VEGETATION CLASSIFICATION FOR FUEL LOAD MAPPING USING SOFTCOPY PHOTOGRAMMETRY

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ABSTRACT

Fire-adapted forest ecosystems make up a large component of historic coastal plain vegetation types in the southeastern US. Fire suppression over the last century has resulted in elevated fuel loads in these forests, increasing wildfire risk and stressing the resources of land managers. Prescribed fire is a potential management tool to reduce fuel loading, but accurate data on fuel loading and fuel consumption is not currently available. Generating this data is a necessary step in accomplishing fuel reduction management goals. In this study we use 1:6000 color infrared aerial photography and softcopy photogrammetry techniques to map National Vegetation Classification System (NVCS) ecological associations. Next, we use USDA Forest Service Forest Inventory and Analysis (FIA) phase 3 protocol field plots to characterize the levels of 1, 10, and 100 hour fuels specific to each NVCS association. In addition, FIA phase 2 protocol plots are used to characterize live and standing dead tree biomass and forest canopy structure for use in fire behavior models. The final product is a geodatabase consisting of NVCS associations with additional divisions based on understory type and fuel loading level. The geodatabase will be used with fire behavior and smoke dispersion models to generate pre- and post-prescribed burn fuel loading.

INTRODUCTION

Naturally occurring fire is an important factor in the development and maintenance of coastal plain forests in the eastern United States. Many plant species which grow in this environment are either fire tolerant or adapted to reproduce after a destructive fire. These species include longleaf pine (*Pinus palustris*) on sandy xeric sites, and pond pine (*Pinus serotina*) and Atlantic white cedar (*Chamaecyparis thyoides*) on organic soil wetland sites. On coastal wetland sites, fire frequency and organic soil depth are the two major gradients that shaped historical vegetation patterns (Frost 1995).

The advent of modern wildland firefighting techniques in the 1950's caused significant modifications to coastal plain wildfire regimes. This era of successful fire suppression has caused fire return intervals to increase in many coastal areas. With continued fire exclusion, there is a risk that ecosystems will become simplified as short fire interval communities become more rare and long fire interval communities become more prevalent (Frost 1995).

Increasing the fire return interval also has effects on nonliving plant matter. Naturally occurring fires remove fuels that build up as plants die, slough off branches, and drop litter. When periodic reductions in wildland fuels are halted through fire exclusion, fuels can build up to such a high level that wildfires become uncontrollably large, costing land managers millions of dollars annually in suppression procedures, lost timber, and lost man-hours.

The cycle of fire suppression, fuel buildup, and costly wildfire can be seen clearly on the Dare county peninsula in coastal North Carolina. The mainland of Dare County, NC, is a coastal plain peninsula typified by histosol soils and fire-dependant vegetative communities. The majority of the peninsula is divided between two major ownership units: The 152,000 acre Alligator River National Wildlife Refuge (ARNWR), and the 40,000 acre Dare County Bombing Range (DCBR), operated by the US Fish and Wildlife Service (FWS) and the US Department of Defense (DOD) Air Force, respectively. Because the range is surrounded by refuge property, land managers for both organizations manage similar forested wetland ecosystems, and the two organizations must work together on fire management issues. The DCBR is an active military bombing range which sees over 8,000 practice sorties per year (GlobalSecurity.org 2004). Though no live bombs are dropped, the marking charges used to score bombing accuracy start an average of 100 wildfires yearly. Though most wildfires are suppressed immediately by on-site

North Carolina Forest Service staff, the combination of over 50 years of fire suppression and ignitions from errant bombs, lightning, and arson have resulted in several large blowup fires since 1970. Combating a major blowup fire costs between $108 and $923 per acre for suppression. Reducing fire risk through prescribed burning has been identified as a less expensive alternative, costing from $20-30 per acre.

Prescribed burning is a potential fuel-reduction strategy which may also have secondary ecosystem management benefits. In prescribed fires, fires are deliberately set during conditions where the fire may be controlled or confined to a specified area. For prescribed burning to be safe for practitioners and effective at removing fuel loads, accurate fuel loading measurements and maps are necessities. Remote sensing provides a method to create these maps for large areas quickly and efficiently. Recent advances in softcopy stereo photogrammetry have made the tools applicable to fine scale vegetation mapping available at a very affordable cost. In this study, we use commercially available softcopy photogrammetry software and hardware in conjunction with USDA Forest Service Forest Inventory and Analysis (FIA) field protocols to map forest fuel loads and plan for prescribed fire implementation in a 3,000 acre forested tract.

