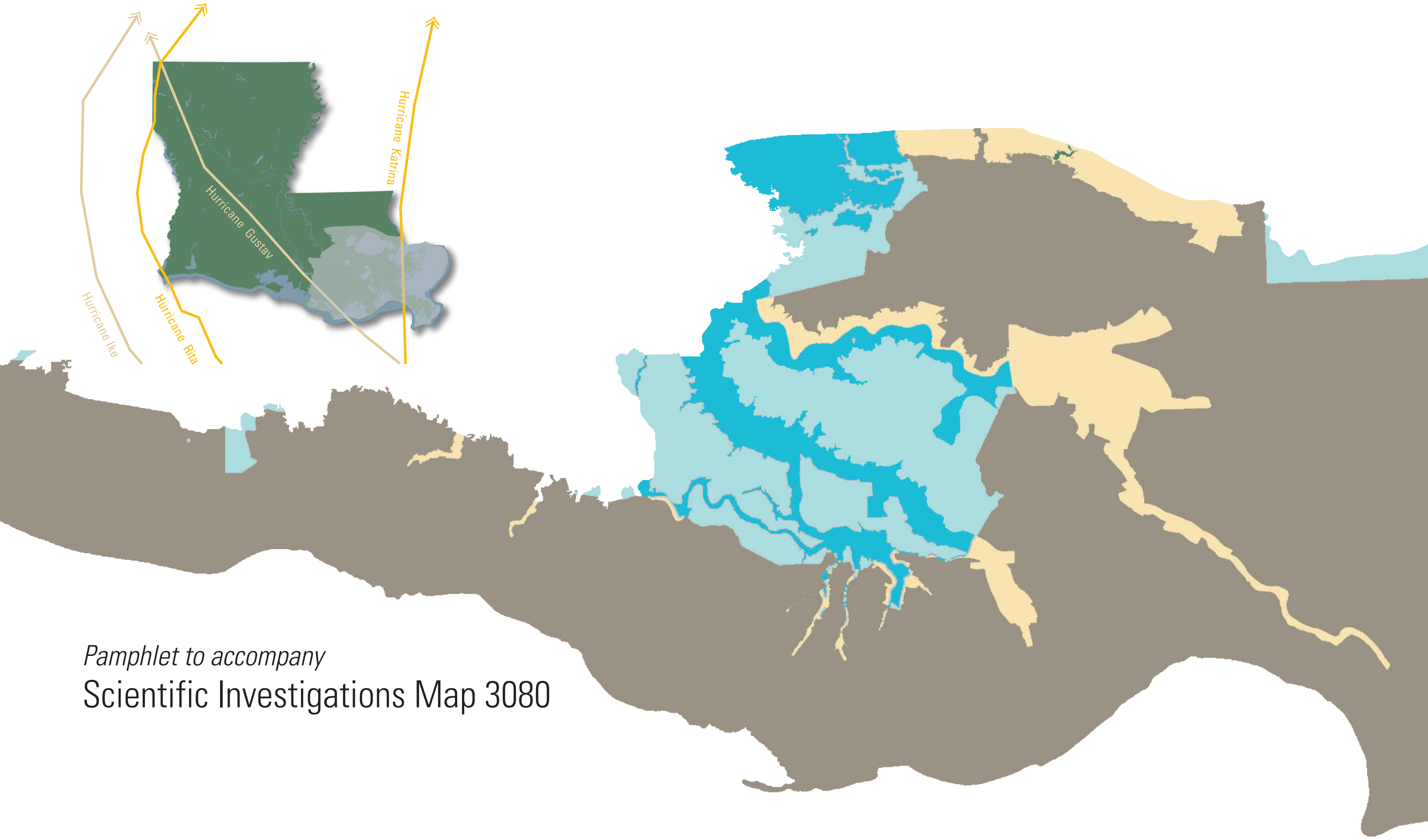
Land Area Change and Overview of Major Hurricane Impacts in Coastal Louisiana, 2004-08

By John A. Barras



Pamphlet to accompany
Scientific Investigations Map 3080

U.S. Department of the Interior
U.S. Geological Survey

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Suggested citation:
Barras, J.A., 2009, Land area change and overview of major hurricane impacts in coastal Louisiana, 2004-08: U.S. Geological Survey Scientific Investigations Map 3080, scale 1:250,000, 6 p. pamphlet.

