10 Case Study *Accuracy Assessment for the NOAA Next-Generation C-CAP Pilot Project*

This chapter details an actual case study of thematic accuracy assessment design, data collection, and analysis. The first section reviews the goals of a case study mapping project and briefly summarizes the classification methods used. Next, the questions raised in Chapter 1 are answered for this specific case study. The chapter concludes with a review of lessons learned during the design and implementation of the accuracy assessment.

OVERVIEW OF THE CASE STUDY

The National Oceanic and Atmospheric Administration (NOAA) currently relies on Landsat TM and ETM+ moderate resolution imagery for the creation of its Coastal Change Analysis Program (C-CAP) land use and change products. Recognizing the power of higher-resolution imagery, in September of 2004, NOAA contracted with several organizations to develop methodologies for successfully introducing high spatial resolution imagery and land cover products into NOAA's current C-CAP effort. This case study reviews the accuracy assessment of one of those efforts.

The project area is located in the vicinity of Panama City, Florida, as displayed in Figure 10.1. The area is characterized by little elevation variation and is highly diverse in both land cover and land use. Spanning parts of Bay and Washington Counties, the project area also crosses six Florida physiographic groups including Crystal Lake Karst, Delta Plain, Coastal Strip, Hosford Delta, and a sliver of Fountain Delta and Betts Delta (see Figure 10.2). Land use types are intermixed throughout the area, as are uplands and wetlands.

The mapping methods used in the project were fairly straightforward. To understand how the land use/cover classes vary on the ground, a training data/calibration field trip was conducted and field samples of all classes to be mapped were collected. To understand how the variation in land cover/use classes was correlated with variation in the imagery and ancillary data, a Classification and Regression Tree (CART) analysis was performed on the nonaccuracy assessment sample data

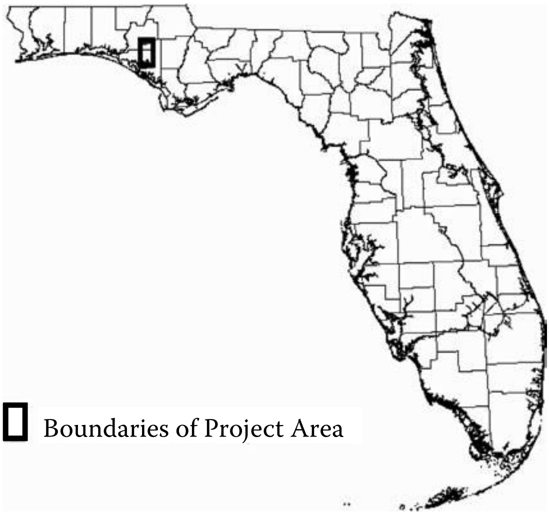

FIGURE 10.1 Location of the pilot project area in Florida.

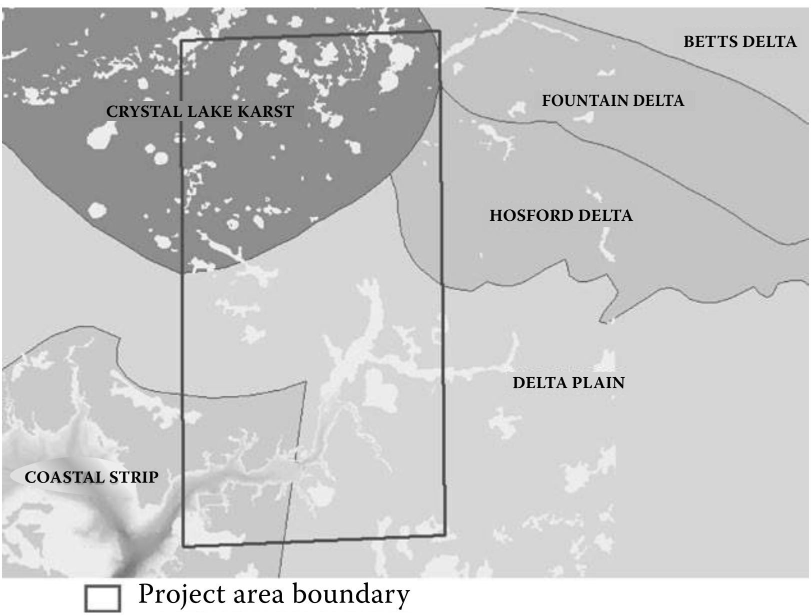

FIGURE 10.2 (***Color version follows page 112***) Project area boundary over Florida physiographic groups.

from the imagery and ancillary data layers. To link variation in land cover/land use with variation in the imagery and ancillary data, Visual Learning Systems' Feature Analyst software was used to classify DigitalGlobe QuickBird imagery and ancillary data into 26 classes of land use and land cover.

