TEXAS AND LOUISIANA 2010 COASTAL CHANGE ANALYSIS PROGRAM ACCURACY ASSESSMENT

National Oceanic and Atmospheric Administration (NOAA)
Coastal Services Center

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NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

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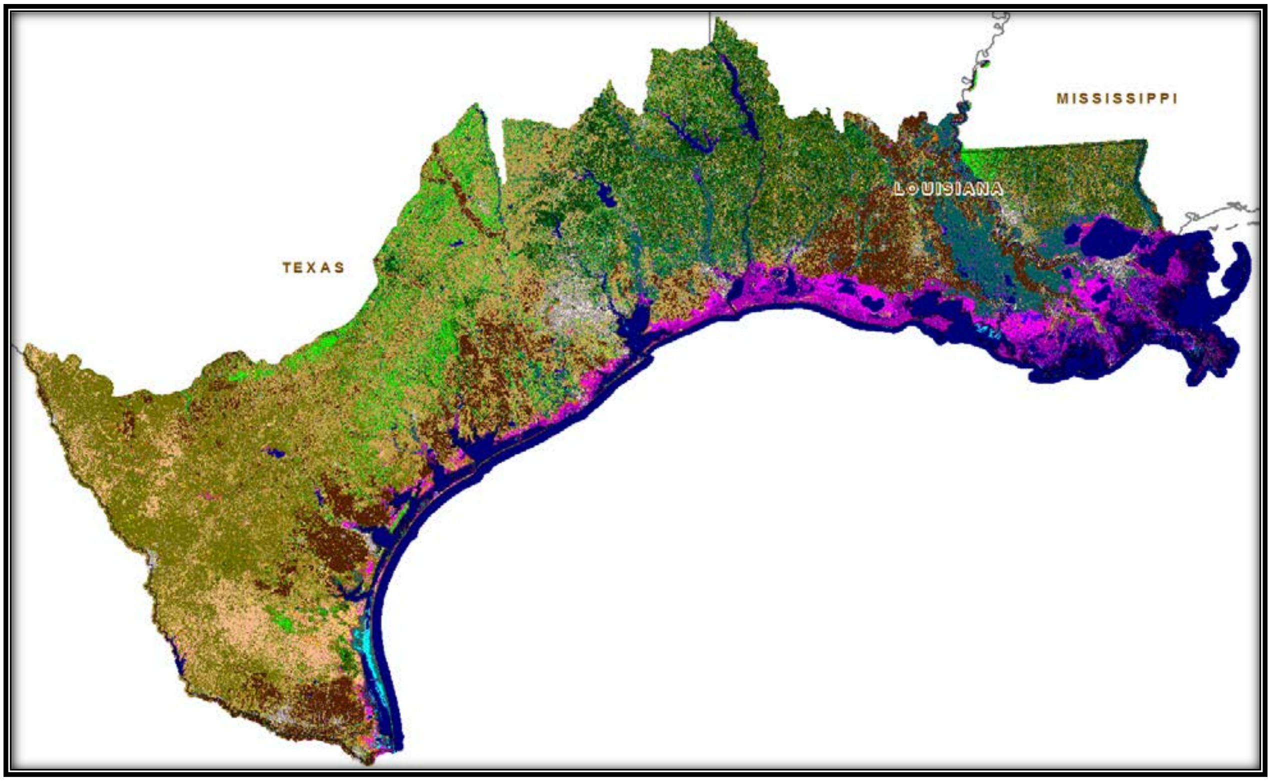

Overview

This report describes the accuracy assessment that was performed on the National Oceanic and Atmospheric Administration (NOAA) 2010 Coastal Change Analysis Program (C-CAP) land cover update for Texas and Louisiana. This area covers nearly 110,000 square miles. Before this update, the last accuracy assessment of C-CAP data for the region was performed on the 2001 baseline map product. This previous assessment was focused on the 2001 map accuracy alone and included no assessment of the change mapped. Since that time, the region has experienced a considerable amount of land cover change, and improvements have been made in detecting and mapping change. For these reasons, C-CAP determined that an accuracy assessment that included mapped change would be part of the 2010 land cover update cycle.

