Eastern Gulf of Mexico 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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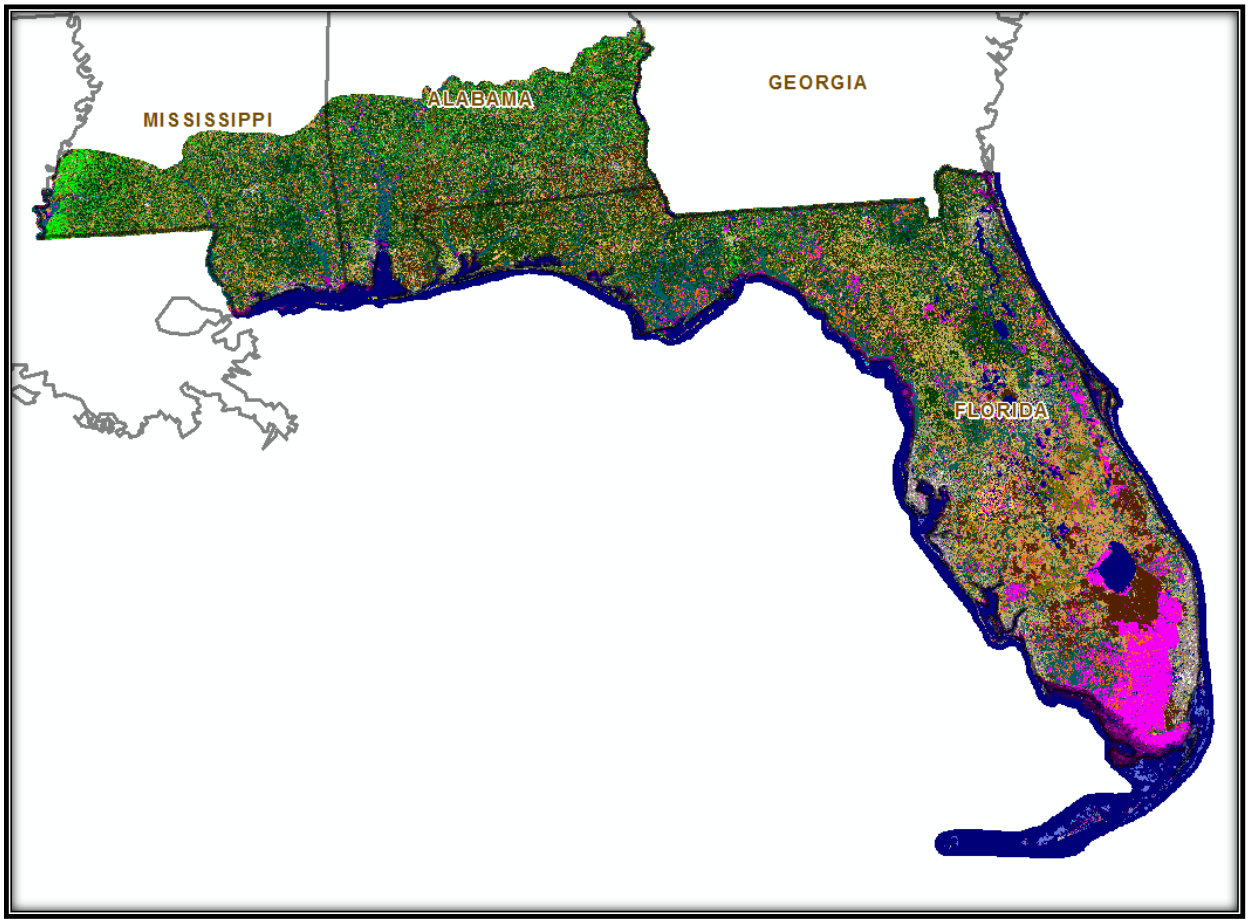


Overview

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 the Eastern Gulf of Mexico. This area covers over 103,000 square miles and includes the coastal portions of Mississippi and Alabama, and all of Florida. 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, there has been both a considerable amount of land cover change in the region and improvements in detecting and mapping change. For these reasons, it was determined that an accuracy assessment that included mapped change would be part of the 2010 land cover update cycle.