Following development and review of the draft map, a validation trip to the project area was conducted. Field visits focused on known areas of confusion, and specific areas noted by NOAA. Upon return from the field, additional Feature Analyst classifications were conducted on subareas, and extensive editing was performed. Figure 10.3 presents a portion of the imagery and the final map of the project area.

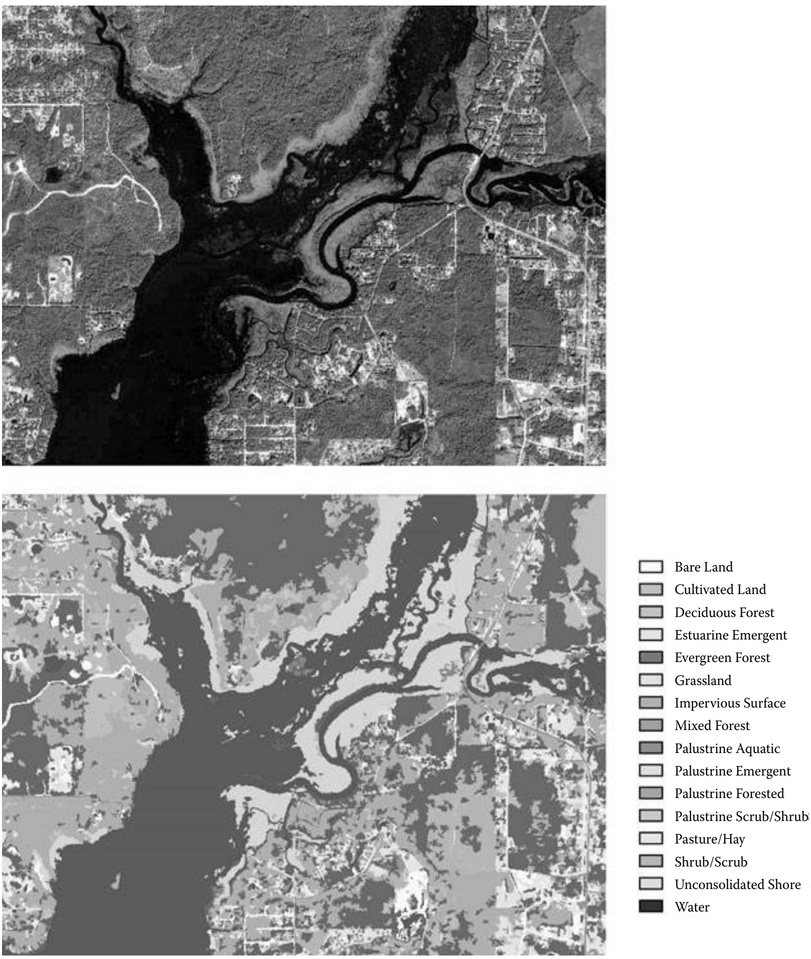

FIGURE 10.3 (***Color version follows page 112***) Detailed area of the case study including the QuickBird multispectral imagery and the final map.

TABLE 10.1
Land Cover/Land Use Classes and Subclasses Mapped for the Project

C-CAP Class	Subclass
Impervious	None
Cultivated Land	None
Pasture/Hay	None
Grassland	None
Deciduous Forest	None
Evergreen Forest	None
Mixed Forest	None
Scrub/Shrub	None
Water	None
Palustrine Forested Wetland	Deciduous
	Evergreen
Palustrine Scrub/Shrub Wetland	Deciduous
	Evergreen
Palustrine Emergent Wetland	Persistent (*Typha*/*Cladium*)
	Persistent (Sedges)
Estuarine Scrub/Shrub Wetland	Deciduous
	Evergreen
Estuarine Emergent Wetland	Persistent — High Marsh (*Juncus*)
	Persistent — High Marsh (*Salicornia*)
Unconsolidated Shore	None
Bare Land	Dirt Roads
	Other Bare Land
Palustrine Aquatic Bed	Floating Vascular
	Rooted Vascular
Estuarine Aquatic Band	Algal
	Rooted Vascular

DESIGN OF THE ACCURACY ASSESSMENT

What Are the Thematic Classes to Be Assessed?

NOAA chose the revised C-CAP Coastal Land Cover Classification[†] for this project and requested the development of a more detailed classification scheme that could be collapsed up into the C-CAP classes. Table 10.1 lists the land cover/use class labels used. Appendix 10.1 presents the totally exhaustive, mutually exclusive, and hierarchical classification scheme rules used in the project.

† http://www.csc.noaa.gov/crs/lca/tech_cls.html

The minimum mapping units for the project were

- 1/20th of an acre for impervious areas,
- 1/10th of an acre for areas that had been classified with moderate-resolution imagery as high, medium, low, or open-space development, and
- 1/8th of an acre for all other areas.

What Is the Appropriate Sampling Unit?

