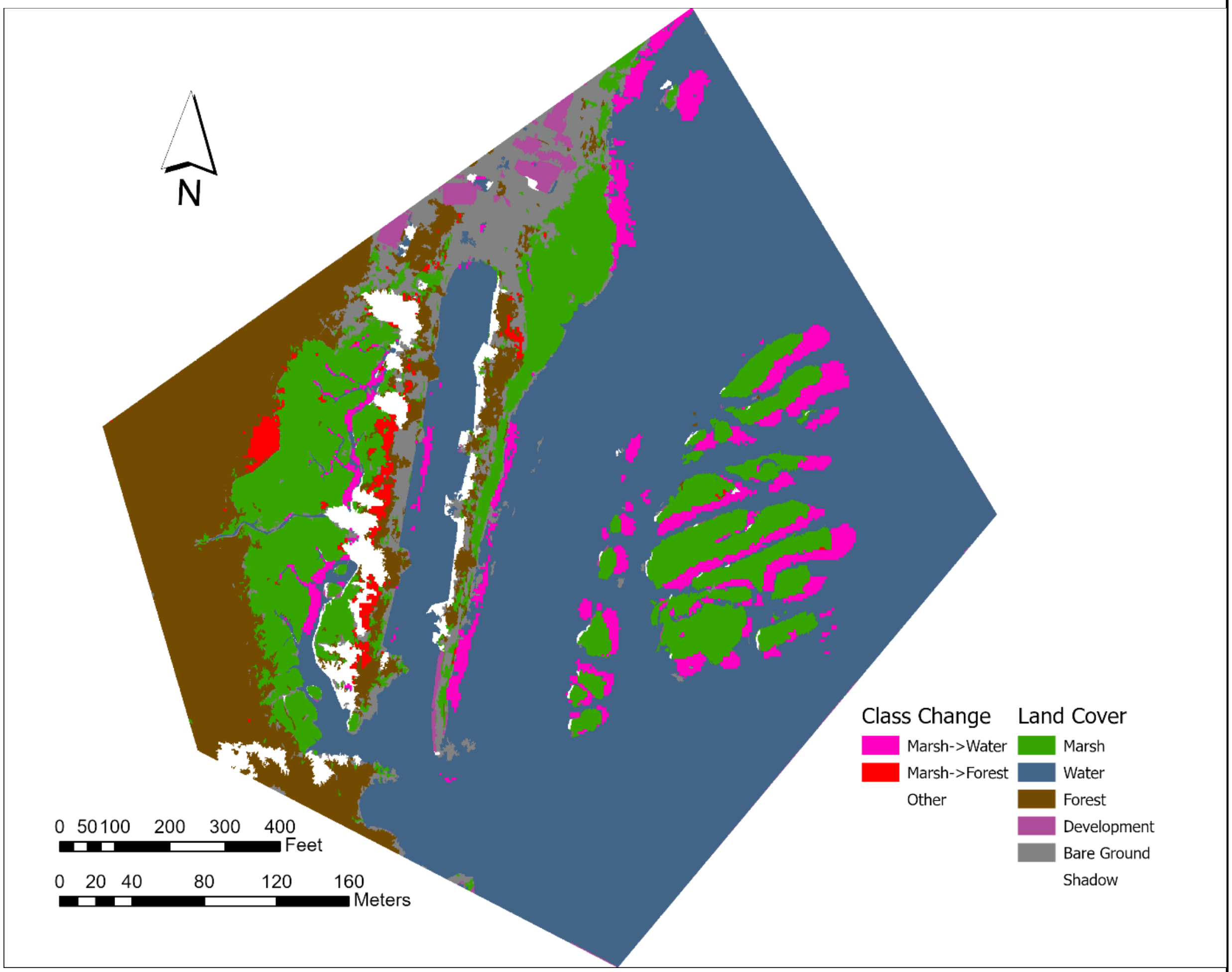


Appendix Figure 4. Map layouts of Metcalf Marsh and Islands near Charleston, OR. A.) Classified land cover raster of Metcalf Marsh and Islands from the 2005 image with land cover class change layer (Purple and yellow) of forest and water classes that changed to marsh between 2005 and 2018. B.) Classified land cover raster of Metcalf Marsh and Islands from 2018 imagery with land cover class change layer (Pink and Red) of marsh class that changed to forest or water land cover classes between 2005 and 2018.