The 2010 Texas and Louisiana C-CAP land cover update was conducted through the contract vehicle at the NOAA Coastal Services Center. The 2010 land cover was completed by MDA Information Systems. Once the external contractor completed its efforts, in-house edits were performed on all dates of land cover to address issues identified during quality assurance reviews. The C-CAP team takes extra effort to address errors in previous land cover to make a more accurate final product. Finalized land cover for the region was completed in February 2014.

Significant findings from the accuracy assessment are listed below and discussed in more detail later in this report:

- The overall accuracy for the Texas and Louisiana 2010 C-CAP product was 84.7% (0.84 kappa).
- Two classes fell below 80% for both producer[1] *and* user[2] accuracy; five classes were below 80% for producer accuracy, and six were below 80% for user accuracy (Table 2).
- The accuracy for change/no-change was 89.9%, with the largest error being committed change (76.3% accuracy). It is interesting to note that of these committed change locations (falsely mapped as change) the accuracy was 71.8% for the 2010 call, indicating the 2006 call was incorrect.
- Of the 300 sample locations in mapped change areas, the accuracy was 82.7%.

Methods

The C-CAP team met and discussed accuracy assessment on multiple occasions and determined three essential requirements:

1. Ability to report overall map accuracy
2. Ability to report change/no-change mapping accuracy
3. Ability to report categorical change accuracy

A three-stratum approach (Figure 1) was chosen, including (1) current change, (2) near current and recent change, and (3) the remaining area. Stratum 1 (red) was the 2006-2010 mapped change areas. The team wanted to sample enough locations within currently mapped change to be able to assess the quality of the newly mapped areas, as well as comment on the change/no-change mapping accuracy. The team

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[1] Related to errors of omission when an area is excluded from the category to which it belongs.

[2] Related to errors of commission when an area is included incorrectly in a category.

attempted to split the non-change area evenly into the other two strata. Stratum 2 (purple plus gray) was determined by combining all changes from 1996-2010 and buffering until the area target was approximated, in this case an 8 pixel buffer. This second stratum *did not* resample Stratum 1. From past experience team members have noticed that change is often spatially auto-correlated, which means that new change tends to occur near previous change. This can easily be seen in urban expansion or in the clustering of timber activity. The team felt that sample units in this stratum may be useful in potentially identifying missed change, as well as be used for wall-to-wall accuracy. The remaining area was Stratum 3 (blue). These points may pick up missed change but would be most useful in assessing wall-to-wall accuracy. Each stratum contained 300 accuracy assessment sample units.

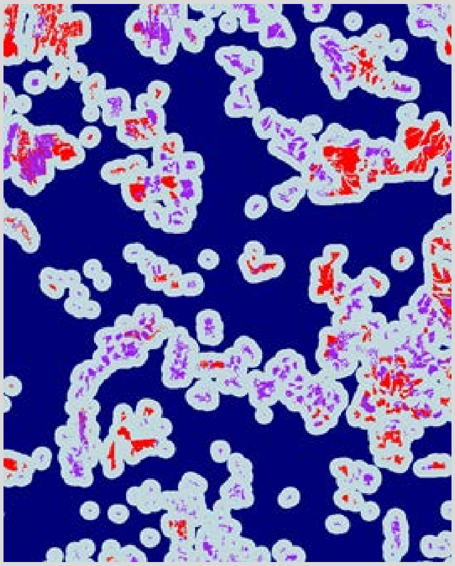


Figure 1: Accuracy Assessment Strata

Sample units were identified using the ERDAS Imagine Accuracy Assessment tool. A total of 300 sample units per stratum (total 900) were placed with the following criteria: stratified random placement; a minimum of 10 per class (not always met); and six out of nine land cover pixels around the location had to be homogenous, or else the location was discarded. The sample locations were then buffered by 45 meters to assist in interpretation of the appropriate land cover and change call.

