

# NATIONAL 2010 COASTAL CHANGE ANALYSIS PROGRAM ACCURACY ASSESSMENT

---

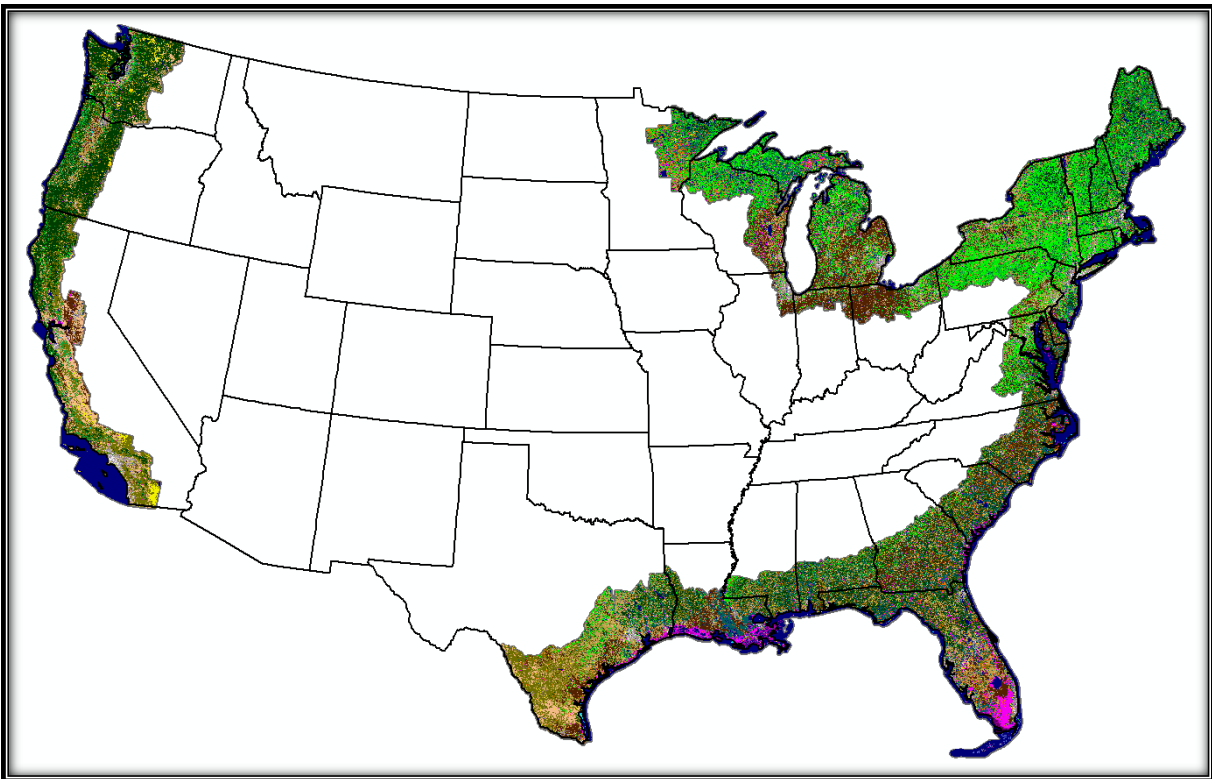
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)  
OFFICE FOR COASTAL MANAGEMENT



**Office for Coastal Management**  
2234 South Hobson Avenue  
Charleston, South Carolina 29405-2413  
(843) 740-1200  
[www.coast.noaa.gov](http://www.coast.noaa.gov)

## Table of Contents

Overview .....	1
Methods .....	2
Sample Unit Distribution .....	3
Results and Discussion .....	4
2010 Land Cover .....	4
2006-2010 Change .....	8
Conclusions .....	11



