Millinor, William A.: Digital Vegetation Delineation on Scanned Orthorectified Aerial Photography of Petersburg National Battlefield (Under the Direction of Dr. Hugh A. Devine).

Abstract

I developed a new methodology to produce an orthorectified mosaic and a vegetation database of Petersburg National Battlefield using mostly digital methods. Both the mosaic and the database meet National Map Accuracy Standards and proved considerably faster than traditional aerial photograph interpretation methods. I classified vegetation polygons to the formation level using the Nature Conservancy's National Vegetation Classification System. Urban areas were classified using Mitchell's Classification Scheme for Urban Forest Mapping with Small-Scale Aerial Photographs. This method reduced the production time by 2/3, compared to traditional methods. It also reduced the chance of user error because re-tracing of the linework is not required.

My method started with scanning 75 aerial color IR photos, provided by Petersburg National Battlefield, at 600 dpi. Erdas Imagine was used to rectify the images using United States Geological Service (USGS) Digital Elevation Models (DEM) and black and white USGS Digital Orthophoto Quarter Quadrangles (DOQQ) as reference. The images were then mosaiced to create a seamless color infrared orthorectified basemap of the park. The vegetation polygons were drawn onscreen using ArcMap from Environmental Systems Research Institute, Inc. (ESRI) with the color, orthorectified mosaic as a background image. Stereo pairs of the aerial photos were referenced as needed for clarification of the vegetation. I used a minimum mapping unit (mmu) of 0.2 hectares, which exceeds guidelines defined by the United States Geological Survey –

National Park Service Vegetation Mapping Program. This methodology is easily learned quickly and has already been applied to several other studies.

The production of an orthorectified mosaic, created during the process, from the aerial photographs greatly increases the value of the photographs at little additional cost to the user. The orthorectified basemap can then be used as a backdrop for existing data layers or it can be used to create new GIS data layers. I used a minimum mapping unit (mmu) of 0.2 hectare, which exceeds guidelines defined by the United States Geological Survey-National Park Service Vegetation Mapping Program

Traditionally, vegetation polygons are delineated on acetate for each photograph. The linework on the acetates is then transferred to a basemap using a zoom transfer scope or other transfer instrument. The linework is traced again to digitize it for use in a GIS program. This process is time consuming, and the linework is drawn three times. The redundant tracing increases the chance of user error. My new methodology requires that polygons be delineated only once. I wanted to avoid using the zoom transfer scope and to avoid the redundant linework.

A total of 228 polygons were delineated over 20 separate vegetation and land cover classes with an overall thematic accuracy of 87.42% and a Kappa of .8545. Positional accuracy was very good with a RMSE of 1.62 meters in the x direction and 2.81 meters in the y direction. The Kappa and RMSE values compare favorably with accuracies obtained using traditional vegetation mapping methods.

Digital Vegetation Delineation on Scanned Orthorectified Aerial Photography of Petersburg National Battlefield

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Dedication

This work is dedicated to my wife Shannon Millinor, without her love and support this would not have been possible. It is also dedicated to my parents Robert Millinor and Nancy Talarski who helped me become who I am today and put up with me for so long. And last but not least, to Merlin.

Biography

The author received a Bachelor of Science in Wildlife Ecology and Conservation from the University of Florida in 1995. He is currently a Research Associate at North Carolina State University completing his thesis for a Master of Science in Natural Resources specializing in Spatial Information Systems. His research interests lie in application of GIS in conservation, ecology, and park management and he would like to continue utilizing new technology for spatial analysis.

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Introduction

The goal of this study was to create a digital methodology for vegetation classification that would meet National Map Accuracy Standards. A secondary goal was to classify the vegetation of the Main Unit of Petersburg National Battlefield following the guidelines of the United States Geological Service (USGS) and National Park Service (NPS) Vegetation Mapping Program (USGS, unknown). This new method uses scanned and rectified aerial photography with vegetation polygons digitized directly onscreen.

Petersburg National Battlefield (PETE) provided seventy-five color infrared aerial photographs of the Main Unit in Petersburg Virginia. The photographs are very large scale at 1" = 250 ft (1:3000) and were taken in March 1992 in leaf off conditions. The USGS-NPS Field Methods for Vegetation Mapping require a minimum mapping unit (mmu) of at least 0.5 hectare, but with such large-scale photography an mmu of 0.2 hectares was attainable. The USGS-NPS Field Methods also call for at least 80% accuracy across all vegetation classes. The USGS-NPS guidelines require that The Nature Conservancy's (TNC) National Vegetation Classification be used, but they do not specify which level of the vegetation hierarchy must be mapped. The Federal Geographic Data Committee (FGDC) standards note that Formation level is the most detailed level that can be reached without extensive fieldwork (FGDC, unknown).

The TNC classification system is based on vegetative land cover types and is quite extensive in its classifications; but, the TNC system lacks any classifications for urban or built up areas. Because Petersburg National Battlefield is an urban park, it is surrounded by development. To better mange the park, Petersburg personnel were interested in the areas surrounding the park. In order to classify these urban areas, another classification system was needed to complement the TNC system. Mitchell's Classification Scheme for Urban Forest Mapping with Small-Scale Aerial Photographs was selected (Mitchell, 1995).

The general methodology for delineation on aerial photographs has always been to delineate the polygons on acetate overlain on each aerial photograph. This linework is then transferred to a basemap using transfer instrument such as a zoom transfer scope (ZTS) (Paine, 1981). Once the basemap has been created it is then digitized in order to display the linework onscreen. The final output using this method is a vector coverage that overlays on existing imagery. Heather Cheshire (personal communication) estimated that vegetation delineation using this methodology requires eight to nine hours per photograph. I wanted to create a new methodology that reduces the time as well as the redundant tracing of the linework. In doing so I also produced an orthorectified mosaic that is a new orthorectified image that can be used for a backdrop or to delineate new GIS data.

