Mid-Atlantic 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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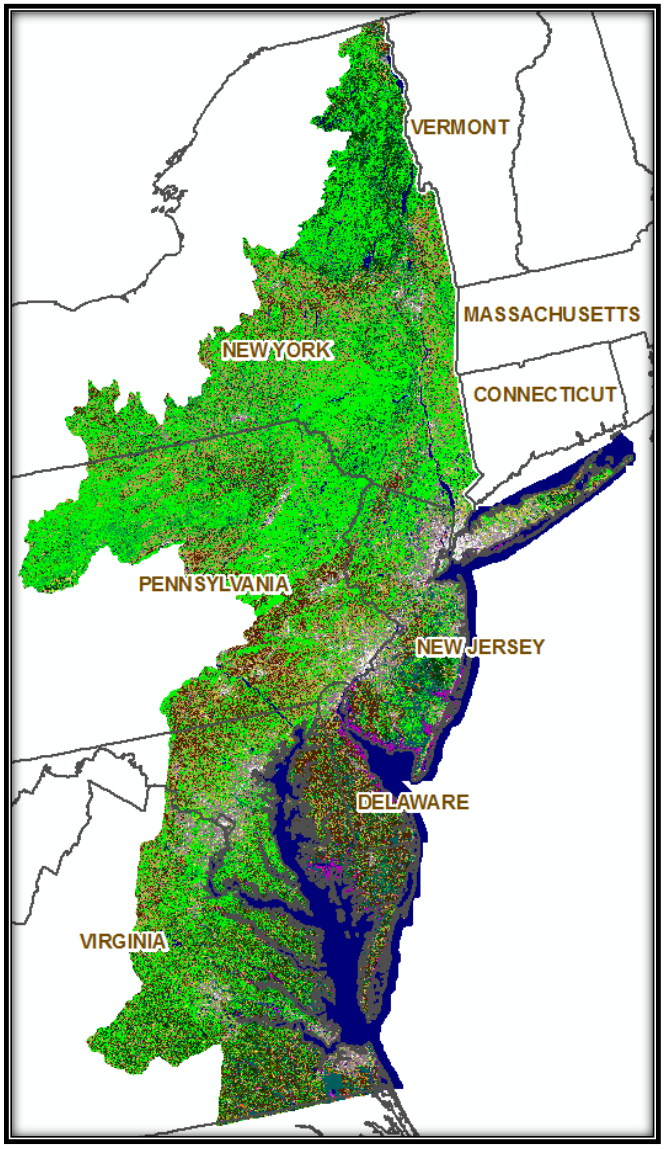


Overview

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 Mid-Atlantic. This area covers over 86,000 square miles and includes the coastal portions of New York, Pennsylvania, New Jersey, Delaware, and Virginia. 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, which included mapped change, would be part of the 2010 land cover update cycle.

The 2010 Mid-Atlantic 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 June 2014.

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

- The overall accuracy for the Mid-Atlantic 2010 C-CAP product was 82.7% (0.83 kappa).
- Three classes fell below 80% for both producer[1] *and* user[2] accuracy; seven classes were below 80% for producer accuracy, and eight were below 80% for user accuracy (Table 2).
- The accuracy for change/no-change was 86.4%, with the largest error being committed change (66.0% accuracy). It is interesting to note that of these committed change locations (falsely mapped as change) the accuracy was 64.7% for the 2010 call, indicating the 2006 call was incorrect.
- Of the 300 sample locations in mapped change areas, the accuracy was 76.3%.

Methods

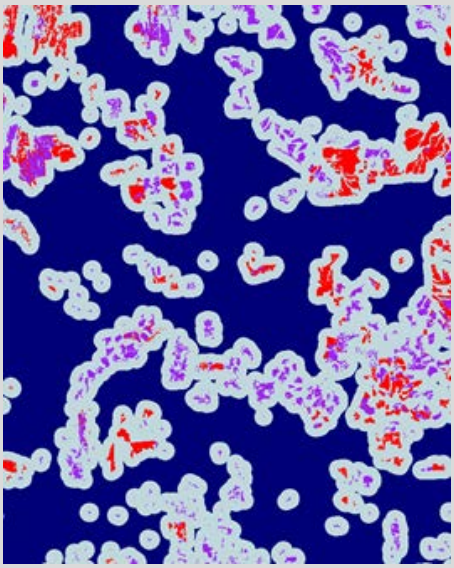
The C-CAP team met and discussed accuracy assessment on multiple occasions and determined three essential requirements:

