Northeast 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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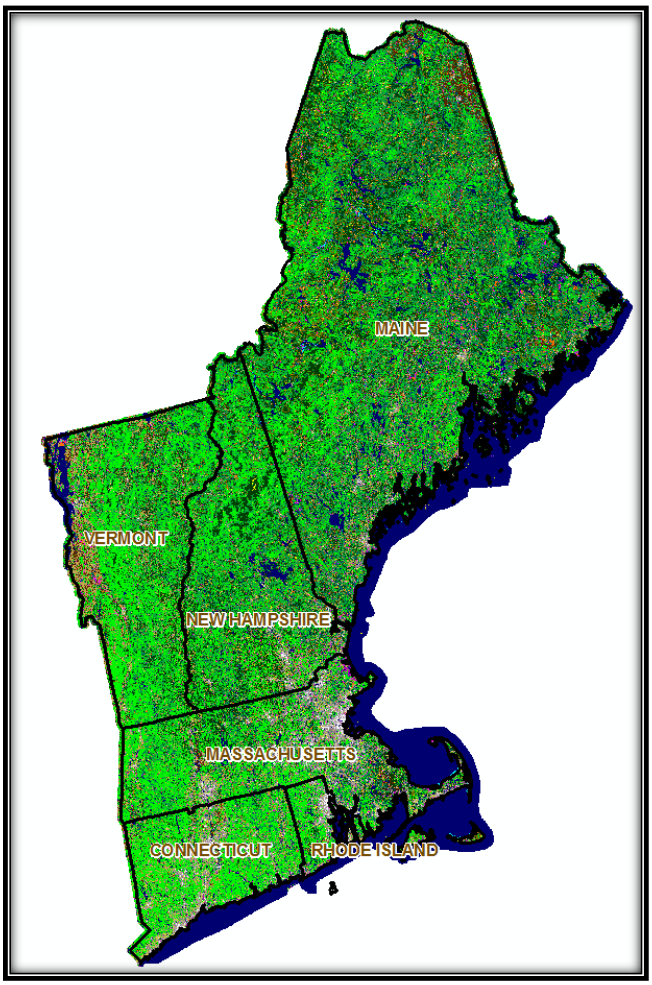


Overview

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 Northeast, covering nearly 75,000 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 Northeast 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 MDA Federal. 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 Northeast 2010 C-CAP product was 84.0% (0.83 kappa).
- Four classes fell below 80% for both producer[1] *and* user[2] accuracy; six classes were below 80% for producer accuracy, and nine were below 80% for user accuracy (Table 2).
- The accuracy for change/no-change was 88.2%, with the largest error being committed change (66.7% accuracy). It is interesting to note that of these committed change locations (falsely mapped as change) the accuracy was 70.0% for the 2010 call, indicating the 2006 call was incorrect.
- Of the 300 sample locations in mapped change areas, the accuracy was 83.0%.

Methods

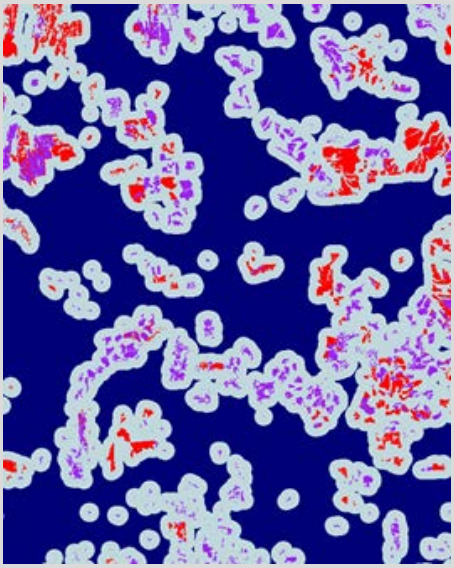
The C-CAP team met and discussed accuracy assessment on multiple occasions and determined three essential requirements:

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 attempted to split the non-change area evenly into the other two strata. Stratum 2 (purple plus gray) was

[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.