The 2010 Eastern Gulf of Mexico C-CAP land cover update was conducted through the contract vehicle at the NOAA Coastal Services Center. The 2010 land cover classification was completed by Photo Science. 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 December 2013.

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

- The overall accuracy for the Eastern Gulf of Mexico 2010 C-CAP product was 84.6% (0.84 kappa).
- Two classes fell below 80% for both producer[1] *and* user[2] accuracy; seven classes were below 80% for producer accuracy, and six were below 80% for user accuracy (Table 2).
- The accuracy for change/no-change was 90.6%, with the largest error being committed change (82.7% accuracy). It is interesting to note that of these committed change locations (falsely mapped as change) the accuracy was 71.2% for the 2010 call, indicating the 2006 call was incorrect.
- Of the 300 sample locations in mapped change areas, the accuracy was 87.0%.

Methods

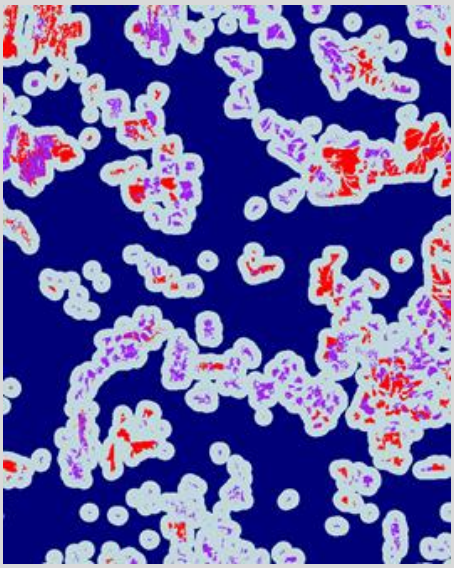
The C-CAP team met and discussed accuracy assessment on multiple occasions and determined three essential requirements:

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

[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 a 6 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.



Accuracy Assessment Strata
Figure 1: Accuracy Assessment Strata

Sample units were identified using the ERDAS Image 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, Evergreen Forest received the most accuracy assessment sample units (89) and Palustrine Aquatic Bed received the fewest (17). 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 4.3% of the accuracy assessment (AA) sample units and comprised 3.3% of the region. The largest discrepancy is with Palustrine Forested Wetland receiving 7.1% of the AA sample units and comprising 15.2% 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	6	10	10	26	2.9%	0.5%
Developed, Medium Intensity	13	11	11	35	3.9%	1.4%
Developed, Low Intensity	13	14	12	39	4.3%	3.5%
Developed, Open Space	12	12	11	35	3.9%	2.3%
Cultivated Crops	12	14	16	42	4.7%	5.6%
Pasture/Hay	12	17	16	45	5.0%	7.1%
Grassland/Herbaceous	30	14	11	55	6.1%	3.9%
Deciduous Forest	2	12	11	25	2.8%	1.3%
Evergreen Forest	43	28	18	89	9.9%	16.8%
Mixed Forest	14	14	11	39	4.3%	3.3%
Scrub/Shrub	49	22	13	84	9.3%	11.4%
Palustrine Forested Wetland	17	23	24	64	7.1%	15.2%
Palustrine Scrub/Shrub Wetland	19	14	13	46	5.1%	4.1%
Palustrine Emergent Wetland	18	13	18	49	5.4%	5.8%
Estuarine Forested Wetland	0	10	11	21	2.3%	0.7%
Estuarine Scrub/Shrub Wetland	2	10	10	22	2.4%	0.3%
Estuarine Emergent Wetland	3	10	11	24	2.7%	1.0%
Unconsolidated Shore	5	10	10	25	2.8%	0.1%
Bare Land	13	10	10	33	3.7%	0.5%
Open Water	13	12	37	62	6.9%	14.8%
Palustrine Aquatic Bed	2	10	5	17	1.9%	0.0%
Estuarine Aquatic Bed	2	10	11	23	2.6%	0.4%
Total	300	300	300	900		
Area (square miles)	8,762	48,792	45,475	103,029		
Percent of Region	8.5%	47.4%	44.1%			

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 84.6% (0.84 kappa). The majority of classes met the C-CAP target specification of 80% per class accuracy. Of the 13 instances where accuracy was below the targeted 80%, 10 of these did exceed 70%.