A.

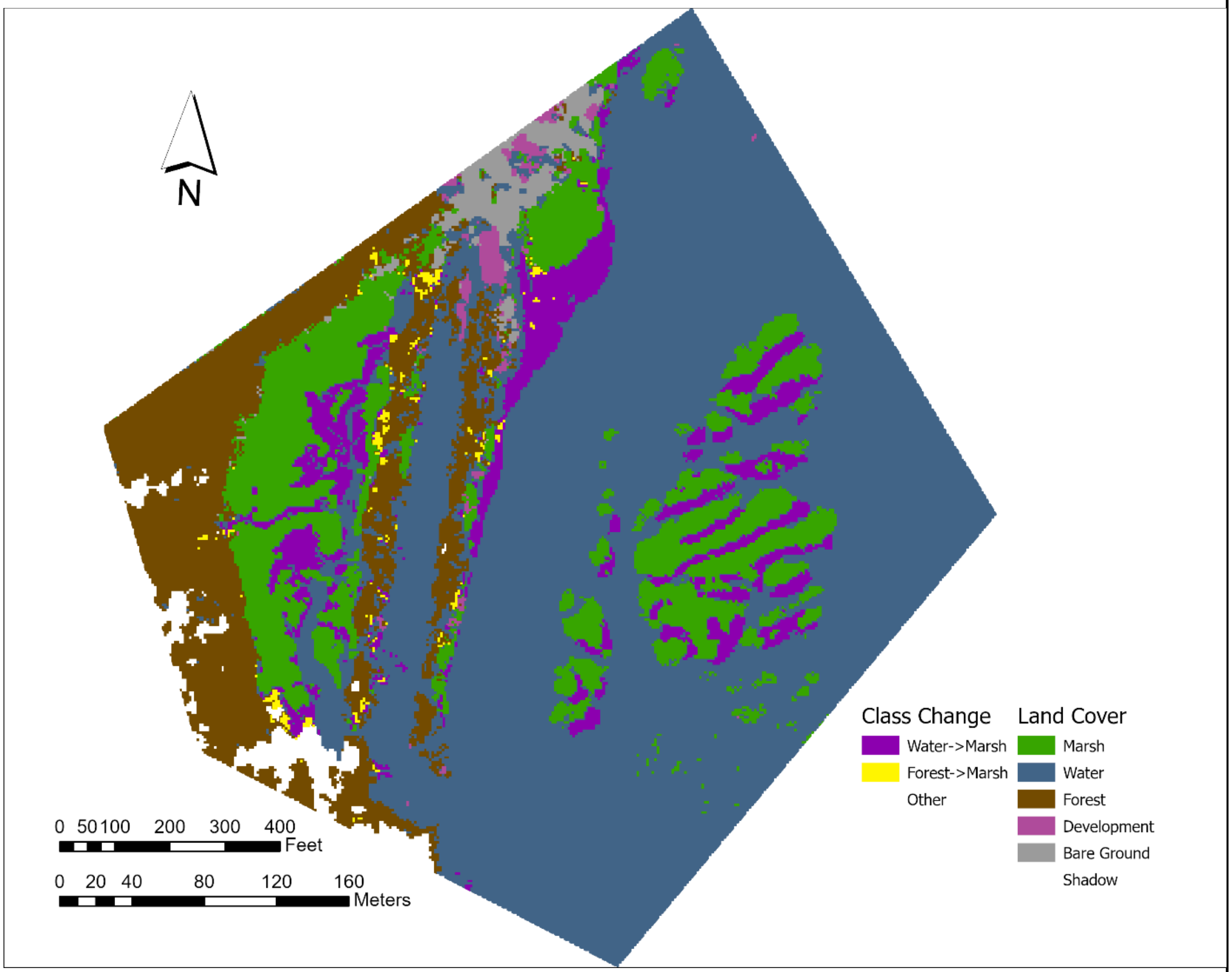

N
Class Change
Water->Marsh
Forest->Marsh
Other
Land Cover
Marsh
Water
Forest
Development
Bare Ground
Shadow
0 50 100 200 300 400
Feet
0 20 40 80 120 160
Meters

B.