Literature Review

This literature review will cover some uses of a vegetation database including those in fire management, restoration, biodiversity analysis, change detection and wildlife management. Different vegetation classification systems will be compared and briefly discussed in order to show why the Nature Conservancy's system was used along with the Mitchell classification system. Finally, some projects with similar goals or methods will be compared.

Satellite Imagery Mapping Applications

Satellite imagery has long been used in vegetation mapping and database creation. Satellite data are available widely and are relatively inexpensive to acquire for large tracts of land; thus they have been used widely for many applications. The following projects all used satellite data and a GIS to map vegetation or used existing vegetation information in many different projects. They are provided as a guide to just some of the practical uses of a vegetation database and should help to clarify the reasons for creating a vegetation database. They also provide a comparison of different methods to classify vegetation and their corresponding accuracies have been provided when known.

Fire management

Geographic information systems are used worldwide in support of fire management systems. Using a GIS in fire management allows for better decision-making as well as better prevention and suppression. In most of the cases where a GIS is used for fire management a vegetation survey has already taken place and the managers have a vegetation basemap to work from. Knowing the vegetation in an area allows an analyst to predict fuel loads and thus make informed decisions when creating a fire management plan.

For example, Hoffman et al. (1999) details a fire information system in Indonesia using GIS to monitor all aspects of fire management. They use large-scale remotely sensed imagery from NOAA, Landsat TM and ERS-2-SAR to derive vegetation types and fuel conditions. This information allows them to implement effective prevention and preparedness measures.

Another use of a vegetation map and fire management is at Kennedy Space Center in Florida (Schmalzer, 1995). In this case the area is broken down into fire management units and each unit has its vegetation type and fuel load in the database. Primary fire management objectives at the Kennedy Space Center are maintaining and restoring biological communities and reducing hazardous fuel loads with prescribed fires

Biodiversity Analysis

Harvey (1996) used vegetation maps in his studies of species composition, habitat and biodiversity. He studied avian biodiversity in New Zealand and demonstrated a methodology combining canonical correspondence (CCA) analysis with GIS in ecological modeling. Vegetation data along with elevation and climate information was used in the analysis. The CCA scores were then used to predict species distributions.

Change detection

Vegetation maps have been widely used in change detection throughout the world and for many different reasons. Change detection has a relatively simple principle behind it. Classify an area using an old source and then reclassify the area using a newer source and compare the differences. The data can come from many different sources such as aerial photography or Landsat imagery and can cover different scales as well depending on the level of detail needed for a particular project.

One example project is a collaboration by the USDA Forest Service and the California Department of Forestry and Fire Protection (FRAP, 2000). They are working on a statewide land cover monitoring program to assess changes in vegetations types. This project uses Landsat Thematic Mapper satellite imagery to derive land cover changes within a five year time period for all vegetation types. At the end of the project the changed areas will be analyzed and a new data layer will be created to show the causes for the changes.

Another example, this one performed by a commercial company, was a change detection analysis performed in the Amazon rain forest in Ecuador (Groth, 1997). Walsh Environmental was hired to study causes and rates of deforestation. They used Landsat Thematic Imagery from 1986 and 1995 with very general vegetation classifications. The data from this study was used to predict deforestation in the future and to minimize the negative impacts of seismic exploration in the Amazon rain forest. Dale et al. (1998) worked on integrating a GIS with computer models to simulate changes in land use cover in response to land use impacts. They incorporated remotely sensed vegetation information along with habitat associations and population models to predict susceptibility of species to changes in habitat suitability and landscape patterns. Ben Gorte (1999) used multi temporal Landsat imagery to classify vegetation and to study deforestation in Brazil over an 11-year period. Gorte's vegeatation classification yielded an overall 71% thematic accuracy. Boyle et al. (1997) shows that there is almost no limit as to how long the window of change can be, provided you have information to work with. They studied changes in vegetation over a 163-year period to gauge the effects on the ecosystem. Not surprisingly, they found that as human populations in the Lower Fraser Basin continue to increase, the quality of air, water, and soil will continue to decline.

Aerial Photography Mapping Applications

The following studies and projects represent a sampling of some of the possibilities available using vegetation databases in projects utilizing aerial photographs. They usually cover smaller study areas and have greater detail when compared to projects using satellite data. This information is included to justify the creation of a vegetation database and to show what can be accomplished when using vegetation information derived from aerial photographs. The accuracies of the various techniques have been included as well when possible for comparison to this method. An existing vegetation database will allow Petersburg National Battlefield to broaden their research efforts and their management strategies to incorporate ideas from the projects listed below.

Wildlife Management

Vegetation maps have always been useful in wildlife management. They allow researchers to relate wildlife species to different areas based on vegetation and ecological types as well as other things like defining home ranges finding suitable areas for relocation. Scott and Sullivan (2000) proposed a new method for selection and design of habitat preserves that is largely dependent on data that can only be obtained from an accurate vegetation database. There have been multiple studies that are based on vegetation data from the Gap Analysis Program (GAP). Campbell (1998) used the GAP vegetation data along with DEM's to determine the most suitable habitat for cougars in New Mexico. A similar study was conducted by Van Deelen et al. (1997) working on the reintroduction of elk to southern Illinois. They used existing GAP vegetation data to determine if there was enough elk habitat available for a reintroduction program as well as to determine potential release sites. Mazzotti (1999) is working on another study using the GAP vegetation data. He is creating an ArcView interface that can be used to display and query databases on potential habitats of terrestrial vertebrates. This will allow them to assess how restoration plans for one species may impact potential habitat for other species.