Sample Unit Distribution and Interpretation

As seen in Table 1, Scrub/Shrub received the most accuracy assessment sample units (93) and Estuarine Scrub/Shrub received the fewest (3). The last two columns in Table 1 can be compared to assess if a class was sampled proportionally to the area it comprised. For example, Mixed Forest received 3.7% of the accuracy assessment (AA) sample units and comprised 2.6% of the region. The largest discrepancy is with Scrub/Shrub receiving 10.3% of the AA sample units and comprising 20.1% of the region. Discrepancies may be due to rarer classes and classes commonly associated with change/transition, such as Bare Land.

The AA sample units were randomly split into three groups of 600 points. Each reviewer (three total) was responsible for labeling the AA sample unit according to its primary land cover using the available Landsat imagery (2010), a “fuzzy call” if necessary, and whether the sample unit changed from 2006. Fuzzy calls were used if the interpreter could not positively identify a single dominant land cover (e.g., natural speckling of land cover classes) or when land classes were very similar (e.g., Shrub vs. Forest are distinguished by a height criteria). Reviewers had access to all 2006 and 2010 Landsat data, Google Earth, National Wetlands Inventory (NWI), Soil Survey Geographic (SSURGO) database, and other high-resolution imagery (e.g., Bing Maps) as available. All points were compiled into a single file for comparison of land cover and change calls. Any locations where the review calls differed were separated for further discussion by the reviewers and project lead, if needed.

The land cover and change determinations, or “calls,” for a 3 x 3 pixel window at each AA location were extracted from the data to compare against the reviewer calls. To be labeled “correct,” six out of the nine map pixels had to match the primary or fuzzy review call (for land cover or change/no-change).

Table 1. Breakdown of accuracy assessment sample units per strata and per land cover class.

	Accuracy Assessment Sample Units				Percent of	
Land Cover	Stratum 1	Stratum 2	Stratum 3	Total	Sample Units	Region
Developed, High Intensity	14	12	10	36	4.0%	0.5%
Developed, Medium Intensity	14	14	11	39	4.3%	1.1%
Developed, Low Intensity	17	14	11	42	4.7%	2.5%
Developed, Open Space	14	13	10	37	4.1%	1.0%
Cultivated Crops	10	16	22	48	5.3%	10.2%
Pasture/Hay	11	22	24	57	6.3%	14.3%
Grassland/Herbaceous	24	16	16	56	6.2%	7.5%
Deciduous Forest	2	13	13	28	3.1%	3.2%
Evergreen Forest	24	18	12	54	6.0%	6.7%
Mixed Forest	9	13	11	33	3.7%	2.6%
Scrub/Shrub	40	26	27	93	10.3%	20.1%
Palustrine Forested Wetland	13	18	25	56	6.2%	8.7%
Palustrine Scrub/Shrub Wetland	17	15	12	44	4.9%	1.8%
Palustrine Emergent Wetland	20	21	12	53	5.9%	2.8%
Estuarine Scrub/Shrub Wetland		2	1	3	0.3%	0.0%
Estuarine Emergent Wetland	11	12	13	36	4.0%	3.1%
Unconsolidated Shore	11	11	11	33	3.7%	0.7%
Bare Land	16	10	10	36	4.0%	0.6%
Open Water	15	14	29	58	6.4%	12.4%
Palustrine Aquatic Bed	10	10	10	30	3.3%	0.1%
Estuarine Aquatic Bed	8	10	10	28	3.1%	0.1%
Total	300	300	300	900		
Area (square miles)	5,465	50,745	53,729	109,938		
Percent of Region	5.0%	46.2%	48.9%			

Results and Discussion

2010 Land Cover

Table 2 represents the error matrix for the 2010 land cover map. Overall accuracy for the 2010 land cover product was 84.7% (0.84 kappa). The majority of classes met the C-CAP target specification of 80% per class accuracy. Of the 11 instances where accuracy was below the targeted 80%, seven of these did exceed 70%. Two classes, Open Space Developed, and Bare Land, fell below the 80% threshold for both producer and user accuracy. Open Space Developed was confused with Low Intensity Developed, Cultivated, and Grassland. Bare Land was confused with Pasture/Hay, Scrub/Shrub, and developed classes. The class with the lowest single accuracy was Estuarine Scrub/Shrub Wetland (33.3% user accuracy). This value may be questionable because of the low number of reference locations (Table 2).