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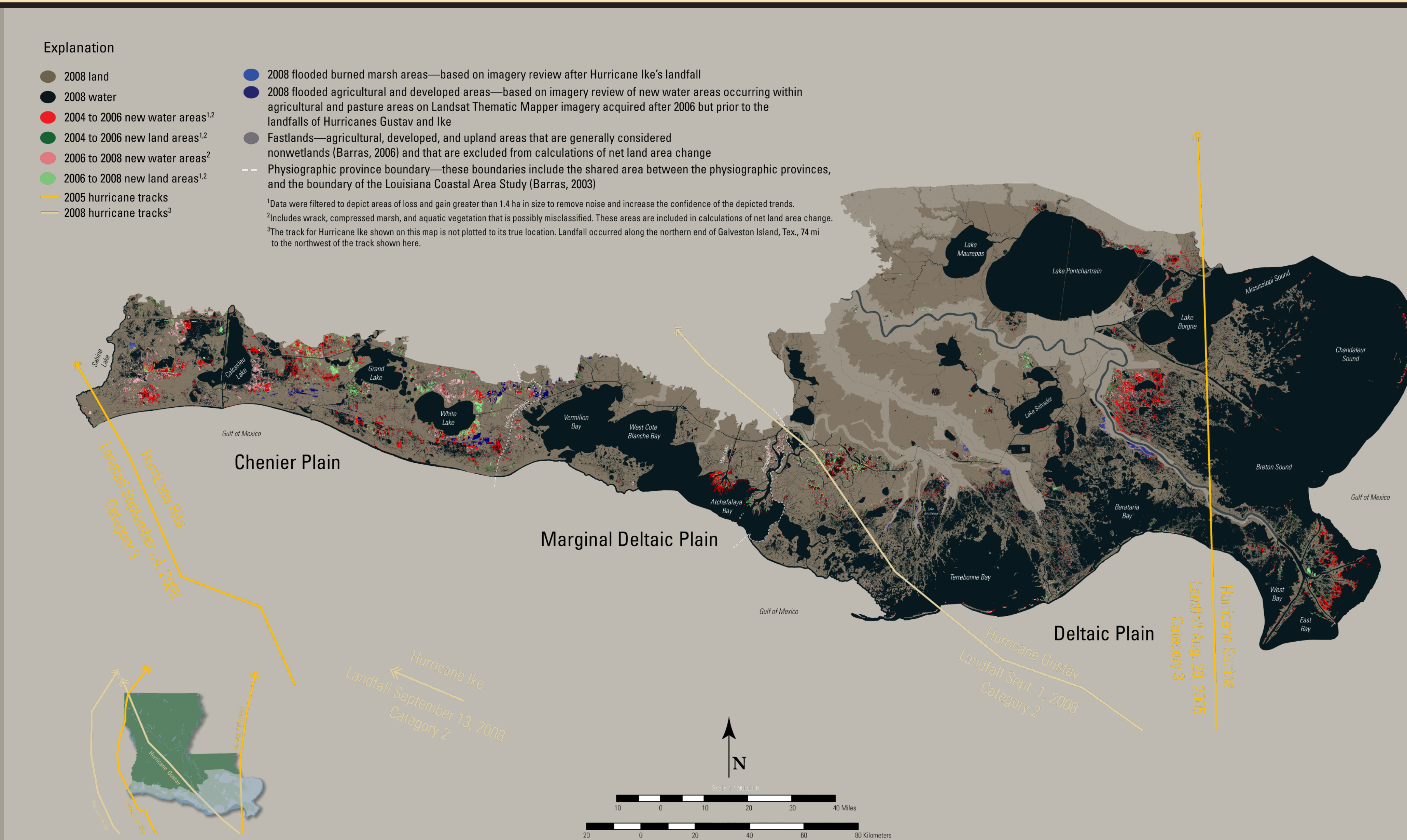
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[2]Includes wrack, compressed marsh, and aquatic vegetation that is possibly misclassified. These areas are included in calculations of net land area change.
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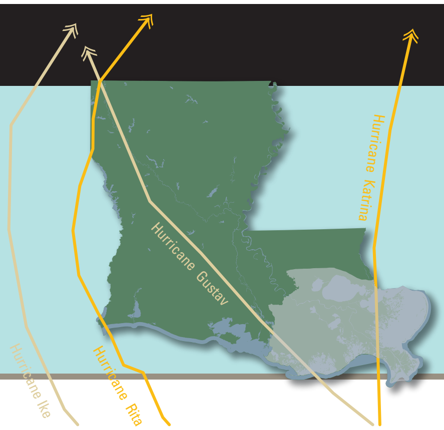
Chenier Plain
Marginal Deltaic Plain
Deltaic Plain
Sabine Lake
Calcasieu Lake
Grand Lake
White Lake
Vermilion Bay
West Cote Blanche Bay
Atchafalaya Bay
Terrebonne Bay
Barataria Bay
Lake Salvador
Lake Maurepas
Lake Pontchartrain
Lake Borgne
Mississippi Sound
Chandeleur Sound
Breton Sound
West Bay
East Bay
Gulf of Mexico
Gulf of Mexico
Gulf of Mexico
Hurricane Rita
Landfall September 24, 2005
Category 3
Hurricane Ike
Landfall September 13, 2008
Category 2
Hurricane Gustav
Landfall Sept. 1, 2008
Category 2
Hurricane Katrina
Landfall Aug. 29, 2005
Category 3
Hurricane Gustav
N
10 0 10 20 30 40 Miles
20 0 20 40 60 80 Kilometers