Biodiversity analysis

GIS has been widely used in the study of biodiversity. A GIS's ability to manage large databases and images quickly and easily makes it well suited for biodiversity research. Biodiversity studies today must use some form of a vegetation database. In most cases the vegetation is surveyed along with species composition and then species distributions are predicted from the vegetation map for large areas.

The Gap Analysis Program maps the land cover of the United States and then maps predicted species distributions based on the vegetation cover types (Maxwell, 2000). The GAP is a national program conducted on a state-level scale and is a cooperative effort among many agencies and groups. The GAP data is provided to the public and to those in charge of land use research, policy, planning, and management. The GAP vegetation data has become widely used for non-biodiversity study as well; from identifying noxious weeds and plants to even modeling one-year cattle prices in Texas (Parker et al., 1997).

Restoration

Vegetation data can be used for revegetation monitoring as well. Walsh Environmental used aerial photographs to monitor regrowth of helipads and a camp clearing for a seismic survey in Peru. The aerial imagery was analyzed within a GIS package to identify size and type of ground cover. Imagery was then acquired a year later to determine growth rate for the revegetated areas according to size of the clearing and ecosystem type (Groth, 2000).

Fire management

National Parks are now using vegetation mapping information as well. Voyageurs National Park is creating a new fire management plan using prescribed fires (Schaberl, unknown). The vegetation classes are converted to fire fuel types and are then inputted into fire behavior models like FARSITE. Zion National Park has a similar program and they use the vegetation data for prescribed fire management and in predicting wild fire behavior (Cohan, unknown).

Review of Land Cover and Vegetation Classification Systems

The following will be a brief review of various land cover and vegetation classification systems. It is included to clarify the differences between the various classifications systems and to justify the use of the TNC classification system along with the Mitchell classification system.

A Land Use and Land Cover Classification System for Use with Remote Sensor Data

In 1971, a committee was formed to develop a national classification system that would "be receptive to inputs of data from conventional sources and remote sensors on high altitude aircraft and satellite platforms, and that would at the same time form the framework into which the categories or more detailed land use studies by regional, State, and local agencies could be fitted and aggregated upward from Level IV toward Level 1 for more generalized, smaller scale use at the national level" (Anderson et al., 1976).

The classification system was broken into 4 categories. Levels I and II were developed for LANDSAT and high altitude data of 1:80,000 scale or higher. Level III was for 1:20000 to 1:80,000 scale data and Level IV was for low altitude data of 1:20,000 scales or less. Levels I and II would generally be of interest to users looking at data on a large scale such as nationwide, interstate, or statewide information. Level I has 9 major classes that were further subdivided into Level II classes (Appendix 1). Levels III and IV were for users at more local levels such as regions, counties or cities. Levels III and IV were left open ended for users to define based on their own observations and particular needs. This system allowed for a good national classification system but only at very broad classes. The open-endedness of levels III and IV allowed for a continuation of the hierarchical system; but, without any definition of classes at this level, there would not be any consistency among projects using this system throughout the nation as local projects continuously defined and created their own new classes.

Classification of Wetlands and Deepwater Habitats of the United States

Lewis Cowardin developed a classification system in 1979 for wetlands and deepwater habitats (Cowardin et al., 1979). This system was designed for use over an extremely wide geographic area and for use by individuals and organizations with varied interests and objectives. The structure of this classification is hierarchical, progressing from Systems and Subsystems, at the most general levels, to Classes, Subclasses, and Dominance Types. The classification system employs 5 System names, 8 Subsystem names, 11 Class names, 28 Subclass names, and an unspecified number of Dominance Types.

The five major Systems are Marine, Estuarine, Riverine, Lacustrine, and Palustrine. Modifiers for water regime, water chemistry, and soils are applied to Classes, Subclasses, and Dominance Types and special modifiers describe wetlands and deepwater habitats that have been either created or highly modified by man or beavers. Below the level of Class, the System is open-ended, only giving some examples and allowing regional users to develop their own classifications. It is very similar to the Anderson Classification in this regard. This allows for usage of the classification system over a wide range or areas but also limits the system in that overlapping classes can be developed that are not strictly hierarchical or mutually exclusive.

UNESCO

United Nations Educational, Scientific, and Cultural Organization (UNESCO) developed a hierarchical classification system of vegetation of the world based on physiognomic characteristics (UNESCO, 1973). It is an open-ended system produced for use with small-scale vegetation maps of 1:1,000,000 (Kuchler and Zonneveld, 1998). The system has five major classes: Closed Forest, Woodland, Scrub, Dwarf-Scrub, and Herbaceous Communities. The lower levels are classified according to leaf phenology and then associations of species. This system has been widely used as a basis for many newer classification systems and introduced some good principles that allowed it to be a highly flexible classification system. It is a true hierarchical system and it's open endedness allowed for it to be widely used in areas that other systems may have fallen short. But, since it was primarily intended for smaller scale maps and it was to be used worldwide, it is not a good one to use for a nationwide program looking to get to very fine levels of classification. The open endedness also disqualified it for use on a national scale since it allows for overlapping and ambiguous classes to be developed.

SAF

In 1980 the Society of American Foresters produced a classification system known as Forest Cover Types of the United Stated and Canada (Eyre, 1980). This classification was based on forest cover types as opposed to forest site type. A forest cover type was defined as “a category of forest defined by its vegetation (particularly its composition) and/or locality (environmental) factors (Eyre, 1980). This definition differed from forest site types that were defined as a category of forest or forestland. This classification was an update of the 1975 edition and 22 types were deleted with 11 new ones added and the total was reduced from 160 classes in 1975 to 145 classes in 1980. The classification system is a 3 level system. Level 1 is the region such as boreal forest. Level 2 is the species type present such as Upland Oaks, and Level 3 is the species present such as Cottonwood. This was a very good classification system but it was not open-ended and it only covered forest types and not other areas such as grasslands or saturated areas. Since it was not open-ended it does not readily allow for new cover types to be added to the system. As such, it was not very exacting for very high level mapping needs in small areas that went to very refined levels and it was not suitable for areas containing anything other than forested land.