## Overview

This report summarizes nine separate accuracy assessment efforts that were performed on the National Oceanic and Atmospheric Administration (NOAA) 2010 Coastal Change Analysis Program (C-CAP) land cover update. The report provides a general overview of the methods used and highlights several statistics at the national and regional levels. Statistics reported at the national level were derived from the combination of detailed regional reports, which are available on NOAA's Digital Coast ([www.csc.noaa.gov/digitalcoast/publications/regional-reports](http://www.csc.noaa.gov/digitalcoast/publications/regional-reports)). Before this update, the last accuracy assessment of C-CAP data 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, new land cover classes have been added, the nation 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 C-CAP land cover data set was obtained through the contract vehicle at the NOAA Coastal Services Center, now the Office for Coastal Management. The 2010 land cover classification was completed by Photo Science and MDA Information Systems. Once the external contractors completed their 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.

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

- The overall accuracy for the 2010 C-CAP product was 84.0% (0.83 kappa).
- No classes fell below 80% for both producer<sup>1</sup> and user<sup>2</sup> accuracy; three classes were below 80% for producer accuracy, and seven were below 80% for user accuracy (Table 3).
- The accuracy for change/no-change was 88.7%, with the largest error being committed change (71.2% accuracy). It is interesting to note that of these committed change locations (falsely mapped as change) the accuracy was 74.6% for the 2010 call, indicating that the 2006 call was incorrect.
- Of the 2,700 sample locations in mapped change areas, the accuracy was 82.3%.

---

<sup>1</sup> Related to errors of omission when an area is excluded from the category to which it belongs.

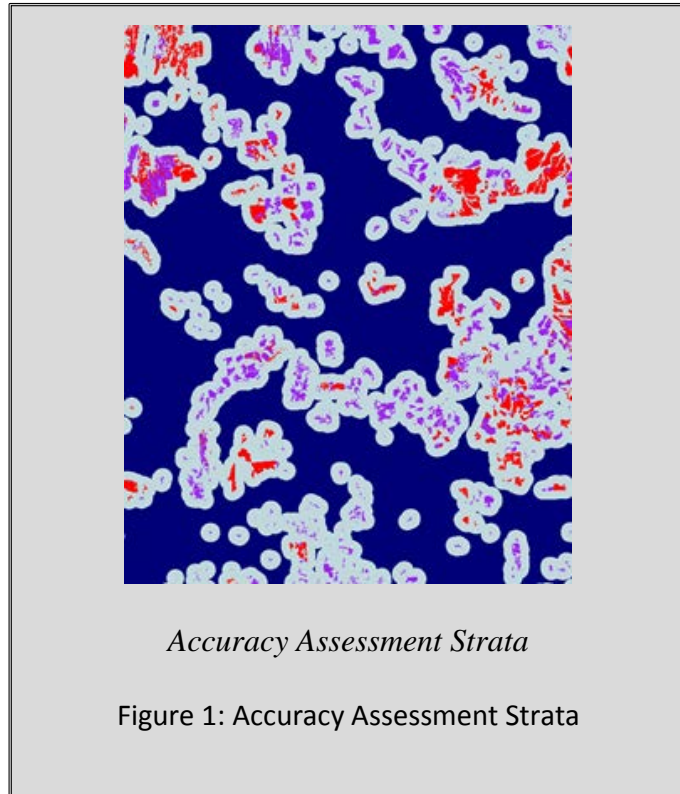
<sup>2</sup> Related to errors of commission when an area is included incorrectly in a category.

## 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 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. 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 one-third of the accuracy assessment sample units.



For each region (Figure 2), 900 sample units were identified using the ERDAS Imagine Accuracy Assessment tool. Sample units were selected per stratum using stratified random placement. Six out of nine land cover pixels around the location were required to be homogenous, or else the location would be discarded.

