# California 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 California, covering nearly 80,000 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, new land cover classes have been added, the region has experienced a considerable amount of land cover change, and improvements have been made in detecting and mapping change. For these reasons, it was determined that an accuracy assessment that included mapped change would be part of the 2010 land cover update cycle.

The 2010 California 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 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 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 California 2010 C-CAP product was 82.8% (0.82 kappa).
- Three classes fell below 80% for both producer[1] *and* user[2] accuracy; seven classes were below 80% for producer accuracy, and ten were below 80% for user accuracy (Table 2).
- The accuracy for change/no-change was 90.4%, with the largest error being committed change (74.3% accuracy). It is interesting to note that of these committed change locations (falsely mapped as change) the accuracy was 71.4% for the 2010 call, indicating the 2006 call was incorrect.
- Of the 300 sample locations in mapped change areas, the accuracy was 80.0%.

## Methods

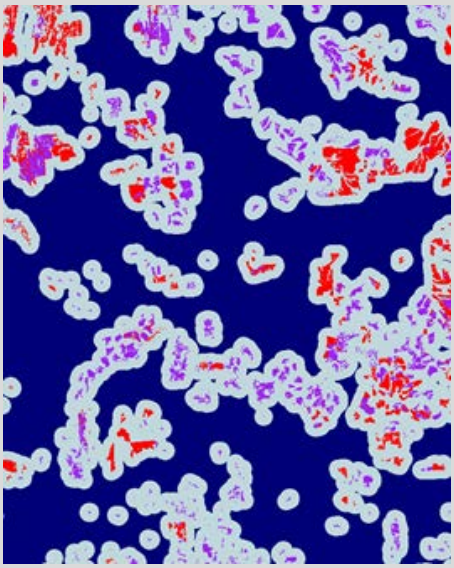
The C-CAP team met and discussed accuracy assessment on multiple occasions and determined three essential requirements:

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

[1] Related to errors of omission when an area is excluded from the category to which it belongs.
[2] Related to errors of commission when an area is included incorrectly in a category.

attempted to split the non-change area evenly into the other two strata. Stratum 2 (purple plus gray) was determined by combining all changes from 1996-2010 and buffering until the area target was approximated, in this case a 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, Scrub/Shrub and Grassland received the most accuracy assessment sample units (98) and Estuarine Scrub/Shrub received the fewest (3). 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 3.3% of the accuracy assessment (AA) sample units and comprised 5.3% of the region. The largest discrepancy is with Open Water receiving 5.9% of the AA sample units and comprising 21.8% 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 | 18 | 11 | 10 | 39 | 4.3% | 0.8% |
| Developed, Medium Intensity | 33 | 14 | 11 | 58 | 6.4% | 2.9% |
| Developed, Low Intensity | 16 | 13 | 18 | 47 | 5.2% | 2.4% |
| Developed, Open Space | 20 | 12 | 13 | 45 | 5.0% | 1.4% |
| Cultivated Crops | 21 | 16 | 41 | 78 | 8.7% | 5.7% |
| Pasture/Hay | 15 | 11 | 11 | 37 | 4.1% | 1.1% |
| Grassland/Herbaceous | 50 | 24 | 24 | 98 | 10.9% | 15.5% |
| Deciduous Forest | 0 | 21 | 12 | 33 | 3.7% | 0.9% |
| Evergreen Forest | 1 | 28 | 20 | 49 | 5.4% | 16.5% |
| Mixed Forest | 0 | 15 | 15 | 30 | 3.3% | 5.3% |
| Scrub/Shrub | 38 | 31 | 29 | 98 | 10.9% | 22.1% |
| Palustrine Forested Wetland | 0 | 12 | 10 | 22 | 2.4% | 0.2% |
| Palustrine Scrub/Shrub Wetland | 3 | 13 | 10 | 26 | 2.9% | 0.2% |
| Palustrine Emergent Wetland | 17 | 14 | 11 | 42 | 4.7% | 0.4% |
| Estuarine Scrub/Shrub Wetland | 0 | 2 | 1 | 3 | 0.3% | 0.0% |
| Estuarine Emergent Wetland | 9 | 12 | 10 | 31 | 3.4% | 0.2% |
| Unconsolidated Shore | 16 | 10 | 4 | 30 | 3.3% | 0.1% |
| Bare Land | 29 | 12 | 13 | 54 | 6.0% | 2.4% |
| Open Water | 14 | 12 | 27 | 53 | 5.9% | 21.8% |
| Estuarine Aquatic Bed | 0 | 10 | 10 | 20 | 2.2% | 0.0% |
| Perennial Snow | 0 | 7 | 0 | 7 | 0.8% | 0.0% |
| Total | 300 | 300 | 300 | 900 | | |
| Area (square miles) | 389 | 39,672 | 39,259 | 79,320 | | |
| Percent of Region | 0.5% | 50.0% | 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 82.8% (0.82 kappa). The majority of classes met the C-CAP target specification of 80% per class accuracy. Of the 17 instances where accuracy was below the targeted 80%, 14 of these did exceed 70%. Three classes, Pasture/Hay, Mixed Forest, and Palustrine Emergent Wetland fell below the 80% threshold