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 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, Evergreen Forest received the most accuracy assessment sample units (91) and Palustrine Aquatic Bed received the fewest (8). 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, Palustrine Forested Wetland received 5.4% of the accuracy assessment (AA) sample units and comprised 6.3% of the region. The largest discrepancy is with Deciduous Forest receiving 9.7% of the AA sample units and comprising 23.6% 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	13	11	10	34	3.8%	0.6%
Developed, Medium Intensity	16	12	11	39	4.3%	1.5%
Developed, Low Intensity	14	13	12	39	4.3%	2.5%
Developed, Open Space	14	12	11	37	4.1%	1.5%
Cultivated Crops	12	13	12	37	4.1%	2.0%
Pasture/Hay	11	14	14	39	4.3%	3.8%
Grassland/Herbaceous	22	11	10	43	4.8%	1.0%
Deciduous Forest	15	32	40	87	9.7%	23.6%
Evergreen Forest	41	27	23	91	10.1%	15.4%
Mixed Forest	17	33	30	80	8.9%	19.8%
Scrub/Shrub	47	17	11	75	8.3%	4.7%
Palustrine Forested Wetland	12	22	15	49	5.4%	6.3%
Palustrine Scrub/Shrub Wetland	14	12	11	37	4.1%	1.6%
Palustrine Emergent Wetland	10	12	11	33	3.7%	0.9%
Estuarine Emergent Wetland	2	10	10	22	2.4%	0.2%
Unconsolidated Shore	10	10	10	30	3.3%	0.2%
Bare Land	19	11	10	40	4.4%	0.5%
Open Water	11	13	36	60	6.7%	13.9%
Palustrine Aquatic Bed	0	5	3	8	0.9%	0.0%
Estuarine Aquatic Bed	0	10	10	20	2.2%	0.1%
Total	300	300	300	900		
Area (square miles)	1,527	36,997	36,249	74,773		
Percent of Region	2.0%	49.5%	49.5%			

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 84.0% (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%, 10 of these did exceed 70%. Four classes, Open Space Developed, Pasture/Hay, Grassland, and Scrub/Shrub fell below the 80% threshold for both producers and user accuracy. Open Space Developed and Scrub/Shrub accuracy values were in the mid-to-upper 70% range, while Pasture/Hay and Grassland were a bit lower. The class with the lowest single accuracy was Pasture/Hay (59.0% user accuracy), which indicates that this class may be overmapped, and appears to be confused with other low vegetation classes (Open Space Developed, Cultivated, and Grassland (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 eight classes were over 40. Only Palustrine Aquatic Bed had less than 20 sample location, which can be explained by the limited area this class represents in the landscape.

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

1. **Scrub/Shrub and Upland Forest** – In the Northeast, there is a considerable amount of timber activity, which results in the cycling of Grassland to Scrub/Shrub to Forest over time. 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.
2. **Pasture/Hay, Grassland, and Cultivated** – Confusion between Pasture/Hay and Cultivated 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 separation of these classes as the primary driver; thus, they may not have been the best available. Grassland, another low-lying vegetation class, often appears as spectrally similar to Pasture/Hay, and the classes are commonly confused.
3. **Water, Unconsolidated Shore, and Emergent Wetlands** – Open Water was incorrectly mapped as Unconsolidated Shore and Emergent Wetland classes. 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 and large tidal ranges present in the imagery. Varying water levels and different seasons may be responsible for the confusion of Water and the Emergent Wetland classes.