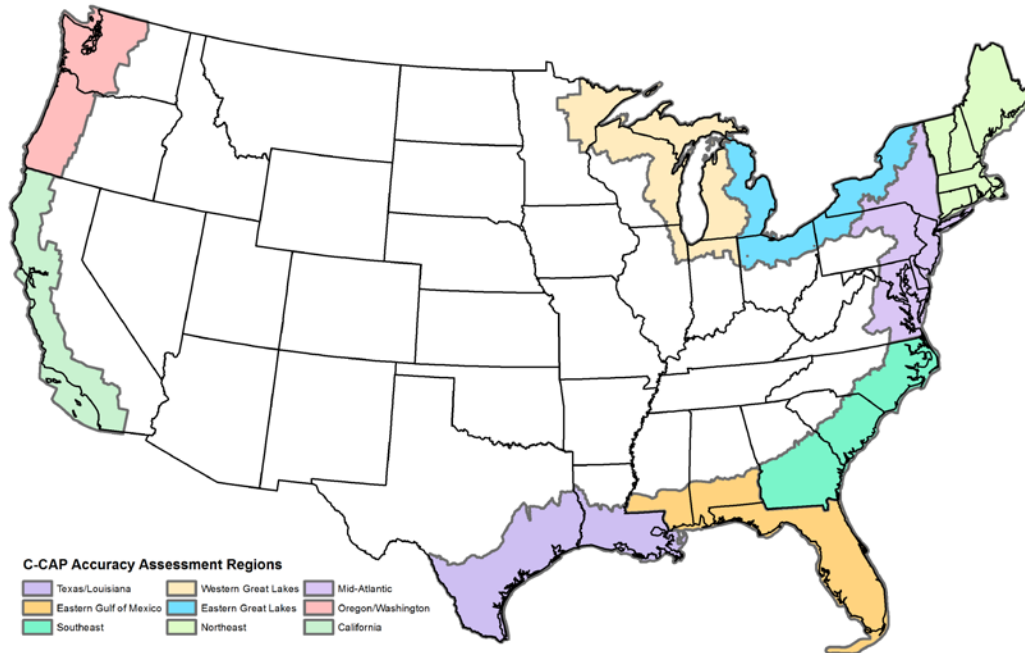


Figure 2. Accuracy assessment regions for the 2010 C-CAP land cover project.

### Sample Unit Distribution and Interpretation

As seen in Table 1, Scrub/Shrub received the most accuracy assessment sample units (788) and Estuarine Forested Wetland received the fewest (21). 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 4.7% of the accuracy assessment sample units and comprised 5.8% of the national coastal region. The largest discrepancy is with Evergreen Forest receiving 7.7% of the accuracy assessment sample units and comprising 14.4% of the national coastal region.

Each accuracy assessment sample unit was labeled by two reviewers. Each reviewer was responsible for labeling the 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 accuracy assessment 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.

Land Cover	Accuracy Assessment Sample Units				Percent of	
	Stratum 1	Stratum 2	Stratum 3	Total	Sample Units	Region
Developed, High Intensity	112	100	90	302	3.7%	0.6%
Developed, Medium Intensity	150	115	95	360	4.4%	1.4%
Developed, Low Intensity	158	129	121	408	5.0%	3.1%
Developed, Open Space	162	110	105	377	4.7%	1.6%
Cultivated Crops	120	185	243	548	6.8%	10.5%
Pasture/Hay	96	155	167	418	5.2%	7.0%
Grassland/Herbaceous	314	136	116	566	7.0%	4.9%
Deciduous Forest	109	218	230	557	6.9%	11.8%
Evergreen Forest	183	243	201	627	7.7%	14.4%
Mixed Forest	72	169	138	379	4.7%	5.8%
Scrub/Shrub	437	202	149	788	9.7%	10.7%
Palustrine Forested Wetland	91	187	187	465	5.7%	8.8%
Palustrine Scrub/Shrub Wetland	141	128	109	378	4.7%	2.6%
Palustrine Emergent Wetland	146	124	106	376	4.6%	2.2%
Estuarine Forested Wetland		10	11	21	0.3%	0.1%
Estuarine Scrub/Shrub Wetland	2	16	21	39	0.5%	0.0%
Estuarine Emergent Wetland	33	76	81	190	2.3%	0.9%
Unconsolidated Shore	68	80	67	215	2.7%	0.2%
Bare Land	153	98	91	342	4.2%	0.7%
Open Water	116	115	283	514	6.3%	12.4%
Palustrine Aquatic Bed	17	37	27	81	1.0%	0.0%
Estuarine Aquatic Bed	20	50	51	121	1.5%	0.1%
Perennial Snow		17	11	28	0.3%	0.0%
<b>Total</b>	<b>2700</b>	<b>2700</b>	<b>2700</b>	<b>8100</b>		
Area (square miles)	29,740	387,164	376,559	793,463		
Percent of Region	3.7%	48.8%	47.5%			