for both producers and user accuracy. Pasture/Hay was most often confused with Cultivated. Mixed Forest was generally confused with the other upland forest categories (Deciduous and Evergreen). The Palustrine Emergent Wetland class was confused predominantly with other wetland classes. The class with the lowest single accuracy was Estuarine Scrub/Shrub Wetland (33.3% user accuracy). This value may be questionable because of the low number of reference locations (Table 2).

Although most classes did not have more than 50 sample units (the coarse "rule-of-thumb" for accuracy assessment), six classes did exceed 50, and ten classes were over 40. Both Perennial Snow and Estuarine Scrub/Shrub Wetland were the only classes with fewer than 20 sample locations, which can be explained by the limited area these classes represent in the landscape.

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

1. **Grassland, Scrub/Shrub, and Bare Land** – Much of the C-CAP region in California can be characterized with low annual precipitation and having large expanses of sparse shrub and natural grasslands. Grassland and sparse Scrub/Shrub land appear very similar at the spatial resolution used by C-CAP (30 meters). The dry climate also contributes to the confusion of Grassland with Bare Land. During times of low or no precipitation, grass and shrub may die back (but still be present) and be confused with bare ground.
2. **Pasture/Hay, Grassland, and Cultivated** – The confusion between Cultivated and Pasture/Hay is fairly common and has been seen in other C-CAP regions. These classes are often best classified through the use of multiple dates of imagery to help detect spectral trends throughout the growing season. Typically two-dates of imagery were available for the 2010 classification, but they were not selected with Cultivated classification as the primary driver; thus they may not have been the best available for these classes. There is also a large amount of native grassland that is being used as pasture, which caused classification confusion.
3. **Upland Forest** – Separating Deciduous, Evergreen, and Mixed forest is typically accomplished through using leaf-on and leaf-off imagery. The spectral differences among these land cover classes can be quite dramatic compared across such imagery as the deciduous trees lose their leaves. Many of the deciduous forest trees in this area act more like evergreens, dropping their leaves only during drought or water stress periods. The expected large spectral change across seasons was not seen and resulted in confusion of these forest classes.

Table 2. Full error matrix for the 2010 California 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.

Reference

| Map | 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 | Estuarine Aquatic Bed | Perennial Snow | Total | Users |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Developed, High Intensity | 39 | | | | | | | | | | | | | | | | | | | | | 39 | 100.0% |
| Developed, Medium Intensity | 10 | 40 | 4 | | | | 1 | | | | | | | | | | | 3 | | | | 58 | 69.0% |
| Developed, Low Intensity | | 4 | 36 | 3 | 1 | | 2 | | | | | | | | | | | 1 | | | | 47 | 76.6% |
| Developed, Open Space | | 1 | | 35 | | | 5 | | | | 4 | | | | | | | | | | | 45 | 77.8% |
| Cultivated Crops | | | | | 73 | 4 | 1 | | | | | | | | | | | | | | | 78 | 93.6% |
| Pasture/Hay | | | | | 8 | 26 | 3 | | | | | | | | | | | | | | | 37 | 70.3% |
| Grassland/Herbaceous | | 1 | | | 4 | | 88 | | | | 2 | | | 1 | | | | 2 | | | | 98 | 89.8% |
| Deciduous Forest | | | | | | | | 26 | | 5 | 2 | | | | | | | | | | | 33 | 78.8% |
| Evergreen Forest | | | | | | | | 1 | 42 | 1 | 4 | | | | | | | | | | 1 | 49 | 85.7% |
| Mixed Forest | | | | | | | 2 | 1 | | 23 | 4 | | | | | | | | | | | 30 | 76.7% |
| Scrub/Shrub | | | | | | 2 | 12 | 1 | 2 | 2 | 75 | | | | | | | 4 | | | | 98 | 76.5% |
| Palustrine Forested Wetland | | | | | 3 | | | | | | | 13 | 3 | 2 | | | | | 1 | | | 22 | 59.1% |
| Palustrine Scrub/Shrub Wetland | | | | | | | 1 | 1 | | | | 1 | 21 | 2 | | | | | | | | 26 | 80.8% |
| Palustrine Emergent Wetland | | | | | 2 | | 2 | | | | | | 1 | 30 | | 1 | 4 | 1 | 1 | | | 42 | 71.4% |
| Estuarine Scrub/Shrub Wetland | | | | | | | | | | | | | 1 | | 1 | 1 | | | | | | 3 | 33.3% |
| Estuarine Emergent Wetland | | | | | | | | | | | | | | 3 | | 27 | | | 1 | | | 31 | 87.1% |
| Unconsolidated Shore | | | | | | | | | | | | | | | | | 25 | 4 | 1 | | | 30 | 83.3% |
| Bare Land | | | | | 1 | 2 | 4 | | | | | | | | | | | 47 | | | | 54 | 87.0% |
| Open Water | | | | | | | | | | | | | | | | | | 1 | 51 | 1 | | 53 | 96.2% |
| Estuarine Aquatic Bed | | | | | | | | | | | | | | | | | | | | 20 | | 20 | 100.0% |
| Perennial Snow | | | | | | | | | | | | | | | | | | | | | 7 | 7 | 100.0% |
| Total | 49 | 46 | 40 | 38 | 92 | 34 | 121 | 30 | 44 | 31 | 91 | 14 | 26 | 38 | 1 | 29 | 29 | 63 | 55 | 21 | 8 | 900 | |
| Producers | 79.6% | 87.0% | 90.0% | 92.1% | 79.3% | 76.5% | 72.7% | 86.7% | 95.5% | 74.2% | 82.4% | 92.9% | 80.8% | 78.9% | 100.0% | 93.1% | 86.2% | 74.6% | 92.7% | 95.2% | 87.5% | | 82.8% |