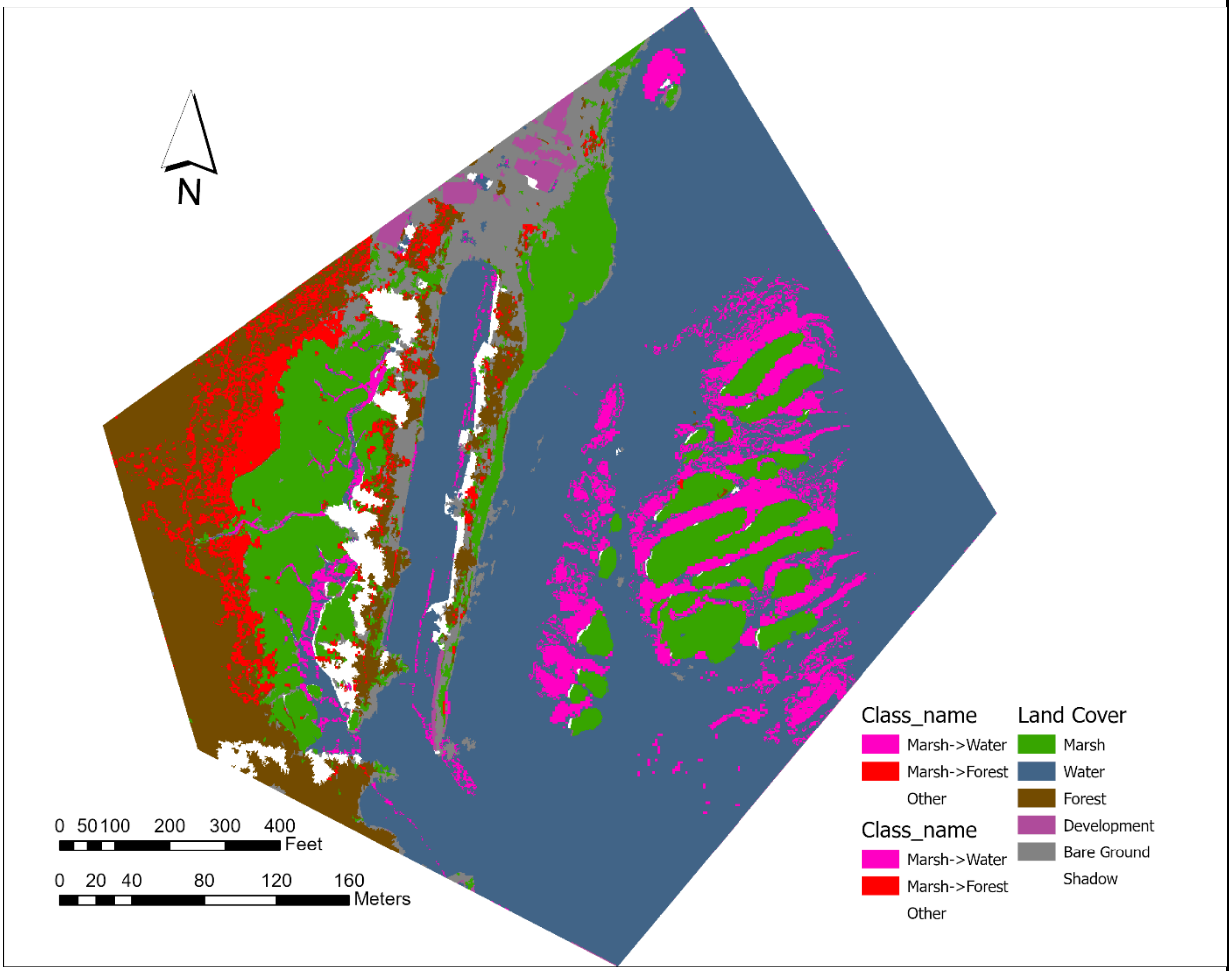


Appendix Figure 5. Map layouts of Metcalf Marsh and Islands near Charleston, OR. A.) Classified land cover raster of Metcalf Marsh and Islands from the 1989 image with land cover class change layer (Purple and yellow) of forest and water classes that changed