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Introduction

The U.S. Geological Survey (USGS) assessed changes in land and water coverage in coastal Louisiana within 2 months of Hurricane Gustav (September 1, 2008) and Hurricane Ike (September 13, 2008) by using Landsat Thematic Mapper (TM) satellite imagery. The purpose of this study is twofold: (1) to provide preliminary information on land-water area changes in coastal Louisiana shortly after Hurricanes Ike and Gustav made landfall and (2) to contrast these changes with prior, widespread land area changes caused by Hurricane Katrina (August 29, 2005) and Hurricane Rita (September 24, 2005) 3 years earlier (Barras, 2006; Barras 2007a,b; Barras and others, 2008). The data presented here serve as a regional baseline for monitoring wetland recovery following these storms.

Methodology

The USGS Center for Earth Resources Observation and Science (EROS) provided multiple Landsat TM images of coastal Louisiana that were acquired immediately before and after the landfalls of Hurricanes Gustav and Ike. Land-water conditions before the storms were represented by using a fall 2006 dataset classified by land and water coverage and developed for assessing area changes 1 year after the landfalls of Hurricanes Katrina and Rita (Barras and others, 2008). A series of seven Landsat TM scenes acquired between September 29 and October 26, 2008, provided a snapshot of land-water area changes after Hurricanes Gustav and Ike. A standard methodology was used to classify land-water conditions and identify changes between 2006 and 2008 (Barras and others, 2003; Morton and others, 2005; Barras, 2006; Barras and others, 2008). The 33,457.6-km^2 area of the Louisiana Coastal Area (LCA) Study, excluding fastlands (Louisiana Office of the State Registrar, 2002), was used as a standard comparison area (Barras and others, 2003). The observed 2006-08 changes were overlaid on existing 2004-06 changes identified by Barras and others (2008). Changes estimated in Barras and others (2008) reflect an estimate of conditions 1 year after the 2005 hurricane season, as compared to the analysis conducted by Barras (2006) immediately after the landfalls of Hurricanes Katrina and Rita in 2005.