METHODS

Aerial photography mission

An aerial photography mission was flown in the spring of 2004 using color infrared (CIR) film. The mission was flown using a Kodak CIR 1443 camera with a focal length of 152.850mm, at an altitude of 917 meters (3010 ft) for an image scale of 1:6000. Because the images were to be interpreted as stereo pairs, the mission plan called for photographs to overlap 60% in the direction of flight and 30% on adjacent lines. 496 hardcopy infrared color positive transparencies were required to achieve stereo coverage of the entire bombing range, and 54 photographs for the study area.

An airborne Global Positioning System (GPS) / Inertial Measurement Unit (IMU) coupled to the camera apparatus recorded the location and orientation of the camera at each exposure station. Horizontal position measurements (x,y axes) were recorded in meters using the Universal Transverse Mercator grid, zone 18, and vertical position measurements (z axis) recorded in meters above the ellipsoid. Camera orientation data were recorded in degrees of rotation around the x, y, and z axes as omega, phi, and kappa, respectively.

Scanning

The transparencies were scanned using a high-quality consumer grade Epson desktop scanning bed with a transparency unit. Scans were conducted in 24-bit color at a resolution of 800 dots per inch (dpi), resulting in a nominal spatial resolution of 19 cm (7.5 in) per pixel. Scanned photographs were saved in Tagged-Image File Format (TIFF), with each uncompressed scanned image requiring approximately 180 megabytes of computer storage space.

Orthorectification

The Leica Photogrammetry Suite (LPS) softcopy photogrammetry software package was used for orthorectification. Image location, projection information, and image orientation parameters were stored in a small portable file called a “blockfile”. Fiducial marks were located using an onscreen display, which allows LPS to calculate interior orientation parameters. Previous vegetation mapping studies using softcopy photogrammetry have established the photograph’s relationship to the earth’s surface, or “exterior orientation”, by establishing ground control points for each image individually (Millinor 2000), or by using in a bundle block adjustment procedure in which image-to-image tie points are established for overlapping areas to orient photographs to each other, and ground control points are used to orient photographs to the earth’s surface (Koch 2001). The use of GPS/IMU data eliminates these tedious and time-consuming processes. The GPS/IMU report was imported when the blockfile was created, and the parameters were used to establish exterior orientation. This methodology eliminates the need for image-to-image tie points and ground control points (Leica Geosystems 2003a).

After establishing orientation parameters, orthophotos were produced using a Digital Elevation Model (DEM) to supply topographic correction. A 15-meter resolution DEM, produced by the North Carolina Floodplain Mapping Program (NCFMP), reflects the subtleties of elevation change on the Dare County Peninsula more accurately than the standard USGS 30-meter dataset. The NCFMP DEM was created by interpolating LiDAR data, and has been hailed as a major advance in mapping elevation in coastal North Carolina. This dataset was imported to Imagine format (*.img) from GRID format and used to orthorectify the images.

In addition to producing standard orthophotos, LPS also allows the user to view stereo pairs on-screen using a pair of stereo viewing goggles. Images are viewed one pair at a time, with heads-up digitizing, zoom, and pan capabilities. The concept is similar to using a stereoscope, but is far more powerful and easy to set up and use. This process occurs simultaneously with the orthorectification process and requires no additional processing time (Leica Geosystems 2003b).

Mosaic

Earth Resource Mapping's ER Mapper software provides a streamlined color enhancement and mosaic production environment. Orthophotos were exported to ERDAS Imagine 7.x (*.lan) format and then imported into ER Mapper's proprietary (*.ers) format. ER Mapper then calculated statistics for all images and implemented a color balancing solution for each photograph individually. After color-balancing, ER Mapper generates polygon regions to define the area of each orthophoto which will be transferred to the final mosaic. Manually editing these polygons further mitigated image hot-spots. When the polygons were complete, the final mosaic was saved in band-interleaved format (*.bil) and imported into Imagine.

