DETECTION AND ANALYSIS OF SHORELINE CHANGES ALONG LOUISIANA BARRIER ISLANDS: GRAND ISLE AND ISLE WEST GRAND TERRE

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ABSTRACT

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Louisiana barrier islands defend inland communities from storms, but they experience the highest rates of erosion in North America. Grand Isle and Isle West Grand Terre are barrier islands that have been subjected to stabilization and restoration. High resolution multispectral images and topographic LiDAR of Grand Isle and Isle West Grand Terre were gathered between 1998 and 2017. The images were processed to identify vegetation, bare earth, and water land classes using supervised classification techniques. Changes in land cover class were identified and quantified using post-classification image comparison tools. Digital elevation models were created from LiDAR point clouds and exported for shoreline extraction. Transects placed perpendicular to shorelines at 10 meter intervals measured shoreline position change.

The study area experienced a 16.67% decline in vegetated land cover, a 47.57% gain in bare earth land cover, and a 0.39% gain in water class area between 1998 and 2017. The shoreline of Grand Isle experienced a landward movement of about 2.1 mm/yr and Isle West Grand Terre also saw landward shoreline movement at a rate of about 20.2 mm/yr. These rates are evidence of land area decline. This study identifies locations prone to change in Grand Isle and West Grand Terre. The results reveal changes that occur on Louisiana barrier islands with heavy human activity. Observations can be compared to long term or small-scale land cover change studies on the same coast.

KEY WORDS: Barrier islands, Remote sensing, Louisiana, LiDAR, Geographic Information Systems

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CHAPTER I

Introduction

Background

The Louisiana coast has historically hosted a large port and unique culture, but it is also known for its vulnerability to natural disasters. Serious disaster risks became a reality as the coastal population grew and human activity increased. The threat of social and economic loss caught the attention of government and educational institutions in the 1930s and stimulated investigations into the processes that shaped the valuable delta and coastline. Decades of intense studies (Penland, 1988, 1990; Britsch et al., 1993; Barras et al., 2003; Kulp et al., 2005) resulted in a complex compilation of Louisiana's historical coastline, the changes experienced since 1930, and predictions for the future of coastal communities. These studies also aimed to identify areas most susceptible to disaster, record the effects of the processes on those locations, and design plans to protect the fragile environments. Continuous monitoring of coastal morphology changes and the drivers is required as humans reside and depend on this transitional margin.

During oceanic regression, a prograding river deposits sediments nearshore to be redistributed by wave action and form coastal features (Kulp et al., 2005). The meandering river eventually abandons the delta, leaving alluvium to be worked by a combination of forces. The establishment and abandonment of river channels are vital to the development of an environment like the Gulf Coast of Louisiana. Penland's three stage model describes the evolution of transgressive depositional systems like the Holocene age delta complex of the Mississippi River (Penland et al., 1988). Erosional headlands and flanking spits are formed from sediment distribution along the shore before waves, tides, storms, and sea transgression separate the headland into barrier islands and eventually erode them to sub-surface shoals (Penland et al., 1988; Kulp et al., 2005). These landforms exist near the currently active Balize corridor. Understanding the drivers of coastal geomorphology is necessary when monitoring shoreline change. Penland's delta transition sequence illustrates barrier island formation and destruction. Lobe switching facilitated the building of Grand Isle and Grand Terre barrier islands in the Barataria Bay. Tides, storms, and human activity keep the two islands separated with Barataria Pass. The same wind, wave, tide, storm, and alternating sea level forces that drive barrier island formation also influence transition from island arc stage to shoal stage (Georgiou et al., 2005).

Grand Isle and Isle Grand Terre (now Isle West Grand Terre) are part of an island arc with a long, documented history of geomorphological change, human activity, and coastal engineering. Evidence of instability was first recorded in 1843 upon the completion of Fort Livingston on the western spit of Grand Terre, which immediately experienced subsidence from overbearing weight (Robinson, 1977). Fitzgerald et al. (1988) report the changes in Barataria Bay since the 1880s. They attribute the formation of Pass Abel and separation of Grand Terre into Isle East Grand Terre and Isle West Grand Terre, appearance of washover patterns, and changes in inlet geometry to the increase in backbarrier tidal volume since the 1880s. This region experiences the same geologic changes as the rest of coastal Louisiana, but at different rates. As of 2005, relative sea level was rising at a rate of 1.03 cm/yr due to subsidence from sediment compaction, clinoform faulting, oil extraction, isostatic rebound, and eustatic sea level rise (Fitzgerald et al., 2004; Georgiou et al., 2005). Microtides at Grand Isle are diurnal with low energy waves generally less than half a meter in height with 5 to 6 second periods transporting sediments alongshore (Fitzgerald et al., 2004).

Besides the relative sea level rise and lack of sediment, another leading driver of coastal change is the frequency of large storms. Tropical cyclones inundate Louisiana's coastal environments during summer months and cold fronts bring rain during the fall. These frequent storms significantly increase wave heights, transport sediments via strong wind, carve inlets through islands, and inundate bay side marshes (Georgiou et al., 2005). Erosive forces threaten the communities that rely on the island arc for residence and resources. The realization that Louisiana was undergoing a significant change, with 775,000 square meters of Barataria wetlands lost to open water in 50 years (Georgiou et al. 2005), prompted concern amongst state and federal government officials after the 1930s.

Louisiana's rich anthropogenic history is focused around the Mississippi River. Settlers built up the land-sea boundary where gulf resources are easily accessed. The susceptibility of these cultural sanctuaries prompted state officials to devise preservation strategies to prevent major loss. Louisiana Department of Wildlife and Fisheries (2005) documented a short compilation of preservation efforts in the Louisiana Comprehensive Wildlife Conservation Strategy. The state began raising awareness amongst coastal communities in the 1930s, and a series of acts were eventually adopted. In 1978, the state chose to participate in the Federal Coastal Zone Management Act, which was followed by the passage of Act 6 in 1989 to create advisory committees, and then composition of the Coastal Wetlands Planning, Protection and Restoration Act of 1990, which consisted of coastal protection and restoration strategies (LDWF, 2005).

The U.S. Army Corps of Engineers website provides a lengthy list of coastal engineering projects for Louisiana. Fact sheets detail the types of hard and soft coastal engineering methods employed, their cost, and the expectations for each project's outcome. Grand Isle has long been a target of restorative processes. The Grand Isle Beach Erosion and Hurricane Protection Plan was enacted in 1976 as part of the Flood Control Act of 1965 (USACE, 2012). Multiple erosion and flood control structures were added to the island and vicinity as part of the legislation. Recent studies continue to monitor changes on these engineered coastlines of Grand Isle and Isle West Grand Terre.

Remote sensing techniques have allowed geologists to detect changes in shoreline position and analyze long-term land change over large regions. USGS conducted multiple long-term change detection analyses over the entire coastal Louisiana region using a combination of historical shoreline maps and Landsat Thematic Mapper data (Barras et al., 2003; Morton et al., 2005; Couvillion et al., 2011). Landsat data TM is limited to a 30-meter resolution and is useful for small scale mapping. Identification of vulnerable areas within a small community requires a detailed shoreline analysis. Historical shoreline maps in Louisiana date back to the 1800s (Morton et al., 2005). Since then, technological advances have led to increases in spatial and radiometric resolutions of satellite data. High resolution IKONOS and QuickBird satellite images can be used to delineate high and low water lines, identify significant structures, and conduct site-specific analyses. LiDAR data with a point spacing of 1-2 meters and a vertical accuracy within centimeters can be used to conduct detailed investigations on coastline topography (Schmid et al., 2011).

Multiple surveys by the National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, U.S. Geological Survey, and National Aeronautics and Space Administration were conducted to collect topographic LiDAR measurements along the northern Gulf of Mexico. Changes along Louisiana's coast have been studied using a combination of historical and remote sensing data (Barras et al., 2003). The availability of multiple historical and current high resolution datasets allows detailed analysis and the production of large scale maps. LiDAR data can be interpolated to create surface models for temporal comparison or flood hazard identification (Poppenga and Worstell, 2015). High resolution images and LiDAR surface models can be integrated for risk assessment and planning. Changes in Louisiana's coastal land type and elevation can be analyzed with accuracy using remote sensing data.

Study Area

Figure 1 shows the study area consisting of two barrier islands, Isle West Grand Terre and Grand Isle, in Barataria Bay of the Mississippi River Delta about 50 miles south of New Orleans, Louisiana. The islands total 10 miles in length and are separated by less than half a mile of water.

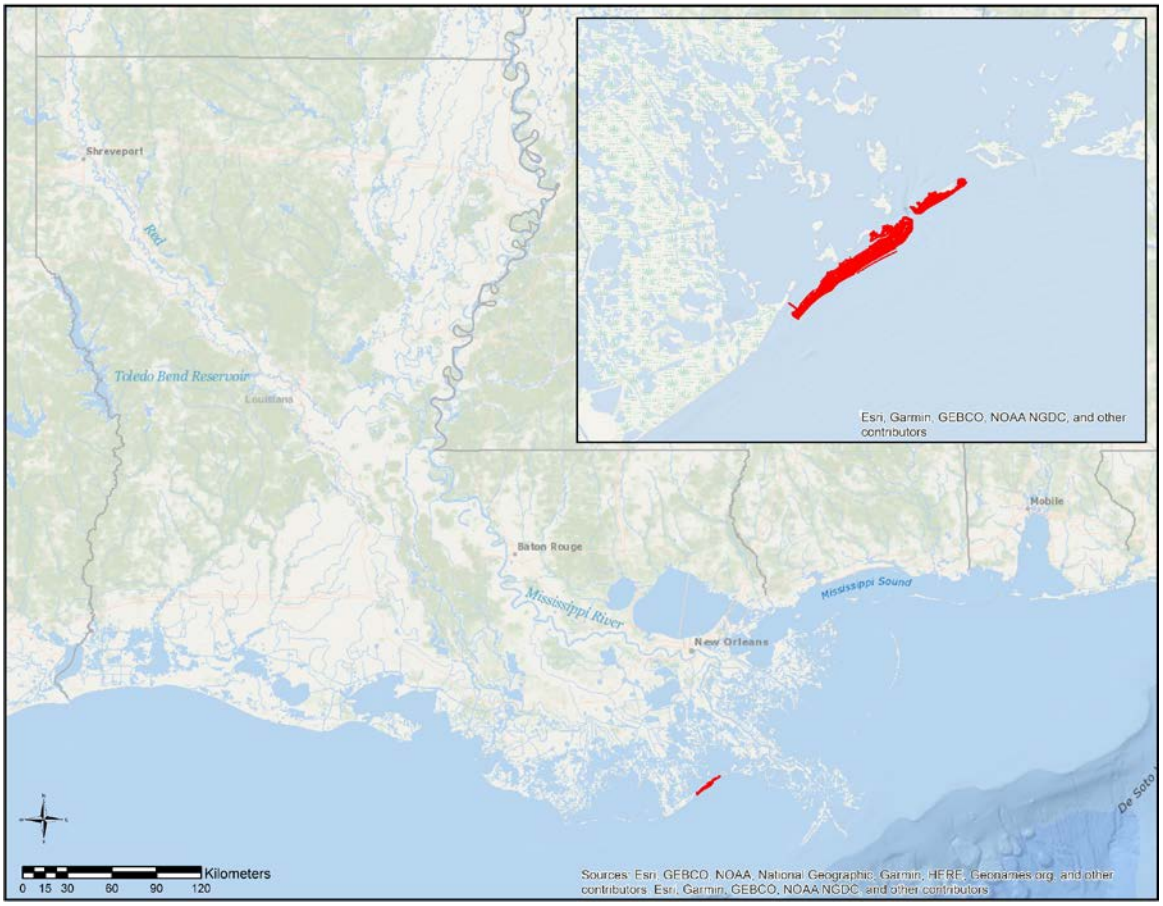


Figure 1. Study Area in Louisiana

This area was included in a long list of remote sensing surveys, including LiDAR and multispectral satellite image data gather. The study area is part of a low-lying barrier island arc with sandy beaches seaward and silty marshes landward (Georgiou et al., 2005). The area is affected by seasonal storms, including tropical cyclones. Table 1 lists the storms that made landfall on or near the study area between 1998 and 2017.

The U.S. Army Corps of Engineers has implemented restoration and preservation efforts including installation of geotextile dunes, rock wall, wave break, and dune fence construction, vegetation nourishment, and sediment sustenance (LCWCRTF,2003, 2006;

USACE, 2012). Regional studies indicate a risk of continued land loss in Barataria Bay, calling for closer investigations of shoreline location and land area.

TABLE 1. **Tropical cyclones of Grand Isle and Isle West Grand Terre**

Year	Name	Landfall Category	Notes
1998	Frances	TS	Grand Isle submerged completely
	Georges	C2	Major Hurricane, indirect hit
2001	Allison	TS	7-11 inches rain
2002	Isidore	TS	Wind > 65 mph on Grand Isle
	Lili	TS	Wind > 90 mph on Grand Isle
2003	Bill	TS	Wind > 60 mph, 3-5 inches rain
2004	Ivan	C3	2.60 ft storm surge, road flooding
	Matthew	TS	5.85 ft storm surge, extensive beach erosion
2005	Cindy	TS	5-7 in rain
	Katrina	C3	12 ft surge, rain > 10in, wind > 87mph, significant damage
	Rita	C3	No damage reported for study area
2008	Gustav	C2	Post-Katrina repairs damaged, dune breached
2010	Bonnie	TD	Followed BP oil spill
2011	Lee	TS	Dune damage
2012	Isaac	C1	Oil washed onto islands, dune damage
2013	Karen	TS	No significant damage reported in study area
2017	Harvey	C2	5-10 inches rain

Note: TD=Tropical Depression, TS=Tropical Storm, C1-3=Hurricane Category

Problem Statement

Louisiana's rapid land change requires regular coastal monitoring. Past studies focused on marsh transition to open water, but rates of erosion in the Louisiana gulf are highest along barrier island shores (Couvillion et al., 2011; Barras et al., 2004; Morton et al., 2005). The most recent change detection study by the USGS revealed long term trends over the entire Louisiana coastline. It was estimated that Louisiana suffered a loss of 1,883 square miles (4,877 sq km) between 1932 and 2010 (Couvillion et al., 2011), and that Barataria Bay lost more than 775 sq km within that period (Georgiou et al., 2005). Sediment compaction, isostatic rebound, and human activity contributed to local subsidence (Salenas et al., 1986; Yuill et al., 2009). Eustatic sea level rise plus regional subsidence has resulted in a local sea level rise of 1.03 cm/yr in Grand Isle (Fitzgerald et al., 2004; Georgiou et al., 2005). Further, hurricanes are an annual threat to the human populations on the island and the bayside marsh environments.

Grand Isle and Isle West Grand Terre are expected to continue experiencing land change per the U.S. Geological Society maps (Couvillion et al., 2011). The USGS projections indicate that frequent surveys are necessary to precisely map the progression of geomorphological transformation in southern Louisiana. Historical studies and comparisons provide predictions for today's coastline. A current analysis using remote sensing techniques is needed to provide a finer resolution perspective on how the individual islands are developing, what drivers are forcing the change, if the restoration and prevention efforts are effective, and what the future may look like for Grand Isle residents.

Justification

The 2010 Census report counts 1,296 residents within the city limits of Grand Isle (US Census Bureau, 2010), but the population spikes to approximately 12,000 during fishing and tourism seasons (USACE, 2008). The eastern spit of the island serves recreational purposes and houses a state park with beach camping and gulf fishing. Isle West Grand Terre has been protecting Louisiana communities since before the Civil War.

