# LAND COVER MAPS FOR MONITORING CHANGES IN THE NATION'S COASTAL ZONE

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## Introduction

The National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center has recently completed a national baseline of land cover and change information for the coastal zone of the U.S. as part of its Coastal-Change Analysis Program (C-CAP). C-CAP products inventory coastal intertidal areas, wetlands, and adjacent uplands and can be used for illustrating national and regional landscape changes over time, evaluating impacts on water quality, and planning uses of land.

A multi-year effort to create a baseline of coastal land cover changes is complete for the coastal regions of the lower 48 states (Figure 1). C-CAP has played a role in producing land cover maps for at least two decades. This is the first time, however, that the entire coastal zone was mapped using consistent technology and standards. C-CAP worked in close coordination with the U.S. Geological Survey and the Multi-Resolution Land Characteristics consortium in producing these data sets. C-CAP data is the coastal expression of the National Land Cover Database (NLCD). Standardizing data acquisition and reporting requirements makes it possible to compare maps from different regions and more easily compare maps of the same place using different time frames. This utility greatly increases the value of these maps to those people and organizations who work to protect coastal resources and the quality of life for coastal residents and visitors.


**Figure 1:** C-CAP mapping zones in the coastal zone of the conterminous U.S. The baseline (1996-2001) is complete for all zones. Dark blue zones also have 2006 land cover data, while the green zone has 1992 and 2006 data as well.

### Standardization and Database Approach

One of the strengths of national mapping programs such as C-CAP and NLCD is the ability to compare land cover maps from different mapping regions, projects, and eras. This ability arises from the database approach and classification methodologies used to create the land cover and change maps. The NLCD includes a three-season mosaic of Landsat imagery, as well as a digital elevation model (DEM) and topographic derivatives. From these base layers, various types of data—land cover, percent impervious, and percent tree canopy—are derived (through a suite of methodologies to be addressed in the following section). Ancillary data are also provided, and these include confidence and node maps, a decision tree, cross-validation accuracy, and metadata meeting the compliance standards of the Federal Geographic Data Committee. The open database approach allows for transparency in the process and allows users of the data to understand how the information is derived.

### CART and Classification

The land cover maps are created using a classification and regression tree (CART), a process that relies on accurate input training data. During the early stages of each mapping project, the Center team conducted field calibration trips with their external mapping partner. These trips were undertaken to ensure all staff members understood the complexities of each mapping area, often relying on local experts to help in the field. Training points were then fed into the CART process to create initial land cover maps. Quality assurance reviews were performed and feedback was used to refine future versions of the maps. Custom spatial modeling, ancillary data layers, and finally hand-editing of the maps continued until the final version was approved.

### Change Mapping

Landsat imagery circa 1996 was compared against the 2001 imagery to determine areas of potential change through statistical analysis of the spectral data. Spectral values and ancillary data from areas of non-change were sampled in the 1996 imagery and labeled with the 2001 land cover value. A CART model was built with these data and subsequently used to classify the remaining 1996 area. The resulting change maps went through a series of reviews and modeling to create a final product. Mapping change through this approach promotes consistency because there is less room for interpretation differences, and these products were produced at the same time as the 2001 land cover.

### Accuracy Assessments and Validation

Accuracy assessments performed on each mapping project stipulated an 85 percent overall accuracy rate and 80 percent in individual class accuracies.

Accuracy was reported by the mapping partners. In addition to the accuracy assessment performed by the contractor, the Center performed an independent validation of the land cover maps. Center personnel collected validation points by traveling in small aircraft or car throughout each mapping region to perform a statistical comparison against the contractor-provided accuracy assessment. It is important to note that the maps were judged based on their quantitative as well as quantitative merits in determining whether they were acceptable. In some cases, the required statistical accuracy was not met, but through qualitative reviews the map product was deemed acceptable.

**Results**

The 1996-2001 C-CAP land cover baseline covers approximately 817,500 square miles and was completed through nine separate mapping contracts starting in 2001 and finishing in 2007. The accuracy of each mapping contract was assessed separately by the mapping partner. A total of 11 accuracy assessment efforts and nine validation efforts were performed. The contractor reported that accuracy ranged from 76 percent to 91 percent for the separate areas. Pooling all individual accuracy assessments yielded a nationwide accuracy of 86.3 percent based on 20,405 points. Validation efforts performed by the Center support the accuracy assessment reported by mapping partners. The accuracy computed from the nine validation efforts (2,145 points) ranged from 77.2 percent to 90.2 percent (80.9 ±1.7 percent confidence interval combined).

Throughout the nation there were two dominant trends (development and silviculture) seen within the change data as well as many smaller (in area) but ecologically important changes (e.g., wetland changes). In 2001, more than 48,000 square miles were classified as developed, an area equal in size to Mississippi. From 1996 to 2001, there were 2,274 square miles of new (or increased) developed land. This newly developed land is roughly equal to 7.5 times the area of New York City. New development was not spread evenly throughout regions on the nation's coast. For example, the Southeast Region contained 37 percent of the land area but accounted for over 53 percent of the new "developed" classes (Figure 2.). There were approximately 850 counties in the Center's mapping area, and 10 percent of those counties with increased development account for 46 percent of all developed land.