Table 2. Full error matrix for the 2010 Northeast 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 Emergent Wetland	Unconsolidated Shore	Bare Land	Open Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed	Total	Users
Developed, High Intensity	33		1																		34	97.1%
Developed, Medium Intensity		35	2				1										1				39	89.7%
Developed, Low Intensity			33	2		2	1					1									39	84.6%
Developed, Open Space				29			1	1		2		3		1							37	78.4%
Cultivated Crops				2	24	2	5	1			1	1					1				37	64.9%
Pasture/Hay				4	4	23	5	2			1										39	59.0%
Grassland/Herbaceous						1	29	5		3	5										43	67.4%
Deciduous Forest					1	1		81	1	3											87	93.1%
Evergreen Forest								1	85	2	3										91	93.4%
Mixed Forest								2	2	73	3										80	91.3%
Scrub/Shrub					1			8	4	7	55										75	73.3%
Palustrine Forested Wetland												45	3					1			49	91.8%
Palustrine Scrub/Shrub Wetland												1	34	1				1			37	91.9%
Palustrine Emergent Wetland									1		1	2	2	25				2			33	75.8%
Estuarine Emergent Wetland								1				2		1	16			2			22	72.7%
Unconsolidated Shore																23		7			30	76.7%
Bare Land				2		2	1	2			1						31	1			40	77.5%
Open Water						1					1							58			60	96.7%
Palustrine Aquatic Bed																			8		8	100.0%
Estuarine Aquatic Bed										1	1							2		16	20	80.0%
Total	33	35	36	39	30	32	43	104	93	91	72	55	39	28	16	23	33	74	8	16	900	
Producers	100.0%	100.0%	91.7%	74.4%	80.0%	71.9%	67.4%	77.9%	91.4%	80.2%	76.4%	81.8%	87.2%	89.3%	100.0%	100.0%	93.9%	78.4%	100.0%	100.0%		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 3 shows that although 37.4% of the sample units received a fuzzy call, these calls were rarely responsible (14.4%) for a location being deemed mapped as correct.

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

Fuzzy Reference Calls		
Of the 900 sample locations, 337 (37.4%) had a fuzzy call	For the 756 correctly mapped locations, 109 (14.4%) were correct based on the fuzzy land cover call (647 were correct based on primary call)	Land cover classes with the most fuzzy calls include all upland forests; Palustrine Emergent and Palustrine Shrub; Deciduous and Open Space Developed

2006-2010 Change

Overall change/no-change accuracy was 88.2% (Table 4). Committed change was the largest error with a user accuracy of 66.7% (100 sample locations mapped as change, but deemed no-change by the reviewers). These 100 locations were assessed in their own error matrix and resulted in 70.0% 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, only six were deemed missed change. 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 were limited missed true change sites as well.

Table 4. Change/no-change matrix for the 2010 Northeast 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	594	6	600	99.0%
	1	100	200	300	66.7%
	Total	694	206	900	
	Producers	85.6%	97.1%		88.2%

A final analysis was performed using only sample locations interpreted as change (206 locations). Table 5 shows that the overall accuracy of these locations was 88.3%, which is greater 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

Direct comparisons with the 2001 accuracy assessment cannot be realistically made, since the areas covered, and methods used, varied considerably. Two separate accuracy assessments covered this area in 2001: all of U.S. Geological Survey (USGS) Zone 66 (697 locations) and most of USGS Zone 65 (572 locations). The 2001 accuracy assessment locations were drawn from high-resolution satellite imagery scenes, resulting in clusters of accuracy assessment locations (Figure2) and locations along some roadways along the coast. The distribution of accuracy assessment sites in 2010 is shown in Figure 3. The overall accuracy for the two areas in 2001 was 85.3% (Zone 66) and 85.1% (Zone 65). These are similar to the 2010 overall accuracy (84.0%).