Although most classes did not have more than 50 sample units (the coarse “rule-of-thumb” for accuracy assessment), seven classes did exceed 50, and ten classes were over 40. Only Estuarine Scrub/Shrub had fewer than 20 sample location, which can be explained by the limited area this class represents in the landscape.

Few clear patterns were found during the examination of the off-diagonal values in the error matrix. Closer examination of the errors did reveal some trends in the classification.

1. **Pasture/Hay and Grassland** – Both Pasture/Hay and Grassland were undercalled in general for this area. Both of these classes were confused with lower levels of development as well as Scrub/Shrub. The confusion with development was seen around the edges of true development, where there may have been an overestimation of the developed class. The confusion with Scrub/Shrub was most common in Texas, where there are large areas of natural grass and scrub lands that are occasionally used for grazing.
2. **Open Space Developed** – There was confusion between this class and Low Intensity Developed, which is not a surprise, since these classes are only separated by a percent impervious threshold. A slight error in the percent impervious value may cause mapping issues. It also appears that Open Space Developed was generally overmapped at the expense of other land cover classes, but most frequently Pasture/Hay or Grassland. This confusion may be explained by the fact that all these classes are generally similar, physically and spectrally.
3. **Bare Land** – True Bare Land was classified as developed categories. This is most common when a site is being prepared for development but construction has not yet begun. The proximity to existing development, and the bright reflectance of the bare soil, allows for easy confusion with developed land. There were also several instances where recently tilled Cultivated or Pasture/Hay fields were mislabeled as Bare Land. The bright appearance of the soil caused this problem.
4. **Scrub/Shrub** – Although this class did meet our accuracy standard, there was still confusion with many classes, commonly with upland forest classes. This error was also seen in the Eastern Gulf of Mexico region. Scrub/Shrub is generally a transitional class between Grassland and Forest classes and is distinguished in C-CAP by a height criterion. Since height cannot be directly measured in the Landsat data used, other criteria must be used (tone, texture, shadow, etc.), resulting in the confused classes. There was also confusion with Palustrine Scrub/Shrub.
5. **Misclassified water** – Typically, Open Water, one of the more easily distinguished classes, was incorrectly mapped as Unconsolidated Shore and both classes of Aquatic Bed. In coastal locations, nearshore wave action, water turbidity, and tidal stage all influence the separation of Unconsolidated Shore and Open Water. Examination of these incorrect sample locations seemed to show that the Unconsolidated Shore class is most likely overmapped in general, often because of wave action present in the imagery, or clear water causing sediment and bottom being mapped. Aquatic Bed posed a problem in palustrine conditions often because of its ephemeral nature. The date of the imagery used in classification may cause this class to be missed, or overclassified.

Table 2. Full error matrix for the 2010 Texas and Louisiana C-CAP mapping region. Map classes are along the left edge, and reference calls are along the top of the matrix. Correct locations are highlighted in green along the diagonal of the matrix. Individual class accuracies that fall below the target 80% are highlighted in orange.

