Southeast 2010 Coastal Change Analysis Program Accuracy Assessment

National Oceanic and Atmospheric Administration (NOAA)
Coastal Services Center

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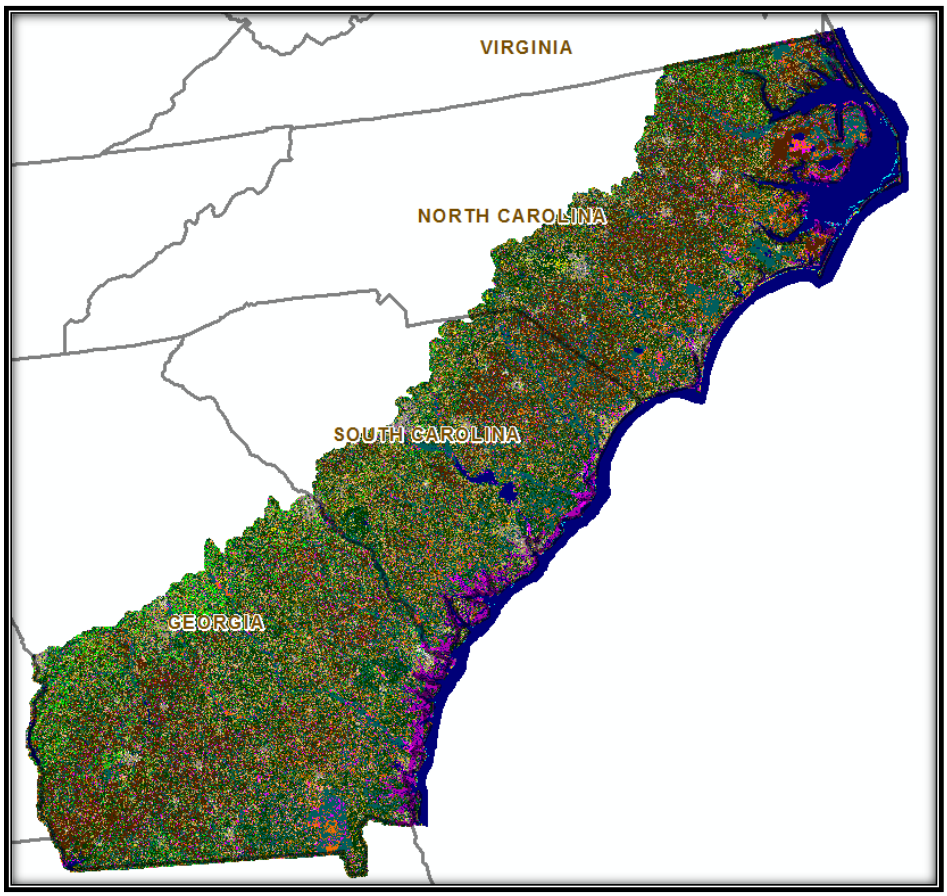


Overview

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 Southeast. This area covers over 88,500 square miles and includes the coastal portions of North Carolina, South Carolina, and Georgia. 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, which included mapped change, would be part of the 2010 land cover update cycle.

The 2010 Southeast C-CAP land cover update was conducted through the contract vehicle at the NOAA Coastal Services Center. The 2010 land cover 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 August 2013.

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

- The overall accuracy for the Southeast 2010 C-CAP product was 82.3% (0.80 kappa).
- Two classes fell below 80% for both producer[1] *and* user[2] accuracy; five classes were below 80% for producer accuracy, and nine 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 83.1% for the 2010 call, indicating the 2006 call was incorrect.
- Of the 300 sample locations in mapped change areas, the accuracy was 84.7%.