North Carolina CGIA

In 1994 the North Carolina Center for Geographic Information and Analysis (CGIA) produced a classification system for the mapping of land use and land cover (CGIA, 1994). This system is a dual classification scheme focusing on the differences between land use and land cover. The land cover scheme focuses on describing the physical qualities of the vegetated or non-vegetated surface. Example classes are broadleaf deciduous forest, shrubland, or inland water bodies. The land use scheme looks at types of human activity or modification of the land surface such as residential land or cropland. The NC CGIA is a hierarchical system with 4 levels. Level I is the most general classification while Level 4 is the most detailed classification. This system is loosely based on Anderson's classification system and is very detailed for the state of North Carolina's land use and land cover. It is not a national classification system and therefore would need to have its scope increased to be applied nationally; meaning it would not include species and cover types not found in North Carolina. It also has the same drawbacks as some of the other systems listed above in that it is open-ended to allow users to create their own classes as needed.

NOAA C-Cap

The National Oceanic and Atmospheric administration (NOAA) Coastal Change Analysis Program (C-CAP) Coastal Land Cover Classification System includes three Level I super classes Upland, Wetland , Water and Submerged Land (Klemas, et al., 1993). These super classes are subdivided into classes and subclasses at Levels II and III, respectively. The classification system is hierarchical, reflects ecological relationships, and focuses on land cover classes that can be discriminated primarily from satellite remote sensor data. It was adapted and designed to be compatible with other nationally standardized classification systems, especially Anderson's and Cowardin's systems. This system is mainly focused on areas around water bodies and coastlines as suggested by its name. This system is not an open-ended system and would therefore be a good classification system to apply nationally but it was mainly developed for remotely sensed high altitude work and lacks detailed vegetation classifications.

MRLC

In 1996, the Multi-Resolution Land Characteristics (MRLC) Consortium developed a new classification system based on two systems (C-CAP and Anderson) that have undergone significant review and operational testing over a long period (MRLC, 1996). This land cover classification was developed to be compatible with Level I of the USGS Anderson System and to use categories that can be consistently mapped across the country using Landsat TM and computer-assisted classification methods. It is a 4 level hierarchical system with the Level I classes based on the C-CAP system and the Level II classes based on a mixture of a reorganized version of C-CAP and the Federal Geographic Data Committee (FGDC) Vegetation Standard.

Like the C-Cap system and the Anderson system, Level I is the most general class with Level IV being the most specific. This would be a good system to use nationally as it is not an open-ended system but it is specifically aimed for use with Landsat data and is not tailored for use with large scale aerial photography. Therefore it fails to scale to a fine enough level of vegetation classification.

Terrestrial Vegetation of the Southeastern United States

The Nature Conservancy developed a classification system in 1998 based on the UNESCO classification system and its revisions (Weakley et al., 1998). The Nature Conservancy's goal was to create a standardized, hierarchical classification system that could be used across the United States. The system emphasizes existing vegetation as the primary attribute for classification as opposed to land cover or land use employed by some of the previously mentioned systems.

The system has seven levels. The top five levels are based on physiognomic attributes and the 2 lower levels are based on floristic characteristics (Figure 1). The system level shown is the terrestrial system used for classification within this project. The physiognomic classes are based on the structure of the vegetation determined by height and relative percentage of cover of the dominant life forms. There are seven classes such as forest, woodland etc. The physiognomic subclass is based on leaf phenology of classes, such as evergreen shrub or deciduous forest. The formation group is based on

Figure 1. Terrestrial Vegetation Classification System Breakdown

System

- Formation Class
  - Formation Subclass
    - Formation Group
      - Subgroup
        - Formation
          - Alliance
            - Plant Association

leaf characters such as broad-leaved or needle leaved. The subgroup is a separation between natural vegetation and planted or cultivated vegetation. The formation level represents species that share structural and environmental factors such as elevation and hydrologic regime. Some examples or formations are mixed needle-leaved evergreen cold deciduous woodland and lowland or submontane cold deciduous forest. Appendix 2 lists the formations found in this project and gives a brief description.

The two lower classes, Alliance and Association, are very fine levels of classification that require extensive groundwork to classify. Alliance is based on a uniform group of plant associations that share one or more diagnostic species found in the dominant strata. Association is the finest level of classification and is differentiated from the alliance level by additional species found within any strata. Examples of these classes are the *Quercus alba* – (*Quercus nigra*) Forest Alliance and the *Quercus alba – Carya glabra* / Mixed Herbs Coastal Plain Forest Association. Table 1 shows some sample classes divided to association level.

Table 1. Illustration of the Terrestrial Vegetation Classification System Hierarchy

Class	Forest	Woodland	Shrubland
Subclass	Deciduous Forest	Deciduous Woodland	Deciduous Shrubland
Group	Cold-deciduous Forest	Cold-deciduous Woodland	Temperate Broad-leaved Evergreen Shrubland
Subgroup	Natural/Semi-natural	Natural/Semi-natural	Natural/Semi-natural
Formation	Lowland or Submontane Cold-deciduous Forest I.B.2.N.a	Cold-deciduous Woodland II.B.2.N.a	Temperate Broad-leaved Evergreen Shrubland III.A.2.N.a
Alliance	*Castanea dentate – Quercus prinus* Forest Alliance I.B.2.N.a.120	*Quercus laevis* Woodland Alliance II.B.2.N.a.100	*Ligustrum sinense* Shrubland Alliance III.A.2.N.a.010
Association	*Castanea dentate – Quercus prinus* Forest	*Quercus laevis / (Andropogon virginicus, Aristida spp. Schizachyrium scoparium)* Woodland	*Ligustrum sinense* Upland Shrubland

The real advantage of this classification is that it was made for use with aerial photographs and therefore has very fine classes that complement the level of detail found in large scale aerial photographs. This system is also not open ended. This is a great benefit for a nationwide program such as the USGS/NPS Vegetation Mapping Program in that classifications can be applied nationally without fear of duplicate or overlapping classes. These are the 2 main reasons why this system was chosen for the USGS/NPS program and why it was used for this project; but, since this classification system is mainly focused on vegetation types it lacks in classes for developed areas.