The identification of potential hurricane impacts on the map is based on visual interpretation of multiple satellite images from a variety of sensors, including Landsat TM 5 and the Enhanced Thematic Mapper Plus (ETM+) aboard Landsat 7, as well as the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Satellite Pour l'Observation de la Terre (SPOT) 5. Visual interpretation of multiple images acquired after the consecutive landfalls of Hurricanes Gustav and Ike was used to identify potential surge-induced land loss. The same technique was used to successfully discern surge-caused land loss from remnant flooding after Hurricanes Katrina and Rita (Barras, 2006; Barras, 2007a, b).

This report presents changes in land area across coastal Louisiana, broken into three physiographic provinces (the term "coastal Louisiana" is used to present data on the collective area.) These provinces subdivide coastal Louisiana into the Deltaic Plain on the east, the Marginal Deltaic Plain between the Atchafalaya River and Freshwater Bayou, and the Chenier Plain to the west of Freshwater Bayou. The term "Marginal Deltaic Plain" is sometimes used interchangeably with "Chenier Plain" but is used to describe the central Louisiana coast in this study (boundaries are shown on the accompanying map; further definitions of the Deltaic and Chenier Plains can also be found in Saucier, 1994).

Quantification of preliminary changes in net land area was based on a limited snapshot of cloud-free TM imagery, primarily from Landsat 5. The Landsat TM 5 images of the western Chenier Plain were acquired on September 29, 2008, a little over 2 weeks after landfall of Hurricane Ike. The images of the eastern Chenier Plain, the Marginal Deltaic Plain, and the western and central portions of the Deltaic Plain were acquired during the first week of October 2008. The image representing the eastern Deltaic Plain was acquired during the last week of October 2008. The accompanying map depicts all gains or losses that occurred within the comparison intervals; however, tables 1 and 2 list net area changes only and do not account for gross gains and losses between comparison dates.

Table 1. Land and water areas in coastal Louisiana by physiographic province, 2004–08.

[Area measurements provided in km^2; TM, Landsat Thematic Mapper imagery classified by land and water]

Data set information			Deltaic Plain			Marginal Deltaic Plain			Chenier Plain			Coastal Louisiana		
Date	Julian date[1]	Data source	Land	Water	Total	Land	Water	Total	Land	Water	Total	Land	Water	Total
11/7/2004	2004.9	TM	9,686.6	14,592.1	24,278.7	1,833.7	1,958.0	3,791.7	3,820.3	1,567.0	5,387.3	15,340.6	18,117.1	33,457.7
10/28/2006	2006.8	TM	9,456.1	14,822.6	24,278.7	1,831.1	1,960.6	3,791.7	3,527.6	1,859.7	5,387.3	14,814.8	18,642.9	33,457.7
10/1/2008	2008.8	TM	9,331.8	14,946.9	24,278.7	1,771.6	2,020.1	3,791.7	3,387.7	1,999.6	5,387.3	14,491.1	18,966.6	33,457.7

[1]Represents the acquisition date for Landsat Worldwide Reference System, Path 22 and Rows 39–40 only, and provides a general date of reference for other scenes making up each coastal land-water dataset.

Table 2. Changes in land area and rates of land loss in coastal Louisiana by period and physiographic province, 2004–08.

[Area change measurements provided in km^2 (negative measurements indicate land loss, while positive ones indicate land gain); percent area change equals area change per period divided by total area change from 2004 to 2008]

Period	Years	Deltaic Plain		Marginal Deltaic Plain		Chenier Plain		Coastal Louisiana	
		Area change	Percent area change	Area change	Percent area change	Area change	Percent Area change	Area change	Percent area change
[1]2004 to 2006	2	-230.5	-65	-2.6	-4.2	-292.7	-67.7	-525.8	-61.9
[2]2006 to 2008	2	-124.3	-35	-59.5	-95.8	-139.9	-32.3	[3]-323.7	-38.1
2004 to 2008	4	-354.8	100	-62.1	100	-432.6	100	[3]-849.5	100

[1]The changes in this period reflect an estimate of conditions 1 year after the 2005 hurricane season as compared to the analysis conducted by Barras (2006) immediately after Hurricanes Katrina (Aug. 29) and Rita (Sept. 24) in 2005.