## Results and Discussion

### 2010 Land Cover

As stated earlier, nine regional accuracy assessments were performed, which were combined to yield the national accuracy assessment. Table 2 shows the overall accuracy for the regions and national total. The lowest regional accuracy was the Southeast (82.3%), while the Western Great Lakes had the highest accuracy (85.6%). Table 3 represents the combined error matrix for

the national 2010 land cover map. Overall accuracy for the national 2010 land cover product was 84.0% (0.83 kappa). The majority of classes met the C-CAP target specification of 80% per class accuracy. Of the ten instances where accuracy was below the targeted 80%, all of these did exceed 70%. No classes fell below the 80% threshold for both producer and user accuracy.

Table 2. Regional and National 2010 C-CAP accuracy assessment values.

Geography	Overall Accuracy (kappa)
California	82.8% (0.82)
Oregon/Washington	84.9% (0.84)
Western Great Lakes	85.6% (0.84)
Eastern Great Lakes	84.8% (0.84)
Northeast	84.0% (0.83)
Mid-Atlantic	82.7% (0.83)
Southeast	82.3% (0.80)
Eastern Gulf of Mexico	84.6% (0.84)
Texas/Louisiana	84.7% (0.84)
<b>National</b>	<b>84.0% (0.83)</b>

All but three classes had more than 50 sample units (the coarse “rule-of-thumb” for accuracy assessment). The three classes that did not exceed 50 locations represented a very small percentage of the mapping area and tended to be more scattered in their distribution. Both of these characteristics resulted in a low probability of them being sampled.

Major sources of classification confusion seen in the error matrix include the following:

1. **Low vegetation** – Pasture/Hay, Cultivated, Grassland, and Scrub/Shrub were all mapped with some confusion. The confusion between Cultivated and Pasture/Hay is fairly common and has been seen in other C-CAP regions. These classes are often best classified through the use of multiple dates of imagery to help detect spectral trends throughout the growing season. Typically, two dates of imagery were available for the 2010 classification, but they were not selected with Cultivated classification as the primary driver and thus may not have been the best available for these classes.
2. **Scrub/Shrub, Grassland, and Upland Forest** – Timber activity, which results in the cycling of Grassland to Scrub/Shrub to Forest over time, occurs heavily in several regions of the coastal area. 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.
3. **Levels of development** – The developed classes were separated from each other through the application of thresholds to a percent impervious surface (e.g., if the percent impervious was 80% or greater, the class was High Intensity Developed). Errors in the percent impervious surface value could translate to errors in the development class label. Because the percent impervious surface is a spectrally derived value, it is susceptible to variation from spectral differences naturally caused by the time of the



year or the reflectivity of different impervious surfaces (e.g., blacktop vs. concrete). Thus, two surfaces that should have the same imperviousness percentage, and Development category, may receive different values.

4. **Bare Land** – Bare Land was occasionally 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, creates confusion with developed land.
5. **Water and Unconsolidated Shore** – Open Water was incorrectly mapped as Unconsolidated Shore. In coastal locations, nearshore wave action, water turbidity, and tidal stage all influence the separation of these two classes. Examination of these incorrect sample locations seemed to show that the Unconsolidated Shore class is most likely overmapped in general, very often because of wave action present in the imagery.