Mitchell

In 1995 James Mitchell developed a Classification Scheme for Urban Forest Mapping with Small-Scale Aerial Photographs (Mitchell, 1995). It was developed specifically for use with small-scale aerial photographs of urban areas and contains good classes for developed areas. The system is made up of 15 categories. Six of these were developed and undeveloped forests, 1 for farmland, 2 for water bodies, and 6 more for features of development. This system was chosen to complement the Nature Conservancy's classification system in order to cover some of the developed areas in and around Petersburg National Battlefield. Some example classes are: 1.1.1 Developed Deciduous Forest and 1.3 Recreational Facilities.

Similar Vegetation Mapping Research

Timothy Hill of Geographic Resource Solutions mapped the Applegate River Watershed for vegetation (Hill, unknown). Landsat TM satellite imagery was used instead of aerial photos and plant community descriptions from the "Management of Wildlife and Fish habitats in Forests of Western Oregon and Washington" were used instead of the Nature Conservancy's system. DEM's were used as reference and the polygons were classified using an ISODATA algorithm. The plant community descriptions were relatively broad such as deciduous hardwood, mixed conifer, and grass but they generated very good results with an overall accuracy of 88%. Franklin et al. (2000) used Landsat TM data as well to produce vegetation databases for USDA Forest Service lands in California. They classified the land cover into 22 classes covering approximately 10 million hectares. The classification took 10 years and yielded and overall thematic accuracy of 85%.

Nilson et al. (1999) worked on a project mapping plant communities using scanned aerial photos and a GIS. The vegetation was sampled in the field to get control areas and the aerial photographs were converted to a raster format. A DEM was then created using a Trimble GPS Unit. Referencing these data the vegetation was then classified using a computer program for multivariate data analysis in ecology and systematics; SYN-TAX version 5.1. They yielded an overall thematic accuracy of 78.5 % ranging from 59 to 99%. This study did not use a classification system but instead broke the existing vegetation into 8 different types using a fuzzy clustering technique.

Ustin et al. (1996) used an Airborne Visible Infrared Imaging Spectrometer (AVIRIS) sensor and a Spectral Mixture Analysis to distinguish five different vegetation types in California. They had a very large study area of 80 square kilometers but there thematic accuracy was relatively low at only 57%.

Wells and Blackwell (1999) generated a methodology to rectify aerial photographs using a rubber sheeting method. 1:12000 scale color infrared DOQQ's produced by the Texas Orthoimagery Program were used to define reference points with 25 GCP's selected for each image. Rubber sheeting is simpler than a full orthorectification but the results are not as consistent or accurate as those from a traditional orthorectification process. 3rd-order polynomial transformation was used to generate the rectified images. The resulting images were found to meet National Map Accuracy Standards for a scale of 1:12000. The success of this project was due to the very accurate DOQQ's that were available to use as reference.

Slocumb (1996) used color infrared photographs of five national parks to classify the vegetation to the formation level of the Nature Conservancy's working draft of the Vegetation Classification System of the Southeastern United States. This project used mirror stereoscopes for the photo-interpretation and classification and a Zoom Transfer Scope to move the data to a basemap. Atlas GIS was then used to digitize the data. He also tried using scanned aerial photography as a basemap so the polygons could be digitized directly onscreen. But, the registration of the aerial photos to ground coordinates was not accurate and the method was rejected.

More recently, Everglades National Park has been the subject of many projects attempting to map the vegetation. McCormick (1999) worked with large-scale aerial photos (1:7000) to map exotic vegetation such as malaleuca and Brazilian pepper within a subset of the park. She achieved an overall thematic accuracy of 94%. McCormick's work is very similar to this project but there is a significant difference in the methodology and the output. The vegetation was delineated on acetate on each photograph and then the delineated linework on the acetates was scanned and then rectified. The linework was imported into ArcInfo for editing and cleanup.

Welch et al. (1999) also worked on the Everglades to produce a vegetation database of the entire park. They worked with 1:40,000 color infrared aerial photography. There methods were similar to McCormick's above in that they delineated the vegetation on overlays and then scanned and rectified the overlays. The digital linework was then imported into ArcInfo for editing. An overall thematic accuracy of over 85% was attained. Similarly, Rutchey and Vilchek mapped cattail vegetation in the Everglades using the methods outlined above for McCormick and Welch; but, Rutchey and Vilchek also focused on comparing the accuracy of air photo interpretation (using 1:24,000 scale color IR) to the accuracy of satellite imagery mapping techniques using SPOT imagery. Their overall accuracies were 95.2% for the air photointerpreted map and 83.4% for the SPOT classified image.

This project seeks to combine and expand on the work from the above projects. Hill (unknown), Nilson et al. (1999), Slocumb (1996), McCormick (1999), and Welch et al. (1999) all mapped the vegetation with a high degree of accuracy but did not produce an orthorectified mosaiced image to be used as a backdrop. Wells and Blackwell (1999) created a rectified image but it was not orthorectified and vegetation was not delineated on the photos. I will create a large-scale orthorectified color infrared basemap mosaic that will be used to delineate vegetation polygons. The vegetation data will be used by Petersburg National Battlefield to create an inventory of the vegetation within the park. The orthorectified basemap will permit Petersburg to use it as a high quality large-scale backdrop for any future GIS work within the park and the mosaic can be used for delineation of other park data as well. Ultimately the park will use the mosaic and the vegetation information to restore Petersburg National Battlefield to its Civil War era state.