Reference

Map

	Developed, High Intensity	Developed, Medium Intensity	Developed, Low Intensity	Developed, Open Space	Cultivated Crops	Pasture/Hay	Grassland/Herbaceous	Deciduous Forest	Evergreen Forest	Mixed Forest	Scrub/Shrub	Palustrine Forested Wetland	Palustrine Scrub/Shrub Wetland	Palustrine Emergent Wetland	Estuarine Scrub/Shrub Wetland	Estuarine Emergent Wetland	Unconsolidated Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed	Total	Users
Developed, High Intensity	35																	1				36	97.2%
Developed, Medium Intensity		34	2	1										1				1				39	87.2%
Developed, Low Intensity			28	5			2		1	1	1					1		3				42	66.7%
Developed, Open Space				27		3	3	1		1	1			1								37	73.0%
Cultivated Crops				1	40	2	1				3							1				48	83.3%
Pasture/Hay				1	1	54					1											57	94.7%
Grassland/Herbaceous					1	4	50	1														56	89.3%
Deciduous Forest						1	1	24			1	1										28	85.7%
Evergreen Forest									46	2	4	1	1									54	85.2%
Mixed Forest						1		1	3	27		1										33	81.8%
Scrub/Shrub						3	4		5		80							1				93	86.0%
Palustrine Forested Wetland									2			52	1	1								56	92.9%
Palustrine Scrub/Shrub Wetland							1			1	7	2	28	5								44	63.6%
Palustrine Emergent Wetland						2	1						1	45		1		1	1	1		53	84.9%
Estuarine Scrub/Shrub Wetland														1	1	1						3	33.3%
Estuarine Emergent Wetland							1						1	2		32						36	88.9%
Unconsolidated Shore														1			29		3			33	87.9%
Bare Land					1	3	1				2							28	1			36	77.8%
Open Water																			58			58	100.0%
Palustrine Aquatic Bed					1							1							7	19	2	30	63.3%
Estuarine Aquatic Bed																			2	1	25	28	89.3%
Total	35	34	30	35	44	73	65	27	57	32	100	58	32	57	1	35	29	36	72	21	27	900	
Producers	100.0%	100.0%	93.3%	77.1%	90.9%	74.0%	76.9%	88.9%	80.7%	84.4%	80.0%	89.7%	87.5%	78.9%	100.0%	91.4%	100.0%	77.8%	80.6%	90.5%	92.6%		84.7%

Fuzzy calls were allowed in conditions where the field class was either difficult to positively identify (e.g., Cultivated vs. Pasture, Shrub vs. Forest, different levels of development) or where there was natural variability in the landscape (e.g., near edge features). Using fuzzy calls increases the chance for a correct label but may potentially artificially inflate the reported map accuracy if they are overused. Table 3 shows that although 38% of the sample units received a fuzzy call, these calls were rarely responsible (19%) for a location being deemed mapped as correct.

Table 3. Fuzzy reference calls for the 2010 Texas and Louisiana C-CAP region.

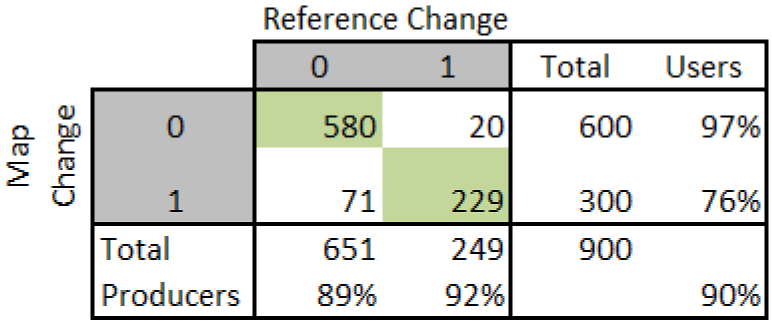
Fuzzy Reference Calls		
Of the 900 sample locations, 339 (37.7%) had a fuzzy call	For the 762 correctly mapped locations, 147 (19.2%) were correct based on the fuzzy land cover call (615 were correct based on primary call)	Land cover classes with the most fuzzy calls include different levels of Development, Scrub and Grass, and Estuarine Aquatic Bed with Unconsolidated Shore and Open Water

2006-2010 Change

Overall change/no-change accuracy was 90% (Table 4). Committed change was the largest error, with a user accuracy of 76% (71 sample locations mapped as change, but deemed no change by the reviewers). These 71 locations were assessed in their own error matrix and resulted in 71.8% overall accuracy. This seems to indicate that the method used to identify potential change pixels (creating the change mask) may be overestimating change, but the methods used to assign a land cover class are reasonably accurate. These locations of committed change may be used in future editing efforts, since they are indicative of potential errors with the 2006 map.

Assessing mapped change is a fairly straightforward task, but assessing missed change is problematic. Of the 600 total sample units in mapped no-change areas, 20 were deemed missed change. Sixteen of these points were within Stratum 2 (specifically designed to try to identify potential missed change). After conducting the change analysis, the team feels that overall change has been slightly overcalled, although there were limited missed true change sites as well.

Table 4. Change/no-change matrix for the 2010 Texas and Louisiana C-CAP region. Correct locations are highlighted in green along the diagonal of the matrix. Change calls were coded *0* for no change, and *1* for change.



