FREQUENT QUESTIONS

Coastal Change Analysis Program (C-CAP) Regional Land Cover

NOAA Office for Coastal Management
www.coast.noaa.gov/digitalcoast/data/ccapregional

What is land cover? And why is it important?

Land cover data document the types of features that cover the surface of the Earth. These data quantify how much of a region is covered by forests, wetlands, impervious surfaces, and agriculture—as well as these feature's locations.

It is difficult to manage any area or land resource without having an accurate picture of existing conditions. Land cover data can help provide that big-picture view. It is also beneficial to understand how these resources have changed. Comparing land resource data from one year to the next can be used to evaluate how a community's past land management efforts are working and can provide valuable information on trends to aid future planning initiatives. Hopefully, this information will provide better context for management decisions.

What is the difference between land cover and land use?

The two terms are often used interchangeably, but strictly speaking land cover captures the physical state of land resources. Examples of land cover include forest, grassland, wetland, and impervious or paved surfaces. Land use on the other hand, denotes how the land is being used—whether the areas are residential, commercial, or industrial development. The same types of cover can be managed or used very differently.

What is C-CAP?

C-CAP is the Coastal Change Analysis Program (C-CAP). Through it, NOAA produces nationally standardized land cover and land change data for the coastal regions of the U.S. C-CAP products provide inventories of coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years.

Using standardized data and consistent methods, NOAA is able to produce data that can be compared through time, as well as information that can be used to evaluate different areas of

the country. This apples-to-apples type of comparison is not allows possible with various regional products that were produced by different groups for different reasons.

How are C-CAP data related to the National Land Cover Database (NLCD)?

NOAA works with the U.S. Geological Survey (USGS) and several other federal programs through the Multi-Resolution Land Characteristics (MRLC) Consortium to incorporate C-CAP land cover directly into the National Land Cover Database (NLCD) product line. NOAA makes more detailed distinctions between wetland categories, such as estuarine (salt) vs. palustrine (freshwater) wetlands. This relationship eliminates duplication of mapping between the two programs and leverages limited resources to complete one common, consistent national product. As such, C-CAP is considered the coastal expression of this national database. To see the areas where NOAA holds primary mapping responsibility, see the following question related to C-CAP's mapping boundary.

What area does C-CAP map?

The minimum inland extent of C-CAP's mapping boundary is based on state-designated Coastal Zone Management (CZM) boundaries, NOAA's Coastal Assessment Framework (which includes definitions of estuarine and coastal drainage areas, or EDAs and CDAs), and designation of coastal counties (counties that are at least 15% within the EDA and CDA). These minimum extents were then modified using Omernik EcoRegions, other visible natural features, and Landsat imagery path/row boundaries. See figure 1. Areas interior to the coasts of the lower 48 states and Alaska are mapped by NOAA's partners at the USGS.