to marsh between 1989 and 2018. B.) Classified land cover raster of Metcalf Marsh and Islands from 2018 imagery with land cover class change layer (Pink and Red) of marsh class that changed to forest or water land cover classes between 1989 and 2018.

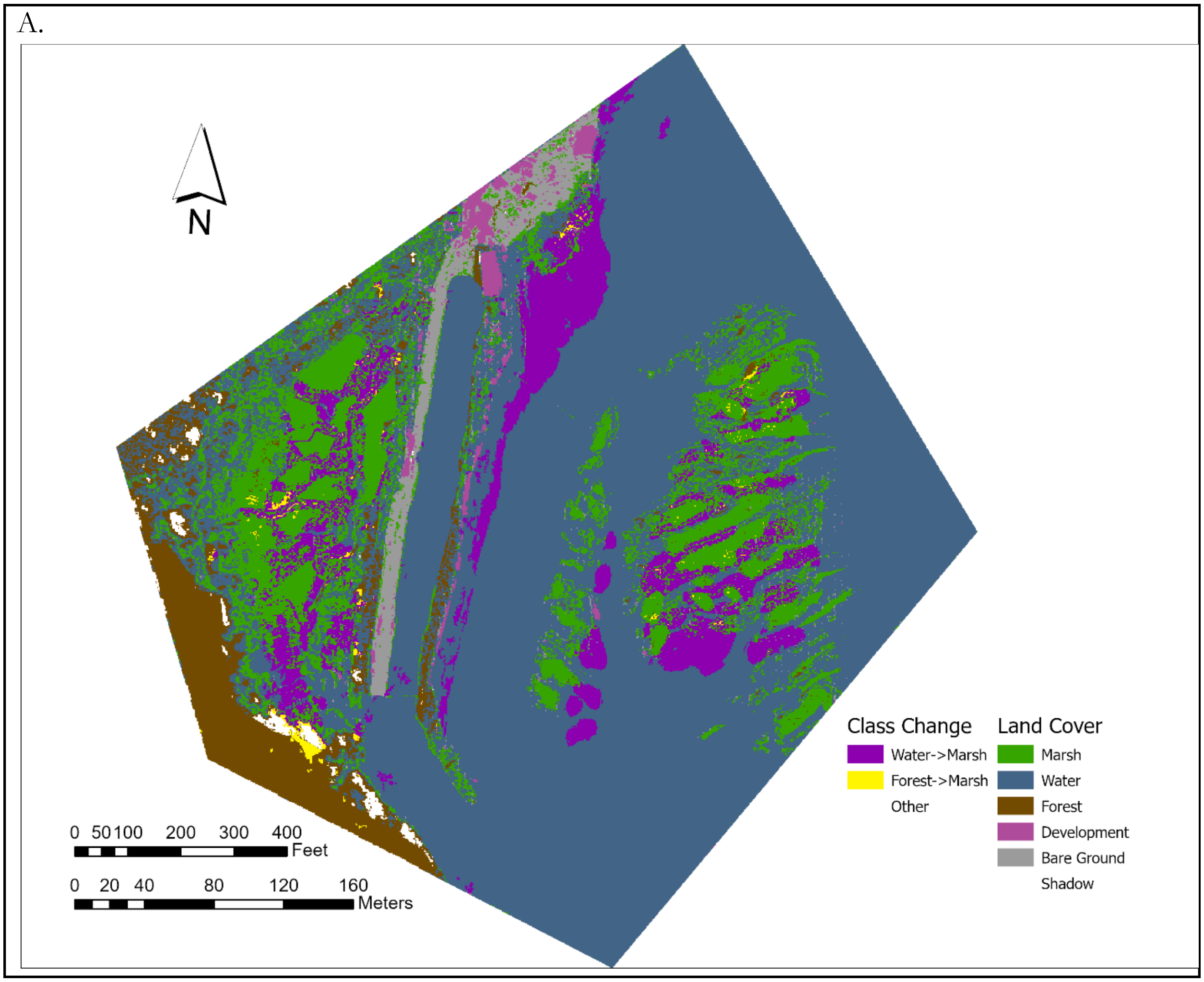
A.