[2]The changes in this period reflect conditions immediately after Hurricanes Gustav (Sept. 1) and Ike (Sept. 13) in 2008.

[3]Flooded burned marsh and flooded agricultural and pasture areas account for 23.1 km^2 of net water area changes.

Discussion

Land-water area totals are provided by physiographic province for 2004, 2006, and 2008 (table 1; fig. 1). Figure 2 presents a historical perspective on land area change before the 2004–08 period. It is important to bear in mind that the 2004 Landsat TM imagery represents the endpoint of the 1978–2004 period, a 26-year interval characterized by low-intensity hurricane landfalls within coastal Louisiana except for Hurricane Andrew on August 26, 1992. Imagery acquired after the 2005 hurricanes conveys a more complex, partially recovered coastal landscape that was again subjected to compound surge impacts from Hurricanes Gustav and Ike in 2008. The compounding effects of multiple, significant hurricane landfalls in the 3-year period (with time for some amount of recovery from temporary impacts in between) thus complicate land-water interpretations. The Chenier Plain is particularly problematic because of the existence of many impoundment areas that may contain wetlands, agricultural and pasture areas, or developed areas. These impoundments can retain water for long periods, further complicating land-water interpretation after a storm event.

Comparison of the 2006 and 2008 imagery showed a total decrease in land area (increase of water) of 323.7 km^2 (tables 1 and 2). This reduction, combined with the 2004–06 land area reduction of 525.8 km^2 results in a total reduction in land area of 849.5 km^2 in coastal Louisiana since 2004. It is important to note, however, that the net gain of new water detected in the 2008 imagery contains approximately 23.1 km^2 of area identified as flooded agricultural impoundments and flooded burned marsh, slightly reducing the estimate of water gain during that interval. The 2006 and 2008 datasets are, nevertheless, comparable because the earlier dataset also contains impoundment areas that were still flooded from Hurricane Rita (2005), as well as areas of flooded marsh burns that were either fully or partially recovered. Some of the partially recovered marsh burns flooded by Hurricane Rita still retained water in 2006 and even in 2008.