Fort Livingston was built in the early 1800s and now faces a different opponent that cannot be overcome. Even though the pre-Civil War fort is no longer of use, the island still protects inland environments from waves, storm surge, rising seas, and uncontained oil spills. Louisiana's economy relies heavily on the health of the coastline. Seafood and tourism are large industries affected by change in necessary resources. Losing the barrier islands would result in economic hardship. Detecting and analyzing changes will help understand the current morphology and changes along the coastline of Louisiana.

Monitoring the changes through remote sensing will enable the creation of visual models to educate the public. Revealing local change trends will enhance preservation and restoration efforts. Poor hazard planning in populated locations can lead to disaster. Ineffective restoration methods require new plans for community preservation. If Louisiana's barrier islands are experiencing a high rate of negative change despite coastal engineering method implementation, there is a need to discuss managed retreat options. A high resolution, multidimensional, short-term change analysis of Louisiana's Isle West Grand Terre and Grand Isle will reveal whether citizens have reason for alarm. Monitoring the effects of coastal engineering methods implemented in the study area will aid in future coastal engineering strategies.

Objectives

The main objective of this study is to quantify land gain and/or loss on Louisiana's Grand Isle and Isle West Grand Terre from 1998 to 2017. Temporal changes will be analyzed from 1998, 2004, 2008, 2012, and 2017. Specific objectives for the study include:

1. Quantify land use and land type changes over the temporal range to determine rates of change.
2. Delineate and compare shoreline location and estimate shoreline change.
3. Identify locations of coastal engineering efforts and effects on changes over time.

Research Questions

The research questions to be addressed in the study are:

1. Have any changes in shoreline position occurred in the study area?
2. If observable changes are recorded, what is the rate of change over the period?
3. Are there any land cover or land use changes, and what is the rate?
4. Does the data reflect any effects from coastal engineering efforts?

CHAPTER II

Literature Review

Coastal environments are popular study locations for historical, present, and future change. The Louisiana coastline has drawn attention since the 1930s, and scientists are still studying the processes that shape the unique landscape. Investigations by Penland (1990), Kulp (2005), Couvililon and Beck (2013), and local Louisiana agencies reveal the change observed on the coastal margin, predict the future geomorphology, and discuss the drivers of change. The United States Army Corps of Engineers, Louisiana Department of Natural Resources, Louisiana Coastal Wetlands Conservation and Restoration Task Force, Theis (1969), and Combe (1987) provide detailed lists of stabilization, preservation, and restoration projects conducted on Grand Isle and Isle West Grand Terre. Remote sensing technologies are often employed to record data on coastal areas with limited or difficult access. Purkis (2009), Renslow (2012), Brock and Poppenga (2015) examine the applicability of remote sensing analysis in coastal environments. Specific processing methods for remote sensing data are detailed by Petzold (1999), Wijekoon, Hadley, and Schmid (2011) while Barras (2004), Jensen (2005), and Couvillion (2011) discuss different types of multispectral data and their applicability in coastal studies. This review covers history of the Louisiana coastline, human activity near the study area, and the application of remote sensing surveys on these types of environments.

Louisiana's Coastline

A list of fluvial and oceanic mechanisms constructed Louisiana's coastal geomorphology. The Mississippi River is responsible for delivering the materials that compose the marshes, cheniers, beaches, and barrier islands that separate and protect Louisiana's populations from the Gulf of Mexico. The meandering river switched between delta lobes throughout the Holocene Epoch, abandoning channels after depositing alluvium on the wide, shallow continental shelf (Kulp et al., 2005). The abandonment of the channel results in a lack of sediment input and the initiation of barrier island development. These accumulations of uncompacted alluvium are shaped by the waves, tides, and seasonal storms that interact with the island sediments. Sea level gauges on Grand Isle measured a rise in relative sea between 1932 and 2006 (Couvillion and Beck, 2013). Sea level rise in this type of low lying environment prompts change in the geomorphology. A study of sea level rise in the Gulf of Mexico discovered Louisiana's barrier islands undergo the highest rates of beach erosion in North America (Penland and Ramsey, 1990). These rates are attributed to a list of factors, including the long term use of the wetland environment for human activity, regional subsidence, clinoform faulting, flood control structure development, hurricane impacts, and global sea level change (Morang, Rosati, and King, 2013). The predominant response of government agencies to sea level rise and land loss is design and creation of structures that, ideally, will stabilize and preserve the existing landforms.

Coastal Engineering History

Manipulation of Louisiana's coastline began with the creation of navigational channels and eventually began to include preservation and restoration efforts. Grand Isle and Isle West Grand Terre in Jefferson Parish, Louisiana quickly became an area of interest. In 1951, 14 timber breakwaters were constructed to stabilize the highway on the Gulf beach side of Grand Isle near the western end of the island and near the beach center

(LDNR, 2007). The groins installed in this project were positioned perpendicular to the shoreline, and more than 1,600,000 cubic yards of sediment were used to fill in the spaces between each set of structures (LDNR, 2007).

Construction on the island continued in 1954 with the creation of a jetty east of Grand Isle to protect Barataria Pass (Theis, 1969; Combe, 1987; LDNR, 2007). Hurricane Carla of 1961 removed 350,000 cubic yards of sediment from the 1954 sediment disposal site (LDNR, 2007). The jetty east of Grand Isle, in Barataria Pass, underwent construction in 1964 and 1965 to extend it 1,400 ft and repair damage caused by Hurricane Betsy, and an emergency rubble mound was built just south of the jetty by the U.S. Coast Guard in 1967 (Theis, 1969; LDNR, 2007). The 1951 groins were noticeably damaged by 1969, and they were blamed for downdrift beach erosion (Theis, 1969; HNTB, 1993; LDNR, 2007). A new 2,600 foot jetty was constructed west of Grand Isle, in Caminada Pass, in 1971 with sand fill deposited on the northeast side in 1972 (HNTB, 1993). A dune crest at 11.5 feet NGVD29 and berm were constructed along the length of Grand Isle on the Gulf beach side of the island in 1984 using 2.8 million cubic yards of sediment, but 480,000 cubic yards were removed by 4 hurricanes in 1985 (LDNR, 2007). In 1987, the jetties on either side of Grand Isle were extended 200 feet and 500 feet respectively by the U.S. Army Corps of Engineers (LDNR, 2007). A significant 1989 project, which became known as the Town Rock Project and The Mayor’s Rock Project, installed a 700-foot long seawall along the dune centerline, connecting the land-side edge of two 300-foot T-shaped groins, as well as four 6-8-foot MSL tall, 700-foot long breakwaters between the groins, with 70-foot gaps, built 350 feet offshore (LDNR, 2007). Hurricane Andrew breached Isle West Grand Terre in 1992, leading the USACE to deposit dredged material over a 130-acre area in 1996 (LCWCRTF, 2006). At the same time, 23 offshore breakwaters were constructed on the ocean side of Grand Isle (Figure 2), east of the Town Rock Project (LDNR, 2007).

Figure 2. Grand Isle shoreline and breakwaters.

By 1998, the center breakwaters that were constructed 350 feet off of the 1989 shore were landlocked, and the beach had developed two bars due to offshore dredging (LDNR, 2007). The Louisiana Department of Transportation added 13 breakwaters in 1999, east of the USACE breakwaters of 1994 and 1995, and a maintenance event was performed on Isle West Grand Terre to install a 5-foot rock dike on the bay side of the previous 1996 deposition site (LCWCRTF, 2006). The 185-acre space was filled with over 600,000 cubic yards of dredged sediment to create a land area with 3.3 feet elevation. The two Isle West Grand Terre disposal sites were vegetated by a 2001 project that also removed 20 goats and 70 cows from the island (CPRA, 2016). A series of tropical storms caused damage to historical Fort Livingston on Isle West Grand Terre in 2002, and the Louisiana Department of Natural Resources commissioned the construction of a rock breakwater (Figure 3) along the Barataria Pass side of the Gulf-facing shore (Green, 2006).

Figure 3. Fort Livingston and breakwater on Isle West Grand Terre.

Hurricane Katrina caused a national disaster in August of 2005. Grand Isle and Isle West Grand Terre were in the storm path and suffered heavy damage from 114 mph winds and high storm surge (LDNR, 2007). The damaged area was nourished by

850,000 cubic yards of sediment on Grand Isle, just east of the Town Rock Project, and a clay-cored, geotextile dune (Figure 4) was covered by 2 feet of sediment (LDNR, 2007).

Figure 4. Grand Isle artificial dune.

The dune was uncovered in 2008 by Hurricane Gustav and required reconstruction (USACE, 2012). In 2010, a major oil spill washed up on the coast of Louisiana, mixing with sediment on the beaches of Grand Isle, Isle West Grand Terre, and other locations. Oil remains on Isle West Grand Terre, especially in the sediments trapped under Fort Livingston. Twenty-four new 300-foot long breakwater structures were constructed by Jefferson Parish on the bay-side of western Grand Isle in 2012 (CPRA, 2015). Future projects are planned for Isle West Grand Terre, including nourishment on the western backbarrier and beach face near Barataria Pass (CWPPRA, 2017).

Remote Sensing of Coastal Environments

Coastal surveys are often time consuming, can be interrupted by severe weather, and locations are often hard to reach. The development of remote sensing technologies has provided access to data that was previously unavailable or difficult to gather. Two useful types of remote sensing data applied to geological surveys are multispectral images acquired as either satellite or aerial photographs, and Light Detection and Ranging (LiDAR) elevation measurements. LiDAR is a relatively new type of remote sensing used to survey sea and land elevations, human activity, vegetation canopy heights, and geologic events. One of the most useful applications of LiDAR is in coastal studies (Renslow, 2012). Coastal topography was historically mapped using nautical charts before being replaced by ground surveys and multispectral image analysis, and recently has shifted to aerial LiDAR surveys (Brock and Purkis, 2009). Point clouds with at least 1-meter spacing produce surface models that reflect beach and dune morphological features, and surfaces from multiple years can be compared to quantify changes in sediment volume (Liu, Sherman, and Gu, 2007; Brock and Purkis, 2009).

Extensive airborne LiDAR topographic profiles have been collected along the United States coastline (Brock et al., 2002). Sesli and Caniberk (2015) used LiDAR to analyze long-term, short-term, and sudden changes on a small part of the California coast. Poppenga and Worstell (2015) use airborne LiDAR to detect low elevation locations, connect hydrologic features, and predict flooding on part of Staten Island, New York. Applications of topographic LiDAR to marsh environments encountered errors in vertical accuracy due to canopy density (Schmid et al., 2011). Schmid, Hadley, and Wijekoon (2011) suggested increasing Digital Elevation Model accuracy by designating control elevations through ground truthing, classifying return points, and filtering data. Filtering points to generate a Digital Elevation Models (DEM) produces a rough model using the lowest points and filters out points that exceed a named limit. Repeating the process a named number of iterations to smooth the DEM removes roads and buildings (Petzold et al., 1999). Another useful method reviewed was a change detection algorithm by Murakami et al. (1999), which produced Digital Surface Models (DSM) for each survey year, then the subtracted differences reflected in an image. The same concept is applicable to Digital Elevation Models (DEM) produced by aerial topographic surveys along the coast. Airborne LiDAR data from multiple years can be compared to calculate rates of shoreline change and attempt to predict future change (Kim et al., 2017). Cross sections of vertical data can easily be controlled using ground survey transects.

Satellite-mounted sensors like Landsat Multispectral Scanner (MSS) and Landsat Thematic Mapper (TM) are useful when conducting land use and land cover surveys due to their spectral resolutions, but they are spatially limited (Jensen, 2005). Other satellite-mounted sensors, like IKONOS, WorldView, and QuickBird, produce images with spatial resolutions near 1 meter, but have limited spectral resolutions. Large scale satellite data is expensive, and aerial images provide similar spectral and spatial resolutions without the cost. Digital Orthophoto Quarter Quadrangle (DOQQ) images are projected, 3.75 minute by 3.75-minute, aerial photographs with 1-meter ground resolution, preprocessed to remove distortion. Small-scale investigations of long term change on Louisiana’s coastline reveal a change in shoreline location and land class.

Britch and Dunbar (1993) compared aerial photographs with topographic maps between 1932 and 1990 to find a loss rate of 25 square miles per year from Johnson Bayou, east, to Cat Island, and from Covington, south, to South West Pass on the Mississippi River Delta. The study area was re-evaluated by Barras (2003) by comparing aerial photographs from 1978 to Landsat images from 1990, 1999, and 2002. The net loss reported from 1978 to 2000 was 658 square miles, or 29.9 square miles per year, and the projected future loss rates for 2000 to 2050 are 10.26 square miles per year. (Barras et al., 2003). A later study by the United States Geological Survey (Couvillion et al., 2011) measured land loss by comparing historical surveys from 1932, aerial photography from 1956, and Landsat images from 1973-2010. The net loss from 1932 to 2010 was 1,883 square miles, and the rate of loss from 1985 to 2010 increased to 16.57 square miles per year (Couvillion et al., 2011). These studies all compared land and water change using historical data and small-scale images, but the results are generalized over a region. Even with the limited spectral resolution, similar classification methods can be applied to the high resolution aerial images. Post-supervised classification comparison can be applied to images with 2 or more classes. Reducing the classes to land and water prevents error caused by misclassification of bare earth and built-up areas.

CHAPTER III

Data and Methodology

Data Description

Passive and active data collected between 1998 and 2017 were employed during this study. The two types of remotely sensed data used are LiDAR point clouds (Table 2) and Multispectral Orthorectified images (Table 3). Multiple data collections were downloaded for each type, and subsets were created from the collections. Only secondary data was used, and the primary purpose of each dataset varies. All data was downloaded free of charge from the USGS EarthExplorer, Louisiana ATLAS GIS portal, and NOAA DataViewer. Projection and coordinate information was applied before datasets were made available. All datasets were downloaded prior to May 20, 2017 due to removal of select collections.

TABLE 2. **LiDAR data description**

Acquisition Date	Title	Spatial Resolution	Accuracy
October 29-November 9, 1998	1998 Fall Gulf Coast Airborne LiDAR Assessment of Coastal Erosion	1 meter	H: 80 cm V: 15 cm
September 9-10, 2001	2001 USGS/NASA Airborne Topographic Mapper Lidar: Coastal Alabama, Florida, Louisiana, Mississippi, Texas	1 meter	H: 1m V: 15 cm
October 12-December 11, 2005	USACE NCMP Topobathy LiDAR Post Hurricane Katrina	1 meter	H: 0.75m V: 20 cm
April 9-26, 2010	USACE NMCP Topobathy LiDAR: Louisiana Coast, Lake Pontchartrain, and Mississippi Barrier Islands	1 meter	H: 1m V: 15cm
March 6-8, 2013	LA_Barataria LiDAR 2013	1 meter	H: 1m V: 15cm

TABLE 3. **Orthoimage data description**

Acquisition Date	Title	Spectral Resolution	Spatial Resolution	Accuracy
January 24, 1998	SE quadrant of Barataria Pass Quadrangle, LA	Red, Green, NIR	1 meter	RMSE: 7m
February 24, 1998	SW quadrant of Barataria Pass Quadrangle, LA NW quadrant of Grand Isle Quadrangle, LA NE quadrant of Caminada Pass Quadrangle, LA		1 meter	RMSE: 7m
January 21-22, 2004	Barataria Pass, SE, LA Barataria Pass, SW, LA Grand Isle, NW, LA Caminada Pass, NE, LA	Red, Green, Blue	1 meter	RMSE: 7m
October 19, 2005	Barataria Pass, SE, LA Barataria Pass, SW, LA Grand Isle, NW, LA Caminada Pass, NE, LA	Red, Green, Blue	1 meter	RMSE: 7m
October 1, 2008	HRO: SES HRO: NES HRO: NWS HRO: SWS	Red, Green, Blue, NIR	1 meter	RMSE: 7m
October 20, 2012	HRO: SW HRO: NW HRO: NE HRO: SE	Red, Green, Blue, NIR	1 meter	RMSE: 7m
April 1-19, 2017	2017 NOAA NGS Ortho-rectified Oblique Imagery of the Gulf Coast	Red, Green, Blue, NIR	0.30 meter	RMSE: 5-10m

Multispectral image data.