Table 5. Error matrix for the 2010 Northeast 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	Unconsolidated Shore	Bare Land	Open Water	Total
Developed, High Intensity	7																	7
Developed, Medium Intensity		10					1									1		12
Developed, Low Intensity			3				1											4
Developed, Open Space				6										1				7
Cultivated Crops					4		3									1		8
Pasture/Hay						2	2				1							5
Grassland/Herbaceous							19			1	2							22
Deciduous Forest								8										8
Evergreen Forest									32		1							33
Mixed Forest									2	8	2							12
Scrub/Shrub					1				1		34							36
Palustrine Forested Wetland												9	2					11
Palustrine Scrub/Shrub Wetland													7					7
Palustrine Emergent Wetland														7				7
Estuarine Emergent Wetland														1				1
Unconsolidated Shore															5			5
Bare Land																15		15
Open Water																	6	6
Total	7	10	3	6	5	2	26	8	35	9	40	9	9	9	5	17	6	206

Correct	182
Percent Correct	88.3%

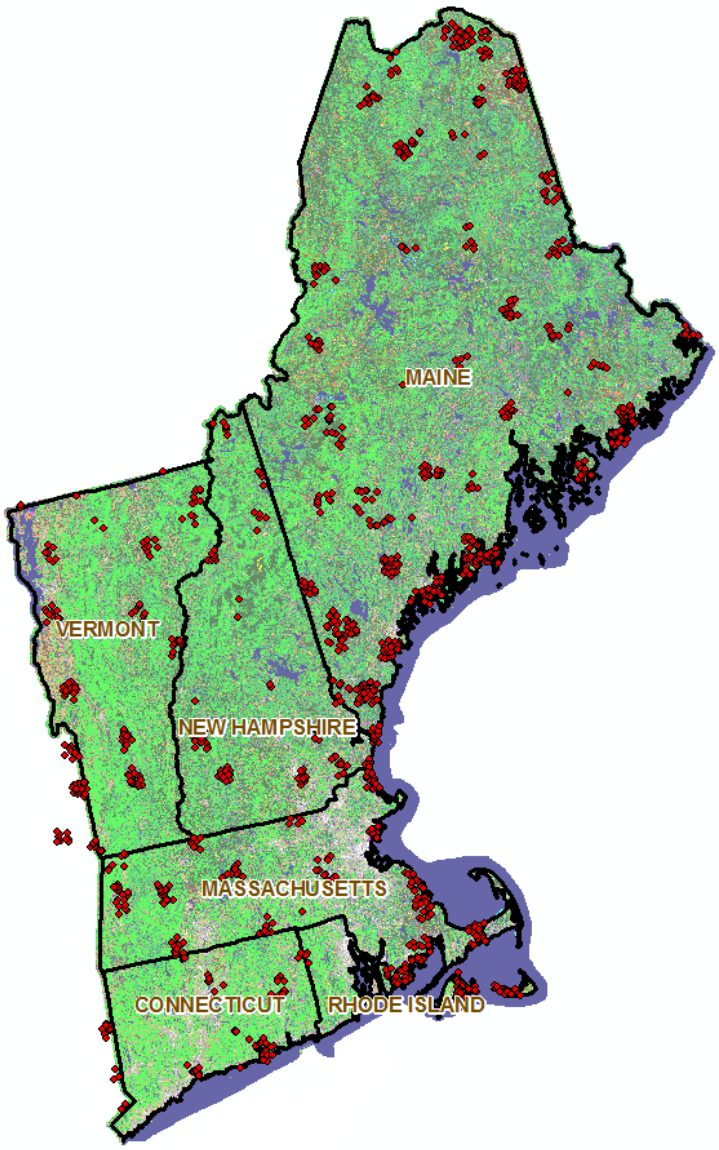


Figure 2. Accuracy assessment locations for 2001 Northeast C-CAP area draped on the 2001 land cover. Two separate accuracy assessments covered this area (extending into New York, but not shown on this image). Sampling within high-resolution satellite imagery (clusters) and along road networks (along coast) can be seen within the map.