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 36% 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 California C-CAP region.

| Fuzzy Reference Calls | | |
|---|---|---|
| Of the 900 sample locations, 322 (35.7%) had a fuzzy call | For the 745 correctly mapped locations, 116 (15.6%) were correct based on the fuzzy land cover call (629 were correct based on primary call) | Land cover classes with most fuzzy calls include different levels of Development; Bare Land and Grass; upland forest categories |

**2006-2010 Change**

Overall change/no-change accuracy was 90% (Table 4). Committed change was the largest error with a user accuracy of 74% (77 sample locations mapped as change, but deemed no-change by the reviewers). These 77 locations were assessed in their own error matrix and resulted in 71.4% 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 nine were deemed missed change. Six 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 California 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 | 591 | 9 | 600 | 99% |
| | 1 | 77 | 223 | 300 | 74% |
| | Total | 668 | 232 | 900 | |
| | Producers | 88% | 96% | | 90% |

A final analysis was performed using only sample locations interpreted as change (232 locations). Table 5 shows that the overall accuracy of these locations was 77.2%, slightly lower 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 realistically be made, since there are different land cover classes and methods varied considerably. The accuracy assessment locations (3,781 sites) for the 2001 data set were primarily drawn from field sample locations along roadways (Figure 2). The overall accuracy for the 2001 map was 88%. There are a couple reasons for the apparent decrease in accuracy from 2001 to 2010. The 2010 map includes more detailed developed classes plus the Pasture/Hay class, all of which are difficult to map. Also, the reference sites for 2010 were randomly located, as opposed to the 2001 placement method along roads. 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.

Table 5. Error matrix for the 2010 California 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 | Scrub/Shrub | Palustrine Scrub/Shrub Wetland | Palustrine Emergent Wetland | Unconsolidated Shore | Bare Land | Open Water | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Developed, High Intensity | 16 | | | | | | | | | | | | | 16 |
| Developed, Medium Intensity | 6 | 17 | 2 | | | | | | | | | 2 | | 27 |
| Developed, Low Intensity | | 2 | 7 | 3 | | | 2 | | | | | 1 | | 15 |
| Developed, Open Space | | | | 16 | | | 1 | | | | | | | 17 |
| Cultivated Crops | | | | | 7 | | | | | | | | | 7 |
| Pasture/Hay | | | | | | 3 | | | | | | | | 3 |
| Grassland/Herbaceous | | 1 | | | | | 43 | | | 1 | | 2 | | 47 |
| Evergreen Forest | | | | | | | | 1 | | | | | | 1 |
| Scrub/Shrub | | | | | | 2 | 5 | 22 | | | | 4 | | 33 |
| Palustrine Forested Wetland | | | | | | | | | | 1 | | | | 1 |
| Palustrine Scrub/Shrub Wetland | | | | | | | | | 1 | 1 | | | | 2 |
| Palustrine Emergent Wetland | | | | | | | 1 | | | 12 | 2 | 1 | | 16 |
| Unconsolidated Shore | | | | | | | | | | | 12 | | | 12 |
| Bare Land | | | | | | | | | | | | 22 | | 22 |
| Open Water | | | | | | | | | | | | | 13 | 13 |
| Grand Total | 22 | 20 | 9 | 19 | 7 | 5 | 52 | 23 | 1 | 15 | 14 | 32 | 13 | 232 |