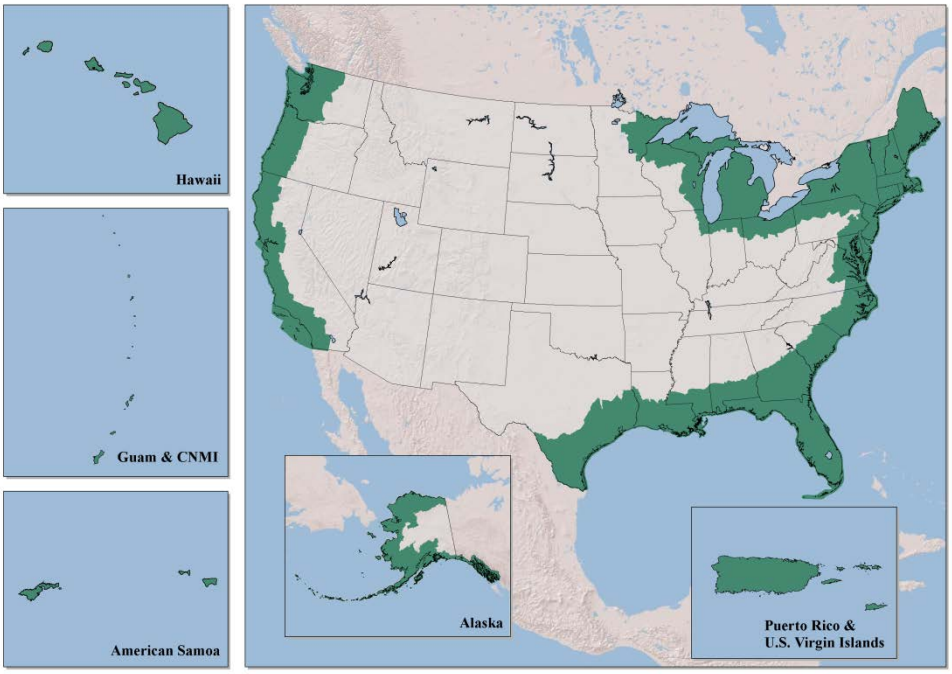


Figure 1: NOAA's Coastal Change Analysis Program (C-CAP) mapping boundaries highlighted in green.

What land cover types do C-CAP products map?

C-CAP includes 25 categories of land cover. C-CAP puts particular emphasis on providing more detailed, up-to-date wetland information than is currently available in other national land cover products.

Access our full classification scheme and class definitions.

These categories represent features that are effectively observed via moderate-resolution satellite imagery on a national scale, as well as national classification scheme standards. The upland categories are based on the Anderson Level II classification system (Anderson and others 1976). This is the same system and scheme utilized by the National Land Cover Database (NLCD), which C-CAP data feeds into (see table 1). The more detailed wetland categories are based on Cowardin's *Classification of Wetlands and Deepwater Habitats* (Cowardin and others 1979). This is where the more detailed palustrine and estuarine wetland categories are derived and is the same national standard used by the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) program.

Table 1: C-CAP land cover classes compared to the National Land Cover Database (NCLD) and Anderson, 1976 Categories.

Anderson Level 1 Category	NLCD Category	C-CAP Category
Urban or Built-up Land (1)	Developed, High Intensity (24)	High Intensity Developed (2)
	Developed, Medium Intensity (23)	Medium Intensity Developed (3)
	Developed, Low Intensity (22)	Low Intensity Developed (4)
	Developed, Open Space (21)	Open Space Developed (5)
Agricultural Land (2)	Cultivated Crops (82)	Cultivated Land (6)
	Pasture/Hay (81)	Pasture/Hay (7)
Rangeland (3)	Grassland / Herbaceous (71)	Grassland (8)
	Scrub / Shrub (52)	Scrub Shrub (12)
Forest (4)	Deciduous Forest (41)	Deciduous Forest (9)
	Evergreen Forest (42)	Evergreen Forest (10)
	Mixed Forest (43)	Mixed Forest (11)
Wetlands (6)	Woody Wetlands (90)	Palustrine Forested Wetlands (13)
		Palustrine Scrub Shrub Wetlands (14)
		Estuarine Forested Wetlands (15)
		Estuarine Scrub Shrub Wetlands (16)
	Emergent Herbaceous Wetlands (95)	Palustrine Emergent Wetlands (17)
		Estuarine Emergent Wetlands (18)
Open Water (5)	Open Water (11)	Open Water (21)
		Palustrine Aquatic Bed (22)
		Estuarine Aquatic Bed (23)
Barren Land (7)	Barren Land (31)	Unconsolidated Shore (19)
		Barren Land (20)
Tundra (8)		Tundra (24)
Perennial Ice/Snow (9)	Perennial Ice/Snow (12)	Perennial Ice/Snow (25)

How are C-CAP change maps produced?

C-CAP products are developed using multiple dates of remotely sensed imagery. Change detection analysis compares the two dates of imagery to identify the areas that have likely changed during this time frame. These areas are then classified through a combination of models, use of ancillary data, and manual edits. NOAA contracts out much of this work to private industry. The classified land cover for these areas of change is then superimposed over the land cover from the original date of analysis to create a new wall-to-wall classification for the second time period.

Many of the areas that are identified as potentially changed in the change detection and masking may be changes that do not result in a change in class. Agricultural field rotation or forest stand thinning are two examples.

Remapping only areas that contain change leads to greater efficiency and more consistent data through time than would procedures that remap the full land cover for an area for each time period. By looking only at areas that have changed, we remove any difference that could result from differences in interpretation. This method also reduces cost, since only a small percentage of the total area must be classified in the change product (i.e., typically less than 20% of any area changes in a five-year period).

The NOAA Office for Coastal Management is always interested in partnering with organizations that may be seeking additional or more frequent intervals of C-CAP land cover. The Office for Coastal Management can facilitate financial partnerships through the indefinite delivery, indefinite quantity (IDIQ) coastal geospatial services contract (CGSC). For more information about the CGSC contract, please visit the following link: *http://coast.noaa.gov/idiq/geospatial.html*.