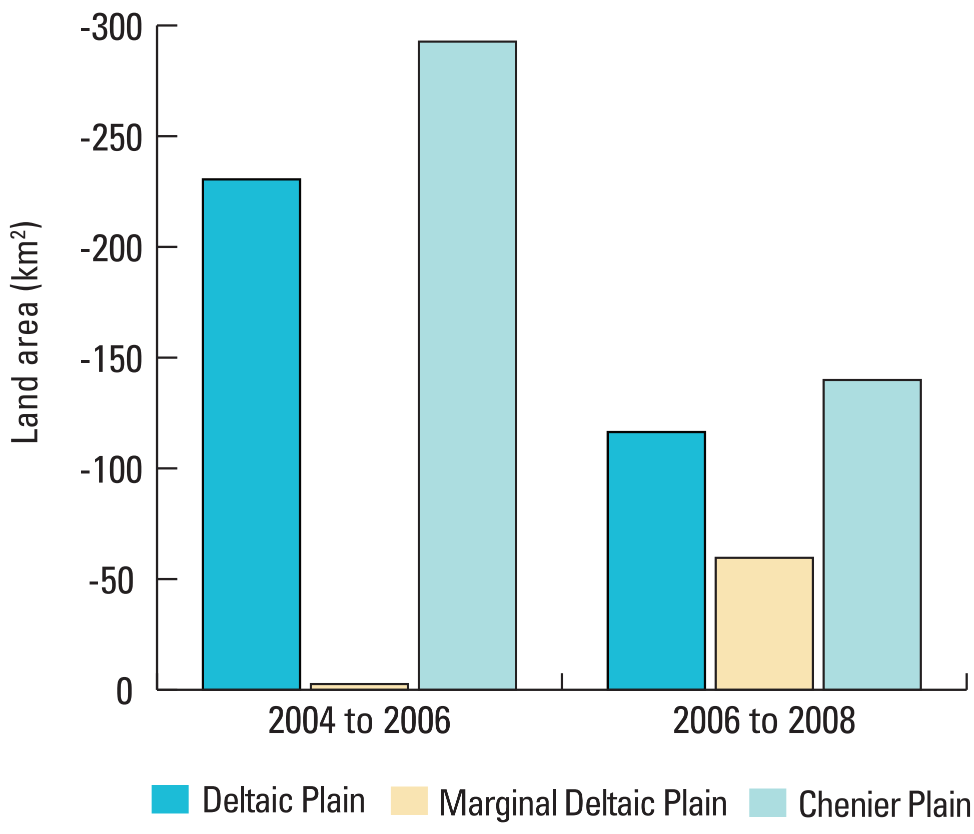

Figure 1. Net land area change by period and by physiographic province in coastal Louisiana, 2004–08.

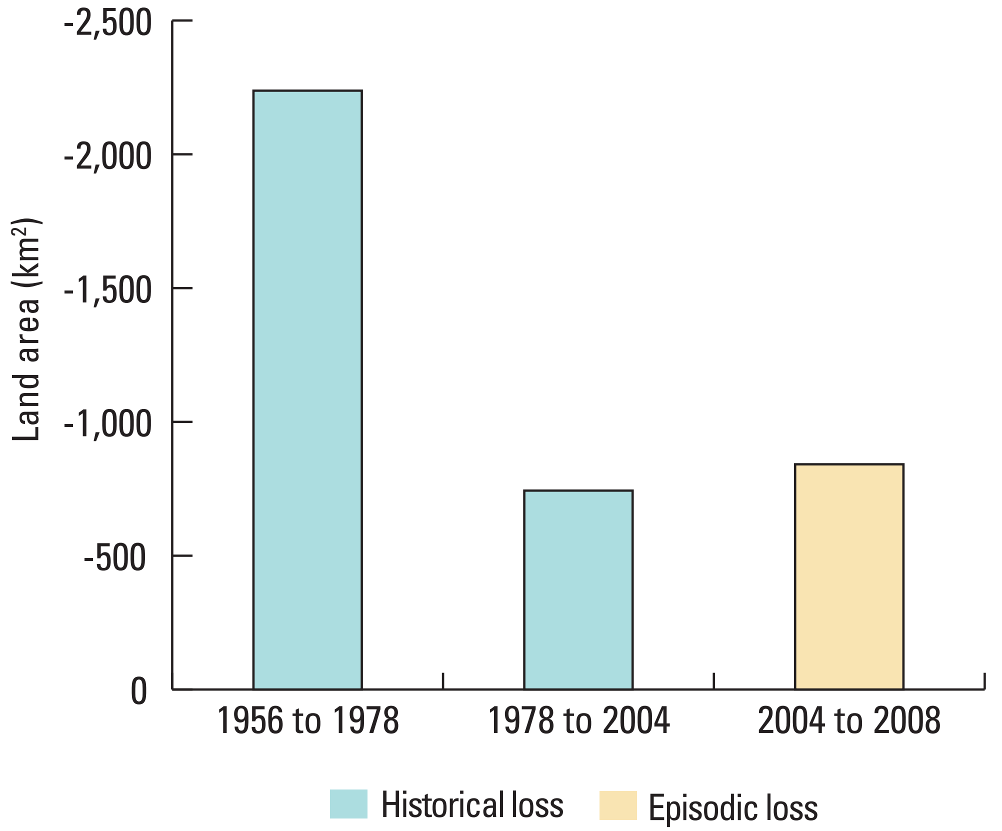

Figure 2. Net land area change by period in coastal Louisiana, 1956–2008. The net decrease in land area is estimated at 3,841 km². Estimates of land area change from 1956 to 1978 and from 1978 to 2004 are from Barras (2008).