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 14 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 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 required 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, Deciduous Forest received the most accuracy assessment sample units (100) and both Estuarine Scrub/Shrub and Palustrine Aquatic Bed received the fewest (2). 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 5.0% of the accuracy assessment (AA) sample units and comprised 6.9% of the region. The largest discrepancy is with Deciduous Forest receiving 11.1% of the AA sample units and comprising 29.5% 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	13	11	38	4.2%	1.0%
Developed, Medium Intensity	22	18	11	51	5.7%	2.0%
Developed, Low Intensity	25	17	13	55	6.1%	4.9%
Developed, Open Space	22	14	14	50	5.6%	3.0%
Cultivated Crops	15	25	17	57	6.3%	10.7%
Pasture/Hay	13	21	19	53	5.9%	9.2%
Grassland/Herbaceous	26	11	11	48	5.3%	1.0%
Deciduous Forest	16	37	47	100	11.1%	29.5%
Evergreen Forest	13	17	18	48	5.3%	7.0%
Mixed Forest	1	25	19	45	5.0%	6.9%
Scrub/Shrub	42	14	12	68	7.6%	3.5%
Palustrine Forested Wetland	14	18	22	54	6.0%	6.3%
Palustrine Scrub/Shrub Wetland	15	11	10	36	4.0%	0.7%
Palustrine Emergent Wetland	14	11	10	35	3.9%	0.5%
Estuarine Scrub/Shrub Wetland	0	2	0	2	0.2%	0.0%
Estuarine Emergent Wetland	7	11	12	30	3.3%	1.3%
Unconsolidated Shore	10	10	10	30	3.3%	0.1%
Bare Land	18	11	10	39	4.3%	0.4%
Open Water	12	13	34	59	6.6%	12.0%
Palustrine Aquatic Bed	1	1		2	0.2%	0.0%
Total	300	300	300	900		
Area (square miles)	1,442	43,198	41,796	86,436		
Percent of Region	1.7%	50.0%	48.3%			

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 82.7% (0.83 kappa). The majority of classes met the C-CAP target specification of 80% per class accuracy. Of the 15 instances where accuracy was below the targeted 80%, 11 of these did exceed 70%. Three classes, Cultivated, Scrub/Shrub, and Estuarine Scrub/Shrub Wetlands fell below the 80% threshold

for both producer and user accuracy. Cultivated was most confused with Open Space Developed, Pasture/Hay, and Grassland. Similar to other regions, Scrub/Shrub was confused with upland forest types.

Although most classes did not have more than 50 sample units (the coarse "rule-of-thumb" for accuracy assessment), nine classes did exceed 50, and 12 classes were over 40. The accuracy of Estuarine Scrub/Shrub (50%) and Palustrine Aquatic Bed (100%), both may be questionable, since only two sample locations were assessed per class.

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

1. **Pasture/Hay, Cultivated, Grassland, and Open Space Developed** – 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; thus they may not have been the best available for these classes. Minor confusion was also seen with Grassland and Open Space Developed for the same reasons.

2. **Scrub/Shrub, Forests, and Grassland** – All of these classes are often directly related to each other, as one class transitions to the next 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.

3. **Upland Forest** –Separating Deciduous, Evergreen, and Mixed Forest is typically accomplished through using leaf-on and leaf-off imagery. The spectral differences among these land cover classes can be quite dramatic compared across such imagery as the deciduous trees lose their leaves. While deciduous forests dominate this region, it is common for an evergreen understory to be present. During the growing season, the forests appear as deciduous, then may transition into an evergreen appearance as the overstory canopy trees lose their leaves and the evergreens become visible. This changing appearance creates confusion during the classification process.

4. **Water and Unconsolidated Shore** – Open Water was confused with 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.