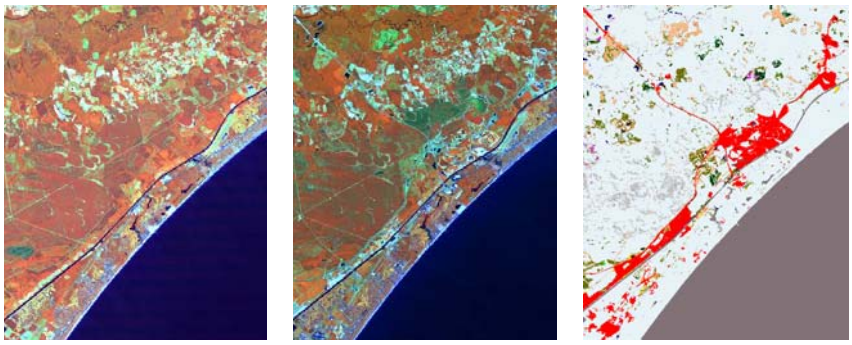

**Figure 2:** Development increased in many coastal counties as represented by Myrtle Beach, South Carolina. Areas of change from 1996 (left) to 2001 (center) are colored according to their 2001 class (right). Areas of increased development are colored red.

Silvicultural practices account for the largest area of change seen, though there is often little net change as the cycle of timber cutting and forest regrowth occurs. From 1996 to 2001 there was a net loss of 5,683 square miles of forest (~2 percent), but this number results from 12,294 square miles of forest loss offset by 6,611 square miles of forest gain. Although the forest class may appear stable based on net changes, the transitional nature of forest may have dramatic impacts on quality of wildlife habitat and potential erosion. An example of this offsetting gains and losses is shown in Figure 3.

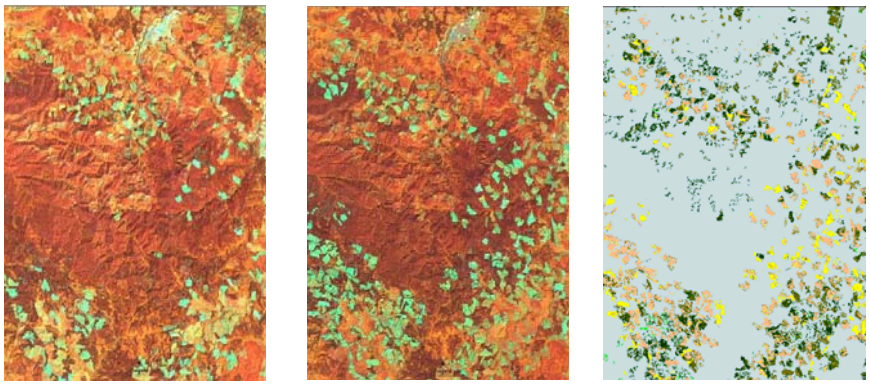

**Figure 3:** Silviculture activities in southern Washington show the offsetting nature of forest loss and gain. Areas of change from 1996 (left) to 2001 (center) are colored according to their 2001 class (right). The dominant changes are forest loss indicated by bare (yellow) and grass (tan), and regrowth indicated by forest (green) and shrub (olive) regrowth. No change areas are pale blue.

Of the smaller categories of change, perhaps the most ecologically significant one is the loss of wetlands. Of the 117,000 square miles of wetlands in the

mapping zones, 216 square miles were lost to development, primarily in the Southeast Region. This area is approximately the same amount of wetlands impacted by Hurricane Katrina. Other wetland changes include 287 square miles lost to farm and pasture and 160 square miles of wetland that either dried up or converted to open water.

## Discussion

The availability of multiple dates of land cover over an area gives coastal managers an opportunity to track development trends and evaluate past policy decisions, and the data can also be "fed" into tools to estimate water quality and help make management decisions. Two such tools, both provided by the Center, are the Nonpoint Source Erosion and Comparison Tool (N-SPECT) and the Habitat Priority Planner (HPP). N-SPECT relies on accurate land cover to estimate surface water runoff, nonpoint source pollution, and erosion. HPP is a spatial decision support tool designed to assist coastal managers in identifying important areas in the landscape for conservation of restoration. Both tools are provided by the Center (*www.csc.noaa.gov/bins/products/dst.html*).

The C-CAP approach to creating land cover offers interested groups the opportunity for partnerships and cost sharing. For instance, the State of Maine was interested in creating a land cover map with a higher resolution than that provided by C-CAP, and officials wished to map additional classes. The Center partnered with Maine in a cost-sharing effort in which C-CAP land cover products were created and delivered to the state. Maine then was able to leverage this effort to create a higher-resolution mapping product. This collaboration resulted in over $300,000 in cost savings for Maine. The Center continues to look for similar relationships, as this service is as important as the data produced.

The Center is currently working on the Land Cover Atlas (LCA) tool to assist users in compiling more detailed information from C-CAP data sets. The LCA is a Web-based tool through which users will be able to create standard and custom land cover change reports for various areas of interest. These features will give both technical and non-technical users access to detailed land cover change information that can be used in reports, water and habitat studies, and economic analyses.

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