Table 3. Full error matrix for the National 2010 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																						Total	User Accuracy	
		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 Forested Wetland	Estuarine Scrub/Shrub Wetland	Estuarine Emergent Wetland	Unconsolidated Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed			Perennial Snow
Map	Developed, High Intensity	289	2	1	1			2													7				302	95.7%
	Developed, Medium Intensity	28	297	11	6	1		5			2				1						9				360	82.5%
	Developed, Low Intensity	1	13	325	22	5	6	9	3	4	1	2	2	1	1				1		8	4			408	79.7%
	Developed, Open Space		1	1	310	2	7	22	5	1	4	11	5	1	2						5				377	82.2%
	Cultivated Crops		1	2	16	455	22	21	3	3	1	12	2	1	5						4				548	83.0%
	Pasture/Hay		1	4	18	43	305	25	4	1	1	13			3										418	73.0%
	Grassland/Herbaceous	1	1	2	9	21	13	455	12	9	5	25	1	1	5					5	1				566	80.4%
	Deciduous Forest			1	1	1	3	4	493	12	17	17	4	1	3										557	88.5%
	Evergreen Forest				2			3	577	17	21	3	2								1			1	627	92.0%
	Mixed Forest					1	2	14	25	320	15	2													379	84.4%
	Scrub/Shrub			1	3	3	10	33	44	49	39	578	8	9	4						7				788	73.4%
	Palustrine Forested Wetland				2	1	4		2		5	1	2	426	14	5						3			465	91.6%
	Palustrine Scrub/Shrub Wetland					1	2	1	3	2	1	2	9	37	300	17			1	1		1			378	79.4%
	Palustrine Emergent Wetland						4	4	6		1		1	8	15	313		1	4	4	6	6	3		376	83.2%
	Estuarine Forested Wetland															20			1						21	95.2%
	Estuarine Scrub/Shrub Wetland													1	1	2		28	7						39	71.8%
	Estuarine Emergent Wetland						1		1	1				2	1	9			171	1		3			190	90.0%
	Unconsolidated Shore									1						3				167	4	39		1	215	77.7%
	Bare Land			1		6	9	7	12	2	6		7	1		2				1	284	4			342	83.0%
	Open Water				1		1		1		1	1	2		3				1		1	500	4	1	514	97.3%
Palustrine Aquatic Bed						1						1		1				2	3		11	59	3	81	72.8%	
Estuarine Aquatic Bed										1	1										10	1	108	121	89.3%	
Perennial Snow											1									1			26	28	92.9%	
Total	319	317	351	396	553	380	602	587	695	410	718	505	347	379	20	29	188	177	342	582	63	113	27	8100		
Producer Accuracy	90.6%	93.7%	92.6%	78.3%	82.3%	80.3%	75.6%	84.0%	83.0%	78.0%	80.5%	84.4%	86.5%	82.6%	100.0%	96.6%	91.0%	94.4%	83.0%	85.9%	93.7%	95.6%	96.3%	84.0%		

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 4 shows that although 36.2% of the sample units received a fuzzy call, these calls were rarely responsible (16.5%) for a location being deemed mapped as correct.

Table 4. Fuzzy reference calls for the National 2010 C-CAP accuracy assessment.