The images used in this study were commissioned by the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA). Orthophotos are aerial images with a datum and coordinate system assigned. The Geodetic Reference System of 1980 and North American Datum of 1983 were applied to all images during preprocessing. Data captured between 1998 and 2012 were projected using the Universal Transverse Mercator zone 15N or 16N with meters as units. Images from 2017 used the Louisiana State Plane Coordinate System zone 1702 in feet. All datasets included 8-bit images with pixels arranged in columns and rows. Brightness values range from 0 to 255. The tiles captured between 1998 and 2012 were 3.75 x 3.75 minutes, or one quarter quadrangle, with a 50-300 meter overlap for mosaic. Images from the same time frame have a 1-meter spatial resolution, are scaled at 1:12,000, and have a RMSE of 7 meters.

The 1998 survey was created by the National Aerial Photography Program (NAPP) for multiple purposes, like map creation and geographic analysis, and includes four images that cover the study area. The Carl Zeiss Phodis sensor used was calibrated for 3 bands within the visible and infrared wavelengths. The four datasets downloaded from the 2004 survey were collected by NAPP on January 21-22, 2004. The spatial resolution of these tiles is also within the visible and infrared wavelengths. The four study area images from the October 1, 2008 NAPP survey include wavelengths in the Red, Green, Blue, and Near-Infrared wavelengths. The 2012 survey also includes four quarter quadrangle images captured by the USGS for Digital Orthophotoquadrant (DOQ) creation, and has 4 bands with spectral resolutions within the red, green, blue, and near-infrared wavelengths. The 2017 NOAA NGS Ortho-rectified Oblique Imagery of the Gulf Coast was collected April 1-19, 2017 by NOAA's Coastal Mapping Program (CMP) for multiple uses. Each image tile has a geographic extent of 2.5 km x 2.5 km. The Applanix Digital Sensor System was used to collect 3 band images with wavelengths in the red, green, and blue wavelengths. No infrared bands were collected during this survey.

LiDAR Point Clouds. Elevation data was collected over the study area using Laser Ranging and Detection methods during the years 1998, 2001, 2005, 2010, and 2013. All datasets were downloaded in .LAZ format and decompressed using a free LAStools program called laszip. The compressed files included metadata and LAS format point clouds. Location data was assigned prior to download. The Geodetic Reference System of 1980, North American Datum of 1983, and North American Vertical Datum of 1988 in meters were assigned to all point clouds. Data collected prior to 2010 was projected using the Louisiana State Plane Coordinate System of 1983 zone 1702 in meters, and tiles collected after 2010 were assigned the Universal Transverse Mercator zones 15N and 16N in meters.

The 1998 dataset was selected from a larger collection that covers the Gulf Coast margin of Louisiana, Mississippi, Alabama, and Florida. The files were saved prior to April 15, 2017 removal. The 1998 Gulf Coast NOAA/USGS/NASA Airborne LiDAR Assessment of Coastal Erosion (ALACE) Project for the US Coastline is elevation data acquired October 29, 1998 through November 09, 1998 by NASA's Airborne Topographic Mapper (ATM). A laser-reflecting, scanning mirror with a 20 hertz rotation and 15 degree off-nadir angle was used to create 350-meter swath width. The study area is included in a point cloud dataset with approximately 4,152,334 total unclassified first returns. Water and vegetation returns were not removed during preprocessing because the ALACE project was conducted for research purposes. Data accuracy was found to be within 15 cm vertically and 80cm horizontally with the 700-meter airplane altitude.

Elevation data collected between September 9, 2001 and October 13, 2001 covers the Gulf Coast of Texas, Louisiana, Mississippi, Alabama, and Florida. The study area subset was collected between September 9, 2001 and September 10, 2001 and consists of 1,425,429 unclassified first returns. The NASA Airborne Topographic Mapper (ATM) used a green-wavelength laser set to pulse at 2 to 10 kilohertz to collect elevation data points spaced 2 meters apart with a 15-centimeter vertical accuracy and one-meter horizontal accuracy.

The 2005 dataset titled 2005 US Army Corps of Engineers (USACE) Post-Katrina Topo/Bathy Project for the Alabama, Florida, Louisiana, and Mississippi Coasts was collected between October 12, 2005 and December 11, 2005 by the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX). The data was collected using the CHARTS system to collect topographic data after Hurricane Katrina to visualize coastal elevations. This file set contains only point cloud data for Grand Isle and does not include information on Isle West Grand Terre. The five tiles used to visualize the study area consist of 30,396,698 unclassified first returns with a 1.3 meter spacing, 0.75 meter horizontal accuracy, and a 0.20 meter vertical accuracy.

The 2010 dataset, titled 2010 US Army Corps of Engineers (USACE) Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) Topographic LiDAR: Louisiana Coast, Lake Pontchartrain and Mississippi Barrier Islands, consists of

14,038,030 elevation points of 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} returns classified as ground points. The survey was conducted April 9-26, 2010 by multiple government and private agencies for The Task Order 007 Aerial Survey 2010 to observe the effects of hurricanes on coastal environments. Points with 1 meter spacing were found to have a horizontal accuracy of 0.5 meters and vertical accuracy of 0.15 meters.

The Topographic LiDAR Survey of the Alabama, Mississippi, and Southeast Louisiana Barrier Islands, from September 5 to October 11, 2012 is a point cloud dataset with 48,381,187 classified returns. The survey was conducted by the U.S. Geological Survey to document changes on barrier islands following hurricanes. The points spaced at 1 meter had a 0.218 meter horizontal accuracy and a 0.072 meter vertical accuracy. The dataset was sectioned into two tiles, one for each island, due to file size and memory shortage. The LA_Barataria_2013 LiDAR dataset included limited metadata. Topographic elevations were acquired over the Louisiana coastline between March 6 and March 8, 2013. The study area consists of 25,365,205 classified 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} returns. Points with a 1.34 meter spacing have a 1 meter horizontal accuracy and a 15 centimeter vertical accuracy.

Approach

A geographic information system approach was used to process and analyze data for this study. All remote sensing data was preprocessed, assigned a coordinate system, and checked for location accuracy prior to download. Ancillary data was provided with each dataset and used for post-processing. Figures 5 and 6 provide visualization of the main steps taken during processing and analysis.

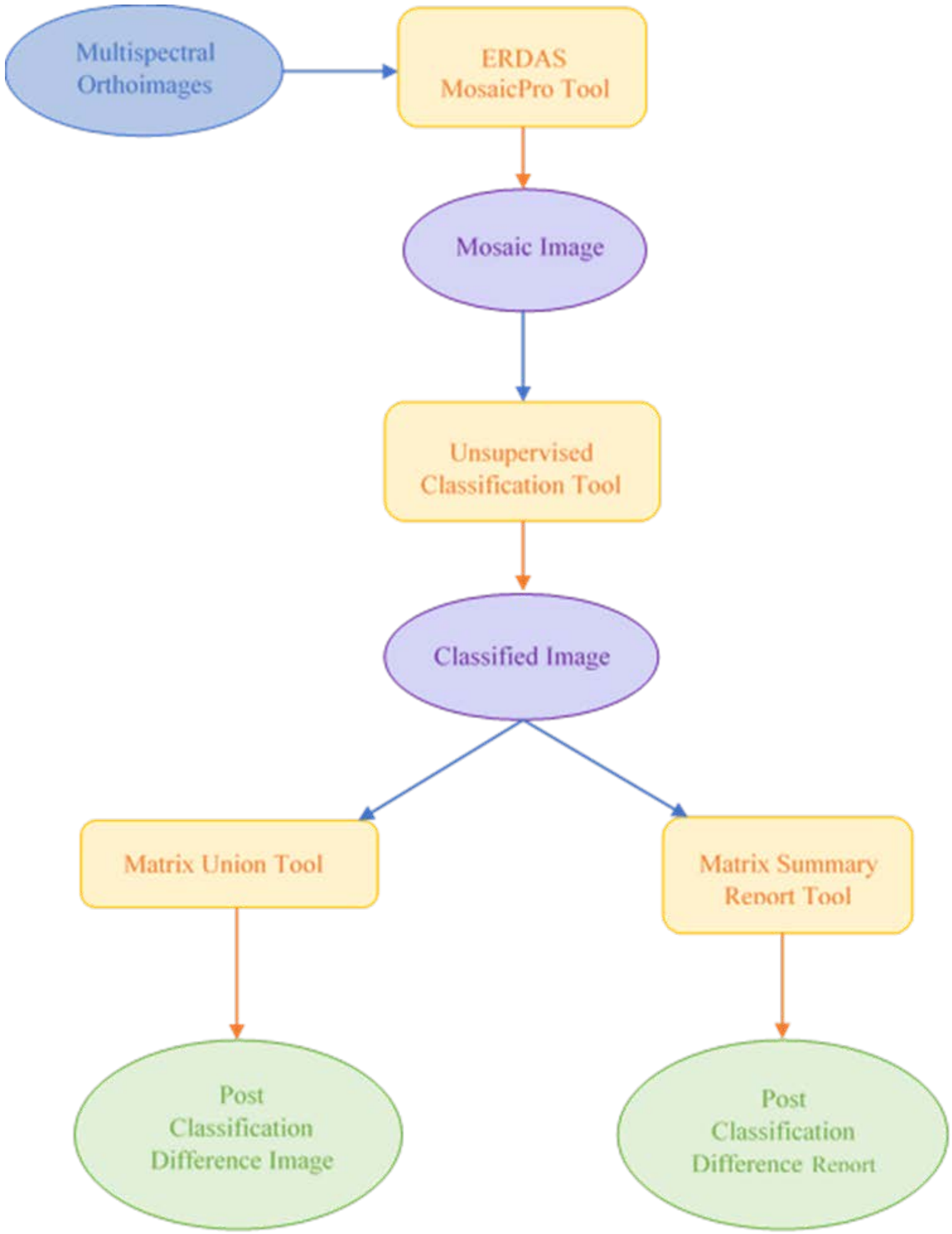


Figure 5. Orthoimage processing steps.

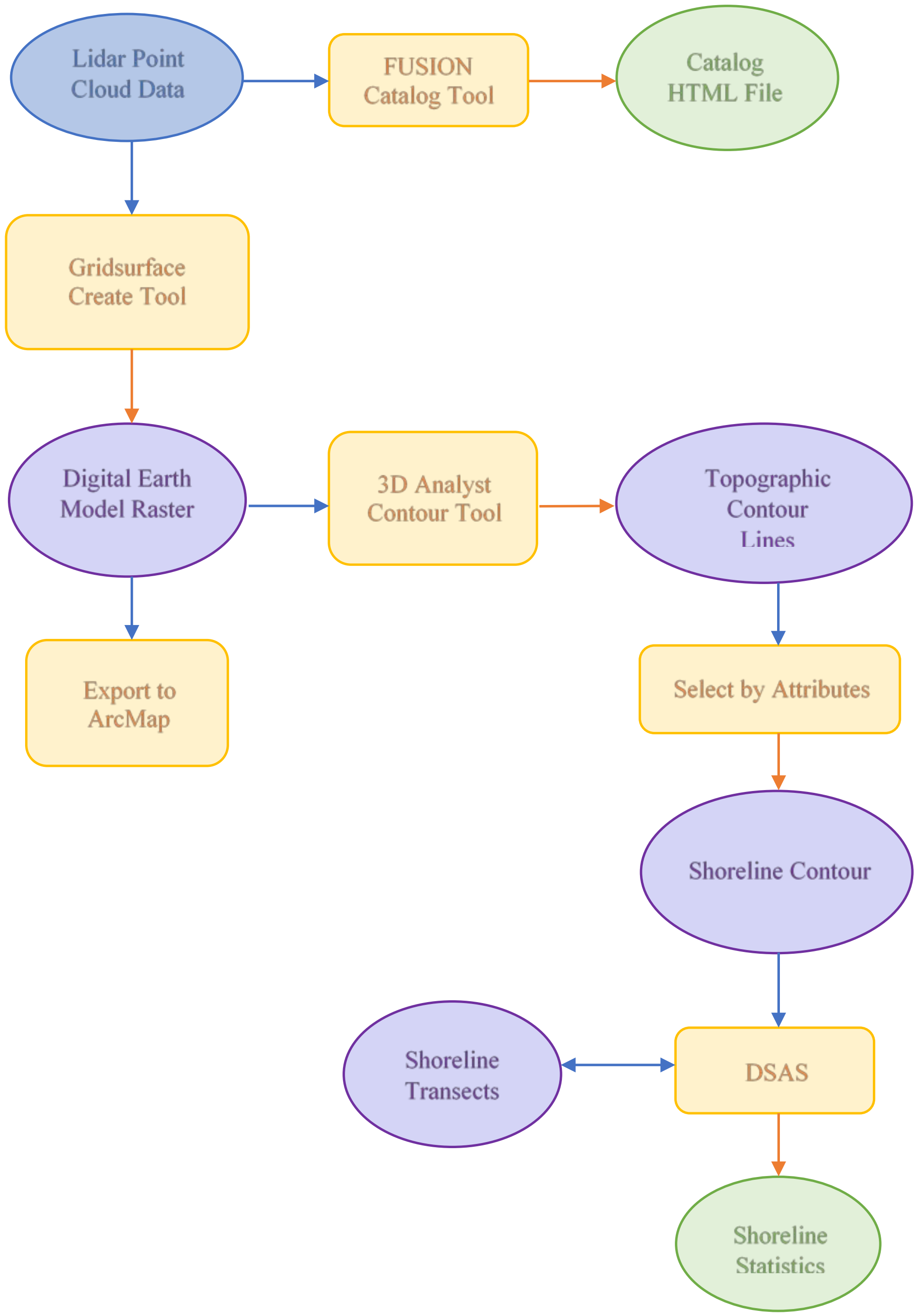


Figure 6. LiDAR processing steps.

Processing. Orthoimages were processed using ERDAS Imagine 2015 software. The image tiles were placed into the Mosaic Pro tool to create a single image for each year. Images from 1998-2012 consisted of four tiles that were cropped 15% on each edge and merged using overlay mosaic and nearest neighbor interpolation. The 2017 image dataset contained six tiles that were combined using the same mosaic techniques, but tiles were not cropped. All images were radiometrically corrected to remove histogram stretch. Two change detection techniques were used to compare the brightness values and spectral differences between each image.

Each dataset was compared in the image differencing tool to locate zones where pixel brightness values changed. Pixels with an increase of more than 30%, 50% or 80% increase in brightness value were highlighted green, and pixels with a decrease in corresponding brightness value were highlighted red to create a change image. Change detection through image comparison is a band-based tool, so layers with the same spectral resolution were matched.