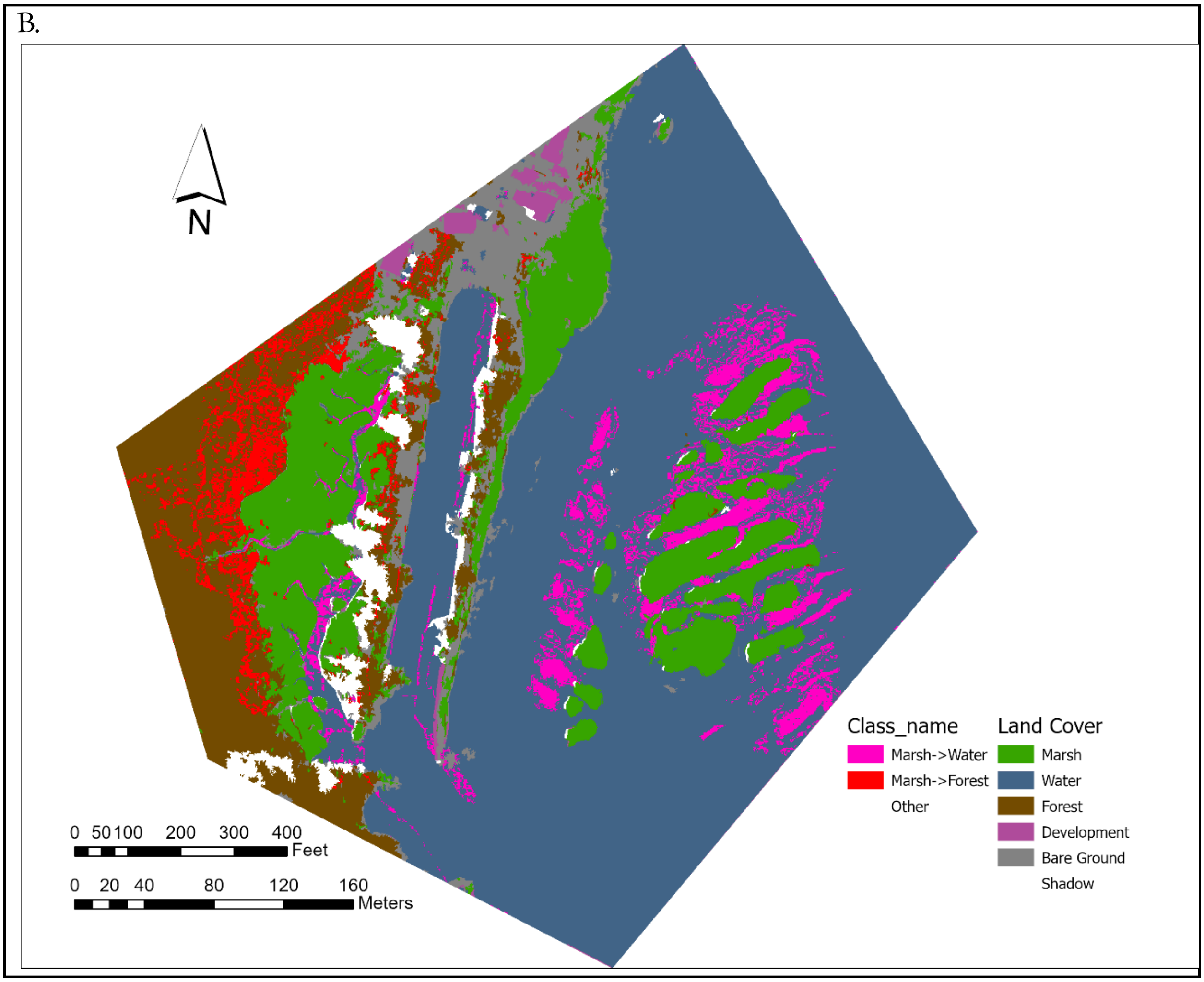

N
0 50 100 200 300 400
Feet
0 20 40 80 120 160
Meters
Class Change
Water->Marsh
Forest->Marsh
Other
Land Cover
Marsh
Water
Forest
Development
Bare Ground
Shadow