Two classes, Developed Open Space and Grassland/Herbaceous fell below the 80% threshold for both producers and user accuracy. Developed Open Space was primarily confused with Grassland/Herbaceous and Bare Land. Grassland/Herbaceous was confused with many similar classes, including Pasture/Hay, Cultivated, and Scrub/Shrub. The class with the lowest single accuracy was Scrub/Shrub (64.3% user accuracy). This indicates that Scrub/Shrub was generally overcalled and confused with Evergreen and Mixed Forest, Grassland, and Pasture/Hay (Table 2.)

Although most classes did not have more than 50 sample units (the coarse "rule-of-thumb" for accuracy assessment), five classes did exceed 50, and nine classes were over 40. The fewest sample units were associated with Palustrine Aquatic Bed (17 locations).

There were two major sources of classification confusion as seen in the error matrix:

1. **Misclassified water** – Typically one of the more easily distinguished classes, Open Water 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 over-mapped in general, often because of wave action present in the imagery, or clear water causing sediment/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. In estuarine areas, clear water in much of Florida allowed submerged vegetation (sea grass beds) to be visible and often misclassified as Aquatic Bed.
2. **Scrub/Shrub confusion** – As mentioned above, this class was generally overcalled and was confused with several classes. All these classes are often directly related to each other, as one class transitions to the next (with the exception of Pasture/Hay) through forest cutting and regeneration. The Scrub/Shrub class 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.

Table 2. Full error matrix for the 2010 Eastern Gulf of Mexico 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.

Map \ Reference	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 Forest	Estuarine Scrub/Shrub Wetland	Estuarine Emergent Wetland	Unconsolidate Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed	Total	Users
Developed, High Intensity	26																						26	100.0%
Developed, Medium Intensity		33	1				1																35	94.3%
Developed, Low Intensity		1	32	1					2		1									2			39	82.1%
Developed, Open Space				26		2	2		1	1	1								2				35	74.3%
Cultivated Crops					35	2	3			1				1									42	83.3%
Pasture/Hay					2	39	2				1			1									45	86.7%
Grassland/Herbaceous				2	4	4	42		1		2												55	76.4%
Deciduous Forest								19	2	3	1												25	76.0%
Evergreen Forest				1					83	3	2												89	93.3%
Mixed Forest								1	5	32	1												39	82.1%
Scrub/Shrub					1	3	4	1	11	5	54	3	1	1									84	64.3%
Palustrine Forested Wetland				1						1		61								1			64	95.3%
Palustrine Scrub/Shrub Wetland					1		1		1			4	37	2									46	80.4%
Palustrine Emergent Wetland						1	2							45					1				49	91.8%
Estuarine Forest															20		1						21	95.2%
Estuarine Scrub/Shrub Wetland														1		21							22	95.5%
Estuarine Emergent Wetland														1			22	1					24	91.7%
Unconsolidate Shore																		17		7		1	25	68.0%
Bare Land				2	1				2		1								27				33	81.8%
Open Water												2		1						59			62	95.2%
Palustrine Aquatic Bed																				3	14		17	82.4%
Estuarine Aquatic Bed																				6		17	23	73.9%
Total	26	34	33	33	44	51	57	21	108	46	64	70	38	53	20	21	23	18	30	78	14	18	900	
Producers	100.0%	97.1%	97.0%	78.8%	79.5%	76.5%	73.7%	90.5%	76.9%	69.6%	84.4%	87.1%	97.4%	84.9%	100.0%	100.0%	95.7%	94.4%	90.0%	75.6%	100.0%	94.4%		84.6%

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 37% of the sample units received a fuzzy call, these calls were rarely responsible (18%) for a location being deemed mapped as correct.

Table 3. Fuzzy reference calls for the 2010 Eastern Gulf of Mexico C-CAP region.