What do we mean when we say C-CAP products are updated every five years?

C-CAP products are produced to provide a single snapshot for the nation's coastal areas. This means that we produce data for all regions using one era of image dates: 2006, for example. It often takes us several years to produce all these data for the nation. We may map the Gulf of Mexico in 2006, the Southeast in 2007, and other areas in subsequent years. This is different than if we were to map each region with imagery from the year in which the mapping occurred: 2006 for the Gulf of Mexico, 2007 for the southeast and so on.

We typically try to cover at least 20% of the nation, completing the entire update in no longer than five years so that we are ready to start the next cycle. It is important to note that we are not producing the most up-to-date data for each region (i.e., mapping 2006 for the Gulf in 2006, a 2007 date for the Southeast in 2007, etc.). While this would provide up-to-date regional data, we would never have one complete national picture.

This also helps us in supporting our commitment and contribution to the National Land Cover Database (NLCD) and our federal partners within the Multi-Resolution Land Characteristics (MRLC) Consortium.

Why don't we map every year instead of only every five years?

Cost is a big reason. Updating the C-CAP data products every year would be almost five times the cost of updating these products once every five years. Many areas of the country also are not changing that rapidly. The highest rates of change that we have seen have been near 20% of a region changing in a five year period, but vast parts of the country change as little as 1-5%.

Shorter periods could be necessary in local areas or in regions undergoing rapid economic development or affected by catastrophic events such as hurricanes or floods. The NOAA Office for Coastal Management is always interested in partnering with organizations that may need additional or more frequent intervals of C-CAP land cover. The organization can facilitate financial partnerships through the indefinite delivery, indefinite quantity (IDIQ) coastal geospatial services contract (CGSC). For more information about the CGSC contract, please visit the following link: *www.coast.noaa.gov/idiq/geospatial.html*.

What do C-CAP change products show?

C-CAP products consist of raster-based land cover maps for the two dates of analysis, as well as a separate file that highlights what changes have occurred between these dates and where the changes were located.

It may be important to note that this analysis is performed for specific time slices (discrete observations) and is not an account of every change that has occurred during the time period being analyzed. Only the land cover at time 1 and time 2 are included. The user can only make inferences about the processes at work between these two dates.

What do we mean by "change from" and "change to" within our change files?

When calculating change, an image *changes from* one land cover type (in time 1) and *changes to* another land cover (in time 2). For example, if a forested area was cleared and a housing development was built in its place, the area's "change from" value is forest and the "change to" value is low intensity developed.

What is a change matrix?

A change matrix is a table that quantifies the amount of change that occurs between all the land cover types (figure 2). The matrix shows the "From" classes as rows and the "To" classes as columns. The number of rows and columns is determined by the number of classes in the land cover image. Each cell represents the area (in acres) of the land cover change. In addition, the matrix can be used during data development to identify changes that are unlikely to occur (e.g., high density developed changed to a forest) for re-evaluation.

		Time 2				
		Developed	Agriculture	Forest	Wetland	Total
Time 1	Developed	200	0	0	0	**200**
	Agriculture	15	100	5	0	**120**
	Forest	17	12	500	0	**527**
	Wetland	2	5	0	25	**32**
	Total	**234**	**117**	**505**	**25**	**879**

Figure 2: Sample change matrix (numbers are square miles).

In the above matrix, the user can see that between time 1 and time 2 there were a total of 34 square miles of new development (red cells): 15 from agriculture, 17 from forest, and 2 from wetlands. Yellow cells indicate areas of no land cover change. Access this spreadsheet to help analyze C-CAP Change data.

How should I interpret this change?

Change can be seen as the change in total area of a given land cover type between two dates (seen as the difference between each category's bar in figure 3 below). This total area difference is referred to as net change. But net change can be deceiving, since there may have been a gain within a particular class in one area, but also losses in the same class elsewhere. The combined gains and losses offset each other, making it appear as if there was no net change. To see the total amount of change in a particular class, it's best to use a graphic depicting losses and gains (figure 4).