B.



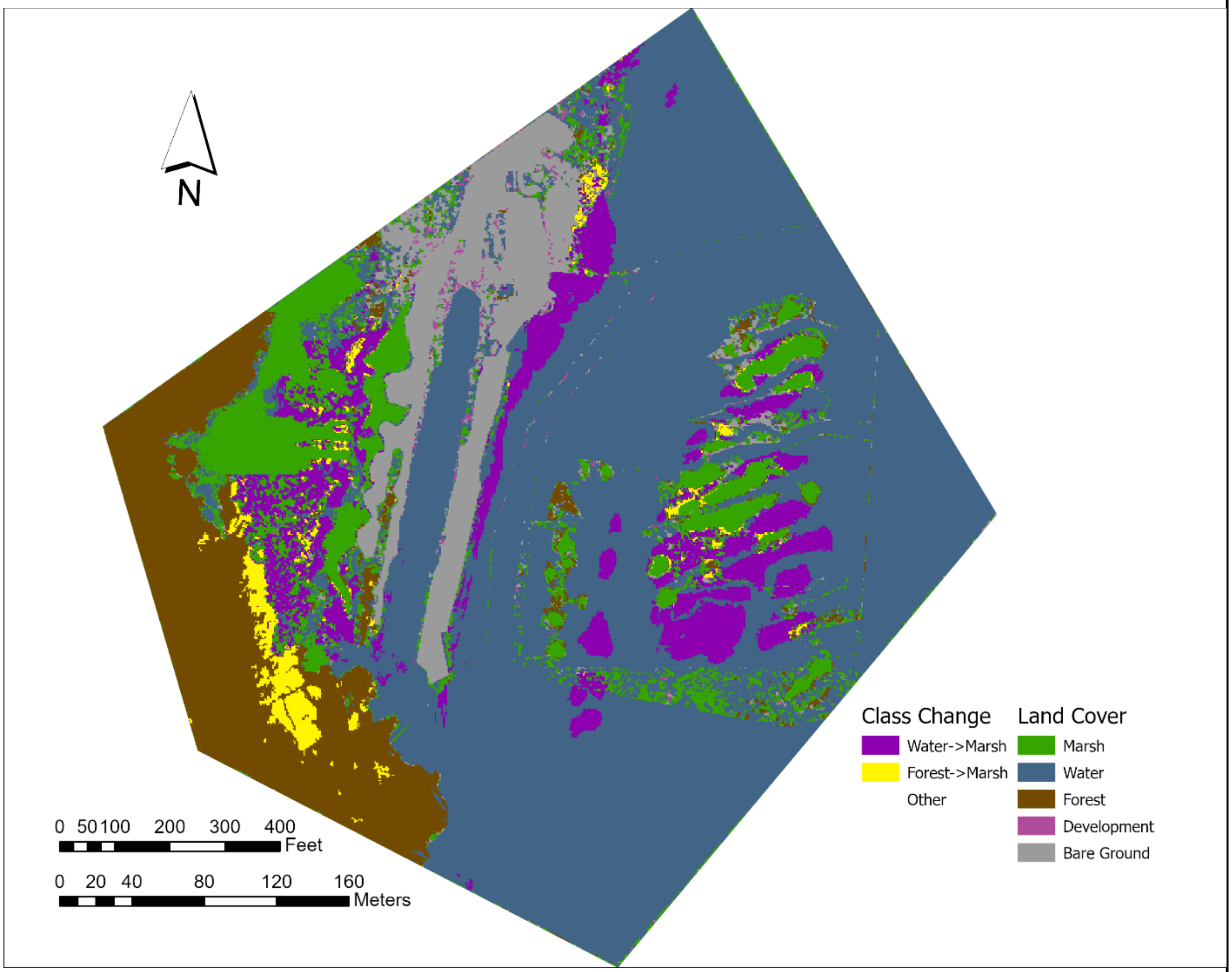
Appendix Figure 6. Map layouts of Metcalf Marsh and Islands near Charleston, OR. A.) Classified land cover raster of Metcalf Marsh and Islands from the 1978 image with land cover class change layer (Purple and yellow) of forest and water classes that changed to marsh between 1978 and 2018. B.) Classified land cover raster of Metcalf Marsh and Islands from 2018 imagery with land cover class change layer (Pink and Red) of marsh class that changed to forest or water land cover classes between 1978 and 2018.

