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Land-Cover Change in Upper Barataria Basin Estuary, Louisiana, 1972–1992: Increases in Wetland Area

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ABSTRACT / The Barataria Basin, Louisiana, USA, is an extensive wetland and coastal estuary system of great economic and intrinsic value. Although high rates of wetland loss along the coastal margin of the Barataria Basin have been well documented, little information exists on whether freshwater wetlands in the upper basin have changed. Our objectives were to quantify land-cover change in the upper basin over 20 years from 1972–1992 and to determine land-cover transition rates among land-cover types. Using 80-m resolution Landsat MSS data from the North American Landscape Characterization (NALC) data archive, we classified images from three time steps (1972, 1985, 1992) into six land-cover types: agriculture, urban, bottomland hardwood forest, swamp forest, freshwater marsh, and open water. Significant changes in land cover occurred within the upper Barataria Basin over the study period. Urban land increased from 8% to 17% of the total upper basin area, primarily due to conversions from agricultural land, and to a lesser degree, bottomland forest. Swamp forest increased from 30% to 41%, associated with conversions from bottomland hardwood forest and freshwater marsh. Overall, bottomland forest decreased 38% and total wetland area increased 21%. Within the upper Barataria, increases in total wetland area may be due to land subsidence. Based on our results, if present trends in the reduction of bottomland forest land cover were to continue, the upper Barataria Basin may have no bottomland hardwood forests left by the year 2025, as it is subjected to multiple stressors both in the higher elevations (from urbanization) and lower elevations (most likely from land subsidence). These results suggest that changes in the upper freshwater portions of coastal estuaries can be large and quite different from patterns observed in the more saline coastal margins.

The extent of coastal and inland wetlands in the United States has declined markedly since European settlement. According to the US Fish and Wildlife Service and the National Wildlife Federation, more than 81 million ha of wetlands were present in the continental United States in the early 1700s, but only 35–40 million ha remained as of the mid-1980s (Dahl and others 1991). Wetland losses have been attributed to a number of factors such as agricultural land conversions, urbanization, and erosive natural processes. The draining and filling of wetlands for agriculture accounted for as much as 54% of total wetland losses between the mid-1950s and the 1970s, while urban land conversions accounted for only 5% (Dahl and others 1991). Because of recent legislation protecting wetlands and changes in how wetlands are valued, it is unclear whether these land use transitions have continued from the 1970s to today.

Natural changes in coastal wetlands result from wind and wave pressures, episodic storm events, land subsidence, variations in hydrological cycles leading to flooding or drying out, and eustatic sea level rise along coastal margins (Mitsch and Gosselink 1986). Currently, coastal Louisiana, which contains approximately 27% of the coastal wetlands found within the continental United States, is experiencing estimated loss rates ranging from 6000 to 12,450 ha/yr (Visser and others 1999). These estimates are the highest rates of wetland

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loss in the United States and have been attributed to high land subsidence rates and sea level rise compounded by the artificial levying of the Mississippi River Deltaic Plain and other factors (e.g., canal dredging and erosion) (Scaife and others 1983, Conner and others 1987, Visser and others 1999). Although coastal estuaries, which are experiencing such high loss rates, have been well studied, there has been less documentation of the changes occurring in the freshwater portions of the estuary systems, which are subject to additional pressure from agriculture and urban development.

In particular, within the Barataria Basin, Louisiana, USA, a large coastal estuary, much attention has focused on the high coastal wetland loss and increases in open water in the lower coastal basin that are a result of anthropogenic modifications and natural processes (Turner 1997, Sklar and Browder 1998, Martin and others 2000). However, little information exists on how other components of the estuary have changed, especially the freshwater wetlands in the upper basin. Some have suggested that increased urbanization, industrialization, and agricultural practices will lead to increasingly eutrophic conditions within the basin's upper freshwater zones (Stow and others 1985). Because the upper basin is tightly linked hydrologically to the lower basin, large changes in the upper basin may strongly impact the lower basin.

Understanding changes in the Barataria is especially important because an estimated 97% of all commercially valuable Louisiana Gulf of Mexico fisheries species depend, for some or part of their life cycle, on the productivity of the Barataria and adjacent coastal estuarine basins. This estimate makes up approximately 20% of the US commercial seafood harvest, approximately 500 million pounds of fish and shellfish per year. However, this region has only recently been officially designated as a nationally valuable resource, being included in the US Environmental Protection Agency's (EPA) National Estuary Program in 1990 as part of the Barataria-Terrebonne estuarine system.