Supervised classification tools were used to identify water, bare earth, vegetation, and built-up land types. Similar techniques were applied in studies by Barras et al. (2003) and Couvillion et al. (2011) when comparing coastal Louisiana images. Areas of interest with normal distribution histograms were used to define classes based on similarities in spectral signatures and ancillary knowledge. At least ten areas of interest were combined for each class to create a thematic image. The output images had large areas with mixed pixels and were not useful in comparison.

Homogeneity in spectral information lead to misclassification, so alternate methods were sought to alleviate recurrence. Unsupervised classification techniques were applied to prevent misclassification and remove mixed pixels. Each image was run through the unsupervised classification tool to create thematic images with 100 classes after 10 iterations and a default convergence threshold. An excess of 3 classes were chosen to separate the pixels into smaller groups that can be combined. The output image attributes were analyzed and assigned either a yellow, blue, or green color code to signify bare earth, water, or vegetation. The classified images were entered in the recode tool to reduce the classes from 100 to three based on assigned hue. Recoded results were analyzed for accuracy using the ERDAS Imagine 2015 supervised classification accuracy assessment tool. Post-classification accuracy assessment quantifies the error in thematic maps produced using supervised or unsupervised classification techniques (Olofsson, et al., 2014). Olofsson, et al. (2014) also discuss the necessity of sampling randomization in accuracy estimation, so this method was applied. The software produced 250 random points to which class values are assigned based on user knowledge and spectral signatures. The tool produces a report of kappa values and overall classification percent accuracy.

Images were cropped to a similar area of interest in attempt to remove noise from ocean glare along the edges. Post classification image comparison techniques were applied using the matrix summary report tool, which reports change statistics for each class as percent and number of hectares changed. Thematic images depicting land class differences were created using the matrix union tool. All thematic images were imported into ESRI ArcMap 10.3 software for visualization.

LiDAR data in the form of point clouds were processed using FUSION 3.6, a free software provided by the US Forest Service. Large datasets required selection of specific footprints that contained the study area. The catalog.exe tool was used to produce a html document that detailed the number of return points, return number, point density, footprint, a density image, intensity image, and the minimum and maximum height for each tile. Select tiles were again run through the catalog.exe tool to acquire the same type of data specific to Grand Isle and Isle West Grand Terre. Each dataset was visually examined in the FUSION LiDAR Data Viewer to ensure completion and observe anomalous measurements. Point clouds were filtered through the grounfilter.exe tool to create exclusively bare earth point clouds as recommended by Schmid, Hadley, and Wijekoon (2011). These point clouds were also examined in FUSION LiDAR Data Viewer (LDV) for unnecessary removal of ground points or inclusion of non-bare earth points. The bare earth point clouds were interpolated in the bare.exe tool to produce bare earth surface models. Digital elevation models were created by interpolating non-bare earth point clouds in the gridsurface.exe tool. These digital elevation models and bare earth surfaces were exported to ArcMap 10.3.1 as ASCII files.

Elevation models were converted to raster files in ESRI ArcMap 10.3.1, assigned coordinate information, and projected. Contour polylines were produced from the digital elevation model raster elevation information. Contours were digitally edited to remove any detached coastal engineering structures and separate Grand Isle from Isle West Grand Terre. The 0 MSL beach-side contour was extracted from the contour intervals and edited to include only the margins. The USGS Digital Shoreline Analysis System 4.3 for ArcGIS 10.3 was downloaded and used to perform linear referencing of the LiDAR derived shorelines.

Analysis. The summary of report by matrix output was entered into Microsoft Excel 2016 for data visualization. Statistical analyses include the area of change per class, the type of change per period, the percent change for each land class, and the rate of change for each land class. Shoreline change rates were determined using methods similar to Kim et al. (2017) by finding the net shoreline movement and calculating rate of change during the entire study period.

Land Area and Type. Total areas of each land class were exported from ERDAS Imagine 2015 to Excel for analysis. The change in area for each class over time was graphed using these measurements. Changes are reported in terms of area (1 hectare equals 10,000 square meters) and percent. The percent of change and quantity of area change are grouped per class. The change in area per class was graphed for visual comparison of the relative differences in land class change. The percent change was entered to bar graphs to show comparisons in the amount of change per class over each interval. The net change per class was visualized using bar graphs to show the increase or decrease in land area per class during each interval. Rates of change per class were determined by calculating the amount of change over each time, and the rates are graphed for visualization.

Shoreline Location. Contour lines extracted from LiDAR-derived digital elevation models represent topographic elevation. LiDAR data references the North American Vertical Datum of 1988, so the contour intervals with zero elevation were used to represent shoreline position. Contour lines were extracted from processed LiDAR data in ArcMap 10.3 after raster DEMs were produced from point cloud files. The shoreline shapefiles were appended to a single feature class for use in the extension, and a baseline was digitized offshore of the most oceanward shoreline. The digitized baseline was used to create transects perpendicular to the appended shorelines at 10-meter intervals where there was more than one shoreline available. The transects were then used to measure changes in the shore position based on the time of data collection. Linear referencing was performed to find the net shoreline movement and rate of change. The transects were edited in the DSAS extension to fit the shoreline change envelope, and the statistical output was entered in Excel for graphing. Transects with fewer than 3 shoreline intersections were not used to calculate the rate of change.

CHAPTER IV

Results and Discussion

The study area consists of two barrier islands, so results are separated into areas of interest to highlight the differences in each island. Land cover classification was conducted on the combined study area before the islands were separated for analysis. Shorelines were identified and compared individually.

Grand Isle

The area of interest for Grand Isle, Louisiana includes a populated, 8 mile barrier island with coastal engineering structures on and near the shoreline. This study investigated the land cover that can be observed in high resolution orthorectified aerial images acquired between 1998 and 2017. Three land cover classes were identified as water, vegetation, and bare earth. Elevation data was analyzed to identify shoreline position and evaluate migration between 1998 and 2013. The 3,574 hectare study area consisted of about 1,022 hectares of land covered by 852 hectares of vegetation in 1998 (Table 4).

TABLE 4. **Grand Isle total area per class in hectares**

	1998	2004	2008	2012	2017
Water	2551.96	2528.66	2678.11	2717.44	2658.67
Vegetation	852.15	712.71	637.35	516.66	665.44
Bare Earth	170.13	332.86	258.78	340.13	250.13
Land Total	1022.28	1045.57	896.13	856.79	915.57

Note: Land Total is the sum of non-water classes.

The same area of interest had an estimated 1,045 hectares of land in 2004, reduced to about 896 hectares in 2008, less than 857 hectares in 2012, and had 915.5 hectares of land in 2017. Most of the total land area loss is due to decreases in vegetated land cover (Figure 7).

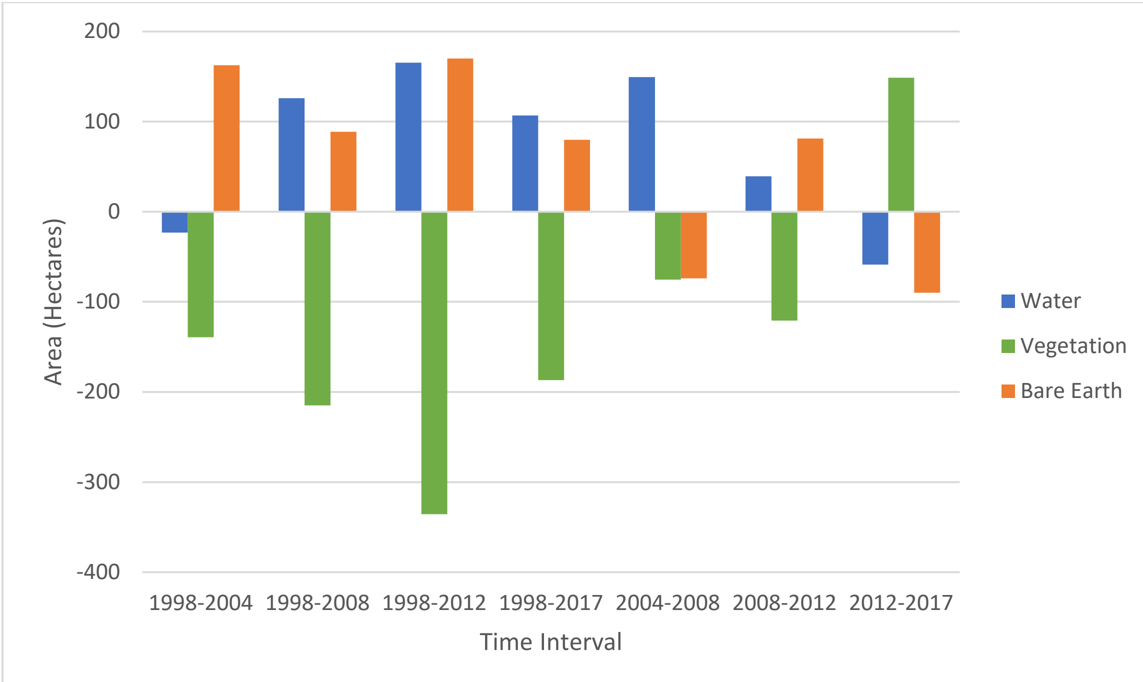


Figure 7. Grand Isle land cover class change per interval.

During the entire 19 year study, more than 20% of the initial 1998 vegetated area was converted to another land class, and the island experienced a 47% gain in bare earth land cover (Table 4). The most significant vegetation change was observed between 1998 and 2012, where more than 300 hectares were converted to other land cover classes. An increase in water cover indicates a net loss of land area, and only two intervals of ~5 years experienced net land gain. Vegetated land cover decreased in all observed time intervals except between 2012 and 2017 (Figure 6 and Table 5). This is possibly due to a relatively low rate of major hurricane activity.

TABLE 5. **Grand Isle change per interval**

	Water		Vegetation		Bare Earth	
	Hectares	Percent	Hectares	Percent	Hectares	Percent
1998-2004	-23.30	-0.91%	-139.44	-16.36%	162.74	95.66%
1998-2008	126.15	4.94%	-214.80	-25.21%	88.65	52.11%
1998-2012	165.48	6.48%	-335.49	-39.37%	170.00	99.92%
1998-2017	106.71	4.18%	-186.72	-21.91%	80.00	47.02%
2004-2008	149.45	5.91%	-75.37	-10.58%	-74.08	-22.26%
2008-2012	39.33	1.47%	-120.69	-18.94%	81.36	31.44%
2012-2017	-58.78	-2.16%	148.78	28.80%	-90.00	-26.46%

A transition from land to water is noticeable in the backbarrier, and an increase in bare earth can be seen on the shoreline facing the Gulf of Mexico between 1998 and 2017 (Figure 8). The eastern most spit of Grand Isle changed shape, and Figure 7c reveals land to water transition. The replacement of spit land area by water may be due to dredging of Barataria Pass for navigation purposes. Accumulations of bare earth land cover observed on the shoreline are near wavebreak structures constructed during the mid- to late- 1990s. Tombolo formation is evident near the island midsection on the Gulf of Mexico side (Figure 8b). Very little vegetation growth was seen during the 19 year study. Human activity increased significantly in the western backbarrier near Caminada Bay in the form of pier construction and offshore structures that protect the new boating location.

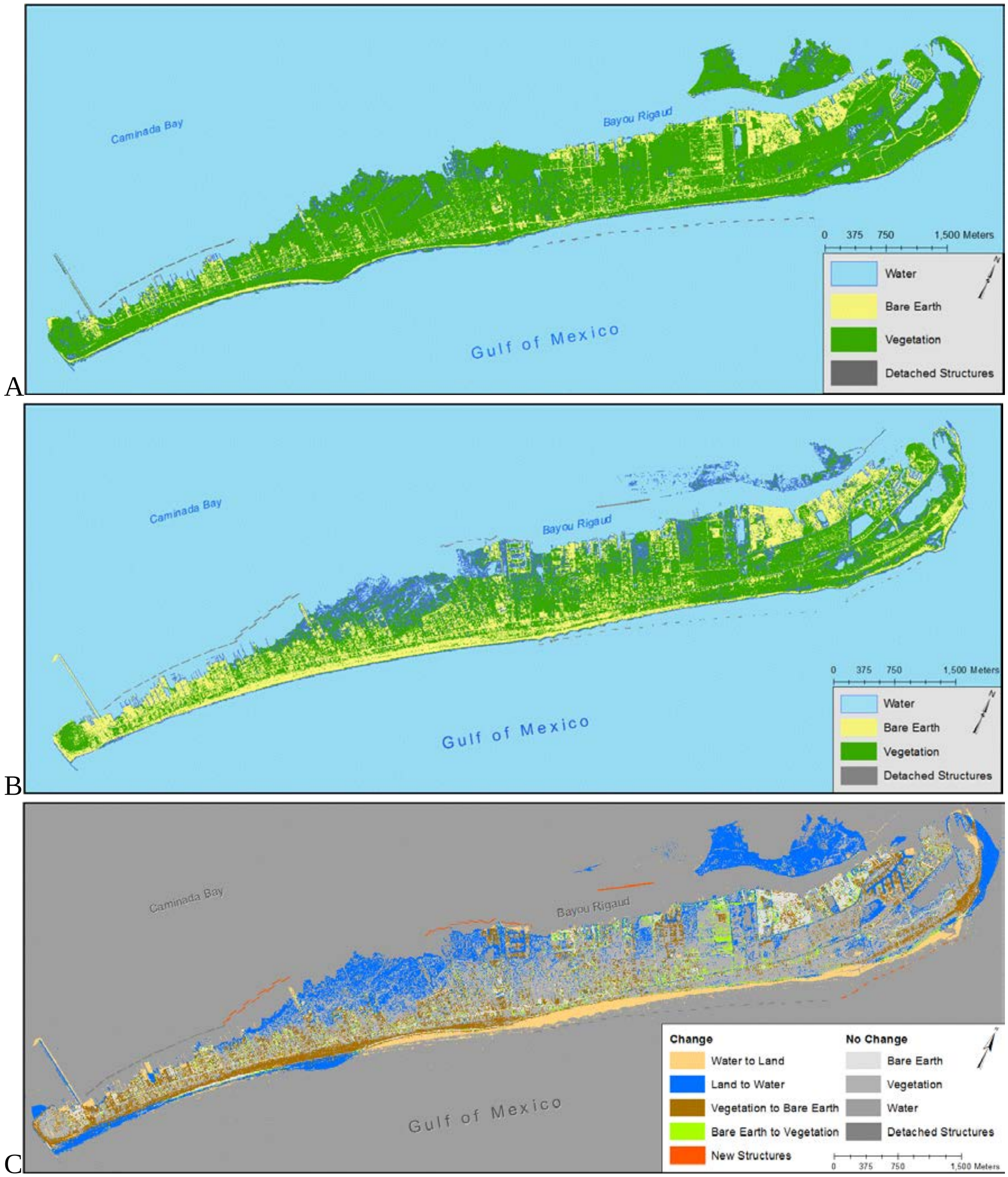


Figure 8. Grand Isle land cover and change 1998-2017. Grand Isle land cover map from 1998 (a), Grand Isle land cover map from 2017 (b), and a map highlighting areas of change that occurred between 1998 and 2017 (c).

Short interval observations were made within the 1998-2017 period. Differences in land cover and island morphology were observed from 1998 to 2004. The most significant change over these 6 years occurred in the form of bare earth land area increase. More than 150 hectares of vegetated land were converted to bare earth (Figure 9).