Area Gained – Area Lost = Net change

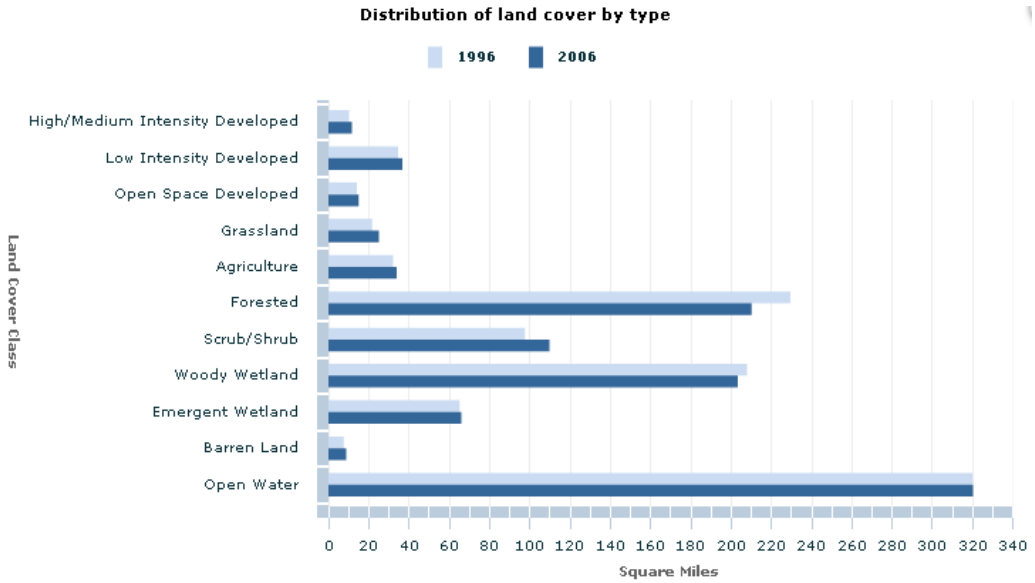


Figure 3: The above example was taken from the C-CAP Land Cover Atlas (www.coast.noaa.gov/digitalcoast/tools/lca) and highlights the distribution of each land cover class mapped by C-CAP for Jackson County, Mississippi, in 1996 and 2006. The net change in any class can be seen as the difference in the bars between the two dates. For example, over this period there was a net loss of about 19 square miles of forested land.

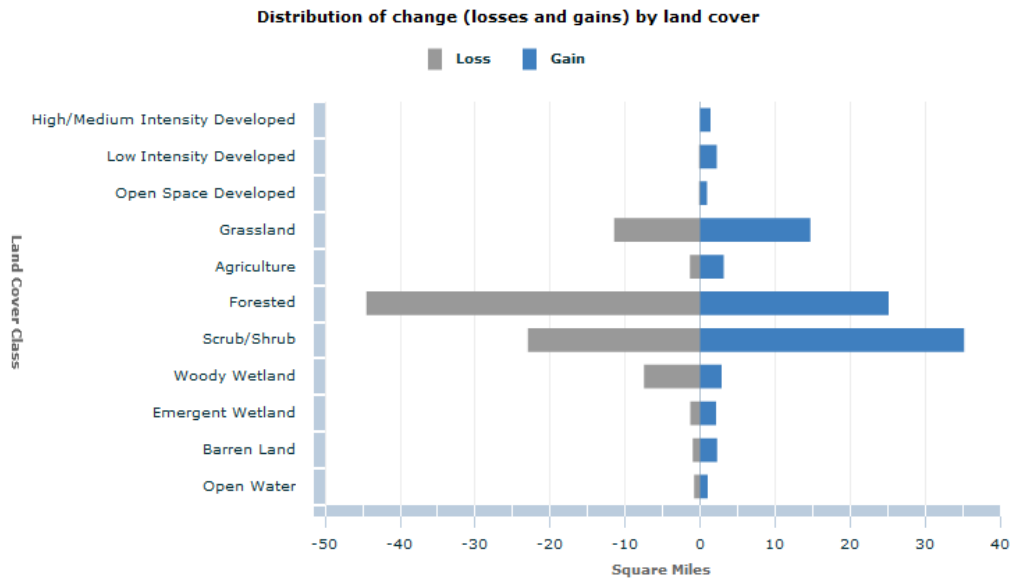


Figure 4: The above example was taken from the C-CAP Land Cover Atlas (www.coast.noaa.gov/digitalcoast/tools/lca) and highlights offsetting losses and gains in land cover for Jackson County, Mississippi, from 1996 to 2006. For example, over this period there was a net loss of about 19 square miles of forested land (also seen in figure 7), but this number may be deceiving because there was actually over 44 square miles lost and 25 square miles gained. Offsetting losses and gains are common with forest, grassland, and shrub, since these classes tend to represent a timber cycle from harvest through regrowth.