Since the early 1980s, remote sensing techniques have become commonly used to detect wetland change. Remotely sensed images and geographic information systems (GIS) are being used to address critical coastal resource management problems, providing researchers with the ability to make rapid decisions at large spatial scales using recent data (Ricketts 1992). However, fewer studies have taken advantage of the wealth of historical data available from the few satellite platforms that have been operating across several decades and that are becoming widely available and inexpensive (Munyati 2000). For example, the images obtained using the Landsat Multispectral Scanner (MSS) sensor presently represent our longest, continuous, remotely sensed satellite historic record. This sensor spans a time period where we know large changes have occurred in land cover (1972–present). Although, few studies have used the MSS sensor's >20-year archival data source for historic wetland change determination, several researchers have used Landsat MSS data to identify wetland change across smaller time periods with a fairly high degree of accuracy (Jensen and others 1986, Haack 1996, Munyati 2000). The coarse resolution of MSS (80 m) provides an additional advantage in that it allows coverage of a large spatial area.

Our objectives were to quantify land-cover change in the upper Barataria Basin from 1972 to 1992, to determine land-cover transition rates among land cover types and to evaluate the accuracy of MSS to detect wetland and other land-cover change. We obtained Landsat MSS data from the North American Landscape Characterization (NALC) data archive and classified land cover in each scene using a supervised image classification approach. We use the term land cover to refer to both human (agricultural and urban) and natural (wetland and forest) land covers. We found large changes in both human and natural land covers across the study period that are different from known changes in the lower, coastal regions of the Barataria basin.

Study Area

The Barataria Basin (Figure 1) makes up the eastern-most region of the Barataria-Terrebonne estuary system. This 628,600-ha area is located in southern Louisiana south of New Orleans and extends into the Gulf of Mexico at its widest portion. Natural and artificial levees, completed in the 1940s, hydrologically isolate the Barataria from sources of riverine sediment input (Conner and others 1987, Miller and others 1995). The Barataria can be divided into three zones based on a salinity gradient. The upper freshwater portion, or upper Barataria Basin, consists of swamp forest–freshwater marshes (0–2 ppt); the middle low salinity portion (2–10 ppt) is made up of brackish marsh; and the lower portion (6–22 ppt) is the saltwater coastal marsh zone (Conner and others 1987, Miller and others 1995). For this study, we focus on the upper swamp forest–freshwater marsh zone only, which makes up 27% (170,370 ha) of the total basin area. There are two open waterbodies within the upper basin: Lac des Allemands and Lake Boeuf, which did not change across the study period and so were removed from the land cover change analysis.

Agriculture and urban land covers are found in

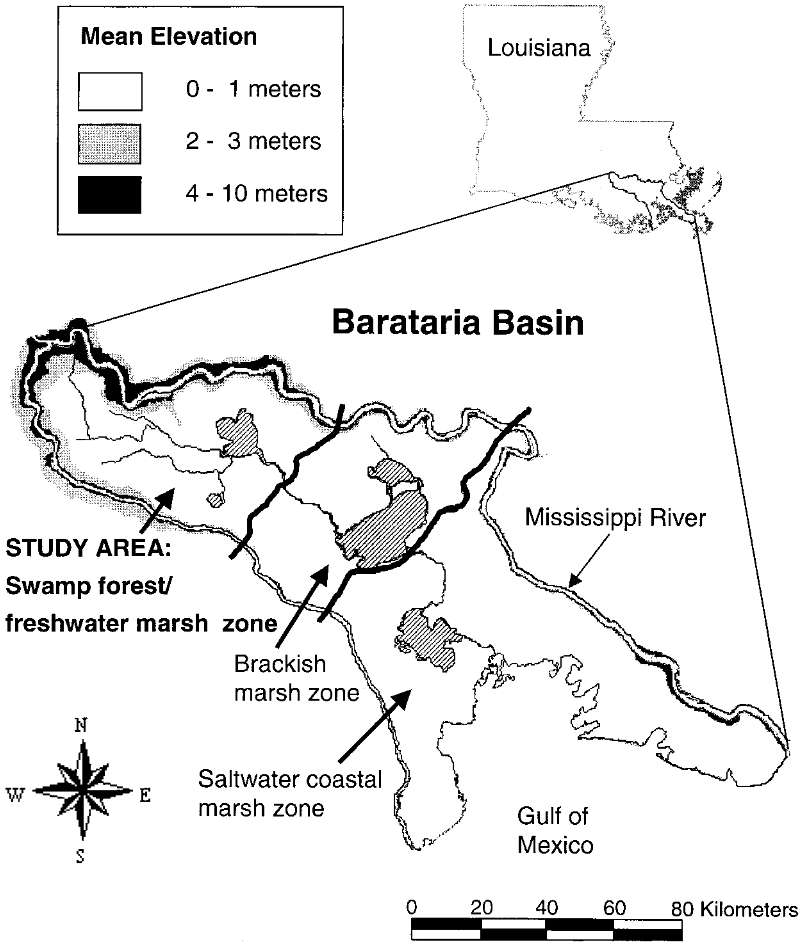

Figure 1. Zones within the entire Barataria Basin, including the upper swamp forest/freshwater marsh zone (this study), the brackish marsh zone and the saltwater marsh zone, which represent the upper, middle, and coastal regions, respectively. Three levels of elevations are shown in white, gray, and black. Hashed areas are inland lakes.