		Reference Change			
		0	1	Total	Users
Map Change	0	580	20	600	97%
	1	71	229	300	76%
Total		651	249	900	
Producers		89%	92%		90%

A final analysis was performed using only sample locations interpreted as change (249 locations). Table 5 shows that the overall accuracy of these locations was 82.7%, slightly lower than the total map accuracy (Table 2). Errors within this matrix were similar to the overall matrix discussed previously.

Comparison between 2001 and 2010 Accuracy Assessments

This 2010 accuracy assessment fully covered the 2001 accuracy assessment for U.S. Geological Survey (USGS) Zones 36 and 37 (brown and red points in Figure 2) and a portion of USGS Zone 46 (blue points in Figure 2). A total of 1,803 locations were used in the 2001 Zone 36/37 accuracy assessment (81.0% overall accuracy), and 1,708 locations for Zone 46 (86.5% overall accuracy). Direct comparisons with the 2001 accuracy assessment should not realistically be made, since there are significant differences between the placement of sample locations and interpretation methods, although the 2010 final accuracy falls within the range of values from the 2001 assessment.

Accuracy assessment locations for the 2001 product were photointerpreted from black and white digital orthophotography and footprints of high-resolution satellite imagery. All sample locations were drawn from a 3 x 3 pixel window of homogenous land cover. Sampling from within imagery footprints can be seen in the clustering of sample locations in Figure 2. The restriction of sample locations to a homogenous area reduced the chance of speckled or more difficult to classify areas being chosen for accuracy assessment.

Table 5. Error matrix for the 2010 Texas and Louisiana C-CAP mapping region based on interpreted change locations. Map classes are along the left edge and reference calls are along the top of the matrix.

	Reference																						
Map	Developed, High Intensity	Developed, Medium Intensity	Developed, Low Intensity	Developed, Open Space	Cultivated Crops	Pasture/Hay	Grassland/Herbaceous	Deciduous Forest	Evergreen Forest	Mixed Forest	Scrub/Shrub	Palustrine Forested Wetland	Palustrine Scrub/Shrub Wetland	Palustrine Emergent Wetland	Estuarine Emergent Wetland	Unconsolidated Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed	Total		
Developed, High Intensity	13																				13		
Developed, Medium Intensity		11															1				12		
Developed, Low Intensity			10	1			2			1							3				17		
Developed, Open Space				8		1	2	1						1							13		
Cultivated Crops					5		1				1						1				8		
Pasture/Hay						4															4		
Grassland/Herbaceous						1	19														20		
Evergreen Forest									18		1		1								20		
Mixed Forest									2	6											8		
Scrub/Shrub						1	2		2		30						1				36		
Palustrine Forested Wetland									2			3		1							6		
Palustrine Scrub/Shrub Wetland							1				1	1	10	2							15		
Palustrine Emergent Wetland						2								12							14		
Estuarine Emergent Wetland													1	1	9						11		
Unconsolidated Shore														1		7					8		
Bare Land						1											13				14		
Open Water																		13			13		
Palustrine Aquatic Bed																			10	1	11		
Estuarine Aquatic Bed																			1	5	6		
Grand Total	13	11	10	9	5	10	27	1	24	7	33	4	12	18	9	7	19	13	11	6	249	Correct	206
																						Percent Corerct	82.7%