What is the smallest feature that C-CAP products map? Or what is the minimum mapping unit (MMU) of C-CAP products?

C-CAP data are developed, primarily, from Landsat Thematic Mapper (TM) satellite imagery. Landsat data have a 30-meter pixel size (spatial resolution). Because C-CAP products are produced from these individual pixels, the smallest feature size that can be mapped would be 30 meters x 30 meters (900 square meters, or 0.22 acres) on the ground. This is commonly referred to as the minimum mapping unit.

But it is recognized that the smallest observable feature that can reliably be identified in this type of data would need to be four contiguous pixels in size (0.88 acres). This is because a quarter-acre-sized feature may not fall entirely within one given pixel but may instead be split among as many as 4 pixels, therefore making up only a minority of any given pixel and not being the dominant feature reflected by the data.

SUMMARY:
0.22 acres = Smallest feature possible to be mapped (minimum mapping unit)
0.88 acres = Smallest feature reliably identified (user expectation of applicability)

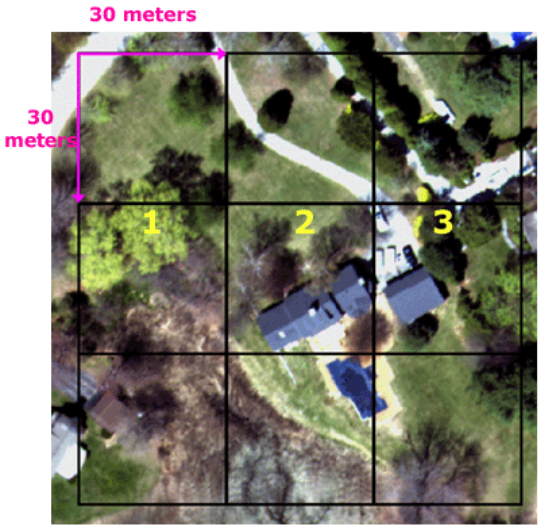


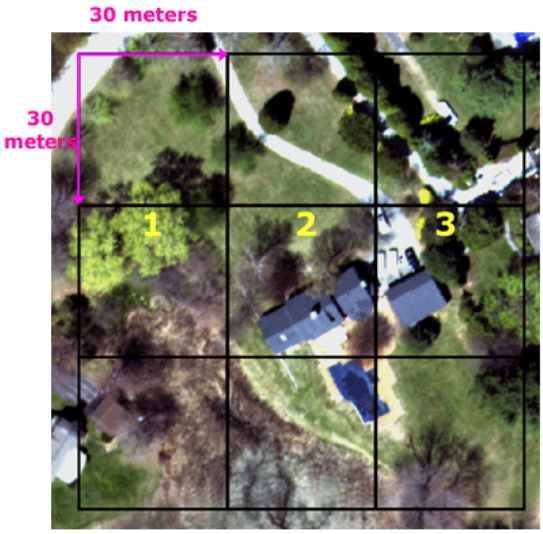
Figure 5: This is a high-resolution aerial photograph, with a 30-meter resolution grid superimposed. Pixel 1 is a homogenous pixel covered by trees, and would be considered as forest, though it is a mix of evergreen and deciduous forest types. This pixel would be mapped as mixed forest. Pixel 2 is a mix of both vegetation and a large house. Since the house makes up more than 20% of the area, this pixel would be designated as low intensity development. Pixel 3 is even more mixed, with the structure and paved surface making up less than 20% of the total area. This pixel would be classified as either open space developed or forested.

University of Connecticut Center for Land Use Education and Research, n.d. Web. 12 Jul 2011. http://clear.uconn.edu/projects/landscape/measuring/index.htm

Note: To determine the appropriate resolution for your applications, you must determine the smallest feature you want to resolve, and the pixel size must be half the smallest dimension of the feature in question. For instance if you want to find a car (which would be ~10 feet x 6 feet), then your pixel size must be 3 x 3 feet to reliably identify cars in a raster context.

At what scale are C-CAP data applicable?