higher elevation areas along the levee system of the upper Barataria, whereas the freshwater marsh and swamp forest are in the lowest elevation areas (Figure 1). Bottomland hardwood forest exists in less frequently flooded lower elevation areas and along the lower perimeter of the levee system. The bottomland hardwood forest land cover is comprised largely of American elm (*Ulmus americana*), sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), and swamp red maple (*Acer rubrum* var. *drummondii*). Swamp forest is comprised of baldcypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*). Freshwater marsh is comprised largely of a floating marsh known locally as "flotant." Flotant consists of vegetative mats of detritus, algae, and plant roots that support maidencane (*Panicum hemitomon*), spikerush (*Eleocharis* sp.) and bulltongue (*Sagittaria falcata*).

The majority of freshwater input into the upper Barataria is from rainfall (Conner and others 1987). Average annual rainfall measured at the New Orleans, Louisiana Weather Data Center from 1972 to 1992 was 171 cm/yr (± 36 cm/yr SD). Annual rainfall for each of the three time periods used in this study was 163, 170, and 208 cm/yr for 1972, 1985, and 1992, respectively. During our study period, annual rainfall showed no significant trends through time ($R^2 = 0.009$, $P = 0.68$).

Methods

Satellite Image Data

We acquired four 80-m resolution, Landsat MSS scenes covering the upper Barataria Basin from the North American Landscape Characterization (NALC) data archive (Earth Resources Observation Systems Data Center, Distributed Active Archive Center, Sioux Falls, South Dakota, USA) for three time periods: 1 and 10 October 1972, 31 August 1985, and 5 October 1992. Because the 1972 data were sensed from the older Landsat (1, 2, and 3) platforms with a larger swath width, these scenes were slightly out of phase with the

Table 1. Error matrix for comparison between 1992 classification to higher resolution Landsat TM (30-m) reference scene from 20 October 1995[a]

	Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	Water	Total
Urban	**41**	1	1	0	0	0	43
Agriculture	9	**42**	0	0	0	0	51
Bottomland forest	1	0	**22**	0	0	1	24
Swamp forest	1	0	4	**107**	0	0	112
Freshwater marsh	2	0	0	1	**11**	0	14
Water	0	0	0	1	0	**11**	12
Total	54	43	27	109	11	12	256

[a] The number of correctly classified pixels for each land cover are on the diagonal in bold.

1985 and 1992 scenes and required two scenes to cover the extent of the upper Barataria Basin. All scenes were geometrically rectified to a digitally scanned, 1:100,000-scale USGS quadrangle topographic map covering the upper Barataria Basin. Each scene was coregistered with a corresponding digital elevation model (DEM) and transformed to Universal Transverse Mercator (UTM). A nearest-neighbor algorithm was used to perform the resampling procedure and the image-to-map registrations, which yielded a root-mean-square error of 0.95 pixels for all data. The two 1972 scenes were mosaicked to create a single 1972 image.

Supervised Image Classification

To ensure consistency among classifications of the three time steps, we performed two preprocessing procedures on each scene. First, each scene was normalized to the 1992 scene by using contrast stretching and histogram matching procedures to reduce atmospheric differences across all three scenes. Second, we developed a ratio of bands 1 and 2 to correct distortions inherent in each scene. The band ratioing procedure reduced the scene distortion by dividing brightness values of pixels in one band by the brightness values of the corresponding pixels in another band.

We then used a supervised classification procedure to classify the 1992 scene using spectral training samples, seed pixels, and a maximum likelihood algorithm. We identified six major land-cover types as described by Conner and others (1987): agriculture, urban, bottomland hardwood forest, swamp forest, freshwater marsh, and open water. Histograms of all bands were developed for each land-cover class to determine average spectral signatures. Spectral signature separability was computed to determine the statistical distance between signatures. The final spectral signatures for the 1992 classification, resulting from a band combination of 4, 2, and our band ratio, were then used to classify the 1972, 1985, and 1992 scenes. We then applied a 3 × 3 focal majority filter model to all three classifications, which is a postclassification smoothing operation to reduce the number of misclassified pixels. Finally, we manually recoded <10% of the pixels in all three classified images that were obviously misclassified when compared to the raw scenes. For example, some obviously urban and agricultural pixels were misclassified as freshwater marshland cover. Freshwater marsh should not occur in the higher elevation areas. This obvious misclassification represented the majority of our manual pixel reclassifications.