Study Area

The Main unit at Petersburg National Battlefield was acquired by the NPS in 1926. It is adjacent to the city of Petersburg, Virginia and consists of 584 hectares (1440 acres). It preserves batteries and fortifications associated with the 10-month siege of the city towards the end of the Civil War. The vegetation map produced in this study will be used by Petersburg National Battlefield to produce an accurate inventory of cover types contained within the park. These data will be used to restore the vegetation and land cover to its historic state at the time of the Civil War battles fought in the area. This will allow the park personnel to recreate accurate views and scenes reminiscent of what the soldiers experienced in that era. The vegetation information will also allow park personnel to micro-manage areas based on the particular needs and attributes of each forest stand. For example, storm damage can be marked for cleanup in one area while the stand directly next to it may be marked for thinning or a reduction of fire loads. This micro-management strategy will allow park personnel to prescribe action plans with much better accuracy and efficiency and will allow for better and more cost efficient management of the park.

Objectives

There were two main objectives of this project:

1) develop a mostly digital method for vegetation classification meeting national map accuracy standards;
2) accurately classify the vegetation at Petersburg National Battlefield to the Formation level of The Nature Conservancy's National Vegetation Classification.

Methodology

Data Preparation

The first step in this process was to acquire the data needed for orthorectification and to ensure that all data were in acceptable digital formats. This methodology requires Digital Orthophoto Quarter Quadrangles (DOQQ) and Digital Elevation Models (DEM) as reference data for orthorectification. DOQQ's are small-scale (1:40,000) orthorectified images produced by the USGS. An orthorectified image has been corrected for scale variation and displacement caused by relief and camera optics. This allows for the direct measurement of distance, areas, angles, and positions. DEMs are also produced by the USGS and are arrays of elevations for ground positions at 30-meter horizontal intervals.

Richard Easterbrook of Petersburg National Battlefield provided black and white DOQQ's in "bsq" format. He also provided DEMs and a boundary coverage of the park in Arc Interchange format (.e00). All the data were received in Universal Transverse Mercator (UTM) Zone 18, N A D 1983, meters. I imported the DEMs into ESRI's ArcGrid program into a grid format using the import command from Arc. The park lies on a boundary of two DEMs, which I merged within ArcGrid. ArcGrid was then used to clip the DEMs to a rectangular box enclosing the park boundary. In an effort to more closely match the ground resolution of the scanned photographs, I resampled the 30-meter DEMs to 10 meters. Appendix 3 lists the actual Arc command lines. The DEMs and the DOQQ's were imported into Imagine file format (.img).

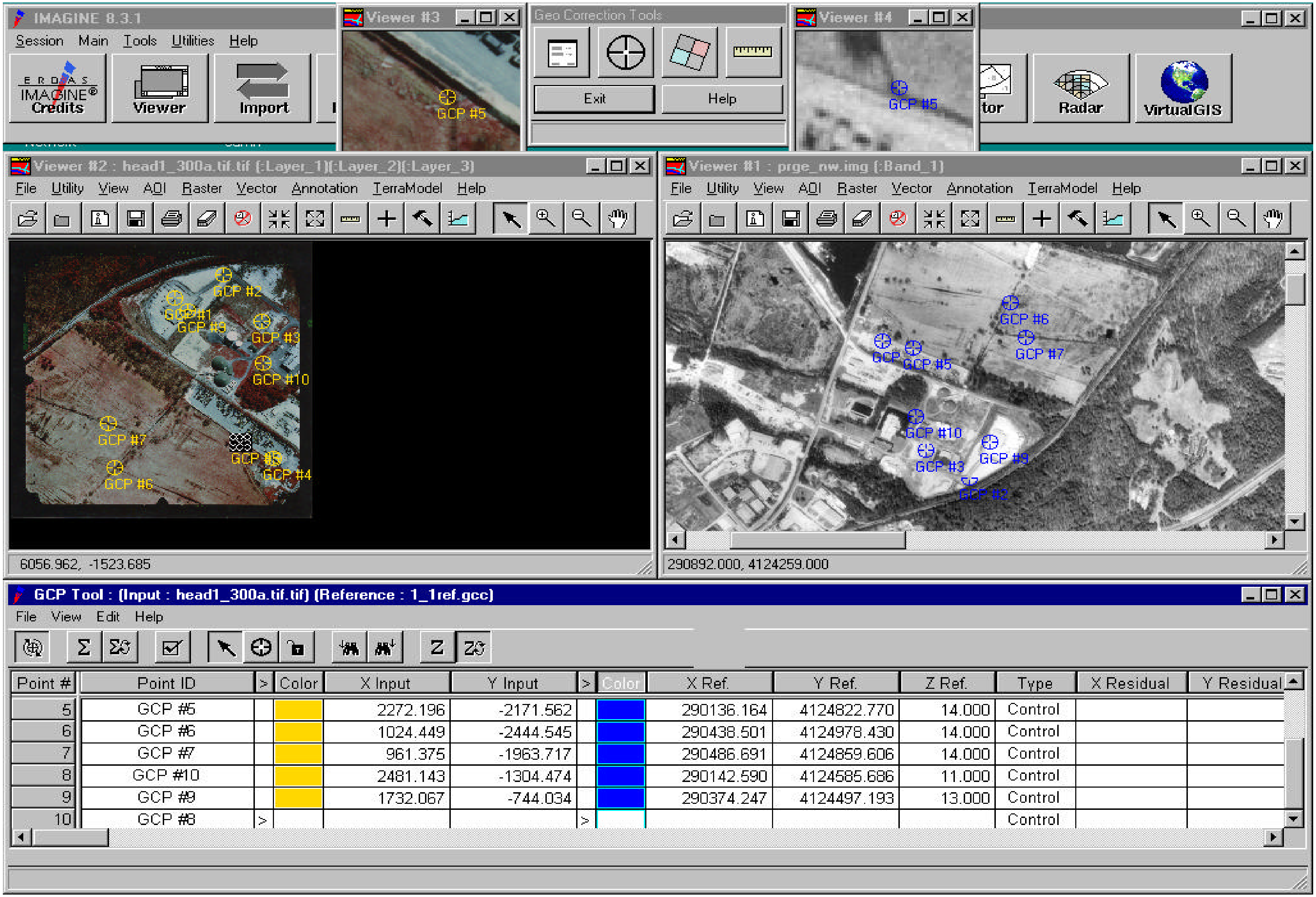
With help from Li Gao I scanned all 75 color infra-red aerial photos in 36-bit color at 600 dpi using Adobe Photoshop. I cropped them to remove as much of the border as possible while preserving the fiducials. The files were saved in Tagged-Image File Format (TIFF) that I imported into Erdas Imagine.