Vegetation Map

Using the orthophoto mosaic and heads-up stereo display, digital elevation model, surface hydrology data, and a county soil survey, polygons representing vegetation extent were delineated at the International Vegetation Classification (IVC) alliance level. Polygons were delineated using heads-up digitization in ArcMap and saved in ESRI Geodatabase format. Geodatabase topology rules were created and enforced so that the dataset was cleaned when each polygon was created.

To differentiate vegetation types on the orthophoto mosaic, we used seven photogrammetric interpretation clues: size, shape, shadow, color, texture, pattern, and association with other objects (Avery 1992). The heads-up stereo photography allowed easy differentiation of vegetation with differing heights, canopy shapes, and tree spacing. This was a great help in determining the overstory vegetation type, which is the critical stratum for discriminating between IVC alliances (Grossman 1998). When necessary, elevation, soil, and hydrology data were used to provide clues to draw boundaries when soft edges were present between vegetation types.

RESULTS

The primary photogrammetric products from the orthorectification process were orthophotos (figure 1), a stereo block setup, and an orthophoto mosaic (figure 2). The orthophotos required post processing color balancing in ER Mapper to remove a hotspot and vignette effect visible across all images. Both artifacts were present in the hardcopy transparencies and could not be removed in the scanning or orthorectification process.

Secondary products derived from analysis of the orthophoto mosaic and stereo block file include detailed International Vegetation Classification System (IVCS) alliance-level vegetation maps (figure 3), hurricane damage maps, forest management geodatabase layers, and threatened and endangered species management habitat analysis products.

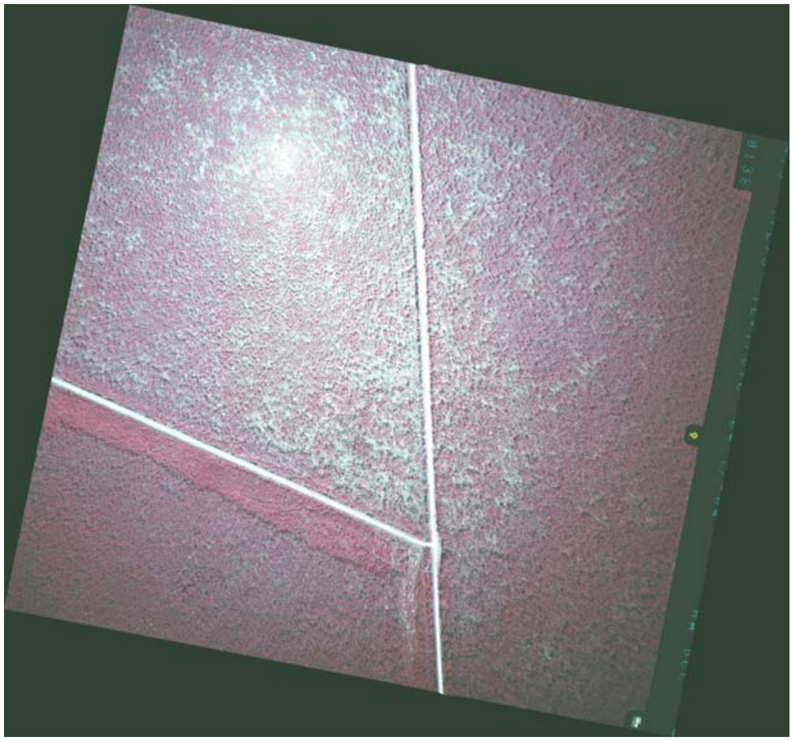

Figure 1. An orthophoto produced in the orthorectification process. The original photograph has been corrected for topographic displacement, photography platform orientation, and photographic distortion, and georeferenced to the UTM Zone 18 coordinate system. The orthophoto has not been color corrected.