Accuracy Assessment

To estimate the classification accuracy, we developed two error contingency matrices from the 1992 classification using two different reference scenes, and calculated the probability of misclassifications through estimates of omission and commission errors. For the first assessment, we used a 28 September 1995 Landsat Thematic Mapper (TM) scene (30-m resolution) that covered 100% of the study area and yielded an overall classification accuracy of 91% using 256 randomly generated points (Tables 1 and 2). For the second assessment, we used high resolution (3-m) photographs from a three-band digital aircraft camera from 20 October 1995 that covered approximately 43% of the study site. The MSS data was subset to match the spatial extent of the aircraft photographs. One hundred ten points were randomly generated to represent 43% of the total area. The overall classification accuracy of this assessment was 87%. Because both assessments yielded similar results, we present data for only the Landsat TM scene since it covered the entire study area. No reference imagery was available for the 1970s and 1980s classifications. However, given the high accuracy of the 1990s classification, we assumed that the identical techniques used in the development of all three classifications would have produced comparable accuracy. Field validation would have provided optimal assessment of our

Table 2. Classification accuracy for comparisons between 1992 classification to higher resolution Landsat TM (30-m resolution) reference scene[a]

	Reference scene totals	Classified totals	Number correct	Accuracy (%)
Urban	54	43	41	76
Agriculture	43	51	42	98
Bottomland forest	27	24	22	82
Swamp forest	109	112	107	98
Freshwater marsh	11	14	11	100
Water	12	12	11	92
Total	256	256	234	91

[a] The reference scene totals column refers to the number of pixels in each land cover identified within the Landsat TM reference scene. The classified totals are the number of pixels in each land cover from our 1992 classification scene. The "number correct" is the number of pixels in our classification that match the Landsat TM scene. Accuracy (%) is the percent correctly classified for each land cover. The overall classification accuracy produced from this assessment was 91% with an overall kappa statistic of 0.88.

classification accuracy. However, due to the large size of our study area and the fact that our study used historical data, ground-truthing was not possible (Jensen and others 1995).

Land Change Analysis and Transition Matrices

Land-cover area and percentages for the entire upper basin were calculated for each time step for individual cover types and for two broader categories: developed land (urban and agriculture) and natural land cover (bottomland hardwood forest, swamp forest, and freshwater marsh). We developed transition matrices to identify shifts between individual land-cover types in successive time steps and overall changes occurring throughout the entire study period. To develop these matrices, we calculated: (1) the area of land in hectares converted from each land cover into each of the remaining categories, (2) the proportional area of land (%) converted from each land cover into other categories, and (3) the total proportion (%) of each individual land category converted into other categories.

Results

In all time steps, agriculture and urban land cover dominated the upland areas around the perimeter of the basin and natural land classes dominated the lower elevation areas (Figure 2). However, distinct changes in land cover occurred across the time steps (Figure 3). Agricultural land, bottomland hardwood forest, and freshwater marsh all decreased through time, whereas urban land and swamp forest increased. Because open water remained unchanged throughout the study period, we removed this category from all further analysis.

Across the broader categories, there were small changes in total human-dominated land cover and in total natural land cover (Figure 4). However, there were large changes within each category. In 1972, agriculture land cover made up 75% of the human-developed land, but only approximately 50% by 1992. Urban land cover made up 25% of the human-developed land in 1972 and increased to approximately 50% by 1992. For the natural land-cover category, bottomland hardwood forest and freshwater marsh decreased, whereas swamp forest increased throughout the entire study period. We further combined two wetland categories (freshwater marsh and swamp forest) to examine total wetland area changes in the upper basin (Figure 5). In 1972, the total wetland area was 64,718 ha (38% of the upper basin). By 1992 this area had increased to 78,488 ha (46%), gaining 13,770 ha over the entire study period.

Table 3 shows the rate of land-cover change between each time step. The largest overall rates of change across the whole study period were an increase of 937 ha/yr of swamp forest from 1972 to 1992, and an increase of 993 ha/yr for urban land cover from 1972 to 1992. However, the rate of change of urban land significantly decreased over the next time step to 288 ha/yr (1985–1992). Freshwater marsh showed a net loss at a rate of 363 ha/yr (4720 ha) between 1972 and 1985, but only 36 ha/yr (249 ha) between 1985 and 1992.

To examine in more detail how land classes changed, we calculated land-cover transition matrices (Tables 4–9). Two land-cover conversions were most prominent: the conversion of land in the upland perimeter of the basin from agriculture to urban land, and the conversion in the lower elevations from bottomland hardwood forest to swamp forest land cover. All land-cover categories changed as might be expected: agriculture land cover primarily changed to urban; freshwater marsh to swamp forest; and bottomland hardwood forest to swamp forest.