The coastwide 323.7-km² area of net land reduction occurring after the 2008 hurricanes is less than the initial, 562.1-km² reduction of land measured immediately after the 2005 hurricanes (Barras, 2006). Nevertheless, observed areas of new water following the 2005 and 2008 hurricane seasons have similar causal processes and morphological characteristics although surge-induced features may vary in scale and magnitude depending on storm characteristics. New water and land areas detected after a weather event are characterized by a combination of permanent and transient features. For example, new water areas may be permanent when caused by direct removal of wetlands by storm surge, but they may also be transitory when caused by remnant flooding of marsh and impounded areas (including agricultural and developed areas), removal of floating and submerged aquatic vegetation, scouring of marsh vegetation, or water-level fluctuations caused by normal tidal and meteorological variation between images. Likewise, new land areas may be transient when wrack deposition, rearrangement of existing marsh areas moved by storm surge, aquatic vegetation that is possibly misclassified, or water-level fluctuations caused by normal tidal and meteorological variation between images. Such transitory gains and losses are included in calculations of net land area change from 2004 to 2008.

The distribution of new water areas after Hurricanes Gustav and Ike shared similar morphologies but varied in magnitude and distribution. Surge impacts of Hurricane Gustav in the Deltaic Plain are smaller in scale and magnitude than surge impacts of Hurricane Ike in the Chenier Plain. Furthermore, Hurricane Katrina caused far more observable damage at TM spatial scales within the Deltaic Plain in 2005 than did Hurricane Gustav in 2008. The most noticeable impacts within interior marsh from Hurricane Gustav were reactivated ponds caused by the surge of Hurricane Katrina; these ponds, some containing disturbance vegetation (Steyer and others, 2007), occurred in intermediate and fresh marshes (Chabreck and others, unpub. data, 2001) located between Lake Lery and the Mississippi River. On the basis of the October 1, 2008, Landsat TM image, an estimated 1,690 ha of wrack was deposited adjacent to the back flood protection levees in this area and appears on the accompanying map as land gain (in green) between 2006 and 2008. Hurricane Katrina deposited a lesser amount of wrack in the same location in 2005. The marsh north of Lake Lery and south of the storm protection levee was scoured heavily in some areas by Gustav's surge, forming a new 182-ha pond. Hurricane Gustav also caused shoreline erosion and some limited marsh-ripping to the west and southwest of Little Lake, south of Montegut, and north of Lake Boudreaux. Scattered areas of land reduction (water gain) bordering Terrebonne Bay that are apparent when comparing the 2006 and 2008 imagery were mostly caused by higher water levels (in 2008) filling small ponds that were partially drained (in 2006) because of a combination of lower water levels and consistent north winds. Although those areas of scattered land reduction are transient, Hurricane Gustav did cause significant erosion of the barrier islands forming the southern boundary of Terrebonne and Timbalier Bays. Furthermore, land area of the Chandeleur Islands was reduced to 544.5 ha, a reduction of 102.6 ha from the island's land area of 647.1 ha in 2006. It is possible that surge impacts of Hurricane Gustav would have been more evident in the interior marsh of upper Breton Sound if not for the major land loss caused by Hurricane Katrina 2 years earlier (fig. 7a in Barras, 2007b). In the absence of those impacts from Hurricane Katrina, surge from Hurricane Gustav would have likely enlarged existing ponds and formed new ponds in this area, as did Tropical Storm Isadore on September 26, 2002 (fig. 9 in Barras, 2007b).