Sample units were polygons of land cover/land use class manually delineated on the Quickbird imagery. Polygons were chosen as the appropriate sample unit because the final map was a polygon coverage.

How Many Samples Should Be Taken?

The calibration field trip resulted in data collection for over 152 field samples. Upon return to the office, an additional 1500+ sites were collected through manual interpretation of the imagery for a total of 1720 project sample sites.

The accuracy assessment was planned with a goal of selecting 50 accuracy assessment sites per class from the total pool of 1720 project samples. However, as Table 10.2 illustrates, less than 50 samples were selected in some classes while more than 50 were collected in others. Reasons for the discrepancies are as follows:

- Because there is not much Palustrine Aquatic Bed or Unconsolidated Shore in the project area, fewer sites were selected for accuracy assessment of these classes, so that enough sites could be retained for making the map.
- Prior to the validation trip, image analysts started to believe that some of the deciduous sites were mislabeled. The confusion occurred with the mistaken identification of live oak trees as deciduous rather than evergreen hardwood trees. During the validation trip, several of these sites were visited, and it was confirmed that this mistake had been made. As a result, the image analyst reinterpreted all of the deciduous accuracy assessment sites[†] and relabeled 16 of them to either evergreen, mixed upland forest, or palustrine forested wetland.

How Should the Samples Be Chosen?

Accuracy assessment samples were selected from the total pool of project samples using a stratified random number generator in a statistical software package (S-PLUS), which randomly selected samples by relevant C-CAP moderate-resolution class (i.e., no tundra sites).

[†] At no time did the analyst have knowledge of which sites were in agreement or disagreement with the map site label.

TABLE 10.2
Accuracy Assessment Sites by C-CAP Class and Subclass

Land Cover Land Use Class/Subclass	Total Sites by Subclass	Total Sites by Class
Bare Land		50
Impervious		50
Cultivated Land		50
Grassland		50
Scrub/Shrub		50
Deciduous Forest		34
Mixed Forest		58
Evergreen Forest		54
Pasture/Hay		50
Palustrine Forest		54
Palustrine Deciduous Forested Wetland	30	
Palustrine Mixed Forested Wetland	10	
Palustrine Evergreen Forested Wetland	14	
Palustrine Aquatic Bed		19
Palustrine Floating Vascular Aquatic Bed	18	
Palustrine Rooted Vascular Aquatic Bed	1	
Palustrine Emergent Wetland		50
Palustrine Emergent Sedge Wetland	23	
Palustrine Emergent Typha Wetland	27	
Palustrine Evergreen Scrub/Shrub Wetland		50
Estuarine Emergent Juncus Wetland		50
Unconsolidated Shore		12
Water		50
Total		**731**

DATA COLLECTION

What Should Be the Source of the Reference Data?

Reference labels were determined through field and office manual interpretation of the QuickBird multispectral 2.4 m Digital Globe imagery collected on November 9, 2004. While at first it may seem unusual to use the same imagery to make the map and also manually interpret for the reference data, the high spatial resolution of this imagery makes this feasible and reasonable. Historically, manual interpretation of medium-resolution imagery, such as Landsat TM imagery, was not typically used to create reference data. The quality of the manual interpretation could not be considered of higher accuracy as required of the reference data set. However, high-resolution satellite imagery and digital camera imagery are of such high spatial quality that manual interpretation provides for excellent reference data collection. While digital image analysis of the entire image to produce a map is more cost-effective and less time consuming than producing the map from manual interpretation, the use of manually interpreted reference labels is certainly reasonable and efficient.

How Should the Reference Data Be Collected?

The reference data were collected through the manual interpretation of the QuickBird 2.4 m resolution imagery either in the field or office. Project samples (the combination of accuracy and training samples) were chosen by field and office personnel at their discretion and were governed by the following criteria:

- *Informational homogeneity*—The site must represent one and only one land use per land cover class.
- *Spectral homogeneity*—The site should have less spectral variation within the polygons than between other polygons.
- *Minimum size*—Sites should be larger than the minimum mapping unit.
- *Projectwide distribution*—For a given class, analysts attempted to distribute the sites evenly across that type's distribution in the project area.

In addition, an unsupervised classification was run on the imagery to capture important spectral variation classes and an ongoing list was kept of the sites in each unsupervised class to ensure that all of the spectral variation in the imagery was captured.