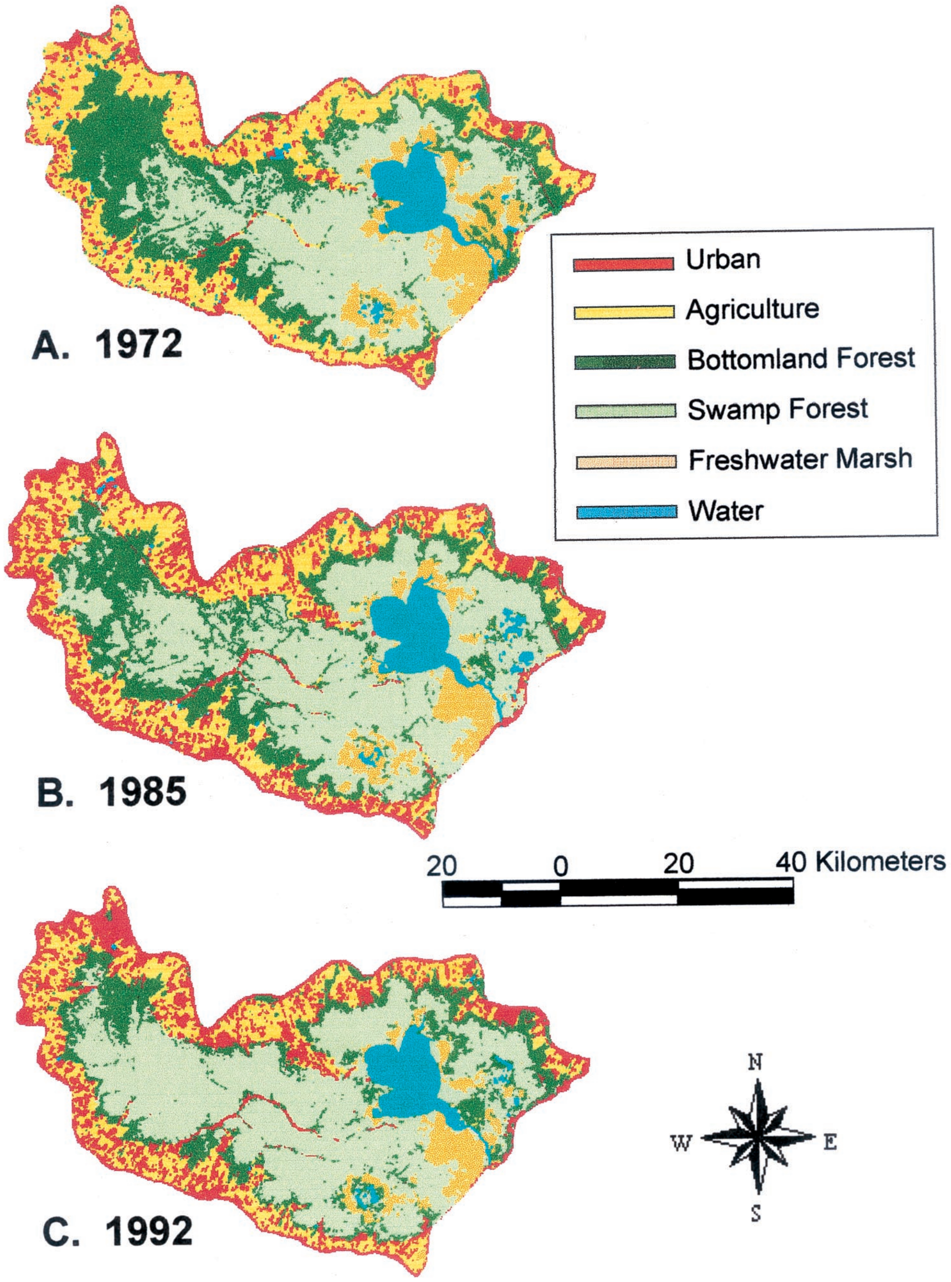

Figure 2. Classified land cover from Landsat MSS images for each time step.

However, although most urban land cover was converted from agricultural land, there were also unlikely transitions from urban land to freshwater marsh, swamp forest, and bottomland hardwood forest. In most cases these transitions occurred at a rate of 1% or less, which is within the error of the data. Another unlikely transition was from urban land cover to agriculture land cover (3%–6% of the total urban area of the upper basin landscape) (Tables 8 and 9). This transition is also likely to be a misclassification, and it also falls within the error of the data.

Discussion

Studies of wetland change in the Barataria basin as well as other coastal estuaries have focused on wetland loss primarily in lower coastal zones (Turner 1997, Martin and others 2000, Day and others 2000). However, because the upper freshwater zones of coastal estuaries are subject to different human influences and physical drivers than the lower coastal zones, different trends in land-cover changes are likely to occur. We found that important changes

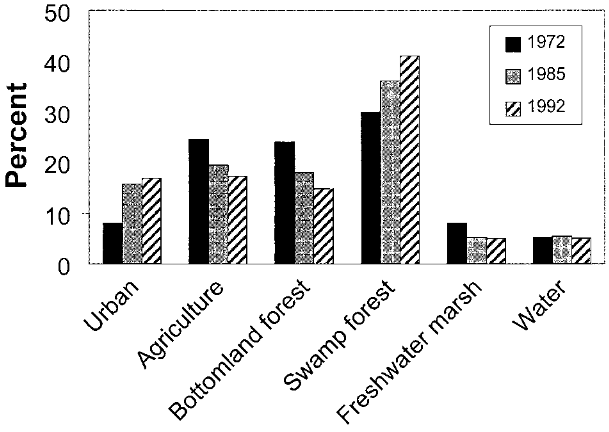

Figure 3. Percent cover of each land-cover class in the upper Barataria Basin in each time step.