Table 2. Full error matrix for the 2010 Mid-Atlantic 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 Scrub/Shrub Wetland	Estuarine Emergent Wetland	Unconsolidated Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Grand Total	Users
Developed, High Intensity	35			1			1											1			38	92.1%
Developed, Medium Intensity	4	40	1	2	1						1							2			51	78.4%
Developed, Low Intensity			47	1		1		3				1	1						1		55	85.5%
Developed, Open Space			1	42	1		4					1						1			50	84.0%
Cultivated Crops				6	41	3	2	1			2			2							57	71.9%
Pasture/Hay				3	3	42	2	1			2										53	79.2%
Grassland/Herbaceous	1		1	3	3	2	32		1	1	4										48	66.7%
Deciduous Forest								93	1	3	3										100	93.0%
Evergreen Forest				1					45	2											48	93.8%
Mixed Forest								4	1	40											45	88.9%
Scrub/Shrub							2	10	6	5	41	1	2					1			68	60.3%
Palustrine Forested Wetland			2		1		2		1		1	45	1	1							54	83.3%
Palustrine Scrub/Shrub Wetland										1		5	29	1							36	80.6%
Palustrine Emergent Wetland					1							2	1	30	1						35	85.7%
Estuarine Scrub/Shrub Wetland												1			1						2	50.0%
Estuarine Emergent Wetland					1									2		27					30	90.0%
Unconsolidated Shore																	22		8		30	73.3%
Bare Land		1			2		2		2			1						31			39	79.5%
Open Water																			59		59	100.0%
Palustrine Aquatic Bed																				2	2	100.0%
Grand Total	40	41	52	59	54	48	47	112	57	52	54	57	34	36	2	27	22	36	68	2	900	
Producers	87.5%	97.6%	90.4%	71.2%	75.9%	87.5%	68.1%	83.0%	78.9%	76.9%	75.9%	78.9%	85.3%	83.3%	50.0%	100.0%	100.0%	86.1%	86.8%	100.0%		82.7%

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 32% of the sample units received a fuzzy call, these calls were rarely responsible (21.5%) for a location being deemed mapped as correct.

Table 3. Fuzzy reference calls for the 2010 Mid-Atlantic C-CAP region.

Table 3: Fuzzy Reference Calls		
Of 900 sample locations, 288 (32.0%) had a fuzzy call	For the 736 correctly mapped locations, 160 (21.5%) were correct based on the fuzzy land cover call (584 were correct based on primary call)	Land cover classes with the most fuzzy calls include different levels of Development, Palustrine Scrub/Shrub–Palustrine Forest, Cultivated–Pasture/Hay, and Unconsolidated Shore–Open Water

2006-2010 Change

Overall change/no-change accuracy was 86% (Table 4). Committed change was the largest error with a user accuracy of 66% (102 sample locations mapped as change, but deemed no change by the reviewers). These 102 locations were assessed in their own error matrix and resulted in a 64.7% overall accuracy. This seems to indicate that the method used to identify potential change pixels (creating the change mask) may be overestimating change, and these areas are somewhat difficult to map accurately. These locations of committed change may be used in future editing efforts, since they are indicative of potential errors within the 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, only 20 were deemed missed change. Thirteen 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 this committed change is generally the correct 2010 call) and that there is little omitted change in the map.

Table 4. Change/no-change matrix for the 2010 Mid-Atlantic 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	102	198	300	66%
	Total	682	218	900	
	Producers	85%	91%		86%

A final analysis was performed using only sample locations interpreted as change (218 locations). Table 5 shows that the overall accuracy of these locations was 81.7%, slightly below the total map accuracy (Table 2). The Scrub/Shrub class appeared to have the most confusion, being mapped as other natural vegetation classes (Grassland and Forest). This confusion is similar to what was seen in Table 2.

Comparison between 2001 and 2010 Accuracy Assessments

This 2010 accuracy assessment cannot be directly compared to the accuracy assessment performed on the 2001 products (Figure 2). The 2010 Mid-Atlantic mapping region is covered by three regions within the 2001 accuracy assessment. The accuracy assessment locations (4,549 total) for the 2001 data sets were primarily drawn from field sample locations along roadways and photointerpreted locations (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 reported overall accuracies for the 2001 products ranged from 71.7% to 81.5%.

Table 5. Error matrix for the 2010 Mid-Atlantic 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	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	Total
Developed, High Intensity	10						1												11
Developed, Medium Intensity	2	9															1		12
Developed, Low Intensity			12	1								1	1						15
Developed, Open Space				11			2										1		14
Cultivated Crops				1	4	1	2				2								10
Pasture/Hay						2	1				1								4
Grassland/Herbaceous							21				3								24
Deciduous Forest								7	1	1	3								12
Evergreen Forest									10										10
Scrub/Shrub									2	1	30		2				1		36
Palustrine Forested Wetland							2				1	3	1	1					8
Palustrine Scrub/Shrub Wetland													9						9
Palustrine Emergent Wetland														11					11
Estuarine Scrub/Shrub Wetland												1							1
Estuarine Emergent Wetland															6				6
Unconsolidated Shore																10		1	11
Bare Land		1															13		14
Open Water																		10	10
Total	12	10	12	13	4	3	29	7	13	2	40	5	13	12	6	10	16	11	218