Methods

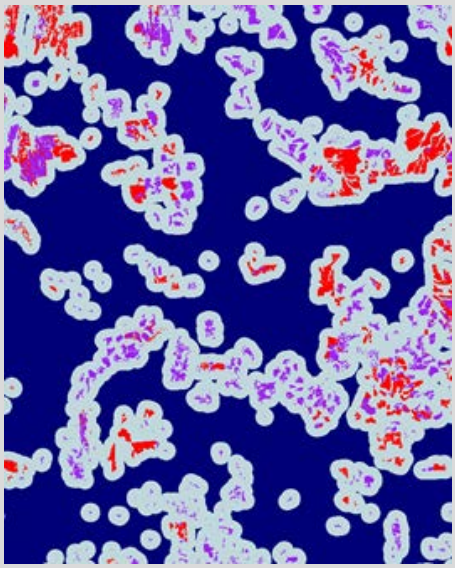
The C-CAP team met and discussed accuracy assessment on multiple occasions and determined three essential requirements:

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

[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 no-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, Scrub/Shrub received the most accuracy assessment sample units (104) and Palustrine Aquatic Bed received the least (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 3.1% of the accuracy assessment (AA) sample units and comprised 2.1% of the region. The largest discrepancy is with Palustrine Forested Wetland receiving 10.0% of the AA sample units and comprising 19.3% 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	9	10	8	27	3.0%	0.2%
Developed, Medium Intensity	13	8	6	27	3.0%	0.5%
Developed, Low Intensity	13	14	16	43	4.8%	2.4%
Developed, Open Space	16	11	12	39	4.3%	1.6%
Cultivated Crops	12	27	40	79	8.8%	16.5%
Pasture/Hay	8	15	14	37	4.1%	3.6%
Grassland/Herbaceous	42	14	6	64	7.1%	4.4%
Deciduous Forest	0	13	15	28	3.1%	2.9%
Evergreen Forest	26	36	28	90	10.0%	17.3%
Mixed Forest	8	13	8	29	3.2%	2.4%
Scrub/Shrub	64	29	13	106	11.8%	11.3%
Palustrine Forested Wetland	15	36	35	86	9.6%	17.1%
Palustrine Scrub/Shrub Wetland	25	16	12	53	5.9%	4.9%
Palustrine Emergent Wetland	20	12	9	41	4.6%	2.4%
Estuarine Scrub/Shrub Wetland	0	0	9	9	1.0%	0.0%
Estuarine Emergent Wetland	1	11	15	27	3.0%	1.7%
Unconsolidated Shore	4	10	8	22	2.4%	0.2%
Bare Land	11	11	9	31	3.4%	0.4%
Open Water	13	11	36	60	6.7%	10.1%
Palustrine Aquatic Bed	0	1	1	2	0.2%	0.0%
Total	300	300	300	900		
Area (square miles)	6,353	42,918	39,017	88,590		
Percent of Region	7.5%	48.5%	44.0%			

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 82.3% (0.80 kappa). The majority of classes met the C-CAP target specification of 80% per class accuracy. Of the 14 instances where accuracy was below the targeted 80%, 9 of these did exceed 70%. Two classes, Mixed Forest and Palustrine Scrub/Shrub Wetland, fell below the 80% threshold for both producer and user accuracy. The Mixed Forest was most often confused with Scrub/Shrub. Two land cover types,

Estuarine Scrub/Shrub Wetland and Unconsolidated Shore, had user accuracies around 45%. The Estuarine Scrub/Shrub Wetland only had nine sample locations, which may contribute to the low accuracy, and this class was mostly confused with Estuarine Emergent Wetland. The low user accuracy for Unconsolidated Shore can be traced to confusion with Open Water.

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 nine classes were over 40. The fewest sample units were associated with Palustrine Aquatic Bed (2 locations).

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

1. **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.
2. **Scrub/Shrub confusion** – This occurred in both upland and wetland conditions. All 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.