Project samples were manually delineated on the imagery in ArcGIS because the map polygons had not been completed prior to sample selection. Manually delineating the samples, rather than choosing map polygons, creates the possibility that the sample polygons will cross multiple map polygons. This problem did occur in this project, as illustrated in Figure 10.4 by the multiple map polygons crossed by the turquoise accuracy assessment polygon. To ensure consistency and lack of bias, map

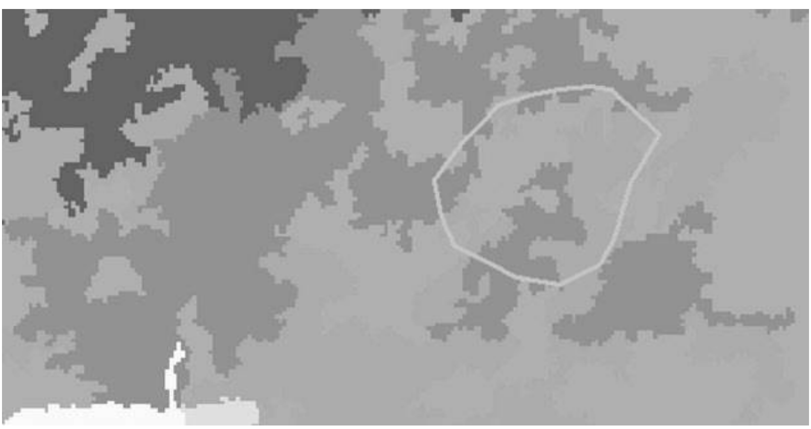

FIGURE 10.4 (***Color version follows page 112***) Illustration of a heterogeneous map accuracy assessment site.

labels for each sample polygon were determined by calculating the majority map class in each sample.

Polygon reference labels were derived using the classification scheme and all information available about the site. Manual determination of the label occurred following:

- Review of ancillary data concerning the site,
- A walkthrough of the site if the analyst was in the field,
- Review of field notes concerning the site if the analyst was in the office, and
- Review of the QuickBird 0.6 m resolution (colorized) imagery.

When Should the Reference Data Be Collected?

The reference data were collected either during the calibration trip or immediately thereafter in the office. Collecting the samples prior to creation of the map is cost-effective and allows for interim accuracy assessment as the map is being created. However, it does not ensure that an adequate number of samples per map class will be collected, which was the situation in this case study as illustrated in Table 10.3, which compares the number of accuracy assessment samples per map to reference class.

TABLE 10.3
Numbers of Map and Reference Samples by Class

	Number of Reference Sites	Number of Map Sites
Bare Land	50	56
Impervious	50	48
Cultivated Land	50	49
Grassland	50	71
Scrub/Shrub	50	51
Deciduous Forest	34	28
Mixed Forest	58	53
Evergreen Forest	54	65
Pasture/Hay	50	39
Palustrine Forested Wetland	54	59
Palustrine Aquatic Bed	19	18
Palustrine Emergent Wetland	50	40
Palustrine Scrub/Shrub	50	48
Estuarine Emergent Wetland	50	50
Unconsolidated Shore	12	6
Water	50	55

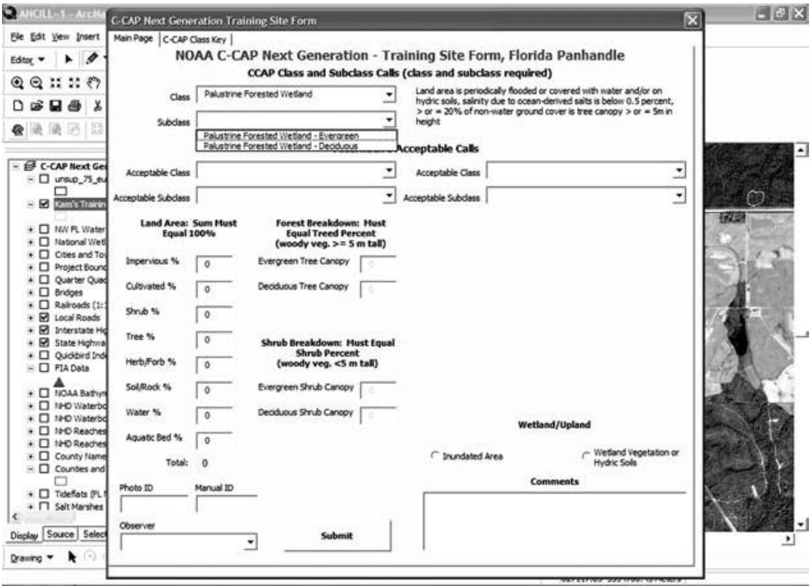

FIGURE 10.5 (*Color version follows page 112*) Digital field form used in the project.

How Do I Ensure Consistency and Objectivity in My Data Collection?

Consistency and objectivity were ensured by:

1. Simultaneous training of image analysts with NOAA personnel in the field for identification of vegetative cover species, recognition of ecological relationships, delineation of polygon samples, and use of the field form (Figure 10.5).
2. Implementation of a digital field form linked to GPS (Figure 10.5). The form's functionality included pull-down menus and automated error checking, and also included the classification scheme rules for easy reference.
3. After all samples had been selected, each sample was reviewed one by one to ensure that the information collected for each site was complete and correct.

ANALYSIS

What Are the Different Analysis Techniques for Continuous versus Discontinuous Map Data?