Correct	178
Percent Correct	81.7%

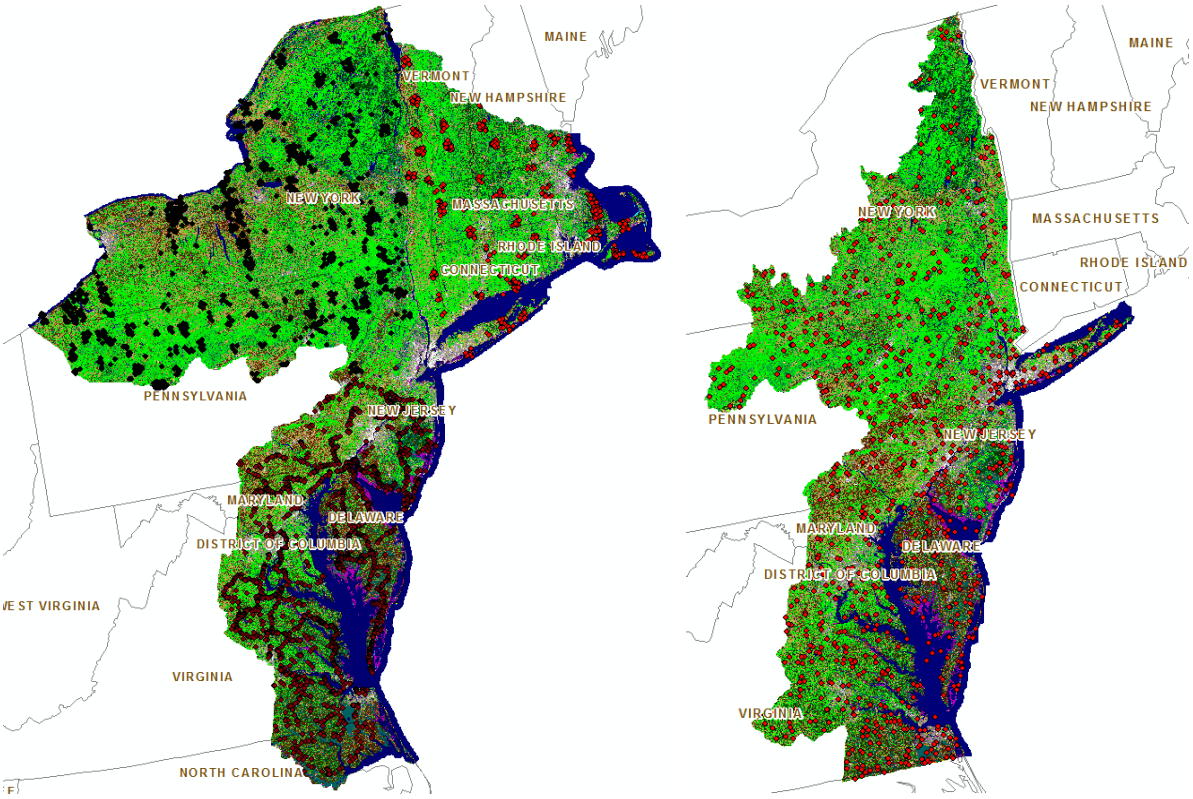


Figure 2. Differences in accuracy assessment site selection method and number of locations can be seen by comparing 2001 C-CAP accuracy assessment locations covering this area (left) against the 2010 C-CAP Mid-Atlantic accuracy assessment locations (right). Sampling along road networks (linear features) and within image footprints (clusters) in the 2001 assessment can be compared in the left map with the stratified random sampling for the 2010 approach on the right.

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 Mid-Atlantic 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 82.7%, with the majority of individual classes exceeding 80% accuracy.

There were few trends to be found in the error matrix outside of confusion between Open Water/Unconsolidated Shore and Grass/Shrub/Forest classes. Change/no-change accuracy for the product was 86%, with committed change being the largest error. It was found that 65% of the false change locations received the correct 2010 call.

Although the accuracy did not meet the target 85%, the overall quality of the map 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 from Open Water may be assisted through the incorporation of 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. These classes are most commonly found in areas with timber activity. Separating Scrub/Shrub from Forest is generally based on 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.