Raster data are not typically attributed to a specific scale (typically reported by resolution), but C-CAP data are developed primarily from Landsat Thematic Mapper (TM) satellite imagery. Landsat has a base scale of 1:100,000 for mapping applications. Maps of 1:100,000 scale are used for regional analyses but are not appropriate for identifying individual plants, or for permitting-type applications. They are more suited to land cover and change analysis on a regional scale, as well as general zoning and planning applications. They should not be evaluated at the single pixel level, which is below the minimum mapping unit of 4 pixels (~1 acre).



These data should be used just as any other 1:100,000 map is used. Road maps at this scale are highly generalized, and if you tried to drive your car on the delineated roads you would quickly find yourself in a ditch or field. This does not mean that the data are not useful, but generalizations and some error are inherent in remotely sensed land cover.

Figure 6: This is a high-resolution aerial photograph, with a 30-meter resolution grid superimposed. Pixel A is an example where a small linear feature, like a road, is likely to not be picked up well. In this case the road makes up less than 20% of the area, so it would not be captured as low-intensity developed. It would be captured as open space developed, since this is what the majority of the surrounding area is. If this road feature was in the middle of forest land, it would be designated as forest.

University of Connecticut Center for Land Use Education and Research, n.d. Web. 12 Jul 2011. http://clear.uconn.edu/projects/landscape/measuring/index.htm

Why not develop land cover from more detailed satellite and aerial imagery?

We do. We just can't afford to develop these products over the entire coastal U.S., since they are very expensive. Learn more about C-CAP's high-resolution land cover product line, and where these data are currently available.

The NOAA Office for Coastal Management is always interested in partnering with organizations that may be in need of more detailed land cover products. The Office for Coastal Management can facilitate financial partnerships through its indefinite delivery, indefinite quantity (IDIQ) coastal geospatial services contract (CGSC). For more information about the CGSC contract, please visit the following link: *www.coast.noaa.gov/idiq/geospatial.html*.

What is the accuracy of C-CAP products?

As a rule of thumb, C-CAP products are produced to meet an 85% overall accuracy specification. This means that 85 times out of 100 we would expect the C-CAP classification to be correct, reflecting what the majority land cover call on the ground is for that same area.

While C-CAP land cover products are produced with a 30-meter pixel resolution accuracy, assessments are performed on homogeneous groups, or neighborhoods of pixels, or clumps. A 3x3 neighborhood of pixels, roughly two acres, or nine pixels, is used for each sample "point" in these accuracy assessments. A majority (six) of the nine pixels in the land cover sample neighborhood must agree with the field call for the sample point to be considered correct.

NOAA also has a goal to meet a per class accuracy of 80% (though not every class meets this specification for every region or time period). There are often difficult distinctions that might cause more issues with these class-based accuracies (such as mapping mixed forest vs. evergreen or deciduous; or in distinguishing the same species of tree as either scrub or forest height).

Note: When a category is represented less in the map than it should based on the accuracy assessment it is said to be "undercalled," or exhibiting errors of omission. When a category is represented in the map more than it should based on the accuracy assessment it is said to be "overcalled," or exhibiting higher errors of commission (false inclusion).

Please see the 2010-2011 C-CAP accuracy assessment reports for more detail.

What is commission and omission error? What do user's and producer's accuracy mean?

Overall map accuracy is the percentage of correctly classified accuracy assessment (AA) points. In the following example, 16 of the 21 total AA points are correctly classified (i.e., where AA point numbers match the class numbers where they occur). This example would be reported as a 76% overall accuracy and give you a good idea of the map's accuracy, but it may also be important to note that not all classes within the map are necessarily mapped as accurately as others.