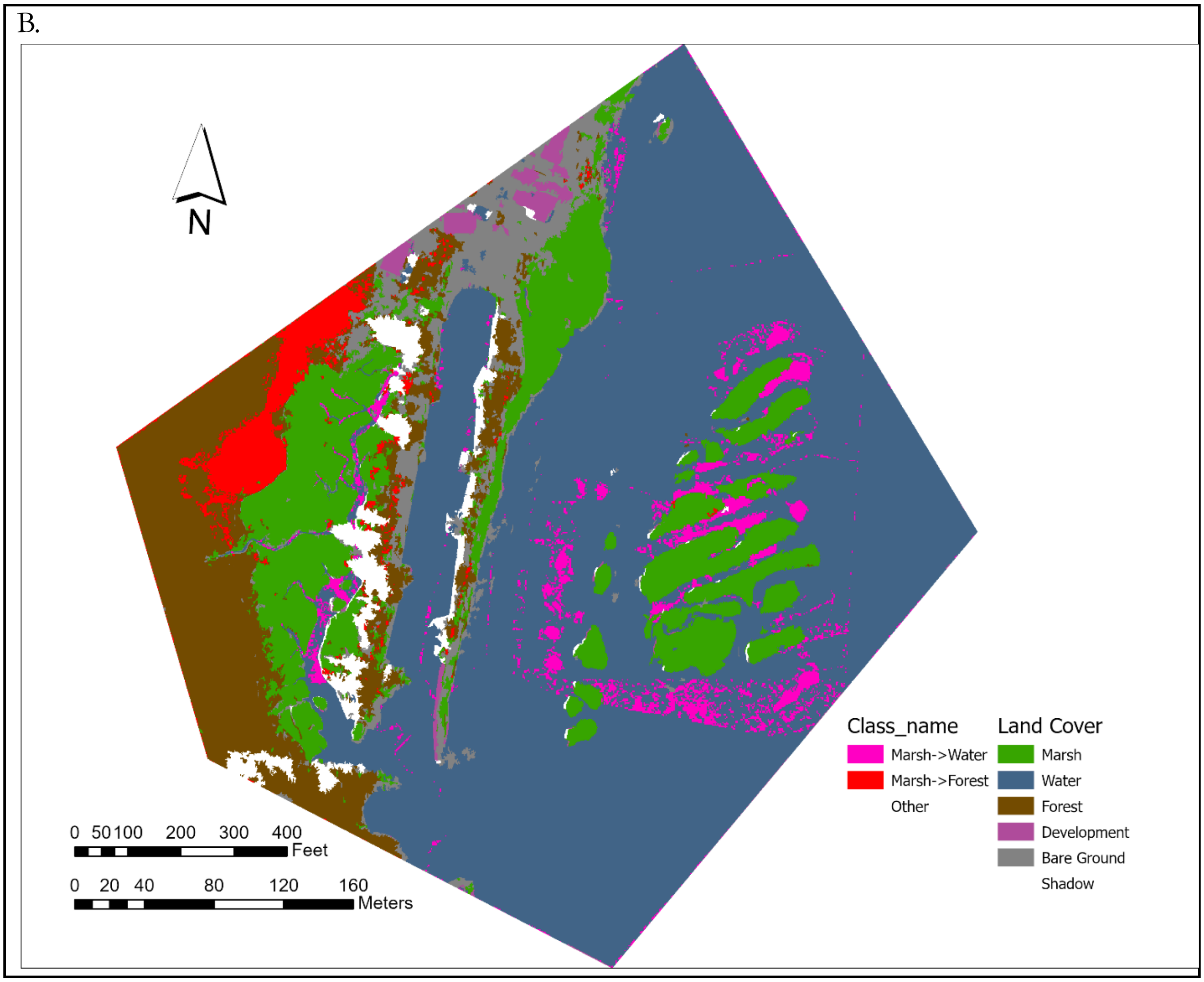

A.
N
Class Change
Water->Marsh
Forest->Marsh
Other
Land Cover
Marsh
Water
Forest
Development
Bare Ground
Shadow
0 50 100 200 300 400
Feet
0 20 40 80 120 160
Meters



Appendix Figure 7. Map layouts of Metcalf Marsh and Islands near Charleston, OR. A.) Classified land cover raster of Metcalf Marsh and Islands from the 1964 image with land cover class change layer (Purple and yellow) of forest and water classes that changed to marsh between 1964 and 2018. B.) Classified land cover raster of Metcalf Marsh and Islands from 2018 imagery with land cover class change layer (Pink and Red) of marsh class that changed to forest or water land cover classes between 1964 and 2018.

A.


N
Class Change
Water->Marsh
Forest->Marsh
Other
Land Cover
Marsh
Water
Forest
Development
Bare Ground
0 50 100 200 300 400
Feet
0 20 40 80 120 160
Meters



Appendix Figure 8. Map layouts of Metcalf Marsh and Islands near Charleston, OR. A.) Classified land cover raster of Metcalf Marsh and Islands from the 1959 image with land cover class change layer (Purple and yellow) of forest and water classes that changed to marsh between 1959 and 2018. B.) Classified land cover raster of Metcalf Marsh and Islands from 2018 imagery with land cover class change layer (Pink and Red) of marsh class that changed to forest or water land cover classes between 1959 and 2018.

"From" Year	Type	Area (Sq. Feet)	Area of Change (Hectares)	Area of Change(Arces)