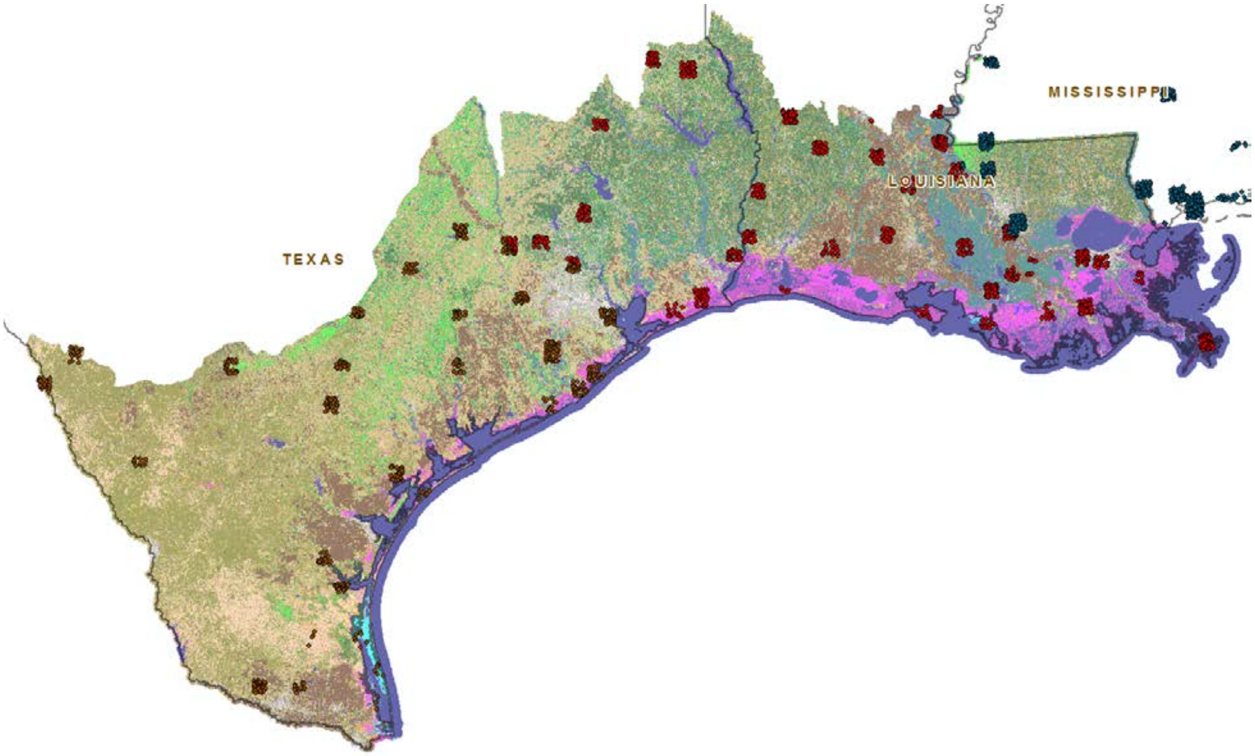


Figure 2. Accuracy assessment locations in the Gulf of Mexico draped on 2001 land cover. Portions of three assessments covered the area shown above. Two collections are fully contained in this area (Zone 36 as brown, Zone 37 as red), with a portion of the third overlapping the area (Zone 46 as blue).