Table 2. Full error matrix for the 2010 Southeast 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	Total	Users
Developed, High Intensity	26																	1			27	96.3%
Developed, Medium Intensity	5	20		2																	27	74.1%
Developed, Low Intensity		3	39															1			43	90.7%
Developed, Open Space				36			1				1	1									39	92.3%
Cultivated Crops			1	3	68	1	2		2		1	1									79	86.1%
Pasture/Hay		1	1	1	5	21	3				4			1							37	56.8%
Grassland/Herbaceous				1	4		48		4	1	3		1	2							64	75.0%
Deciduous Forest						1		24	2	1											28	85.7%
Evergreen Forest									83	4	2		1								90	92.2%
Mixed Forest								1	6	21	1										29	72.4%
Scrub/Shrub					1		3	2	12	8	73	1	4	2							106	68.9%
Palustrine Forested Wetland												84	2								86	97.7%
Palustrine Scrub/Shrub Wetland												9	42	2							53	79.2%
Palustrine Emergent Wetland												1	3	34		1		1	1		41	82.9%
Estuarine Scrub/Shrub Wetland															4	5					9	44.4%
Estuarine Emergent Wetland																27					27	100.0%
Unconsolidate Shore																	10		12		22	45.5%
Bare Land				1	2		1				2			1			1	22	1		31	71.0%
Open Water					1									1		1			57		60	95.0%
Palustrine Aquatic Bed																				2	2	100.0%
Total	31	24	41	44	81	23	58	27	109	35	87	97	53	43	4	34	11	25	71	2	900	
Producers	83.9%	83.3%	95.1%	81.8%	84.0%	91.3%	82.8%	88.9%	76.1%	60.0%	83.9%	86.6%	79.2%	79.1%	100.0%	79.4%	90.9%	88.0%	80.3%	100.0%		82.3%

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 (16%) for a location being deemed mapped as correct.

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

Fuzzy Reference Calls		
Of the 900 sample locations, 337 (37.4%) had a fuzzy call	For the 736 correctly mapped locations, 120 (16.3%) were correct based on the fuzzy land cover call (606 were correct based on primary call)	Land cover classes with most fuzzy calls include different levels of Development, Palustrine Scrub/Shrub–Palustrine Forest, and Deciduous– Mixed Forest

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 an 83.1% 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 fairly 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 20 were deemed missed change. Eighteen of these points were within Stratum 2 (specifically designed to try to identify potential missed change). Based on the change analysis, the team feels that mapped change may be 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 Southeast 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 80.3%, 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, both upland and wetland). This confusion is similar to what was seen in Table 2.

Comparison between 2001 and 2010 Accuracy Assessments

This 2010 accuracy assessment was very similar in extent to the accuracy assessment performed on the 2001 products (Figures 2 and 3). The 2001 accuracy assessment extended slightly further south into Florida and did not fully cover the northern extent of North Carolina. The accuracy assessment locations (1,508 total) for the 2001 data set were primarily drawn from field sample locations along roadways, with limited photo-interpreted 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. Overall accuracy was very similar between the two dates, 81.2% for the 2001 and 82.3% for 2010.

Table 5. Error matrix for the 2010 Southeast 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	Unconsolidate Shore	Bare Land	Open Water	Total
Developed, High Intensity	3																3
Developed, Medium Intensity	2	5		1													8
Developed, Low Intensity		1	7												1		9
Developed, Open Space				3						1							4
Cultivated Crops					2			1		1							4
Pasture/Hay						2	3			1							6
Grassland/Herbaceous							40			2			1				43
Evergreen Forest								20		2		1					23
Mixed Forest								1	4	1							6
Scrub/Shrub							2	3	2	51	1	3	2				64
Palustrine Forested Wetland											11	1					12
Palustrine Scrub/Shrub Wetland											3	17	2				22
Palustrine Emergent Wetland												2	16		1		19
Unconsolidate Shore																2	2
Bare Land				1									1	1	9		12
Open Water					1								1			10	12
Total	5	6	7	5	3	2	45	25	6	59	15	24	23	1	11	12	249