Orthorectification

Orthorectification using Erdas Imagine follows a basic process of using points in a reference data set and then finding those same points in the photo to be rectified (target photo). Erdas Imagine then pulls the coordinates from the reference data and ties them to the points defined to be the same in the target photo. The DOQQ's were used to extract reference points. Imagine can also use the horizontal position from the reference DOQQ's to extract an elevation value from another source, in this case the DEM. To increase the accuracy of the rectification, Imagine also needs information from the camera calibration certificate of the aerial photo flight mission. This information is used to create a Camera Model file that contains information about the optical characteristics of the camera used in taking the aerial photos, such as focal length and fiducial information.

At this point, I selected ground control points from the DOQQ and from each target photo. Erdas Imagine displays the reference DOQQ in one viewer window with the target photo in another window (Figure 2). At least six reference points were marked on the DOQQ for each target photo. The same six points for each target photo were recorded as well. I adjusted the ground control points until an acceptable RMS error of less than 1 meter was achieved. I resampled each photograph to create an orthorectified image. The orthorectification process took one to two hours per photo to complete. All 75 photos were othorectified.

Figure 2. Choosing reference points within Imagine from a DOQQ



Creating a Mosaic

Once all the target photos were orthorectified they could be mosaiced into one large image to cover the entire Main Unit of Petersburg National Battlefield. An area of interest (aoi) layer was created for each target photograph using the Imagine aoi polygon tool. The active area is the area on an image that is only contained within that image and does not contain any endlap or sidelap from the other aerial photos. The aoi layer essentially tells Imagine which part of the photograph to use when joining all the photographs together into one image.

Depending on the quality of each photograph, the aoi was adjusted to remove problem areas from certain photos. For example, if one photo had a dark area, the aoi tool was used to cut that area out and the aoi for the adjacent photo was adjusted to include the area removed from the previous photo. The goal was to use the aoi's to create a continuous coverage of all the aerial photos with as little overlap as possible. The aoi had to be individually created for each image since they have different sizes and shapes and some photographs were higher quality than others. The aoi's were created to have minimal amounts of endlap and sidelap to create a seamless mosaic. Imagine has different ways to handle the overlap areas but I chose the "feather" option, which linearly interpolates the pixels in the overlapping areas. The other options are overlay, average, minimum, and maximum. I tested all the options and selected the feather option because it yielded a better-looking mosaic with less contrast between adjacent photographs.

I entered the images and their corresponding aoi's into Imagine's mosaic image list under the Data Prep icon. The "no cutline" and "feather" options were selected under the function icon. The "no cutline" option was chosen because each image had its own aoi layer created for the active area. I selected "union of all inputs" for the output image and the statistics were set to ignore zero under the Run Mosaic menu. The process ran for about 2 hours and produced a mosaiced output image of all the input aerial photos.

Because sufficient reference coordinates could not be obtained in some photographs of the Petersburg Main Unit, they were not orthorectified. Instead, the aoi layers of the surrounding photos were increased to provide full coverage without any gaps. This resulted in some areas of the mosaic having more tree lean than other areas. This is due to a property of aerial photos called radial displacement. Radial displacement radiates outward from the center of an aerial photo and is much worse at the edges of the photo than closer to the middle. Even though the photographs have been corrected for the radial displacement, trees still seem to lean outward at the edges of the photographs; therefore, in the cases where a larger aoi is used more of that lean can be seen in the mosaic. This is not readily noticeable in the mosaic except upon close inspection and it was better to create a seamless mosaic without any gaps than to not use the larger aoi's.

Vegetation Delineation

The next step was to delineate the vegetation polygons in ArcMap. I added the orthorectified mosaic to ArcMap and the vegetation polygons were digitized directly onscreen with the original stereo pairs used for reference. The first problem working with the orthorectified mosaic was the file size. The orthorectified image file was over 1.6 gigabytes in size causing very slow screen redraws in ArcMap. Mr. SID (Multiresolution Seamless Image Database) from Lizardtech Inc. was used to compress the image file and to test image quality of a compressed Mr. SID image. Mr. SID does not read Imagine files directly so the mosaiced .img file was first exported to a geotiff. I created a worldfile for the geotiff and then Mr. SID was able to compress the image. Mr. SID was set to 20:1 compression with 6 zoom levels. The resulting compressed image was only about 50 megabytes as compared to the original 1.6 GB for the Imagine .img and the geotiff files. The quality of the Mr. SID image was quite good considering the amount of compression (Figure 3 shows a detailed portion of the Mr. SID image). The overall process of creating a Mr. SID file from an Imagine file took less than 1 hour which was easily made up by the faster screen redraws of the 50 MB file versus the 1.6 GB Imagine file.