Fuzzy Reference Calls		
Of the 900 sample locations, 332 (36.8%) had a fuzzy call	For the 761 correctly mapped locations, 136 (17.8%) were correct based on the fuzzy land cover call (625 were correct based on primary call)	Land cover classes with most fuzzy calls include different levels of Development, Palustrine Scrub/Shrub Palustrine Forest, and Water–Estuarine Aquatic Bed

2006-2010 Change

Overall change/no-change accuracy was 91% (Table 4). Committed change was the largest error with a user accuracy of 83% (52 sample locations mapped as change, but deemed no-change by the reviewers). These 52 locations were assessed in their own error matrix and resulted in 71.2% 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, 33 were deemed missed change. Twenty-five 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 are missed true change sites as well. These seemingly offsetting calls (overcalled and missed change) are not surprising, considering the overall large amount of change in this region.

Table 4. Change/no-change matrix for the 2010 Eastern Gulf of Mexico 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	567	33	600	95%
	1	52	248	300	83%
	Total	619	281	900	
	Producers	92%	88%		91%

A final analysis was performed using only sample locations interpreted as change (281 locations). Table 5 shows that the overall accuracy of these locations was 87.9%, slightly above the total map accuracy (Table 2). There were no obvious trends within this error matrix. Grassland, Evergreen, and Scrub/Shrub were mapped as various other natural land cover categories.

Comparison between 2001 and 2010 Accuracy Assessments

Direct comparisons with the 2001 accuracy assessment cannot be easily made, since the geographic extent and methods varied considerably. Portions of three separate accuracy assessments covered this area in 2001: all of U.S. Geological Survey (USGS) Zone 56 (2,071 locations), a portion of USGS Zones 55/58 (1,508 locations), and all of USGS Zone 46 (1,708 locations). The accuracy assessment locations for the 2001 data set were primarily drawn from field sample locations along roadways, and photointerpreted locations within high-resolution satellite imagery footprints (Figure 2). Sampling along roadways may introduce bias because roads are typically located to avoid certain features (e.g., wetlands, mountains, poor soils for construction), and thus land cover types in these locations may not be sampled. The overall accuracy for the three areas in 2001 was 86% (Zone 56), 86.5% (Zone 46), and 81.2% (Zones55/58). These are similar to the 2010 overall accuracy of 84.6%.

Table 5. Error matrix for the 2010 Eastern Gulf of Mexico 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.

Map \ Reference	Developed, High Intensity	Developed, Medium Intensity	Developed, Low Intensity	Developed, Open Space	Cultivated Crops	Pasture/Hay	Grassland/Herbaceous	Evergreen Forest	Mixed Forest	Scrub/Shrub	Palustrine Forested Wetland	Palustrine Scrub/Shrub Wetland	Palustrine Emergent Wetland	Estuarine Forest	Estuarine Emergent Wetland	Unconsolidate Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed	Total
Developed, High Intensity	7																				7
Developed, Medium Intensity		11	1																		12
Developed, Low Intensity			10	1														2			13
Developed, Open Space				11			1										2				14
Cultivated Crops					11		2						1								14
Pasture/Hay						8	1						1								10
Grassland/Herbaceous				1		1	26			1											29
Deciduous Forest								1		1											2
Evergreen Forest								33		1											34
Mixed Forest								2	8	1											11
Scrub/Shrub								2		45	1										48
Palustrine Forested Wetland											13							1			14
Palustrine Scrub/Shrub Wetland							1					17									18
Palustrine Emergent Wetland						1	2						13				1				17
Estuarine Forest														1							1
Estuarine Emergent Wetland															2	1					3
Unconsolidate Shore																2					2
Bare Land																	15				15
Open Water											2		1					8			11
Palustrine Aquatic Bed																			5		5
Estuarine Aquatic Bed																				1	1
Total	7	11	11	13	11	10	33	38	8	49	16	17	16	1	2	3	18	11	5	1	281