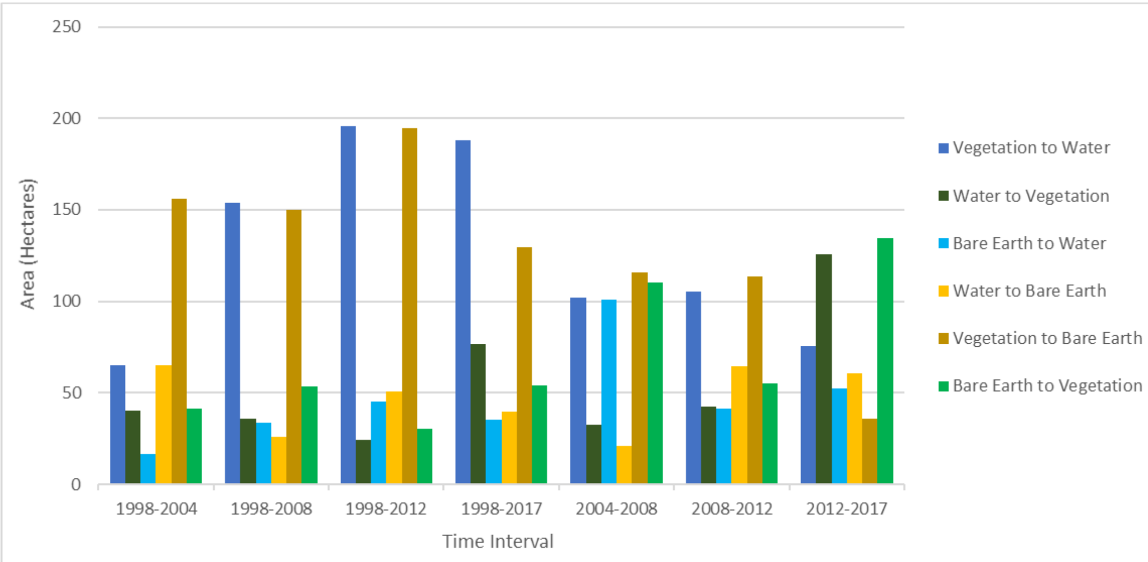


Figure 9. Grand Isle land class transition per interval.

The bare earth land class experienced the highest rate of change between 1998 and 2004 compared to other reported intervals. More than 25 hectares of bare earth were accumulated per year over the 6 years, and more than 20 hectares of vegetation were lost per year during the same time (Figure 10).

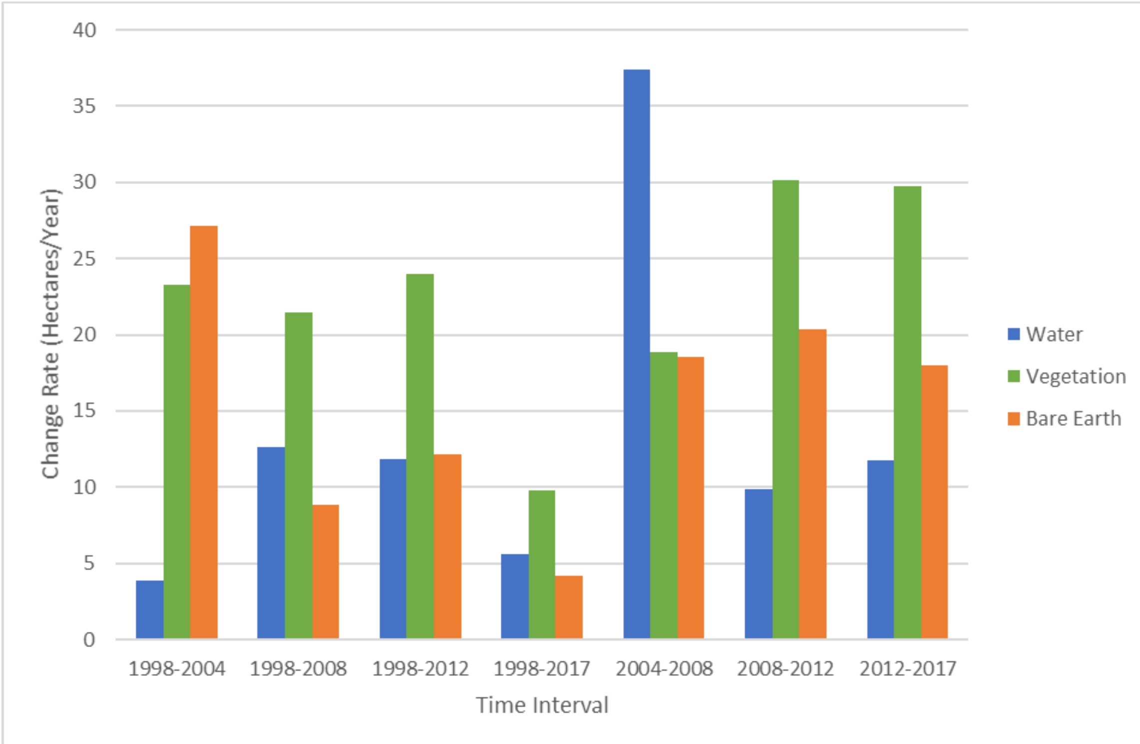


Figure 10. Grand Isle land cover rates of change.

Points of vegetation replacement are adjacent to land removal sites on the shoreline, indicating sediment overwash and plant death (Figure 11). New wavebreak strucutres were added near the eastern spit of Grand Isle in 1999, but the nearby shoreline experienced land to water transition (Figure 11b). Few hectares of bare earth were replaced by vegetation, and vegetation experienced the largest decline in area, but the largest percent of transition was from bare earth to vegetation. Nearly 25% of the existing 1998 bare earth area was replaced by vegetation before 2004 (Figure 12).

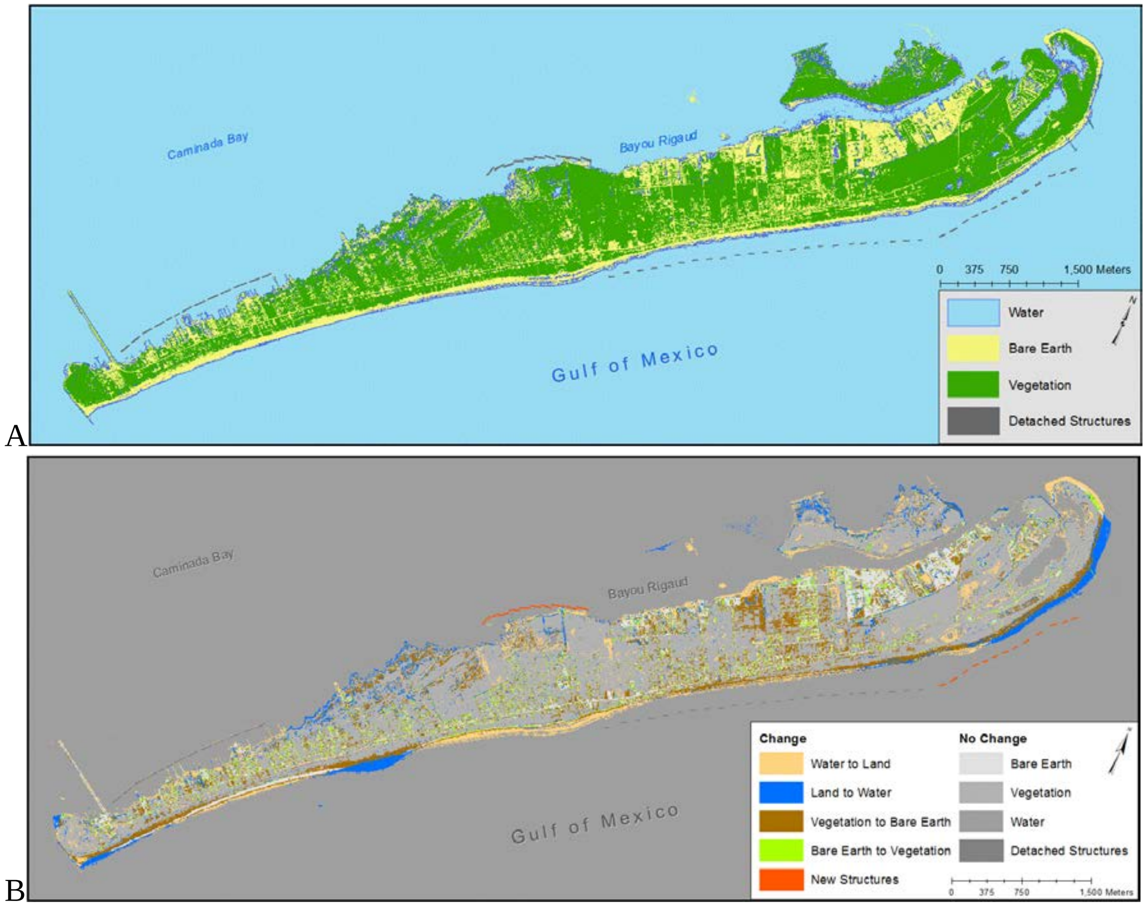


Figure 11. Grand Isle land cover and change 1998-2004. Grand Isle land cover map from 2004 (a) and a map highlighting areas of change that occurred between 1998 and 2004 (b).

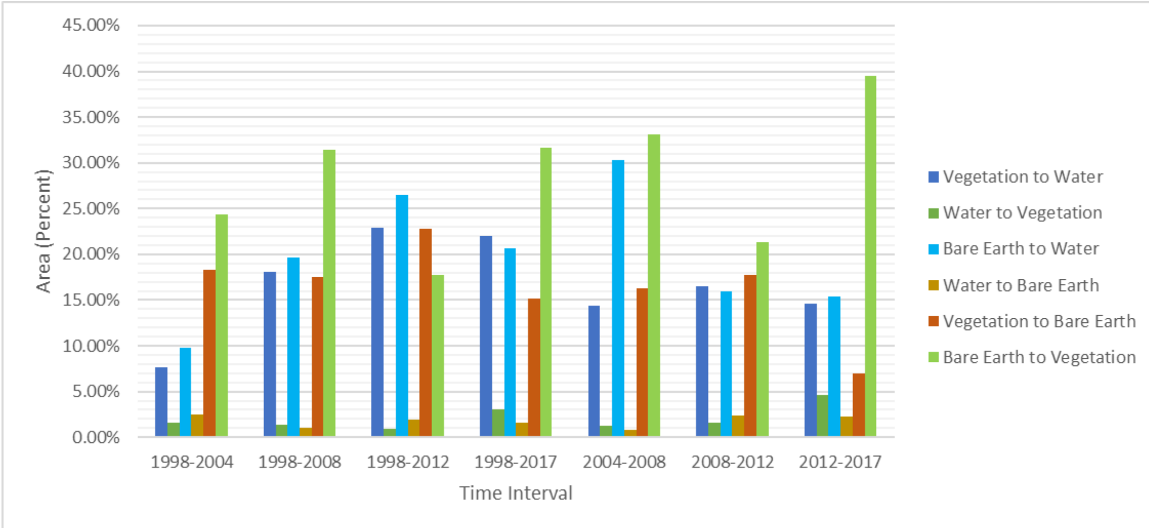
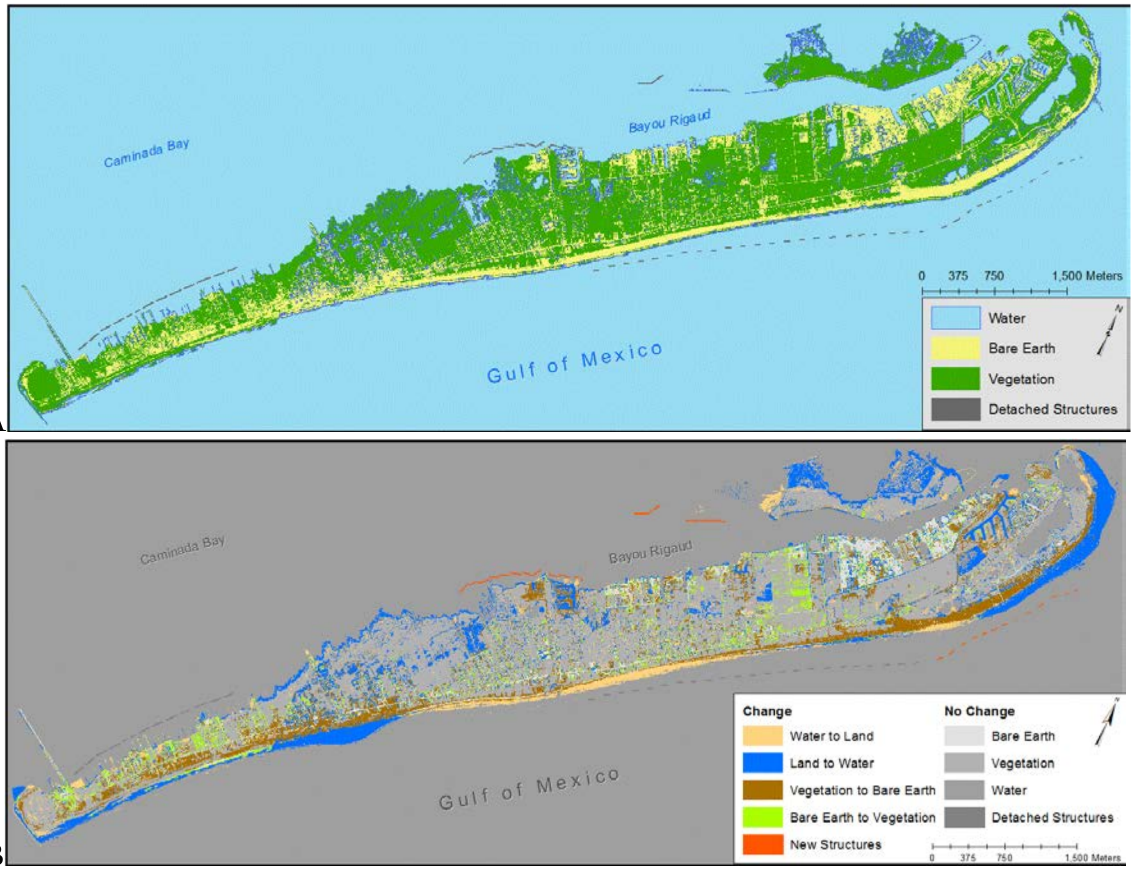


Figure 12. Grand Isle percent change per interval.

The ten year investigation conducted between 1998 and 2008 included effects of hurricanes Katrina and Gustav on the study area. Grand Isle suffered beach and dune breaches on the unprotected western shoreface (Figure 13).



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B

Figure 13. Grand Isle land cover and change 1998-2008. Grand Isle land cover map for 2008 (a) and a map highlighting changes in land cover between 1998 and 2008.

More than 25% of the 1998 vegetated land area was replaced by other classes by 2008. Approximately 150 hectares of vegetation were covered by sediment on the far ends of Grand Isle. The eastern most spit experienced land to water conversion, and man-made canals removed land in the eastern backbarrier. A high percent of 1998 vegetated and bare earth land cover transitioned to water over the 10 years. Large ponds appeared in the backbarrier west of Bayou Rigaud where more than 150 hectares of vegetation were removed. Overwash and erosion from Hurricane Gustav affected vegetation growth near the shoreline, but the highest percent of transition occurred in the backbarrier where bare earth was converted to vegetation.

The greatest loss of vegetation occurred between 1998 and 2012 in the backbarrier marsh of Grand Isle west of Bayou Rigaud (Figure 14).