| | |
|---|---|
| Correct | 179 |
| Percent Correct | 77.2% |

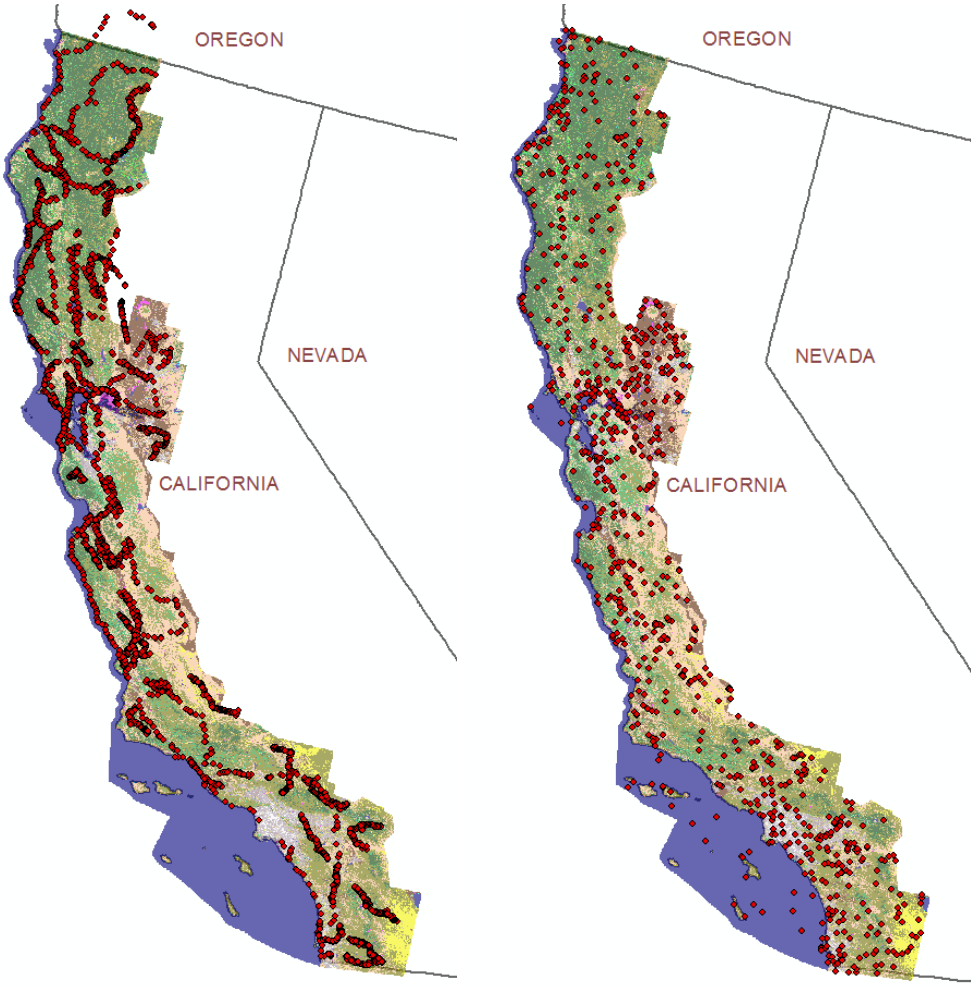



Figure 2. Differences in accuracy assessment site selection method and number of locations can be seen by comparing the 2001 C-CAP California accuracy assessment locations (left) with the 2010 C-CAP California accuracy assessment locations (right). Sampling along road networks (linear features) in the 2001 assessment can be seen within the left map versus the stratified random sample for the 2010 approach.

## 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 California 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 82.8%, with nearly the majority of individual classes exceeding 80% accuracy. There were three classes, Pasture/Hay, Mixed Forest, and Palustrine Emergent Wetland, with accuracy below 80% for both user and producer accuracy. Bare Land and Grassland also were frequently confused with other classes, as discussed earlier. Change/no-change accuracy for the product was 90%, with committed change being the largest error. It was found that 71% 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 Grassland, Bare, and Scrub/Shrub is the largest source of overall error in the map. The spectral similarities of these classes, especially in a dry climate, make them difficult to consistently map. Effort should be made in the future to try and use spectral imagery in the classification that was collected with healthy growing vegetation. Additional effort should also be made to identify potential ancillary maps and data sets to assist in this classification. For example, the Bureau of Land Management may have maps highlighting some of these more natural range conditions.

The second issue to address would be the misclassification of upland forest types. As discussed earlier, the use of leaf-off and leaf-on imagery helps to separate these classes. Future mapping efforts should examine using additional dates of imagery in forested areas to help separate Deciduous Forest, Evergreen Forest, and Mixed 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. In California, native grasslands are often used for grazing, which leads to the confusion of Pasture/Hay and Grassland. This will continue to be a difficult class break to make, and more discussions should be held to address this issue.