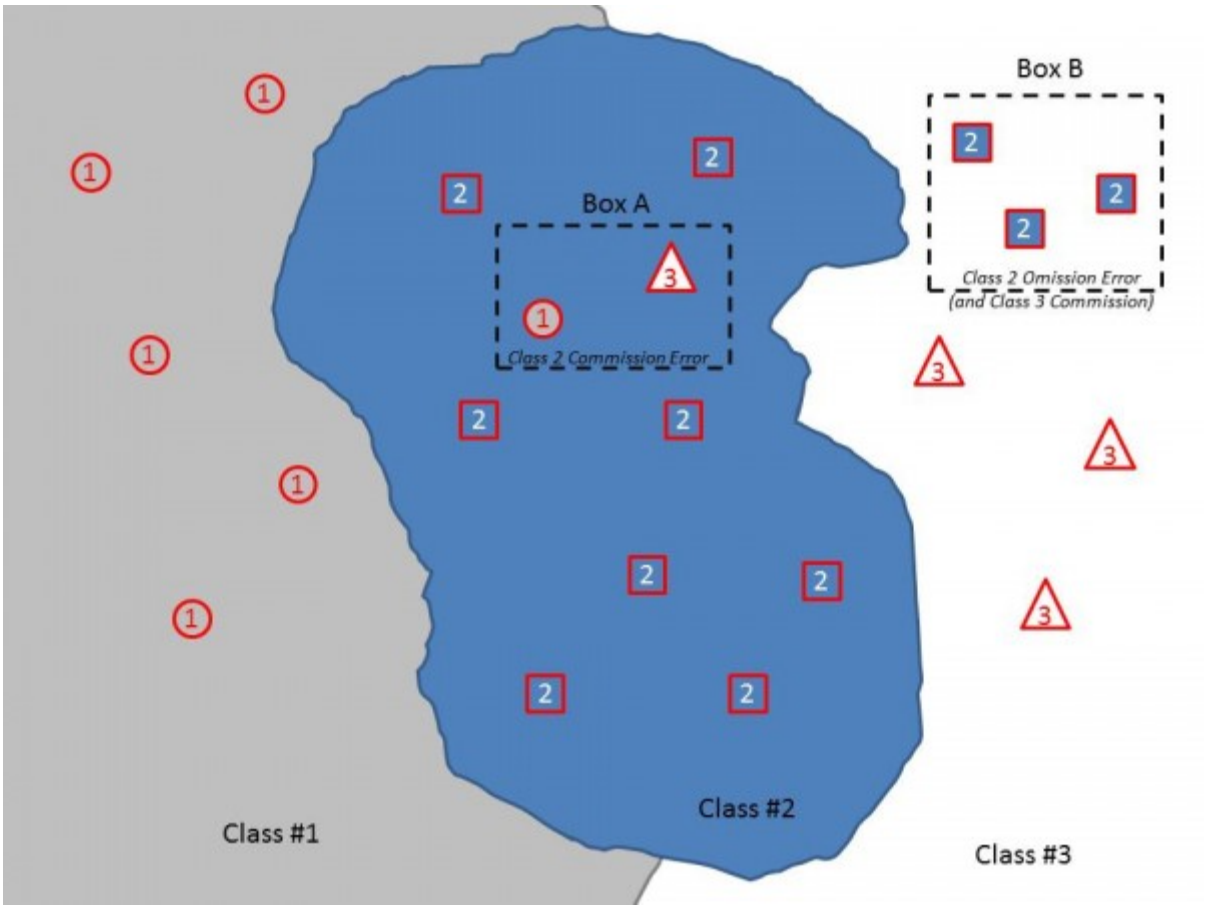


Figure 7. This "map" consists of three classes (noted by number and the gray, blue and white polygons). Example accuracy assessment point locations for each category are differentiated by shape and number.

Commission error refers to things that were incorrectly included in a category, as compared to the AA points (i.e., the map classified them as a class that they are not). The points in Box A above illustrate commission errors for class 2. This would be reported as having a **user's accuracy** of 80% for class 2 (8 out of 10 points within that polygon are correct), meaning that the user should know that what was called class 2 in the map was correct 80% of the time.

Omission error refers to things that were missed, or left out of the classification, as compared to the AA points (i.e., the map should have classified them as one class, but called them another instead). The points in Box B above illustrate omission errors for class 2. This is reported as a **producer's accuracy** of 73% for class 2 (8 out of 11 class 2 AA points are correct), meaning that the producer correctly classified 73% of the known accuracy assessment locations correctly.

It should be noted that an omission error in one category will also be a commission in another. In this example, the three points of class 2 that were omitted (missed) from that map class area are also reflected as commission errors (incorrectly included) in class 3. Class 3's user's and producer's accuracies would be 50% (3 out of 6 correct) and 75% (3 out of 4 correct), respectively.

What is the correct or preferred citation for using Coastal Change Analysis Program data?

"Correct" citation style depends entirely on the style manual chosen by your organization. That said, here is a generic citation that includes the basic information that you can shape to your needs:

National Oceanic and Atmospheric Administration, Office for Coastal Management. "Name of Data Set." Coastal Change Analysis Program (C-CAP) Regional Land Cover. Charleston, SC: NOAA Office for Coastal Management. Accessed Month Year at *www.coast.noaa.gov/ccapftp.*