A

B

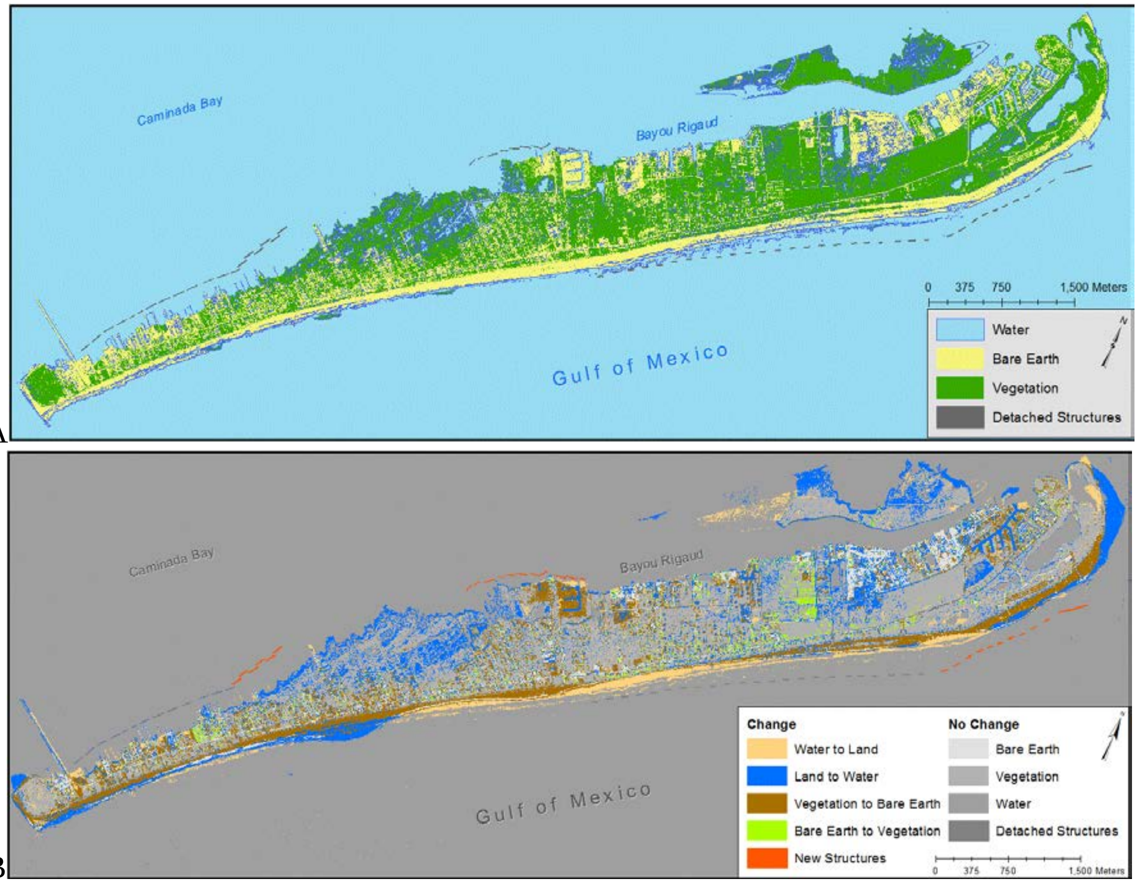


Figure 14. Grand Isle land cover and change 1998-2012. Grand Isle land cover map for 2012 (a) and a map highlighting changes in land cover between 1998 and 2012.

More than 335 hectares of vegetation were removed between 1998 and 2012. During this period, vegetation replaced by sediment is evident as vegetation is converted to bare earth on the beach side of the island and in the backbarrier near Bayou Rigaud. Post Katrina beach sediment nourishment and geotextile dune construction can be seen as water is converted to land. More than 170 hectares of bare earth were added to the island in the form of nourishment and as a result of vegetation removal. Backbarrier breakwaters in

Caminada Bay constructed in 2012 appear near the marsh, which lost nearly 200 hectares of vegetation to water. Land on the eastern spit was replaced by water, and a beach berm on the western shoreface migrated alongshore. The highest rates of change, largest percent of loss, and greatest area of vegetation loss were observed over the 1998 to 2012 period. Eight major hurricanes directly affected the island during this period, contributing to landward shoreline migration. The shoreline of Grand Isle migrated landward at a rate of 0.21 centimeters per year, or 2.1 millimeters per year between 1998 and 2013 (Figure 15).

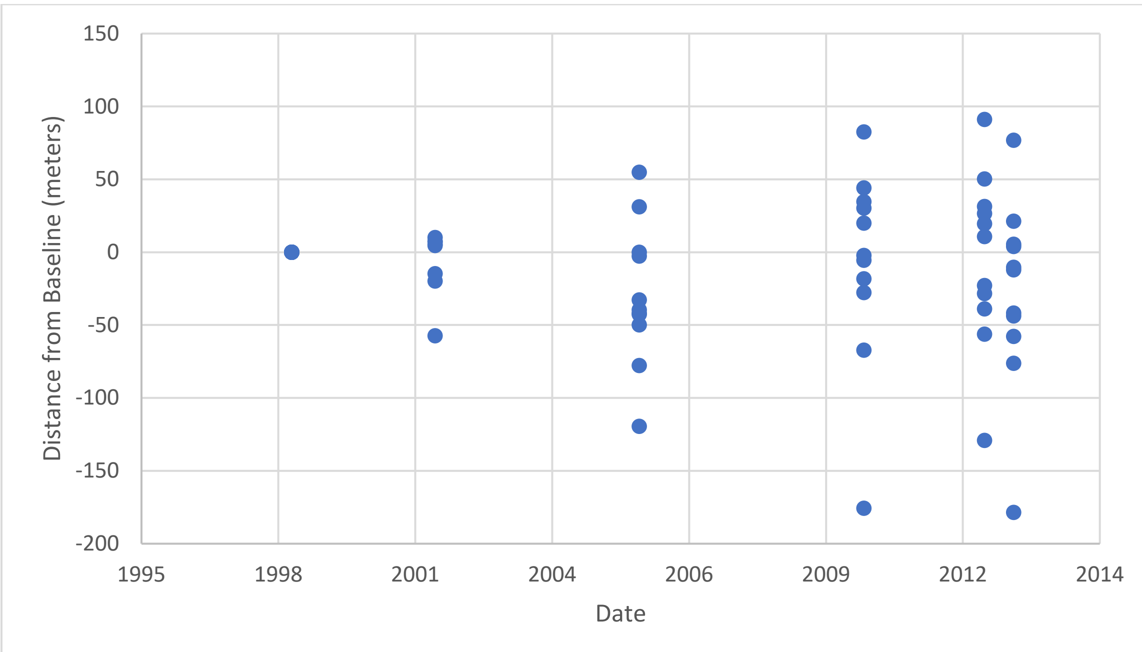


Figure15. Grand Isle shoreline position.

By 2012, the shoreline moved landward more than 150 meters at some points and less than 100 meters oceanward near offshore structures.

The highest rates of change occurred during the short term investigations, and the rates of change changed at higher rates between 1998 and 2008 (Figure 16). Rates of change decreased between 2008 and 2017.

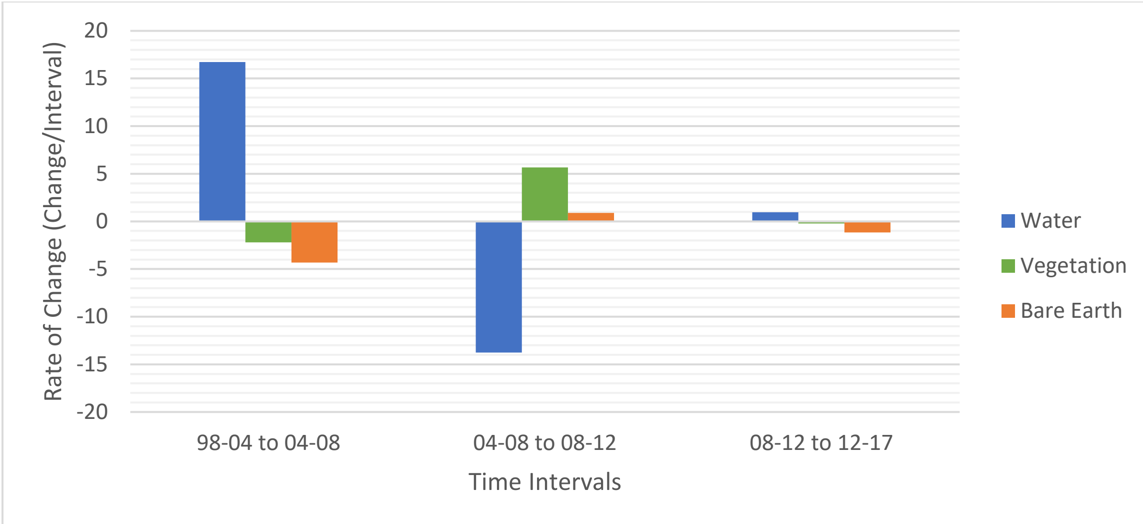


Figure 16. Change rates for rates of change on Grand Isle.

The rates of change and changes in rates of change on Grand Isle correlate with a decline in major cyclone activity after 2012.

Isle West Grand Terre

The unoccupied two mile long barrier island of Isle West Grand Terre, Louisiana was examined for land cover class and change in land cover class using high spatial resolution images collected between 1998 and 2017. Shoreline positions were determined and compared using elevation data collected prior to 2017.

The total non-water land area in 1998 was approximately 182 hectares, which increased to 226.77 hectares by 2004, before experiencing a slight loss by 2008 to 206.59 hectares. The same area continued to decrease into 2012, reaching 189.18 total hectares, and increasing slightly to 198.14 hectares by 2017 (Table 6). The increase in non-water land classes correlates with a decrease in water cover during each interval observed.

TABLE 6. **Isle West Grand Terre total area per class in hectares**

	1998	2004	2008	2012	2017
Water	446.36	401.37	421.72	439.12	430.17
Vegetation	151.51	147.92	182.77	141.35	150.87
Bare Earth	30.83	79.40	23.82	47.83	47.27
Land Total	182.34	227.32	206.59	189.18	198.14

Note: Land total is the sum of non-water land cover class areas.

Increases in total land area over each interval and the entire study period can be attributed to the creation of a 185-acre space and addition of more than 600,000 cubic yards of sediment in Barataria Bay after 1998. The creation of a new backbarrier is represented by water to land transition between 1998 and 2004 (Figure 17). Overwash patterns can be seen on the shoreline of Isle West Grand Terre where vegetation was covered by bare earth. These features are adjacent to shoreline erosion represented by land to water transitional areas, similar to that on Grand Isle. Vegetation gain on the eastern side of the island was observed after 1998. The island was heavily vegetated and has a narrow beach face in 1998, making changes easy to identify.

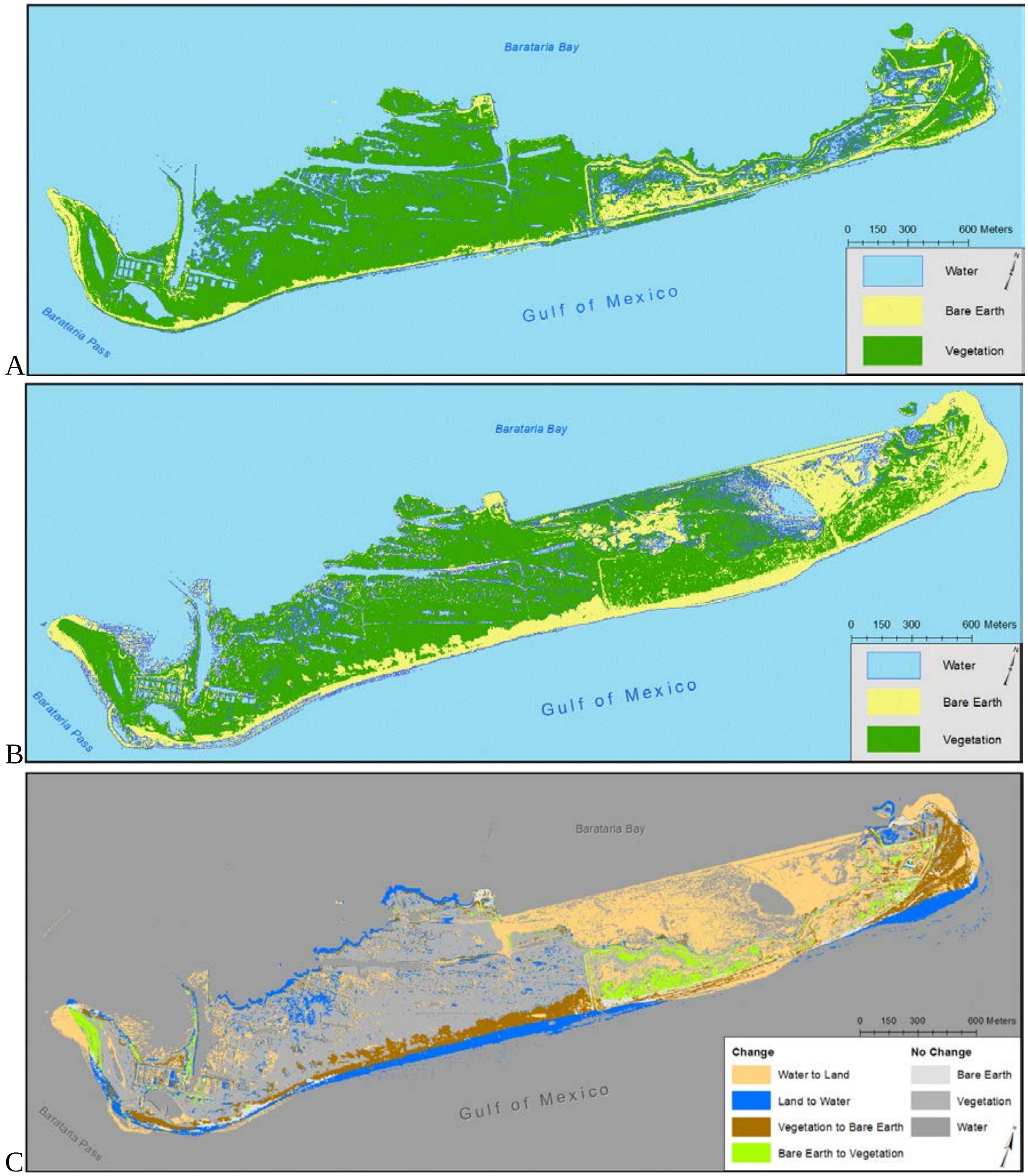


Figure 17. Isle West Grand Terre land cover and change 1998-2004. Isle West Grand Terre land cover map from 1998 (a), from 2004 (b), and the changes observed between 1998 and 2004 (c).

Bare earth was removed from the western beach face following the 2002 installation of a breakwater near Barataria Pass (Figure 17b and 17c). The addition of backbarrier sediment and overwash patterns resulted in a 48.56 hectare bare earth area increase, with 3.58 hectares of vegetation lost (Table 7).

TABLE 7. **Isle West Grand Terre change per interval**

	Water		Vegetation		Bare Earth	
	Hectares	Percent	Hectares	Percent	Hectares	Percent
1998-2004	-44.99	-10.08%	-3.58	-2.36%	48.56	157.51%
1998-2008	-24.64	-5.52%	31.26	20.63%	-7.01	-22.74%
1998-2012	-7.23	-1.62%	-10.16	-6.71%	17.00	55.14%
1998-2017	-16.19	-3.68%	-0.64	-0.42%	16.43	53.29%
2004-2008	20.35	5.07%	34.84	23.55%	-55.58	-70.00%
2008-2012	17.41	4.13%	-41.42	-22.66%	24.01	100.80%
2012-2017	-8.95	-2.04%	9.52	6.73%	-0.56	-1.17%

Note: Percent change calculated from initial 1998 land cover areas.