The project mapped 26 discrete classes of land use/land cover. Because the classes are discontinuous, the only accuracy assessment analysis technique applicable is the error matrix.

What Is an Error Matrix and How Should It Be Used?

Table 10.4 displays the C-CAP class error matrix, which compares the final map and reference labels of the accuracy assessment samples.

What Are the Statistical Properties Associated with the Error Matrix and What Analysis Techniques Are Applicable?

Kappa analysis was performed on the error matrix, and the results are displayed in Table 10.4.

What Is Fuzzy Accuracy and How Can You Conduct a Fuzzy Accuracy Assessment?

As discussed in Chapter 9, one of the assumptions of the traditional or deterministic error matrix is that an accuracy assessment sample site can have only one reference label. However, classification scheme rules often impose discrete boundaries on continuous conditions in nature. In situations where classification scheme breaks represent artificial distinctions along a continuum of land cover, observer variability is often difficult to control, and although unavoidable, can have profound effects on results. While it is difficult to control observer variation, it is possible to use fuzzy logic to compensate for differences between reference and map data that are caused not by map error, but by variation in interpretation (Gopal and Woodcock, 1994). In this project, both deterministic and fuzzy error matrices were compiled and analyzed.

Table 10.5 displays both the deterministic and fuzzy error matrix for the C-CAP class map.

The overall deterministic accuracy is 83% and overall fuzzy accuracy is 91%. Table 10.6 summarizes the user's and producer's accuracies for the C-CAP class map, sorted first by producer's and then by user's accuracies.

The following summarizes the major findings of the accuracy assessment:

- The most accurate classes with combined user's and producer's deterministic and fuzzy accuracies above 80% at the class level are estuarine emergent wetland, water, cultivated land, impervious, bare land, palustrine forested wetland, palustrine aquatic bed, and palustrine scrub/shrub wetland.
- At the class level, all fuzzy user's accuracies exceed 80% except deciduous forest (75%). All producer's fuzzy accuracies exceed 80% except palustrine emergent wetland (72%) and unconsolidated shore (75%).
- Confusion exists between mixed forest and evergreen or deciduous forest. Some of the confusion between mixed forest and evergreen or deciduous forest occurs because the high resolution of the imagery allows for the classification of small polygons of homogeneous evergreen and deciduous trees. Taken together the clumps represent a mixed forest.
- Spatial autocorrelation exists with 4 of the 6 mixed forest reference sites, which are confused with deciduous forest in the error matrix. The 4 sites are all contained within one very large deciduous forest map polygon.

TABLE 10.4
Case Study Error Matrix

		REFERENCE DATA																*User's Accuracies*	
		Bare Land	Imperv	Cult. Land	Grass Land	Scrub/ Shrub	Decid. Forest	Mixed Forest	EG Forest	Past/ Hay	PF Wet	PA Bed	PE Wet	PS/S Wet	EE Wet	UnCon Shore	Water	Totals	Percent
	Bare Land	47	0	0	3	0	0	0	0	0	0	0	6	0	0	0	0	47/56	84.0%
	Impervious	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48/48	100.0%
	Cultivated Land	0	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	49/49	100.0%
	Grassland	2	2	1	39	8	0	0	0	19	0	0	0	0	0	0	0	39/71	55.0%
	Scrub/Shrub	0	0	0	3	38	1	0	1	0	0	0	3	5	0	0	0	38/51	75.0%
	Deciduous Forest	0	0	0	0	0	19	8	0	0	1	0	0	0	0	0	0	19/28	68.0%
M	Mixed Forest	0	0	0	0	0	13	37	1	0	2	0	0	0	0	0	0	37/53	70.0%
A	Evergreen Forest	0	0	0	0	2	0	11	50	0	0	0	2	0	0	0	0	50/65	77.0%
P	Pasure/Hay	0	0	0	3	0	0	0	0	31	0	0	0	0,0	0	0	0	31/34	91.0%
	Palustrine Forest Wetland	0	0	0	0	0	1	2	2	0	48	1	1	2	0	2	0	48/59	81.0%
	Palustrine Aquatic Bed	0	0	0	0	0	0	0	0	0	0	16	1	0	0	1	0	16/18	89.0%
	Palustrine Emergent Wetland	0	0	0	2	0	0	0	0	0	1	1	35	0	0	1	0	35/40	88.0%
	Palustrine Scrub/Shrub Wetland	1	0	0	0	2	0	0	0	0	1	1	2	41	0	0	0	41/48	85.0%
	Estuarine Emergent Wetland	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	50/50	100.0%
	Unconsolidated Shore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	6/6	100.0%
	Water	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	50	50/55	91.0%
	Producer's Accuracies																		
	Totals	47/50	48/50	49/50	39/50	38/50	19/34	37/58	50/54	31/50	48/54	16/19	35/50	41/50	50/50	6/12	50/50		
	Percent	94.0%	96.0%	98.0%	78.0%	78.0%	56.0%	64.0%	93.0%	62.0%	89.0%	84.0%	70.0%	82.0%	100.0%	50.0%	100.0%		