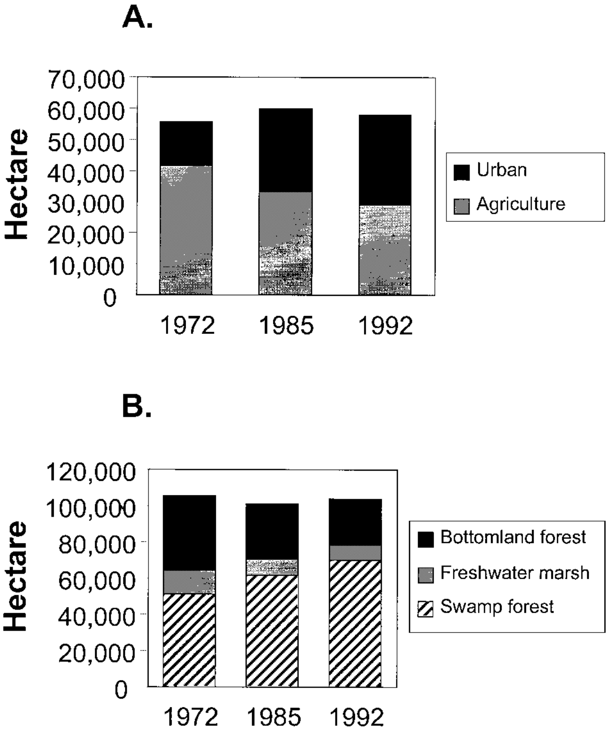

Figure 4. The area (hectare) of land cover occurring within human-developed land-cover classes only (A), and within natural land-cover classes only (B) in each time step.

have occurred in the upper freshwater parts of the basin, which are quite different from trends observed for lower coastal zones. In particular, we found two major land-cover trends in the upper Barataria Basin. The first is a change within human developed land cover (agriculture and urban land cover) in the upland regions of the upper basin, and the second is a change within the natural land cover (swamp forest, bottomland forest and freshwater marsh) in the low elevation regions of the upper basin. We explore both trends in detail below.

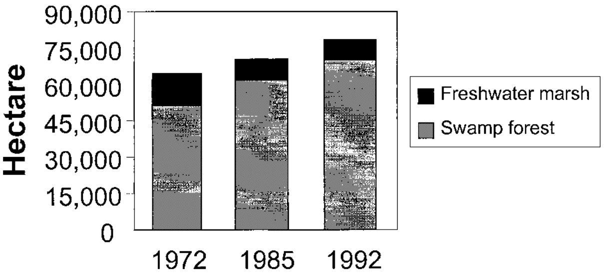

Figure 5. Changes in total wetland area (hectare) and wetland types from in each time step.

For the upper Barataria Basin, Hopkinson and Day (1980) predicted a 321% increase in urban land from 1975 to 1995 based on projections from the Louisiana State Planning Office. We found only a 108% increase in urban land from 1972 to 1992, which is lower than predicted, but still large. Based on data from 1985 to 1992, it appears that urban lands are increasing at a rate of 288 ha/yr at the expense of agricultural lands. The conversion from agricultural lands in 1972 to urban lands in the upper basin in the 1990s and beyond may have significant impacts on nutrient loading to the adjacent swamp forest, the open water areas, and the lower coastal zones, which warrants further research. Any changes that are observed in natural land cover in the lower elevations must be considered in light of these changing patterns in upland areas.

In the low elevation regions of the upper basin, we found that swamp forest increased at the expense of bottomland forest and freshwater marsh, although the transition from bottomland forest was the dominant change. Our results suggest an encroachment of the wetter swamp forest areas into higher elevation edge areas that are dominated by bottomland hardwood forest. We found that 46% of bottomland hardwood forest was converted to swamp forest over this period. It is very likely that land subsidence is the cause of these changes in natural land cover (Kress and others 1996). However, we must also consider other human drivers of change. Although we found only moderate transitions from bottomland forest to urban land cover (115 ha/yr), this rate may increase if urbanization continues and as agricultural lands are diminishing, creating a further threat to bottomland hardwood forests. Based on our results, if

Table 3. Total area of land-cover change between each time step (ha) and rate of land-cover change (ha/yr) between each time step for each land-cover category[a]

	1972–1985		1985–1992		Total: 1972–1992	
	Area (ha)	Rate of Change (ha/yr)	Area (ha)	Rate of Change (ha/yr)	Area (ha)	Rate of change (ha/yr)
Urban	12,906	993	2,013	288	14,919	746
Agriculture	−8,534	−656	−4,075	−582	−12,609	−630
Bottomland forest	−10,228	−787	−5,305	−758	−15,533	−777
Swamp forest	10,582	814	8,157	1,165	18,739	937
Freshwater marsh	−4,720	−363	−249	−36	−4,969	−248

[a] Positive numbers are gains in land-cover area and negative numbers are losses in land cover.

