**NASA DEVELOP National Program**



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North Carolina Ecological Forecasting

Update of NOAA C-CAP Wetland Delineation and Further Disaggregation of Land Use Classes using Remote Sensing

 **Technical Report**

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# I. Abstract

**Keywords**

Remote Sensing, Wetland, Albemarle-Pamlico, North Carolina, Land Use, Landsat 8, Satellite

# II. Introduction

**Background Information:** The Albemarle-Pamlico region is the ‘largest lagoonal estuarine system in the United States’ (EPA, 2007). It consists of six river basins (Fig 1) as well as the Albemarle and Pamlico Sounds. The water bodies generally, and the wetlands specifically, provide enormous value to the southeastern United States through numerous ecosystem services. Wetlands absorb storm surges and strong winds; they minimize eutrophication by retaining and filtering agricultural and urban runoff; and they provide protection for developing fish and amphibian species thereby continuing the existence and proliferation of terrestrial and oceanic biodiversity (APNEP, 2012).

However, the complex and dynamic nature of the Albemarle-Pamlico estuary network makes it a delicate system. Climate change induced sea level rise and land use change secondary to population growth are two significant threats to the Albemarle - Pamlico region (Carpenter 2012). Sea level is currently rising at a faster rate than wetland vegetation can keep pace with, which leads to inundation and erosion (-3.3 feet/year) (ibid). In the twenty years between 1990 and 2010, the Albermarle - Pamlico region’s population grew by 36%, from 2,762,409 to 3,756,019 (APNEP, 2012). This population increase necessitates land change in the form of urban development and agricultural expansion. Even when wetlands are not specifically drained and converted to these purposes, mismanagement of natural resources, waste production, and nutrient runoff have reduced the water quality and human health in the Albemarle-Pamlico watershed (Carpenter 2012).

In order to protect this region, the dynamics and characteristics of the estuary system must be better understood. A previous stage of this investigation, utilizing remote sensing data and indices that measured the extent and health of wetlands, concluded that wetland health has been deteriorating over time. However, to fully grasp the implications of this deterioration we must have clear delineations of the types of wetlands that currently exist, which types are deteriorating, and how this will affect the region as a whole.

**Project Objectives:** The Albemarle-Pamlico National Estuary Partnership (APNEP) currently relies on land use and land cover (LULC) data from NOAA’s Coastal Change Analysis Program (C-CAP) to understand land use designations and wetland types. This information helps to inform their management decisions by enabling them to decide where to allocate resources and to understand temporal trends. However, C-CAP is only updated every five years and is designed for regional coastline classifications. The team aimed to produce an updated classification that was tailored to the Albemarle-Pamlico estuary by providing additional land classification types. Building on the previous portion of this study, the team looked for a correlation between wetland deterioration and type. The objective was not only to provide APNEP with an updated set of images based on most recent available Landsat 8 imagery, but also to create a method of replicability so it would be possible for APNEP to update these classifications on a more regular basis than what C-CAP offers.

**Study Area**: The Albemarle-Pamlico region is located on the coast of northeastern North Carolina and southeastern Virginia. The basin consists of 31,000 square miles of land and water, including two major sounds, Albermarle and Pamlico, and seven major river basins (Fig 1), six of which APNEP monitors. Three major land cover classes: forests (40.1%), croplands (25.3%) and wetlands (15.8%) account for most of the LULC in the basin (APNEP, 2012; Carpenter, 2012).

Figure 1: Map of the Albemarle-Pamlico study area: river basins and major sounds (Original work).

**Study Period:** The Develop collaboration with APNEP began in the spring of 2015 and will end with this project in the fall of 2015.

**National Application Area:** This project focuses on and contributes to the NASA Applied Sciences Application Area of Ecological Forecasting through the delineation of current wetland extent using remote sensing data, and software such as ArcGIS an ERDAS IMAGINE. Although use of Landsat data for LULC is fairly common, this study provided the partner organization with a useful tool for the specific region of focus and ideally a methodology that will be useful not just to APNEP but potentially other areas of the Applied Sciences program at NASA or to the public. The integration of other data from USGS and NOAA as well as comparisons with the results from the previous portion of the project represent other processes which could lay groundwork for future projects. This methodology could contribute to the Application Area by increasing uptake and utilization amongst groups outside NASA by showcasing datasets, their uses and the accessibility of the data NASA produces.

**Project Partner:** Partnership with APNEP started in the spring of 2015. The primary goal of APNEP is to manage, conserve and protect the resources of the Albemarle-Pamlico estuary system. In order to do this they require a better understanding of how the discrete components of the ecosystem function together as a whole and what stressors are adversely impacting this resource. They are focused on analyzing both short and long term trends and utilizing citizen’s groups, researchers and federal agencies as well as governments from the local to federal level to accomplish their objectives (APNEP, 2012).