Overall Accuracy = 604/731 = 83.0 %

KAPPA = 0.814

TABLE 10.5
Case Study Error Matrix Showing Both Deterministic and Fuzzy Accuracies

REFERENCE DATA

User's Accuracies

		Bare Land	Imperv	Cult. Land	Grass Land	Scrub/ Shrub	Decid. Forest	Mixed Forest	EG Forest	Past/ Hay	PF Wet	PA Bed	PE Wet	PS/S Wet	EE Wet	UnCon Shore	Water	Determin. Totals	Percent Determin.	*Fuzzy Totals*	*Percent Fuzzy*
	Bare Land	47	0,0	0,0	1,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,5	0,0	0,0	0,0	0,0	47/56	84.0%	*49/56*	*88.0%*
	Impervious	0,0	48	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	48/48	100.0%	*48/48*	*100.0%*
	Cultivated Land	0,0	0,0	49	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	49/49	100.0%	*49/49*	*100.0%*
	Grassland	1,1	0,2	0,1	39	1,7	0,0	0,0	0,0	19,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	39/71	55.0%	*60/71*	*85.0%*
	Scrub/Shrub	0,0	0,0	0,0	2,1	38	0,1	0,0	1,0	0,0	0,0	0,0	0,3	3,2	0,0	0,0	0,0	38/51	75.0%	*44/51*	*86.0%*
	Deciduous Forest	0,0	0,0	0,0	0,0	0,0	19	2,6	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	19/28	68.0%	*21/28*	*75.0%*
M	Mixed Forest	0,0	0,0	0,0	0,0	0,0	9,4	37	0,1	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	37/53	70.0%	*47/53*	*89.0%*
A	Evergreen Forest	0,0	0,0	0,0	0,0	1,1	0,0	7,4	50	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	50/65	77.0%	*58/65*	*89.0%*
P	Pasure/Hay	0,0	0,0	0,0	3,0	0,0	0,0	0,0	0,0	31	0,0	0,0	0,0	0,0	0,0	0,0	0,0	31/34	91.0%	*34/34*	*100.0%*
	Palustrine Forest Wetland	0,0	0,0	0,0	0,0	0,0	1,0	2,0	0,2	0,0	48	0,1	0,1	0,2	0,0	1,1	0,0	48/59	81.0%	*52/59*	*88.0%*
	Palustrine Aquatic Bed	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	16	0,1	0,0	0,0	0,1	0,0	16/18	89.0%	*16/18*	*89.0%*
	Palustrine Emergent Wetland	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,1	0,1	35	0,0	0,0	0,1	0,0	35/40	88.0%	*35/40*	*88.0%*
	Palustrine Scrub/Shrub Wetland	0,1	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,1	0,1	0,2	41	0,0	0,0	0,0	41/48	85.0%	*42/48*	*88.0%*
	Estuarine Emergent Wetland	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	50	0,0	0,0	50/50	100.0%	*50/50*	*100.0%*
	Unconsolidated Shore	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6	0,0	6/6	100.0%	*6/6*	*100.0%*
	Water	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	2,0	0,0	2,0	50	50/55	91.0%	*55/55*	*100.0%*

Producer's Accuracies

	Bare Land	Imperv	Cult. Land	Grass Land	Scrub/ Shrub	Decid. Forest	Mixed Forest	EG Forest	Past/ Hay	PF Wet	PA Bed	PE Wet	PS/S Wet	EE Wet	UnCon Shore	Water
Deterministic Totals	47/50	48/50	49/50	39/50	38/50	19/34	37/58	50/54	31/50	48/54	16/19	35/50	41/50	50/50	6/12	50/50
Percent Deterministic	94.0%	96.0%	98.0%	78.0%	76.0%	56.0%	64.0%	93.0%	62.0%	89.0%	84.0%	70.0%	82.0%	100.0%	50.0%	100.0%
Fuzzy Totals	48/50	48/50	49/50	45/50	41/50	29/34	48/58	51/54	50/50	50/54	16/19	36/50	46/50	50/50	9/12	50/50
Percent Fuzzy	96.0%	96.0%	98.0%	90.0%	82.0%	85.0%	83.0%	94.0%	100.0%	93.0%	84.0%	72.0%	92.0%	100.0%	75.0%	100.0%