Surge impacts of Hurricane Ike (2008) were very similar to those of Hurricane Rita (2005); however, following Hurricane Ike significant, surge-formed and surge-expanded ponds were not really noticeable east of Vermilion Bay (fig. 21a in Barras, 2007b). Some new scours located on southeastern Marsh Island, shown on the accompanying map, were originally scoured by Hurricane Lili on October 3, 2002 (fig. 18b in Barras, 2007b). Water levels were visibly lower on the 2006 imagery of the Marsh Island area, causing the shallow scours to be classified as land in that dataset. The 2008 water levels were visibly higher, causing the scours to appear as ponds. In some instances, Hurricane Ike's surge formed significant new ponds and expanded existing ponds formed by Hurricane Rita in almost identical locations within intermediate marshes. These features were found adjacent to Freshwater Bayou (fig. 21a in Barras, 2007b), between the western shoreline of Vermilion Bay and the northern boundary of Johnsons Bayou, and east of Sabine Lake. After Hurricane Ike, some of these surge-formed features where the marsh was completely removed exceeded 405 ha in size. Furthermore, during Ike's landfall, north to south anastomosing channels were cut through the intermediate marsh located 11.5 km north-northwest of Johnsons Bayou. Debris from these channels was deposited in existing ponds and appears as areas of land gain (in green) on the accompanying map. After Hurricane Ike, linear striations ranging from 0.5 to 2 km were observed 14 km north-northwest of Johnsons Bayou. These features have similar morphology of surge-induced striations formed by Hurricane Rita 19 km northeast of Johnsons Bayou 3 years earlier (fig. 25 in Barras, 2007b). Large areas of 2006–08 land loss in the marsh to the east and southeast of Calcasieu Lake (8 km northeast of Cameron) were caused by water-level variations in low-elevation brackish and intermediate marsh. These areas also appeared inundated on Landsat TM imagery of the area acquired under higher water-level conditions following Hurricane Rita (fig. 24 in Barras, 2007b). The December 2, 2006, imagery used to create this portion of the 2006 coastal land-water mosaic shows more exposed, low-elevation marsh than does the September 29, 2008, imagery. Higher water levels observed on the September 29, 2008, Landsat TM image inundated these low-elevation marsh areas. Hurricane Ike also formed new ponds and expanded existing ponds in a similar manner as Hurricane Rita did on the eastern Texas Chenier Plain, although this area is not depicted on the accompanying map. One of these expanded ponds, located just north of the Gulf Intracoastal Waterway, exceeded 567 ha and completely encompassed the water body formerly known as Blind Lake. The resistance of brackish and saline marsh communities to surge erosion observed after Hurricanes Katrina and Rita in 2005 (Barras, 2006) was again observed after Hurricanes Gustav and Ike in 2008.

Fresh and intermediate marshes appear to be more susceptible to surge impacts, as observed in Barras (2006). Surge from all four hurricanes formed ponds in stable, contiguous marsh areas and expanded existing, small ponds, as well as removed material in degrading marshes. Land gain from 2006 to 2008 caused by sediment placement for coastal restoration projects was observed in several locations, including 4.3 km south-southeast of Lacombe in the marsh adjacent to Lake Pontchartrain, in the marsh south shore of Little Lake, along the northwestern shoreline of Lake Boudreaux, in the Mississippi River Delta, just north of where Pass a Loutre splits from the main Mississippi River channel, and bordering the Atchafalaya Delta.

Conclusion

Caution must be exercised when interpreting and quantifying immediate land-area changes after a hurricane season. The estimates of land area change presented here are strictly considered to be preliminary and are likely to fluctuate and decrease somewhat with time. The update of the 2006 analysis of land area changes after the 2005 hurricane season (Barras, 2008) illustrates how land area measurements vary after episodic events. More time is required to evaluate the cumulative, long-term impacts of hurricanes on coastal land loss.

The 2008 storms impacted a coastal landscape that was still incorporating the impacts from two significant category 3 storms in 2005 (Barras, 2006; Barras, 2007a, b). Normal seasonal variations with short-term fluctuations in water levels affect interpretation of land area based on satellite imagery and can cause area changes of 5 percent (Morton and others, 2005; Bernier and others, 2007). Combining these normal, short-term land area variations with the effects of multiple episodic impacts over a short 3-year period will cause even greater variation in the classification of land-water configurations (Barras and others; 2008). Although the net reduction in land from 2004 to 2008 (849.5 km^2) exceeds that from 1978 to 2004 (743.3 km^2) (Barras, 2008), it is likely that the 2004–08 estimate will decrease, given time for the coast to recover from those hurricane seasons. Nevertheless, it is likely that the cumulative loss from these hurricane seasons will remain significant. Estimation of permanent losses cannot be made until several growing seasons have passed and the transitory impacts of the hurricanes are accounted for.

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Publishing support provided by
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