Fuzzy Reference Calls		
Of the 8,100 sample locations, 2,932 (36.2%) had a fuzzy call	For the 6,806 correctly mapped locations, 1,120 (16.5%) were correct based on the fuzzy land cover call (5,686 were correct based on primary call)	Land cover classes with most fuzzy calls include different levels of development; Scrub/Shrub, Grass, and Forest; Forest categories; Wetland categories, Unconsolidated Shore, Water, and Estuarine Aquatic Bed

### 2006-2010 Change

Overall change/no-change accuracy was 88.7% (Table 5). Committed change was the largest error with a user accuracy of 71.2% (777 sample locations mapped as change, but deemed no-change by the reviewers). These 777 locations were assessed in their own error matrix and resulted in 74.6% 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 5,400 total sample units in mapped no-change areas, only 137 were deemed missed change. Stratum 2 (specifically designed to try to identify potential missed change) contained 107 of these missed change locations. 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 5. Change/no-change matrix for the National 2010 C-CAP accuracy assessment. 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		Total	Users
		0	1		
Map Change	0	5263	137	5400	97.5%
	1	777	1923	2700	71.2%
Total		6040	2060	8100	
Producers		87.1%	93.3%		88.7%

A final analysis was performed using only sample locations interpreted as change (2,060 locations). Table 6 shows that the overall accuracy of these locations was 84.1%, slightly higher than the total map accuracy (Table 3). Errors within this matrix were similar to the overall matrix discussed previously.

Table 6. Error matrix for the National 2010 C-CAP accuracy assessment based on interpreted change locations. Map classes are along the left edge and reference calls are along the top of the matrix.

		Reference																				Total			
		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 Forested Wetland	Estuarine Emergent Wetland	Unconsolidated Shore	Bare Land	Open Water	Palustrine Aquatic Bed			Estuarine Aquatic Bed	
Map	Developed, High Intensity	83	2					2											1					88	
	Developed, Medium Intensity	11	86	4	1			3			1								5					111	
	Developed, Low Intensity	1	4	70	7			7			1		1	1					8	3				103	
	Developed, Open Space				65		2	6	2			2					2		4					83	
	Cultivated Crops				2	49	2	10		1		6				1			3					74	
	Pasture/Hay					1	27	9		1		3				1								42	
	Grassland/Herbaceous		1		1		2	267		1	1	14							4					294	
	Deciduous Forest			1				1	40	5	2	12				1								62	
	Evergreen Forest									137		9		2										148	
	Mixed Forest									8	35	8												51	
	Scrub/Shrub					1	3	17	2	15	4	344	3	6	2				7					404	
	Palustrine Forested Wetland							2		2		2	45	4	3					1				59	
	Palustrine Scrub/Shrub Wetland							2				1	5	92	6				1					107	
	Palustrine Emergent Wetland						3	3						2	101				2	5		1		117	
	Estuarine Forested Wetland															1								1	
	Estuarine Scrub/Shrub Wetland												1											1	
	Estuarine Emergent Wetland													1	2		17	1						21	
	Unconsolidated Shore														1			42			3			46	
	Bare Land		1		1	2	1	1										1	124					132	
	Open Water					1			1				2		2							85		91	
Palustrine Aquatic Bed																					17	1	18		
Estuarine Aquatic Bed																					1	6	7		
Total	95	94	75	77	54	40	330	45	170	43	402	57	108	126	1	17	47	161	92	19	7	2060	Correct	1733	
																								Percent Correct	84.1%

## 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. Nine regional accuracy assessments were performed on the 2010 C-CAP data. These nine reports were combined to produce this national-level accuracy report. The combined accuracy for the nation was 84.0%, with the majority of individual classes exceeding 80% accuracy.

There were no classes with accuracy below 80% for both user and producer accuracy. Change/no-change accuracy for the nation was 88.7%, with committed change being the largest error. It was found that 75% of the false change locations received the correct 2010 call, indicating the classification approaches appear to be working fairly well.

Although the accuracy did not meet the target 85%, the overall quality of the map was high. During the 2010 land cover update cycle, the C-CAP team expended considerable effort to improve the mapping accuracy and consistency of development and wetland classes across the nation. As C-CAP completes the next round of land cover updates, improvements to other land cover classes will be incorporated as deemed appropriate. Each regional accuracy report highlights several of these areas for improvement.