2005	Water to Marsh	46471	0.431729718	1.066827365
	Forest to Marsh	24491	0.227528836	0.562235996
	Forest from Marsh	25401	0.235983012	0.583126722
	Water from Marsh	100592	0.934530261	2.309274564
1989	Water to Marsh	67970.9291	0.631470595	1.560397821
	Forest to Marsh	14275.05569	0.132619607	0.327710186
	Forest from Marsh	13907.5407	0.129205281	0.319273203
	Water from Marsh	74199.34093	0.689334435	1.703382482
1978	Water to Marsh	109834.1606	1.020392743	2.521445376
	Forest to Marsh	8280.820059	0.076931336	0.190101471
	Forest from Marsh	25192.64411	0.234047323	0.578343529
	Water from Marsh	58830.90072	0.546556953	1.350571642
1964	Water to Marsh	103013.7136	0.957028717	2.364869457
	Forest to Marsh	6489.604916	0.060290403	0.148980829
	Forest from Marsh	51216.84492	0.47582006	1.175776972
	Water from Marsh	89964.12023	0.835794027	2.065292016
1959	Water to Marsh	134772.3374	1.252075987	3.093947139
	Forest to Marsh	27547.99071	0.255929209	0.632414846
	Forest from Marsh	44691.59008	0.415198459	1.025977734
	Water from Marsh	56485.20413	0.524764719	1.296721858
1939	Water to Marsh	103013.7136	0.957028717	2.364869457
	Forest to Marsh	6489.604916	0.060290403	0.148980829
	Forest from Marsh	60063.90336	0.558011923	1.378877488
	Water from Marsh	169617.861	1.575801495	3.89389029

Appendix Figure 9. Chart containing area values produced by all change detection analyses. Area is shown in both acres and hectares for all years