Table 4. Total area (ha) of land converted from one land cover to the next between 1972 and 1985[a]

		1985					
		Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	1972 total
1972	Urban	(8,670)	4,379	102	104	8	13,264
	Agriculture	14,706	(25,335)	1,059	498	21	41,618
	Bottomland forest	1,968	2,784	(23,593)	11,825	356	40,526
	Swamp forest	362	132	4,772	(44,798)	571	50,635
	Freshwater marsh	57	26	1,004	4,236	(7,729)	13,053

[a] The areas of no change are in parentheses. The total column represents the land use areas in the earlier time step.

Table 5. Total area (ha) of land converted from one land cover to the next between 1972 and 1992 and between 1985 and 1992[a]

		1992					
		Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	1972 total
1972	Urban	(8,609)	4,370	329	84	46	13,437
	Agriculture	16,674	(22,663)	2,207	203	94	41,841
	Bottomland forest	2,296	1,698	(17,642)	18,682	355	40,674
	Swamp forest	317	32	2,749	(47,108)	550	50,756
	Freshwater marsh	24	47	2,166	3,373	(7,582)	13,192
							1985 Total
1985	Urban	(15,681)	9,107	871	348	158	26,164
	Agriculture	11,256	(19,389)	2,286	193	65	33,188
	Bottomland forest	640	423	(15,205)	14,048	240	30,556
	Swamp forest	474	229	5,678	(52,846)	2,148	61,375
	Freshwater marsh	5	6	961	1,655	(6,023)	8,650

[a] The areas of no change are in parentheses. The total column represents the land use areas in the earlier time step.

present trends in the reduction of bottomland forest land cover were to continue, the upper Barataria Basin may have no bottomland hardwood forests left by the year 2025, as it is subjected to multiple stressors both in the higher elevations (from urbanization) and lower elevations (most likely from land subsidence). Protections should be put in place now to prevent further loss of this important habitat type of the upper basin.

Previous studies suggest that high rates of land subsidence within the Louisiana-Mississippi River deltaic plain are one of the primary causes of wetland loss within coastal regions of Louisiana (Scaife and others 1983, Conner and Day 1988, Visser and others 1999). Land subsidence within the deltaic plain results primarily from the compaction of sediments within the basin over time. The complete levying of the basin has largely eliminated overflow of the Mis-

Table 6. Area (percent) of land converted from one land cover to the next between 1972 and 1985[a]

		1985					
		Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	1972 total
1972	Urban	(65)	33	1	1	<1	100
	Agriculture	35	(61)	3	1	<1	100
	Bottomland forest	5	7	(58)	29	1	100
	Swamp forest	1	<1	9	(88)	1	100
	Freshwater marsh	<1	<1	8	32	(59)	100

[a] For example, the percent of agricultural land present in 1972 that was converted to urban land in 1985 is 35%. Areas of no change are in parentheses. The total column represents the land use areas in the earlier time step.

Table 7. Area (percent) of land converted from one land cover to the next between 1972 and 1992 and between 1985 and 1992[a]

		1992					
		Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	1972 total
1972	Urban	(64)	33	2	1	<1	100
	Agriculture	40	(54)	5	<1	<1	100
	Bottomland forest	6	4	(43)	46	1	100
	Swamp forest	1	<1	5	(93)	1	100
	Freshwater marsh	<1	<1	16	26	(57)	100
							1985 total
1985	Urban	(60)	35	3	1	1	100
	Agriculture	34	(58)	7	1	<1	100
	Bottomland forest	2	1	(50)	46	1	100
	Swamp forest	1	<1	9	(86)	3	100
	Freshwater marsh	<1	<1	11	19	(70)	100

[a] For example, the percent of agricultural land present in 1972 that was converted to urban land in 1992 is 40%. The areas of no change are within parentheses. The total column represents the land use areas in the earlier time step.