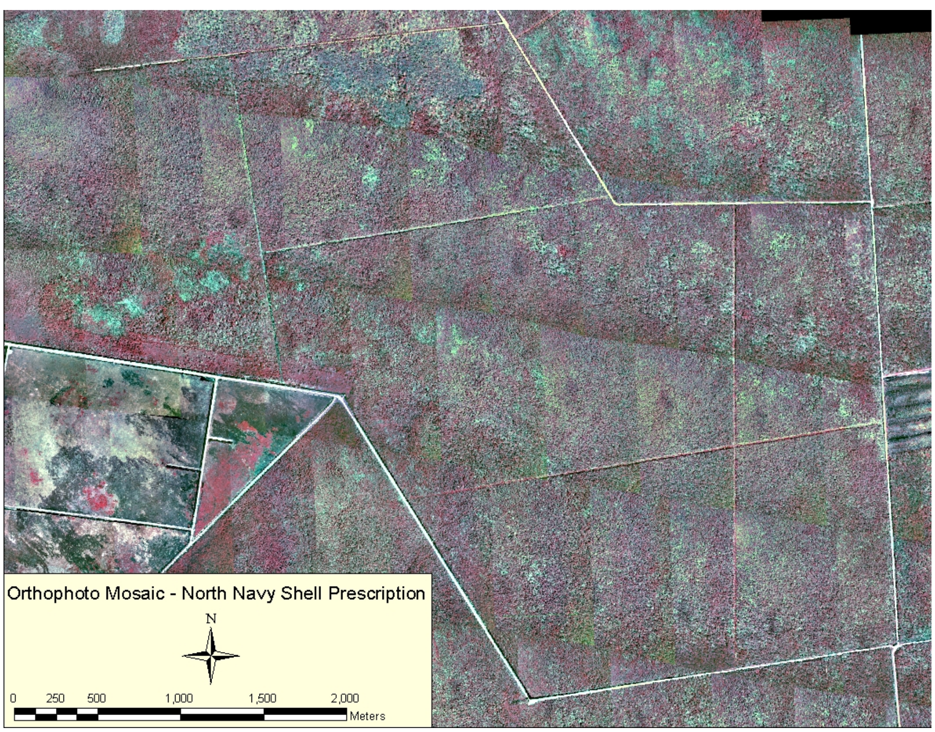

Figure 2. Map of the Dare County Bombing Range/Alligator River National Wildlife Refuge North Navy Shell prescribed burn unit showing orthophoto mosaic. The mosaic is a result of combining color-corrected orthorectified images masked to polygon clip regions.

Table 1. NVCS Alliance-level Vegetation Classes Present in Study Area

Alliance Name	Common Name	Acreage
Loblolly-Bay Saturated Forest Alliance	Bay Forest	2.8
Swamp Blackgum – Red Maple – (Poplar) Saturated Forest Alliance	Maple Forest	68.3
Loblolly Pine – Atlantic White Cedar – Red Maple – Blackgum Forest Alliance	Loblolly Pine Forest	158.8
Pond Pine Saturated Woodland	Pond Pine Woodland	2389.0
Fetterbush – Gallberry Saturated Wooded Shrubland	Pond Pine Shrubland	13.0

The study area contained five different vegetation alliances, described in table 1. The five alliances present in the study area are typical of the Dare County Peninsula. Four of the Alliances are fire-adapted communities, though the swamp blackgum – red maple – (poplar) saturated forest alliance is indicative of a fire excluded state. This alliance occurs at the north of the block (figure 3), where DEM analysis indicates a slight decrease in elevation. In this case, the half-meter decrease in elevation causes water to pool at the soil surface, effectively fireproofing the vegetation.

A distinction in canopy stocking was made in the Pond Pine Saturated Woodland alliance because of the anticipated impact of overstory stocking on fuel loading. The Loblolly Pine – Atlantic White Cedar – Red Maple – Blackgum Forest alliance was divided into loblolly pine forest and mixed pine hardwood forest types based on loblolly pine abundance. The division was made because loblolly pine abundance is expected to have a significant impact on fuel loading.