# III. Methodology

This study conducted a supervised land classification by using elevation, hydrography, soil, and crop data to select calibration points for a Random Forest Land Classification Model (Norning & Wegman 2013). The model runs in the open-source statistical analysis program, R, and converts spectral radiance values as recorded in Landsat 8 images to user - specified land cover types (ibid*)*. The data used is summarized in Table 1 below.

|  |  |  |
| --- | --- | --- |
| **Dataset** | **Source** | **Type/Specific Item** |
| Landsat 8 Operational Land Imager (OLI) | NASA EOS/USGS | Path 14, Row 35Path 14, Row 36 |
| Landsat 8 Climate Data Record (CDR) | NASA EOS/USGS | Path 14, Row 35Path 14, Row 36 |
| National Hydrography Dataset (NHD) | USGS | Waterbodies |
| Coastal Change and Analysis Program (C-CAP) | NOAA | 2010 iteration  |
| Soil Survey and Geographic Database (SSURGO) | USDA |  |
| Digital Elevation Models (DEMs) | USGS | 1/3 arc-second and 1 arc second  |
| Lidar | NOAA | 2001 NC Phase I |
| Cropscape Annual Crop Data  | USDA | 2010-2014 growing seasons for area constrained by the Landsat scenes  |

Table 1: This table provides a brief overview of the data utilized in the completion of this project. Federal agency titles have been abbreviated for the purposes of space. Please consult Appendix I for a list of acronyms.

Some of these data required preprocessing. Landsat 8 OLI scenes were preprocessed by the USGS to correct for surface reflectance as well as atmospheric interference in the Provisional Landsat 8 Surface Reflectance data product, part of the Landsat 8 Climate Data Record (CDR) dataset (USGS, 2015). Images from path 14 row 35 were obtained for three dates, (June 23, 2015, July 25, 2015) and three images for path 14 row 36 (June 23, 2015, July 25, 2015, August 10, 2015) were obtained, for a total of five Landsat scenes. The scenes were chosen due to the relatively high quality of the images: little cloud cover and most recent peak vegetation.

Processing and analysis proceeded by aggregation of these datasets in ESRI’s ArcGIS software. Eight 1/3 arc-second DEMs were mosaicked to create one representative raster of the area covered by the Landsat scenes. The ‘swamp/marsh’ type of the NHD Waterbody feature class was clipped to the study area. The “Ecological Site” and “Hydric Rating” SSURGO attributes were similarly merged for analysis within ArcGIS. The former attribute described an area’s characteristic soils, hydrology, and vegetation; the latter demarcated the percentage of an area’s soil that qualifies as hydric, defined as:

“Soil that is formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part” (USDA, n.d.).

These datasets were contrasted in order to select polygons, the training sites, which would best serve as calibration points for the Random Forest Model. Using ArcGIS and ESRI Imagine, training sites were chosen that clearly delineated a specific landcover type. The C-CAP classifications (Appendix II) guided the choices in land cover types, but some regionally inappropriate classes were ignored (such as tundra), while others of local concern such as crop types and invasive species were added (Appendix III).

The training sites encapsulated a minimum of 30-40 pixelsto allow for a margin of pixel overlap in the Landsat images (30 m2 resolution). 50-70 training sites were selected for each land cover classification type (Appendix IV). The sites and chosen land use classes were then input to the Random Forest Model which extrapolated the classification of the training sites to the entire spectral area (2 Landsat scenes), generating an image of land classification for the whole study area. The classifications produced by the model were compared against the specific case study areas utilized in the previous North Carolina Ecological Forecasting project, to determine if there was a correlation between wetland type and health.

# IV. Results & Discussion

[Forthcoming]

# V. Conclusions

[Forthcoming]

# VI. Acknowledgments

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# VIII. Content Innovation

1. R Land Classification Updater (In development)
2. Albemarle-Pamlico Interactive KML (In development)
3. Interactive Wetland Health Map (In development)

# IV. Appendices

**Appendix I**

|  |  |
| --- | --- |
| TOA | Operational Land Imager |
| APNEP | Top of Atmosphere |
| SWIR | Albemarle-Pamlico National Estuary Partnership |
| NPO | Short-Wave Infrared |
| C-CAP | National Project Office |
| NOAA | Coastal Change Analysis Program/ describes an amino acid in a particular position within a protein or polypeptide |
| DEM | National Oceanic and Atmospheric Administration |
| NHD | Digital Elevation Model |
| USGS  | National Hydrological Dataset |
| USDA  | United States Geological Survey  |
| NOAA | United States Department of Agriculture  |
| LULC | National Oceanic and Atmospheric Administration  |
| SSURGO | Soil Survey and Geographic Database |

**Appendix II**

C-Cap Attributes:

0 Background,

1 Unclassified (Cloud, Shadow, etc),

2 High Intensity Developed,

3 Medium Intensity Developed,

4 Low Intensity Developed,

5 Developed Open Space,

6 Cultivated Land,

7 Pasture/Hay,

8 Grassland,

9 Deciduous Forest,

10 Evergreen Forest,

11 Mixed Forest,

12 Scrub/Shrub,

13 Palustrine Forested Wetland,

14 Palustrine Scrub/Shrub Wetland,

15 Palustrine Emergent Wetland,

16 Estuarine Forested Wetland,

17 Estuarine Scrub/Shrub Wetland,

18 Estuarine Emergent Wetland,

19 Unconsolidated Shore,

20 Bare Land,

21 Open Water,

22 Palustrine Aquatic Bed,

23 Estuarine Aquatic Bed,

24 Tundra,

25 Snow/Ice,

**Appendix III**

[Forthcoming]

**Appendix IV**

[Forthcoming]