Table 8. Area (percent) of land converted from one land cover to the next between 1972 and 1985[a]

		1985					
		Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	1972 total
1972	Urban	(5)	3	0	0	0	8
	Agriculture	9	(16)	1	0	0	26
	Bottomland forest	1	2	(15)	7	0	25
	Swamp forest	0	0	3	(28)	0	31
	Freshwater marsh	0	0	1	3	(5)	8

[a] Changes here show the total percentage of each land cover in the basin as a whole that changed into other categories. For example, 9% of the total basin area was converted from agriculture to urban land from 1972 to 1985. The total column represents the land-cover areas in the earlier time step. The areas of no change are in parentheses.

sissippi River, which was the primary source of marsh-building sediments (Visser and others 1999). Land subsidence may also be related to increases in water level, which has been measured at approximately 8.5 mm/yr within the upper Barataria Basin (Conner and Day 1988). Conner and Day (1988) suggested that water levels should increase over time and, along with decreasing sedimentation rates (vertical accretion), lead to a reduction in forested wetlands as a result of prolonged, deep flooding. We did not find a reduction in swamp forest wetlands in the Barataria upper basin; rather we found that swamp forest area

Table 9. Area (percent) of land converted from one land cover to the next between 1972 and 1992 and between 1985 and 1992[a]

		1992					
		Urban	Agriculture	Bottomland forest	Swamp forest	Freshwater marsh	1972 total
1972	Urban	(5)	3	0	0	0	8
	Agriculture	10	(14)	1	0	0	26
	Bottomland forest	1	1	(11)	12	0	25
	Swamp forest	0	0	2	(29)	0	31
	Freshwater marsh	0	0	1	2	(5)	8
							1985 total
1985	Urban	(10)	6	1	0	0	16
	Agriculture	7	(12)	1	0	0	21
	Bottomland forest	0	0	(9)	9	0	19
	Swamp forest	0	0	4	(33)	1	38
	Freshwater marsh	0	0	1	1	(4)	5

[a] Changes here show the total percentage of each land cover in the basin as a whole that changed into other categories. For example, 10% of the total basin area was converted from agriculture to urban land from 1972 to 1992. The total column represents the land-cover areas in the earlier time step. The areas of no change are in parentheses.

increased 37%. One possible explanation for the increased swamp forest in our study is the existence of numerous oil, gas, and drainage canals throughout the basin. These canals may allow swamp forest areas to periodically drain during drier seasons, providing the necessary dry seed recruitment periods for the baldcypress and water tupelo species that dominate this land-cover class (Conner and others 1986, Souther and Shaffer 2000). However, it is quite possible that the presence of these canals has only slowed changes predicted by Conner and Day (1988). A second possible explanation for the increased swamp forest would be if rainfall had changed in any way over time. However, annual rainfall data measured at the New Orleans, Louisiana Weather Data Center shows no trend through time.

Current management plans, such as the Coastal 2050 management plan (Bourne 2000), call attention to the alarming rate of shoreline erosion in coastal zones, and to a lesser degree, the impacts of inland wetland and marsh change higher in the watershed. Management strategies include reintroducing Mississippi River sediments over portions of the Barataria coastal areas through freshwater diversion projects and filling some canals that have led to saltwater intrusion and tidal action in the middle and lower basins. However, these strategies may do little to affect land-cover changes in the upper basin. Freshwater diversions, which target rebuilding coastal margins of the basin that are subject to erosion and sea level rise, may be instituted at points too low in the watershed to aid in rebuilding land that could eventually be reclaimed by bottomland forest areas in the upper basin. The levee system, which completely isolates both the upper and lower Barataria Basin from Mississippi River sediments, will continue to inhibit vertical accretion, allowing subsidence to continue to increase the lower wetland area in the upper basin at the cost of reductions in bottomland hardwood forests.

Although bottomland hardwood forests provide important habitat for wildlife, migratory bird species, and sport and commercial resources, the expanding wetlands in the upper region may provide benefits as well. Our results suggest that urbanization within this region of the Barataria Basin may continue, which increases the threat of nonpoint source pollution. Expanding wetland areas in the upper basin may provide an increased capacity to buffer excess upland nutrient loading to the inland lakes within this region of the basin and reduce sediment and nutrient export into the Gulf of Mexico. Furthermore, with the alarming rates of coastal wetland loss in this region, upper basin wetlands may prove to be critical in maintaining the rich ecological habitats of southern Louisiana. However, further research needs to be conducted to assess the impacts of losing bottomland forest in this important ecosystem.

Quantifying historical land-cover change provides a reference for investigating current landscape change. However, large-scale studies can be limited by the ability to acquire timely, cost effective, and accurate data. Remote sensing using sensors that span decades allows us to quantify historic land-cover patterns for large areas such as the upper Barataria Basin. Our classification of Landsat MSS data produced an overall estimated accuracy of 89% among the six land-use categories, which is an error rate that is lower than the changes that we detected. Failure to understand the type of changes that are taking place within a watershed, and the degree to which these changes occur, can lead to serious errors in assessing ecological risks. Remote sensing provides both temporal and spatial information on the structure of the landscape. Further study is needed to examine the effects of these observed land-cover changes on water quality within both the upper and lower Barataria basins.

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