Correct	247
Percent Correct	87.9%

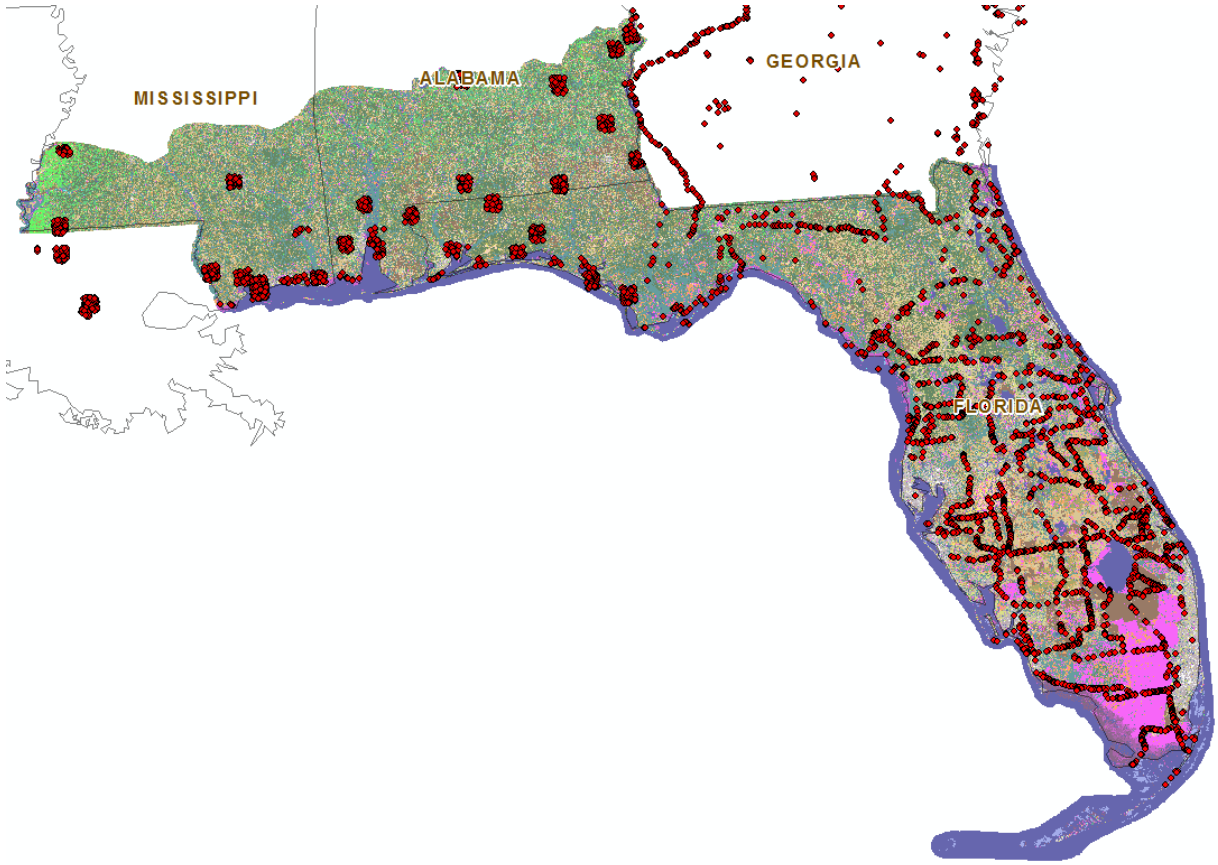


Figure 2. Accuracy assessment locations for 2001 C-CAP Eastern Gulf of Mexico area draped on 2001 land cover. Three separate accuracy assessments covered this area (extended through North Carolina but not seen in this image). Sampling along road networks (linear features) and within high-resolution satellite imagery (clusters) can be seen within the map.