Overall Accuracies			
Deterministic		Fuzzy	
604/731	83.0%	666/731	91.0%

TABLE 10.6
Final Producer's and User's Accuracies by C-CAP Class

	Deterministic Producer's Accuracy (%)	Fuzzy Producer's Accuracy (%)	Deterministic User's Accuracy (%)	Fuzzy User's Accuracy (%)
Estuarine Emergent Wetland	100	100	100	100
Water	100	100	91	100
Cultivated Land	98	98	100	100
Impervious	96	96	100	100
Bare Land	94	96	84	88
Evergreen Forest	93	94	77	89
Palustrine Forested Wetland	89	93	81	88
Palustrine Aquatic Bed	84	84	89	89
Palustrine Scrub/Shrub Wetland	82	92	85	88
Grassland	78	90	55	85
Scrub/Shrub	76	82	75	86
Palustrine Emergent Wetland	70	72	88	88
Mixed Forest	64	83	70	89
Pasture/Hay	62	100	91	100
Deciduous Forest	56	85	68	75
Unconsolidated Shore	50	75	100	100

Use of the random number generator to choose the accuracy assessment sites should have (but did not) preclude this type of problem. Relying on map polygons as sample units, rather than manually delineating samples, would have negated this type of spatial autocorrelation.

- Nineteen pasture hay sites have an acceptable alternative reference label of grassland. Thus, pasture/hay has low deterministic class values, but high fuzzy class values. Of the 19 sites, 18 sites were office interpreted, where it is almost impossible to distinguish between pasture/hay and grassland. Thus, the sites were given fuzzy labels. These 18 sites contribute almost one third of the eight-point difference between the overall deterministic (83%) and fuzzy (91%) accuracies.
- Four palustrine emergent sedge wetland reference sites were confused with bare land map sites. Three of the sites are along newly constructed roads and were probably bare land in the imagery, but populated with vegetation in the months between the capture of the imagery and the calibration trip. Figure 10.6 shows two of these sites.
- Seven scrub/shrub reference sites are confused with grassland. All seven sites are regenerating pine forests with an overstory of turkey oak (which did not have its leaves at the time of the imagery) and an understory of grass, shrubs, and pine seedlings.

Site 1088

Site 1491

FIGURE 10.6 (***Color version follows page 112***) Examples of sites with palustrine emergent scrub/shrub reference labels confused with bare land map labels.

LESSONS LEARNED

As in most projects, lessons are learned continually as the project progresses. Specific lessons learned during the accuracy assessment portion of the case study include:

1. To eliminate spatial autocorrelation in accuracy assessment sites, no more than one accuracy assessment site should be allowed to fall within one map polygon.
2. During the initial training data/calibration trip, the location of accuracy assessment sites should not be delineated on the hardcopy calibration imagery. The sites should only be delineated digitally on a laptop, leaving the hardcopy calibration images for notes only, so that the calibration images can be used in map editing.
3. Determining the map label of a "mixed" (e.g., mixed deciduous/evergreen) class accuracy assessment site is problematic with classification of high-resolution imagery which is often capable of individually distinguishing the components of a "mixed" area. Using the simple majority of the site to create the map label (as was done in this project) is relatively easy but may produce an incorrect label, especially in a site composed of close-to-equal proportions of the components of a mixed site. For example, an accuracy assessment site could intersect several map polygons and be composed of the following components:

- 30% mixed
- 32% evergreen
- 28% deciduous

If a majority rule is used, the map label would be evergreen, but clearly the polygon is actually a mixed forest. Two solutions to this problem are possible:

- If possible, sample polygons should be chosen from the actual map polygons. This is easy to do, if sample selection is to follow map finalization. In situations where sample selection occurs prior to map finalization, it is often possible to create unlabeled polygons early in the mapping project that can be used as the population from which samples are chosen. Reference labels for the polygons can be determined during the calibration trip. Map labels are determined when the mapping portion of the project is complete.

- If it is not possible to create polygons early, and sample selection must be carried out before the map is final, then more complex rules than a simple majority should be considered for labeling the map samples. Using the actual rules from the classification scheme is the best alternative. For example, the classification scheme for the case study project labeled a nonwetland forested polygon as evergreen or deciduous only if the percentage cover of the polygon was 75% evergreen or deciduous, respectively. Under that rule, our example polygon considered earlier would have been labeled "mixed forest" rather than "evergreen."

APPENDIX 10.1

Decision Rules for the Classification Scheme

If land area is > or = to 80% impervious surface over 1/20th acre or more, then **Impervious (1)**

*If land area is designated by moderate resolution map as High, Medium, Low, or Open Space Developed, then minimum mapping unit is 1/10*th *of an acre.*

*Else minimum mapping unit is 1/8*th *of an acre.*

Developed and Undeveloped areas will be determined by the Moderate Resolution map for the project area.