The same backbarrier development is evident in comparison results from 1998 and 2008 (Figure 18). Images from 2008 exhibit an increase in vegetated land cover, especially on the newly developed marsh. Major shoreline changes between 1998 and 2008 are represented by land to water transition areas, especially near Barataria Pass. The loss of land is accompanied by a transition from vegetated land to bare earth on the Gulf of Mexico side (Figure 18b). These changes resulted from Hurricane Gustav making landfall shortly before the 2008 images were acquired.

A

B

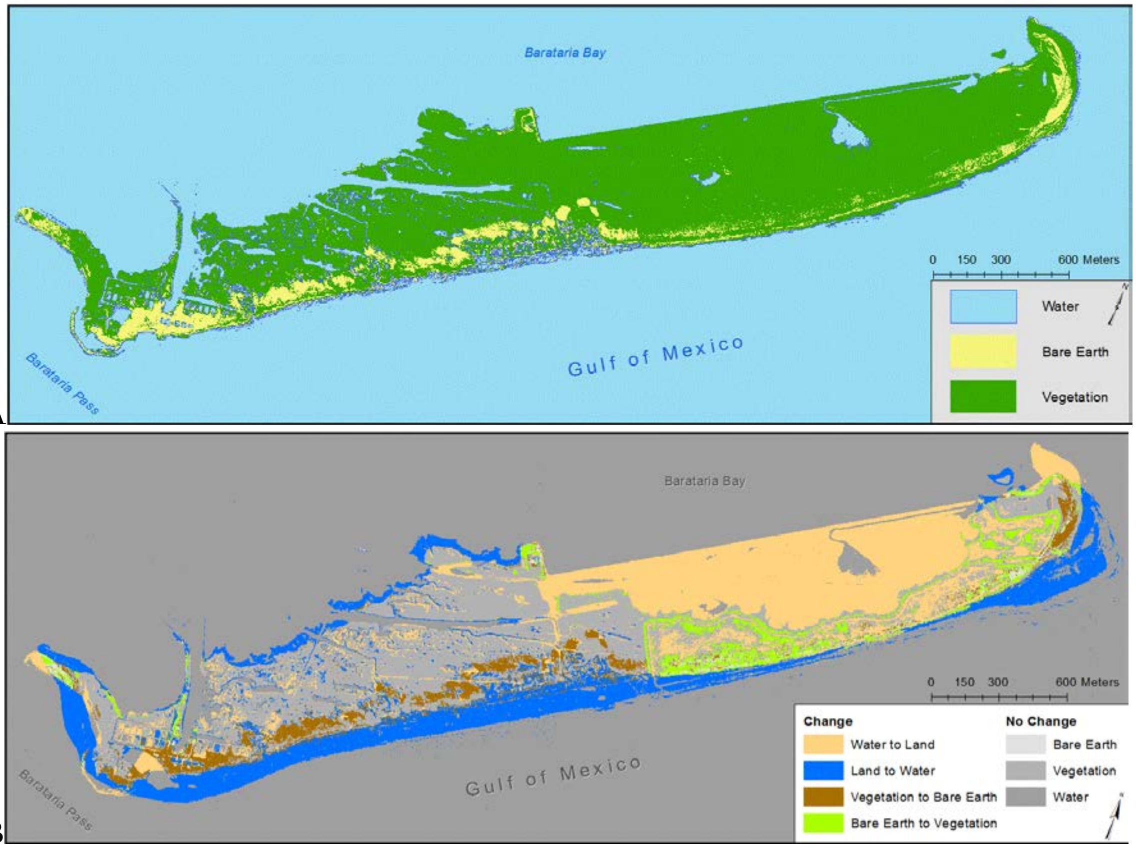


Figure 18. Isle West Grand Terre land cover and change 1998-2008. Land cover map of Isle West Grand Terre in 2008 (a) and a map highlighting changes between 1998 and 2008 (b).

The hurricane damage is represented as a sharp decline in bare earth land cover between 2004 and 2008 (Figure 19). The increase in vegetated land cover between 1998 and 2008 correlates with vegetation projects of 2001 and the removal of herbivores.

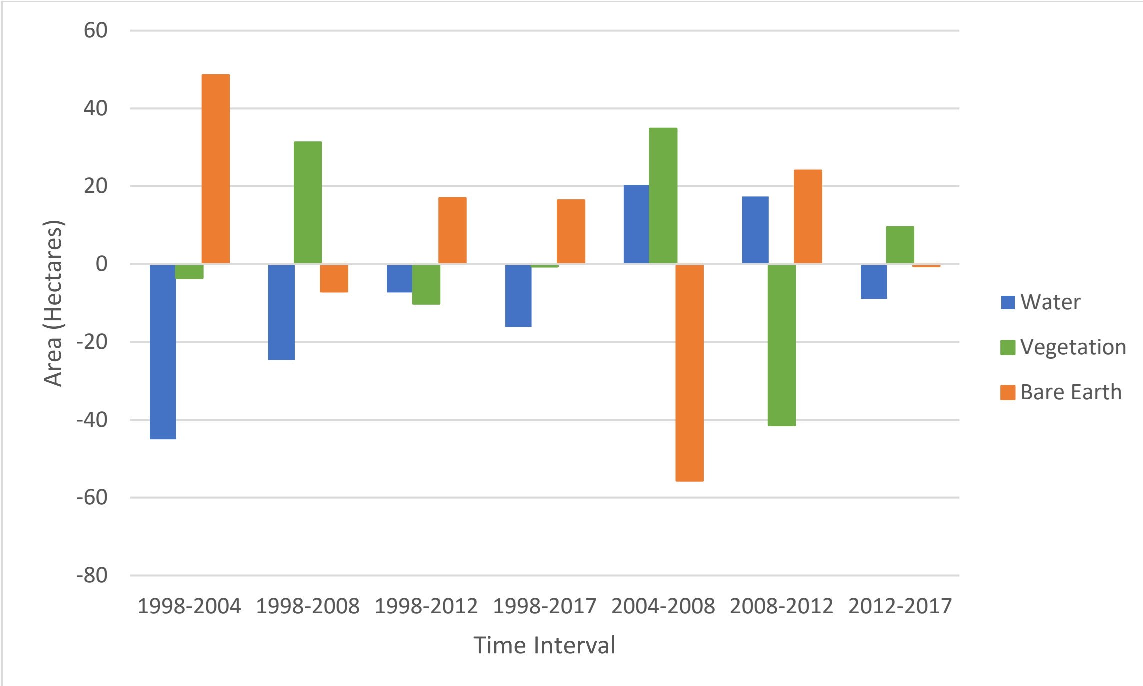


Figure 19. Isle West Grand Terre land class area change per interval.

Despite the relatively small change in area between 1998 and 2012, the island experienced an approximate 55% increase in bare earth area between 2008 and 2012 (Table 7 and Figure 20). The change is due to a combination of back barrier development vegetation replacement near the shoreline, and eastern spit development (Figures 21 and 22).

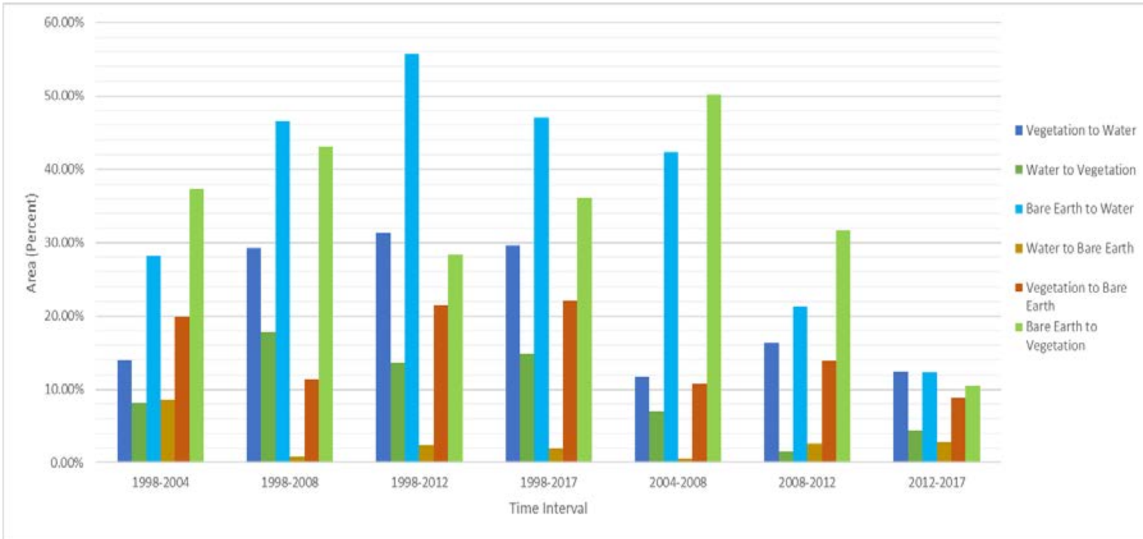
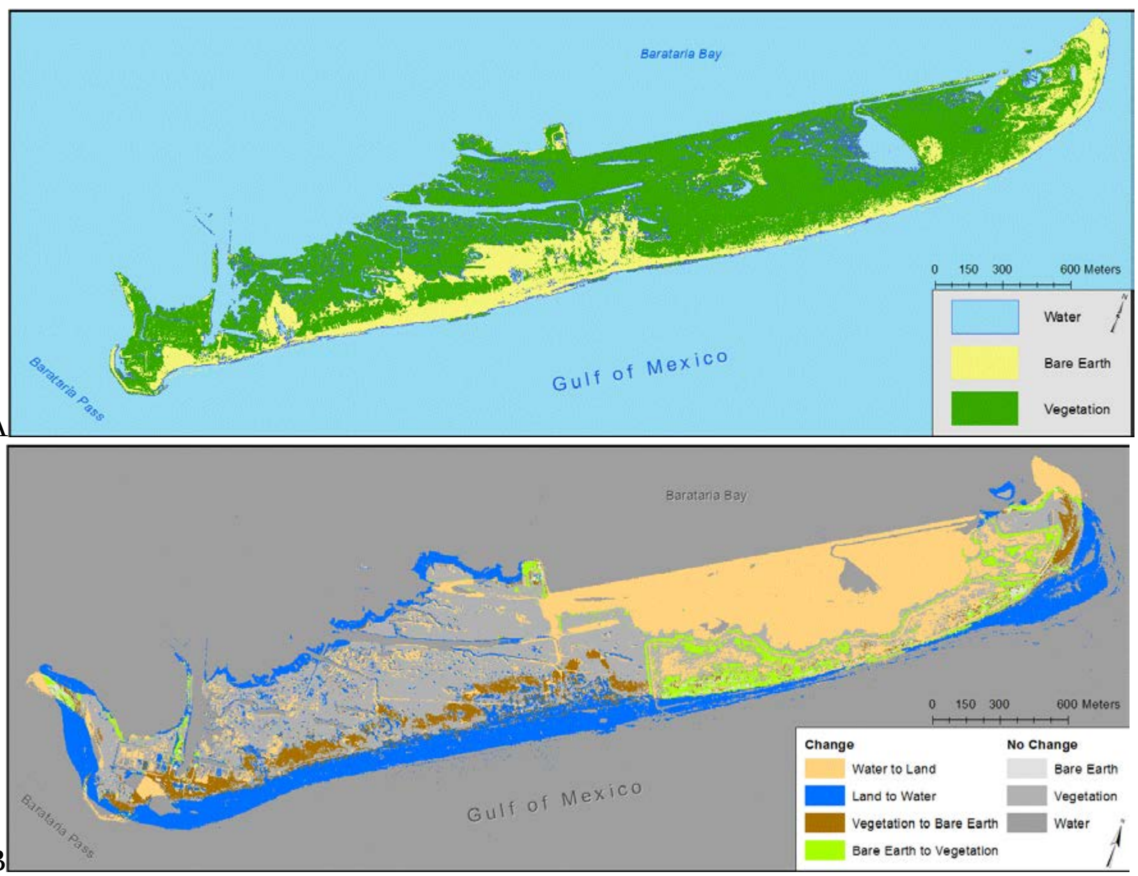


Figure 20. Isle West Grand Terre percent change per interval.



A

B

Figure 21. Isle West Grand Terre land cover and change 1998-2012. Land cover map for Isle West Grand Terre in 2012 (a) and a map highlighting changes between 1998 and 2012 (b).

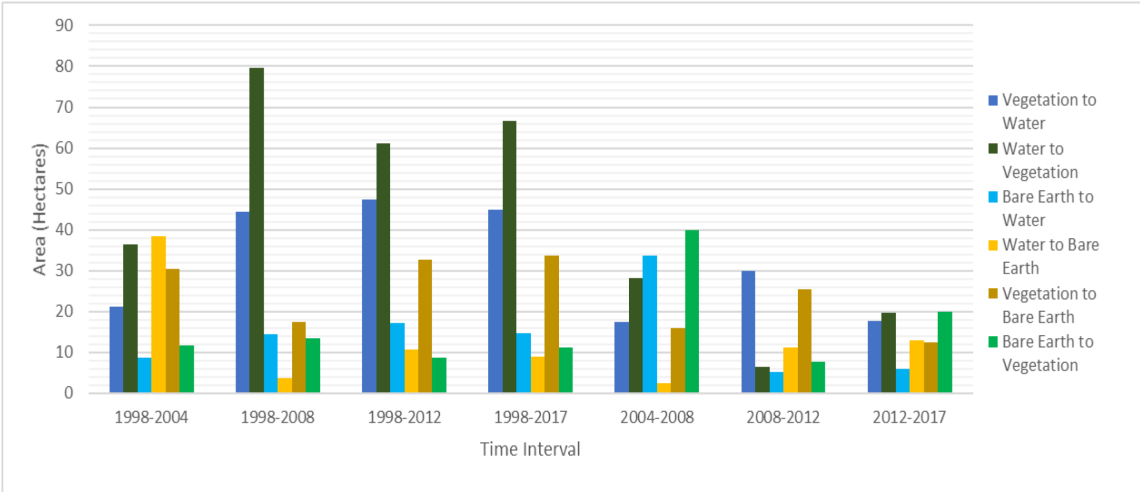
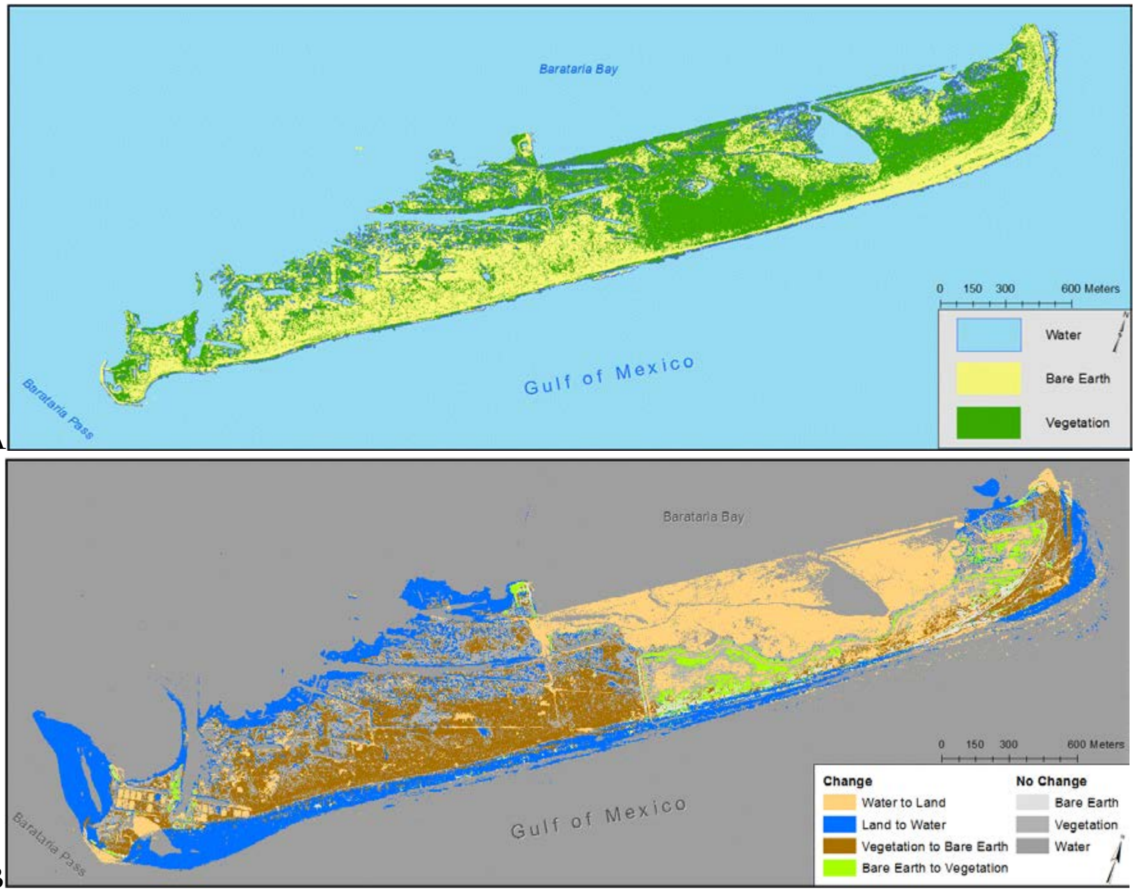