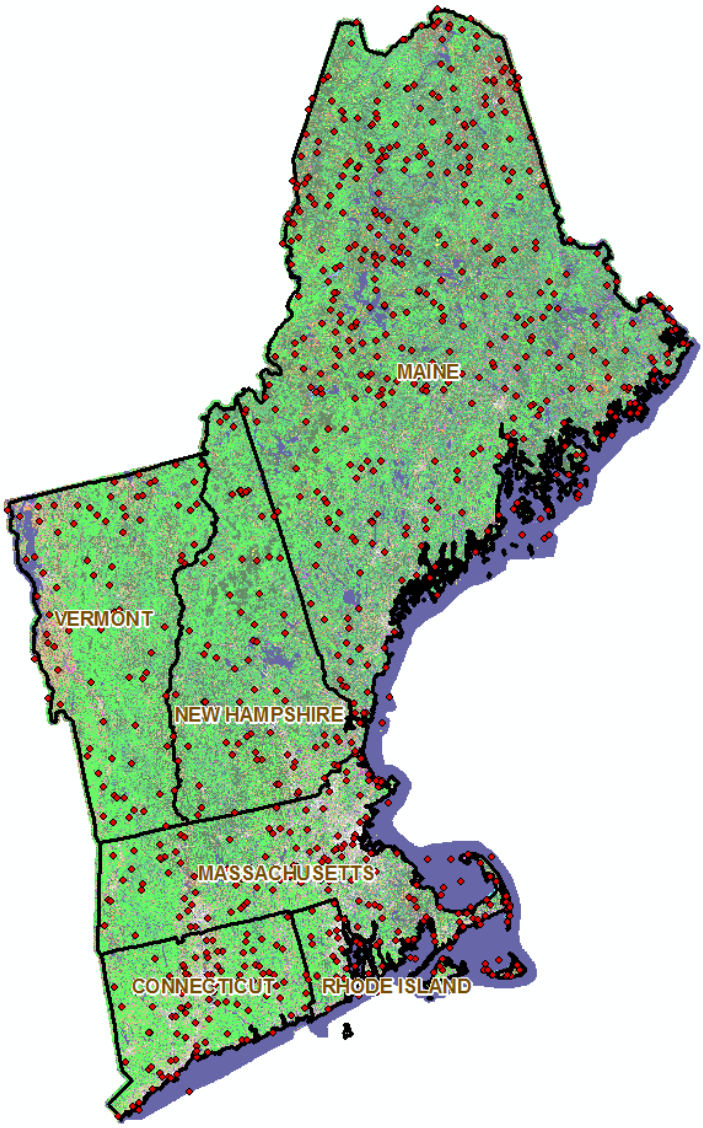


Figure 3. Accuracy assessment locations for the 2010 Northeast C-CAP area draped on the 2010 land cover.

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 Northeast 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 84.0%, with the majority of individual classes exceeding 80% accuracy.
There were four classes, Open Space Developed, Pasture/Hay, Grassland, and Scrub/Shrub, with accuracy below 80% for both user and producer accuracy. Change/no-change accuracy for the product was 88.2%, with committed change being the largest error. It was found that 70% of the false change locations received the correct 2010 call, indicating the classification approaches appear to be working well.

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. The confusion among Scrub/Shrub and upland forests is a large source of overall error in the map and will be difficult to address. 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.

Confusion among Pasture/Hay, Grassland, and Cultivated remains a difficult issue to address. 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. The incorporation of additional seasonal dates of imagery may help detect planting and harvest practices throughout the year, which may aid in classification. These will continue to be difficult class breaks to make, and more discussions should be held to address this issue.

Separating Open Water from Unconsolidated Shore and Emergent Wetland 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.

Although not a large source of error in the map, there is potential confusion among the upland forest types, as determined by the use of fuzzy calls between Deciduous, Evergreen, and Mixed forests. The use of leaf-off and leaf-on imagery helps to separate these classes. Future mapping efforts should use additional dates of imagery in forested areas to help separate Deciduous, Evergreen, and Mixed forests.