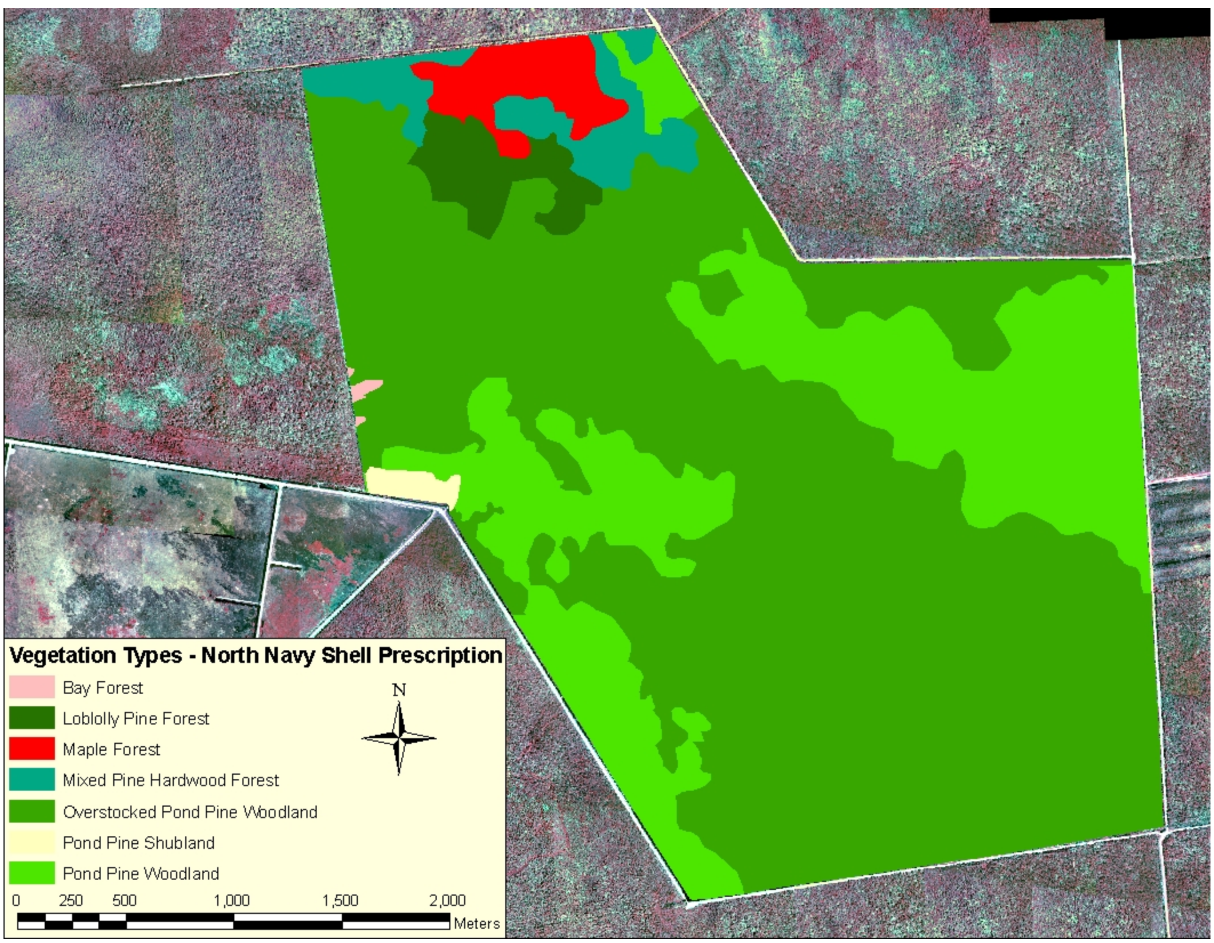

Figure 2. Vegetation map for North Navy Shell prescribed burn unit classified to the NVCS Alliance level, using common names for alliances.

DISCUSSION AND FUTURE APPLICATIONS

Softcopy photogrammetry software and hardware for desktop PC workstations provides a powerful set of tools for mapping forest fuel types. Very high resolution stereo photography enables the user to see individual tree canopies, forest structure, and landforms, and to transfer that information quickly and accurately into geodatabase format for distribution. This is a major improvement over previous systems that allow heads-up digitizing on 2-D images, or using a stereoscope to delineate polygons in 3-D before transferring the polygons to digital format.

Field data to quantify fuel loads will be acquired using plots based on the US Department of Agriculture Forest Service Forest Inventory and Analysis phase three protocols. Phase two protocols will be used to map standing live biomass and characterize forest structure. A geodatabase containing fuel loading data by IVCS vegetation alliance and fuel type will be created and used in fire behavior, smoke dispersion, and smoke emissions modeling efforts. Following prescribed burning in the study area, plots will be re-inventoried to determine fuel consumption rates and quantify forest structure change. Over the next two years, these methods will be implemented beyond the study area to build a wildland fire fuel loading geodatabase for the entire Dare County Bombing Range.

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