Figure 22. Isle West Grand Terre land cover transition type per interval.

By 2017, Isle West Grand Terre experienced major changes in shape and land cover. The heavily vegetated western portion of the island was replaced by bare earth and water (Figure 23). The western spit of Isle West Grand Terre that once bordered Barataria Pass no longer exists, and Fort Livingston is surrounded by water. Between 1998 and 2013, the shoreline migrated landward at a rate of 2.02 cm/year with some locations moving more than 300 meters (Figure 24). Rates of change on this island were highest in the bare earth class, but decreased over time (Figures 25 and 26).



A
B

Figure 23. Isle West Grand Terre land cover and change 1998-2017. A land cover map of Isle West Grand Terre from 2017 (a) and a map highlighting changes between 1998 and 2017 (b).

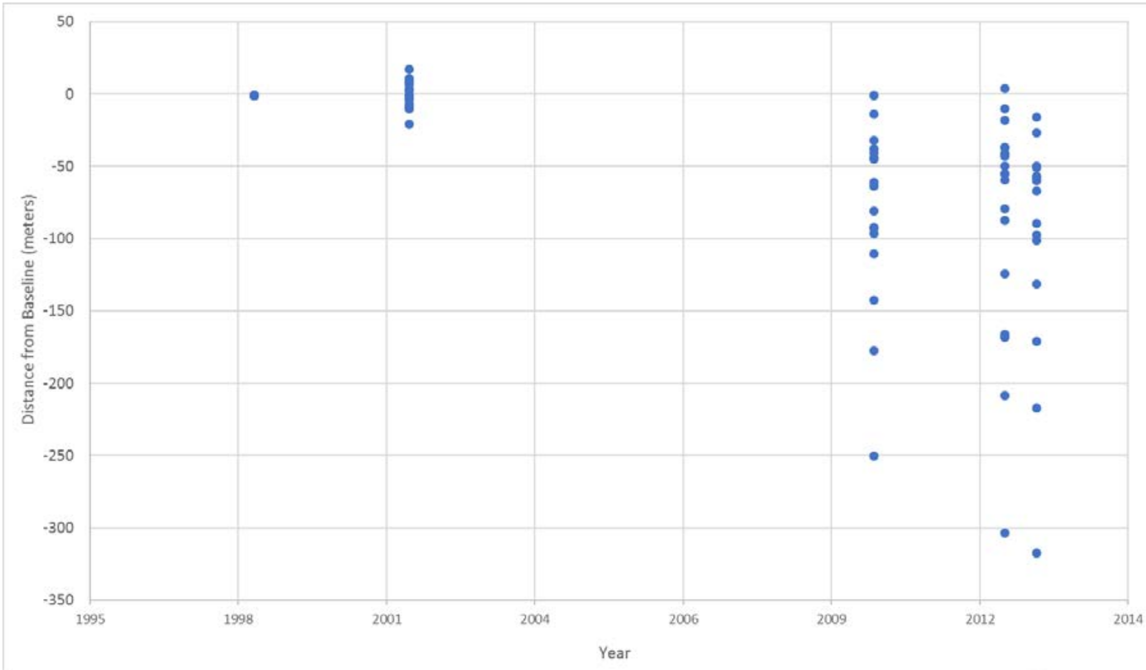


Figure 24. Isle West Grand Terre shoreline position and change.

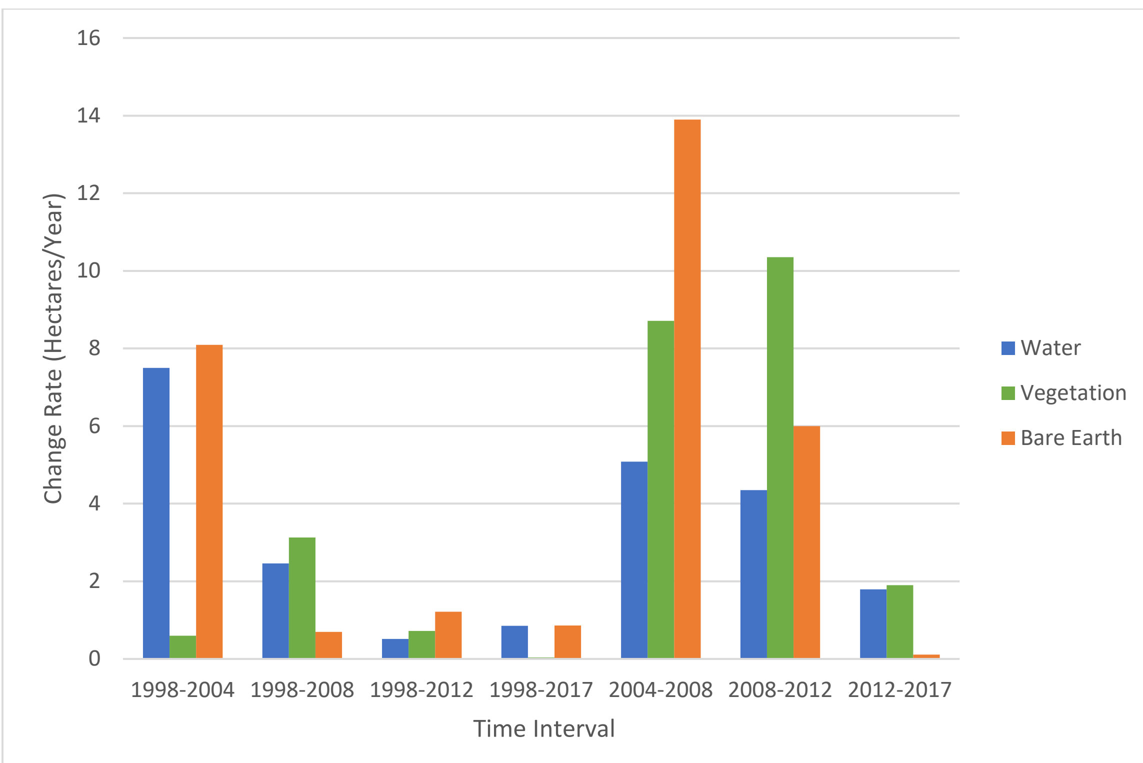


Figure 25. Isle West Grand Terre land cover class rates of change.

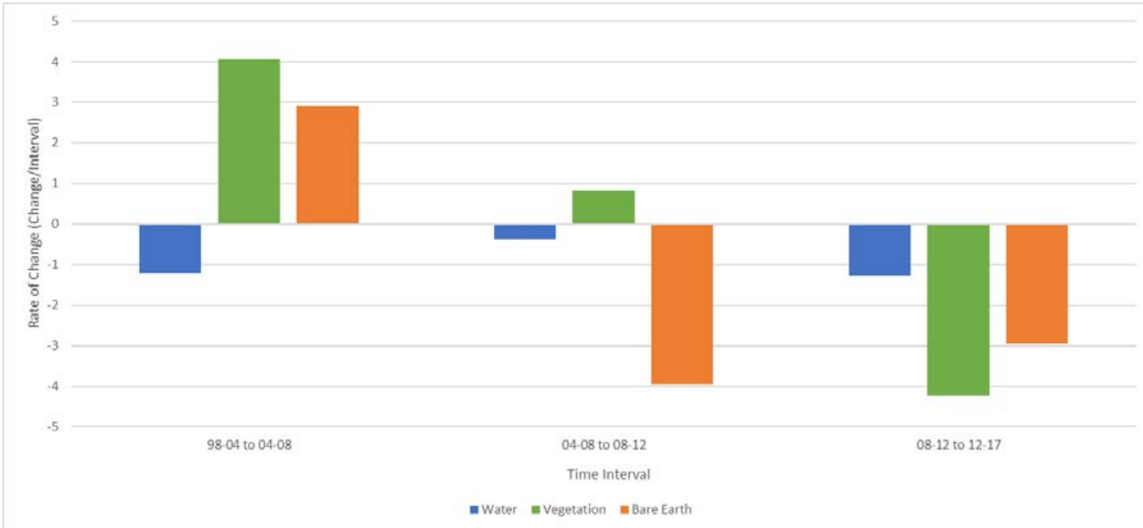


Figure 26. Isle West Grand Terre change in rates of change.

Caveats

Multiple problems occurred during this study. Free data has shortcomings, including the lack of accurate metadata, and incomplete data. Multiple datasets were rendered unusable due to the excess of noise, multi-day acquisition, or differences in sun angle. Seasonal variations in vegetation and differences in water level between survey dates increase the likelihood of statistical error (Morton et al., 2005; Couvillion et al., 2011). The 2005 LiDAR dataset lacked Isle West Grand Terre point clouds. The information provided by government sources for this study were temporary, meaning most of the data acquired is no longer available from the same sources.

Errors in processing and analysis occurred when attempting supervised classification. Water classes were often difficult to identify in the back barrier marshes due to vegetation moisture and a lack of sediment. Wet sand identified as water for the purpose of this study. Similarities in spectral signatures prevented differentiation of built-up and bare earth classes and resulted in the combination of the two classes. This may be due to the human habit of using the nearest substrate available for construction and the clearing of vegetated lands. Thematic images were analyzed for error. Reports included the overall accuracy and kappa (Table 8).

TABLE 8. **Classification Accuracy Assessment**

	Grand Isle		Isle West Grand Terre	
	Accuracy	Kappa	Accuracy	Kappa
1998	96.04%	0.8971	88.39%	0.7447
2004	95.03%	0.8815	89.02%	0.7782
2008	91.29%	0.7980	91.22%	0.8284
2012	90.54%	0.7893	91.94%	0.8286
2017	91.79%	0.8153	85.67%	0.6776

The desired overall accuracy of 85% (Thomlinson, et al., 1999; Foody, 2002) was satisfied for all classified images. Cohen's kappa coefficient compensates for agreement that occurs by chance (Foody, 2002), but it has been suggested that kappa is redundant when overall accuracy is also reported (Olofsson, et al., 2014). However, both reports are included in this study.

Shoreline interpolation returned gaps in contour intervals on Isle West Grand Terre. Major hurricanes and winter storms cause flooding, beach erosion, barrier overwash, and breaching (Georgiou et al. 2005), which created gaps in shoreline data. Limits to hardware and software capabilities required use of selected transects in rate calculations. Coordinate and projection information was provided for all data. This required reprojection of some datasets for comparison and analysis. Reprojecting data introduces exaggerations in size, shape, area, and distance. These data sets required spatial references that matched the preexisting coordinate information to project the resulting raster and vector data. Despite obstacles, the data provided useful for relative comparisons within the study area.

CHAPTER V

Conclusion

Grand Isle and Isle West Grand Terre are experiencing changes in land cover and shoreline position. Backbarrier marsh vegetation is transitioning to water and dune vegetation is being overtaken by sediment. Similar overwash observations were made by Kindinger et al (2013) concerning the transition of Isle West Grand Terre dune vegetation. Backbarrier vegetation loss observed by Georgiou, et al. (2005) led to predictions that barrier islands will succumb to changes in tidal dynamics. The same vegetation loss was observed in this study. Sea level rise and subsidence are taking part in the loss of land classes, and humans are not helping the cause (Kindinger et al., 2013). Vegetation that stabilizes the uncompacted sediments are being converted to bare earth, and bare earth beach sediments are eroding at high rates.

Grand Isle is losing marsh land on the bay side, and the western half of Isle West Grand Terre is disappearing. Coastal engineering efforts seem to have an effect on Grand Isle. Breakwaters are trapping the sediments added through beach nourishment, and the geotextile "burrito" is taking the brunt of seasonal storms. The combined efforts are slowing shoreline migration rates. Comparatively, Isle West Grand Terre is not protected from storms and experiences landward shoreline migration 10x faster than the neighboring island. Backbarrier restoration efforts are effective, but the lack of protection leaves the island susceptible to hurricane overwash, vegetation death, and sediment erosion. Stabilization and restoration efforts are not preventing shoreline erosion, subsidence, sea level rise, or sediment starvation, but the effects are reduced significantly.

Engineering efforts have a high cost and take years to complete. Addition of vegetation to 297 acres of the constructed Isle West Grand Terre backbarrier cost $340,000 in 1998, and the project was completed 3 years after approval (LCWCRTF, 2006). A project responsible for the addition of the geotextile dune and jetties on Grand Isle cost $52 million and was completed before 2010 (USACE, 2012). Repairs to preexisting structures on Grand Isle cost more than $68 million after hurricanes Katrina and Gustav (USACE, 2008). These are just a few of the expenses reported by the federal and state agencies responsible for island rehabilitation. The monetary cost will eventually outweigh the cultural benefit of maintenance. The forces of change do not yield to budgetary concerns, and project delays are contributing to the alteration of island morphology.

Residents and visitors of barrier islands should be informed about the impact of human activity, local sea level rise, the effect of storms on coastal environments, and the risk involved in choosing to live on an island that experiences rapid change in a short period of time. One short term investigation discovered erosion rates to be higher between 1996 and 2005 than the average rates from 1890 to 2005 (Kindinger et al., 2013). Long term, site specific studies should be conducted to provide a prediction of the future change that is expected to occur on Grand Isle and Isle West Grand Terre. Shorelines that undergo stabilization and restoration require monitoring, and the effects should be compared to similar environments with limited human activity.

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