Correct	200
Percent Correct	80.3%

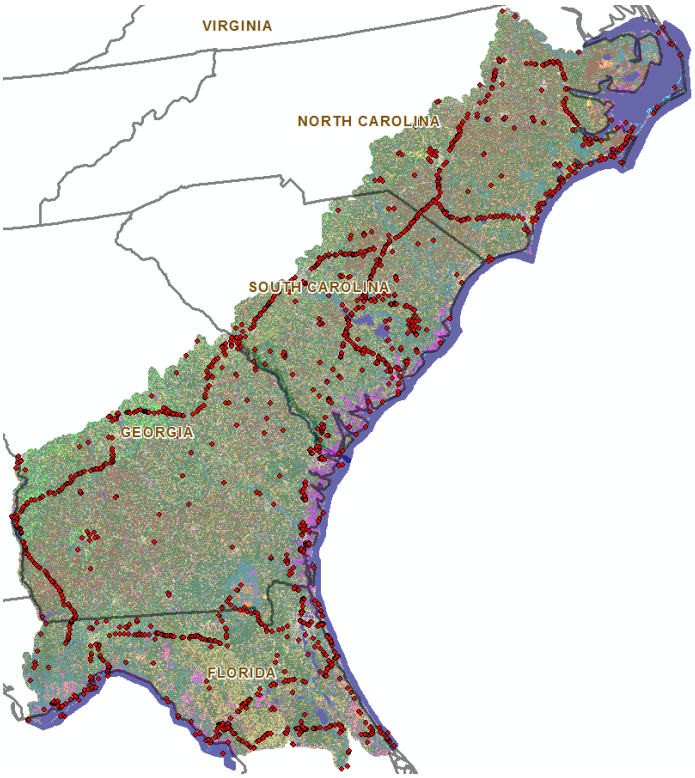


Figure 2. Accuracy assessment locations for the 2001 C-CAP Zones 55/58 area draped on 2001 land cover. Sampling along road networks can be seen as the linear features within the map.

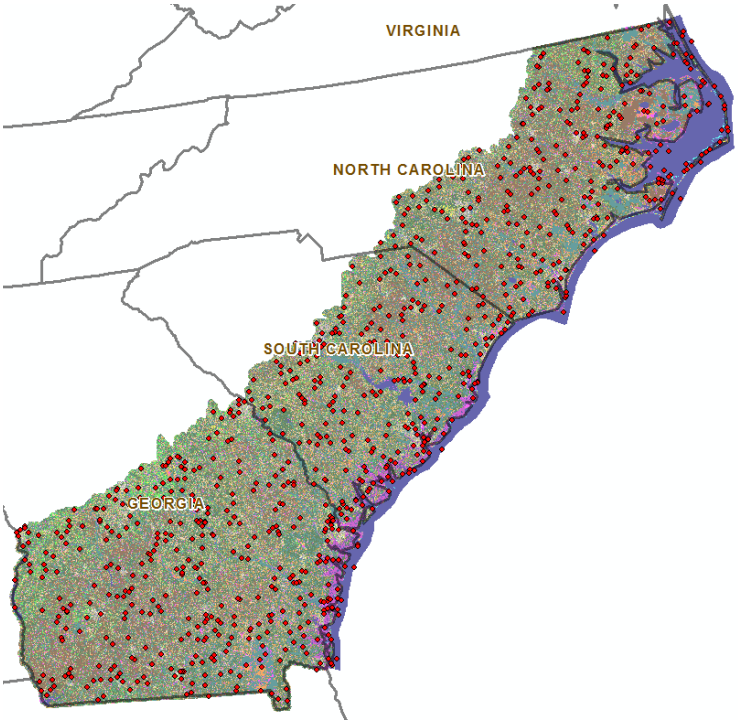


Figure 3. Accuracy assessment locations for the 2010 C-CAP Southeast area draped on the 2010 land cover.

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 Southeast 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 82.3%, 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 and Grass/Shrub/Forest classes. Change/no-change accuracy for the product was 90%, with committed change being the largest error. It was found that 83% 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 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. 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 becomes more available in the future, these data may be used to estimate vegetation height, and help separate Scrub/Shrub from Forest.