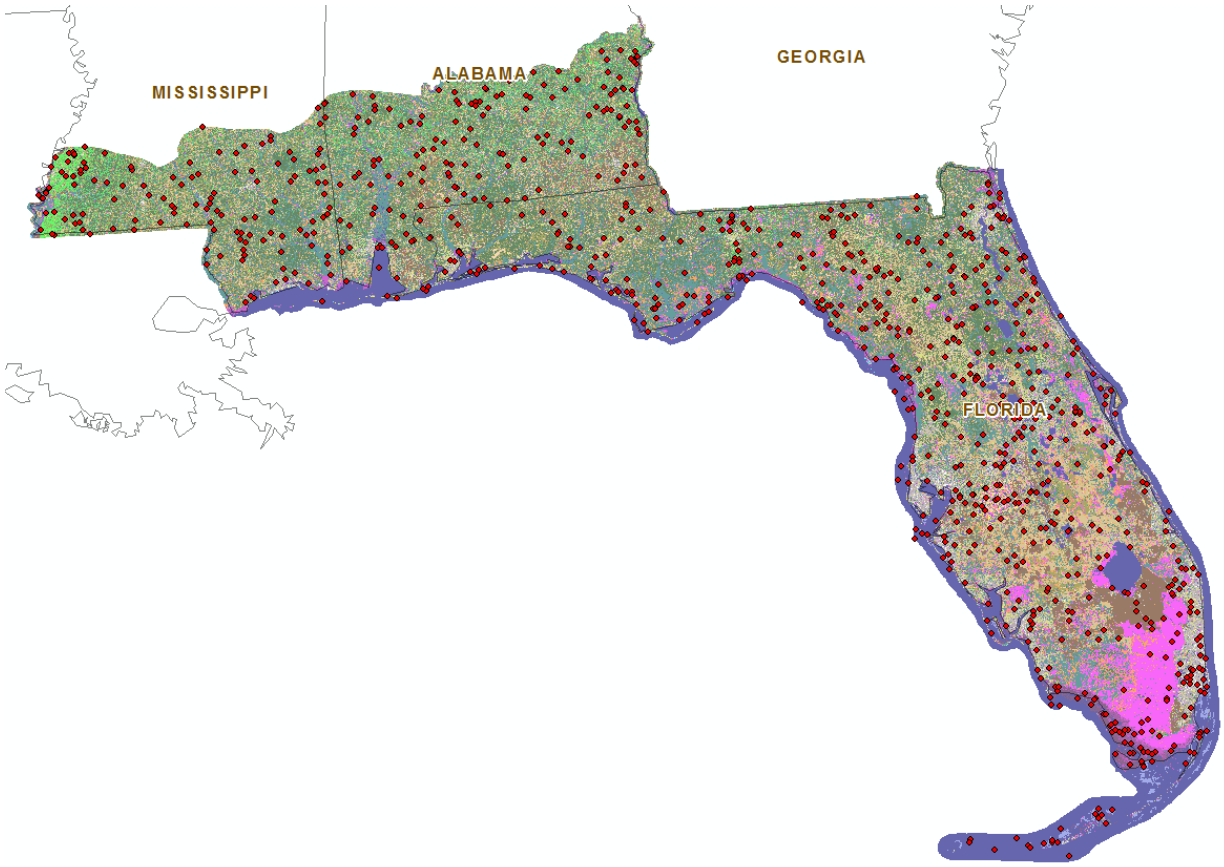


Figure 3. Accuracy assessment locations for the 2010 C-CAP Eastern Gulf of Mexico area draped on the 2010 land cover.

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 Eastern Gulf of Mexico 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 84.6%, with nearly the majority of individual classes exceeding 80% accuracy. There were very few trends to be found in the error matrix outside of confusion between Open Water/Unconsolidated Shore/Aquatic Bed and Grass/Shrub/Forest classes. Change/no-change accuracy for the product was 91%, with committed change being the largest error. It was found that 71% of the false change locations received the correct 2010 call, indicating the classification approaches appear to be working well.

Although the accuracy was high, potential improvements could be performed on the map in the future, or as part of the next update cycle. First, separating Unconsolidated Shore and Aquatic Bed from Open Water may be assisted by incorporating national shoreline data or modeled high/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 based on high-resolution lidar elevation data and the VDatum computer program.

Second, the Cultivated vs. Pasture/Hay classes may be improved through future work with the National Agricultural Statistics Service (NASS). As NASS develops and improves its crop-mapping approaches, its data may be incorporated into C-CAP.

Confusion among Grassland, Scrub/Shrub, and Forest remains a difficult issue to address. This is especially common because of the high amount of timber activity and the fast-growth rate of most commercial timber species in the region. Separating Scrub/Shrub from Forest is generally accomplished by using a height criterion, which cannot be directly measured from Landsat. As lidar data become more available in the future, these data may be used to estimate vegetation height and help separate Scrub/Shrub from Forest.