Else if land area is > or = to 75% open water, then **Water (2)**

Else if land area is periodically flooded and/or covered with water, or if image signature is "wet," then **Wetland (3)**

If salinity due to ocean-derived salts is below 0.5%, then **Palustrine Wetland (3.1)**

If > or = 20% of nonwater ground cover is tree canopy > or = 5 m in height, then **Palustrine Forested Wetland (3.1.1)**

If > or = 75% of nonwater cover is deciduous tree, then **Palustrine Deciduous Forested Wetland (3.1.1.1)**

Else if > or = 75% of nonwater cover is evergreen tree, then **Palustrine Evergreen Forested Wetland (3.1.1.2)**

Else **Palustrine Mixed Forested Wetland (3.1.1.3)**

Else if > or = 20% of nonwater ground cover is woody < 5 m in height, then **Palustrine Scrub/Shrub Wetland (3.1.2)**

If a majority (> or = 51%) of shrub cover is deciduous, then **Palustrine Deciduous, Shrub Wetland (3.1.2.1)**

Else **Palustrine Evergreen Shrub Wetland (3.1.2.2)**

Else if > 50% plants growing and forming a continuous surface principally on or at the water surface, then **Palustrine Aquatic Bed (3.1.3)**

If a majority of vegetative cover is floating vascular, then **Palustrine Floating Vascular Aquatic Bed (3.1.3.1)**
Else if a majority of vegetative cover is rooted vascular, then **Palustrine Rooted Vascular Aquatic Bed (3.1.3.2)**
Else **Palustrine Emergent Wetland (3.1.4)**
If a majority of cover is persistent *Typha* spp. *or Cladium* spp, then **Palustrine Typha/Cladium Persistent Wetland (3.1.4.1)**
Else if a majority of vegetative cover is persistent *Scirpus* spp, then **Palustrine Scirpus Persistent Wetland (3.1.4.2)**
Else if a majority of vegetative cover is persistent Sedges, then **Palustrine Sedge Persistent Wetland (3.1.4.3)**
Else if a majority of vegetative cover is persistent *Phragmites* spp, then **Palustrine Phragmites Persistent Wetland (3.1.4.4)**
Else **Palustrine Emergent Mixed Wetland (3.1.4.5)**
Else if (salinity due to ocean-derived salts is equal to or > 0.5%), then **Estuarine Wetland (3.2)**
If > or = 20% of nonwater ground cover is tree canopy that = or > 5 m in height, then **Estuarine Forested Wetland (3.2.1)**
Else if > or = 20% of nonwater ground cover is woody < 5 m in height, then **Estuarine Scrub/Shrub Wetland (3.2.2)**
If a majority (> or = 51%) of shrub cover is deciduous, then **Estuarine Deciduous Shrub Wetland (3.2.2.1)**
Else **Estuarine Evergreen Shrub Wetland (3.2.2.2)**
Else if > 50% plants growing and forming a continuous surface principally on or at the water surface, then **Estuarine Aquatic Bed (3.2.3)**
If a majority of vegetative cover is rooted vascular, then **Estuarine Rooted Vascular Aquatic Bed (3.2.3.1)**
Else if a majority of vegetative cover is algal, then **Estuarine Algal Aquatic Bed (3.2.3.2)**
Else **Estuarine Emergent Wetland (3.2.4)**
If majority of vegetative cover is low marsh *Spartina* spp, then **Estuarine Emergent Spartina Wetland (3.2.4.1)**
Else if majority of vegetative cover is low marsh *Juncus* spp, then **Estuarine Emergent Juncus Wetland (3.2.4.2)**
Else if majority of vegetative cover is high marsh *Salicornia* spp, then **Estuarine Emergent Salicornia Wetland (3.2.4.3)**
Else if majority of vegetative cover is nonpersistent, then **Estuarine Emergent Non-persistent Wetland (3.2.4.4)**
Else if land area is characterized by herbaceous vegetation that has been planted or is intensely managed for the production of food, feed, or fiber, then **Cultivated Land (4)**
Else if land area is characterized by grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seeds or hay crops, then **Pasture/Hay (5)**
Else if land area is > 50% tundra vegetation, then **Tundra (6)**
Else if land area is > 75% snow/ice throughout the year, then **Snow/Ice (7)**

Else if land area is > 85% covered with bare rock, gravel, sand, silt, clay, or other earthen materials, then **Undeveloped Bare Land (8)**

If characterized by intertidal, or intermittently flooded areas (mud flats), then **Unconsolidated Shore (8.1)**

Else **Bare Land (8.2)**

Else if tree canopy (woody vegetation) > 20% of land area and tree canopy (woody vegetation) > or = 5 m tall, then **Forest (9)**

If tree canopy (woody vegetation) > or = 75% deciduous, then **Deciduous Forest (9.1)**

Else if tree canopy > or = 75% evergreen, then **Evergreen Forest (9.2)**

Else **Mixed Forest (9.3)**

Else if tree canopy (woody vegetation) > 20% of land area and tree canopy ≤ 5 m tall, then **Shrub/Scrub (10)**

Else **Grassland (11)**