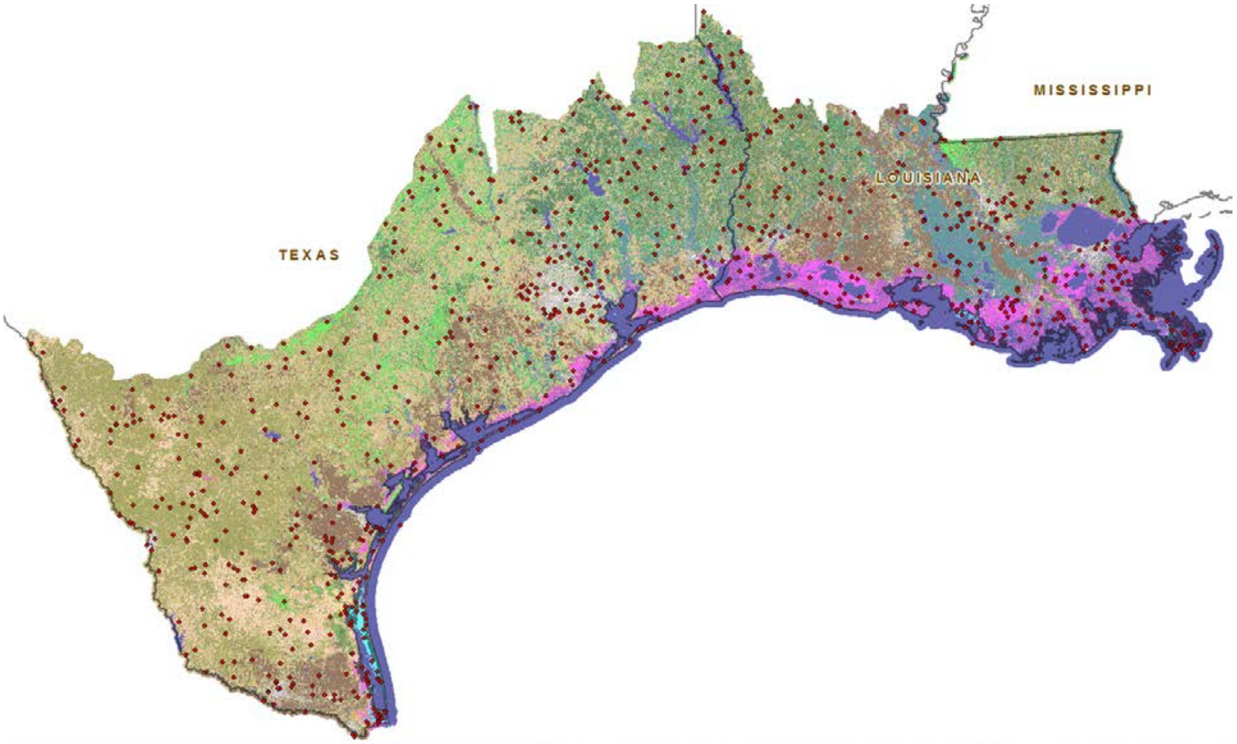


Figure 3. Accuracy assessment locations for the 2010 C-CAP Texas and Louisiana area draped over the 2010 land cover.

Conclusions

C-CAP uses consistent methods and approaches for mapping land cover and land cover change for the coastal regions of the U.S. with a stated accuracy target of 85% overall and 80% per class. The 2010 Texas and Louisiana region was assessed for accuracy through in-house efforts. Sampling strata were established to estimate overall accuracy, as well as change mapping accuracy. The overall accuracy of the region was 84.7%, with the majority of individual classes exceeding 80% accuracy. Change/no-change accuracy for the product was 90%, with committed change being the largest error. The analysis found that 72% of the false change locations received the correct 2010 call, indicating the classification approaches appear to be working well.

There were two classes, Open Space Developed and Bare Land, with accuracy below 80% for both user and producer accuracy. The errors associated with these two classes have been seen in previously mapped regions and discussed earlier. Addressing both of these errors will most likely involve creating better developed surface masks to help define the bounds of developed versus not developed. Other errors within the map were difficult to categorize, although some basic trends were detected.

A large portion of the Texas mapping area contained a mixture of Scrub/Shrub, Pasture/Hay, and Grass. Much of this land is grazed but has little active management (e.g., watering or mowing) and is left in a natural condition. This allows the land to appear (spectrally and physically) as Scrub and Grass, but could be classified as Pasture. The use of this land for grazing changes over time, as herds are moved or land use changes, creating more difficulties. The amount of rainfall in the area also created change detection and classification problems. Vegetation signatures appeared healthy, with significant infrared reflectance, if there was adequate rainfall, but dead and brown during dry or drought conditions. The land cover may be the same in both situations but may appear drastically different. A “wet” appearing Landsat mosaic (chosen from multiple dates) was created to assist with this classification.

A significant effort was spent on this 2010 product to improve the separation of wetland from upland classes through the use of a wetland potential layer during post-classification editing. Unfortunately, this layer was incomplete for large areas in Louisiana and therefore not as helpful. Editing was performed in these areas, but the resulting changes may not have been as consistent as in other areas. This may be seen in the confusion of Scrub/Shrub and Palustrine Scrub/Shrub. Future edits may be performed if the needed layers are made available for the wetland potential map.

Cleaning up the classification of Unconsolidated Shore and Aquatic Bed from Open Water may be assisted by the incorporation of national shoreline data of modeled high and low tide levels. NOAA maintains vector shoreline data created from NOAA T-sheets and georeferenced aerial photos. The NOAA Coastal Services Center has also created a modeled raster layer depicting various tidal stages that is based on high-resolution lidar elevation data and the VDatum computer program.