Figure 3. Detail of a Mr. SID Image

The Mr. SID image was added to ArcMap instead of the original Imagine file. I initially drew the differing vegetation polygons as arcs. I did not classify the polygons at this point. They were differentiated onscreen using the seven basic traits for differentiation; tone, texture, pattern, shape, shadow, size, and association with surrounding objects (Avery, 1992). Polygon topology was later added to the arcs using ArcInfo and the build command. ArcMap and ArcEdit were both used to clean up slivers, dangles and other editing artifacts. The polygons were cleaned, built and reedited until no errors remained.

I classified the polygons to The Nature Conservancy's National Vegetation Classification System Formation level using a list of possible formations occurring in the Petersburg, Virginia area. I worked with PETE GIS Specialist Richard Easterbrook to create the list from The Nature Conservancy's Terrestrial Vegetation of the Southeastern United States (Weakley et.al, 1998).

I created metadata for each of the three datasets: the Erdas Imagine image, the Mr. SID image, and the vegetation coverage (Appendices 11-13). The metadata follow the FGDC guidelines (FGDC, 1995).

Accuracy Assessment

I performed an accuracy assessment for both thematic and positional accuracies based on guidelines outlined by the USGS-NPS program. These specify a stratified random sample based on abundance of different classes that takes into account the number of polygons of each class as well as total area of each class (Appendix 4). Following these guidelines, a total of 159 of 228 polygons needed to be sampled in the field. The centroid of each polygon was visited in order to reduce the chances of a point falling on or near a boundary. Boundary areas are “fuzzy” or “blurred” areas resulting from intermixing of different species types. Styron (1991) showed that the probability of correctly classifying a vegetation point decreases the closer that point is located to a boundary. The USGS-NPS guidelines specify a study area of a 50-meter radius be used based on an mmu of 0.5 hectare. The mmu for this project was reduced to .2 hectare so the radius for the study area was proportionately decreased to 20 meters. This helped to minimize polygon boundary problems as well as ecotonal zone effects. Once it was determined how many of each class needed to be sampled in the field then the NPS-akso ArcView extension (available from the Alaska Region and Support Office of the National Park Service) was used to randomly select which polygons would be visited. For example, if there were ten total polygons of cultivated pine and the guidelines called for five of them to be sampled then the NPS akso extension was used to randomly select the five to be visited for that class.

A Trimble Pro XR GPS unit with real time correction was used to navigate to sample points in the field. Once the correct location was reached for each polygon, the accuracy form for the USGS-NPS Vegetation Mapping Program was completed (Appendix 5). Data collected at each site included elevation, canopy closure, topographic description, aspect, major species present by strata, as well as vegetation formation. Data was collected in a 20-meter radius around each centroid. The USGS – NPS guidelines state a sample radius of 50 meters for use with an mmu of 0.5 hectare. But since the mmu was decreased to 0.2 hectare then the sample radius was decreased proportionally to 20 meters.

Positional accuracy was determined by choosing readily identifiable points on the rectified image. The points were then located in the field and a positional fix was taken for three minutes with a Trimble Pro XR GPS unit using real time correction. Real time correction uses a radio signal to correct for selective availability and other errors inherent in GPS. The radio signal can sometimes be lost so the data were checked within Trimble's Pathfinder software to make sure all the points had been corrected.

ESRI's Arcview program was then used to identify the coordinates for each point from the orthorectified image. The coordinates found in the field (reference) were then compared to the photo coordinates from ArcView. Appendix 6 shows the forty-two positional accuracy points spread through all quadrants of the orthorectified image. The difference between each reference coordinate and photo coordinate was noted. JMP, a statistical analysis package from SAS, was then used to check for outliers. JMP identified four possible outliers. I analyzed the outliers for any possible causes of the error other than bad GPS points. Inaccurate GPS points can be attributed to various factors such as satellite position or multipath errors due to items in the area such as fences or other metal objects. No other causes of error were found and the outliers were removed leaving a total of 38 points sampled for positional accuracy.

Results

Overall 228 polygons were delineated using 20 classifications: 13 formations from the Nature Conservancy's system and seven classes from the Mitchell classification (Table 2). "Count" is the number of polygons per class and class desciptions are shown in Appendix 2. Figure 4 shows the final mosaiced orthorectified image created in Imagine and displayed in ArcView. Figure 5 shows the vegetation map delineated in ArcMap using the orthorectified mosaic as a backdrop. Developed open land has the largest area of any of the classes but had a relatively low number of polygons. Mixed needle-leaved evergreen - cold deciduous forest (I.C.3.N.a) was the predominant formation in both numbers of polygons and area.

Table 2. Results of Photo Classification, By Class

Vegetation Class	Count	Acres	Hectares
I.A.8.C.x	17	99.19	40.14
I.A.8.N.b	45	376.56	152.39
I.B.2.N.a	35	439.35	177.80
I.B.2.N.d	2	16.90	6.84
I.C.3.N.a	65	513.65	207.87
I.C.3.N.b	3	12.36	5.00
I.C.3.N.d	1	2.76	1.12
II.A.4.N.a	5	15.90	6.43
II.B.2.N.a	2	23.82	9.64
II.C.3.N.a	2	4.95	2.00
III.A.2.N.a	3	18.94	7.67
V.A.5.N.e	14	144.19	58.35
Ag and Cultivated 2	3	83.17	33.66
developed coniferous 1.1.2	1	8.13	3.29
developed deciduous 1.1.1	1	7.27	2.94
developed mixed 1.1.3	5	40.51	16.40
developed open land 1.2	22	554.20	224.28
recreational facilities 1.3	1	2.49	1.01
transitional land 5.3	1	6.11	2.47
Sum	228	2370.43	959.30

Figure 4. Mosaiced Image of the Main Unit at Petersburg National Battlefield

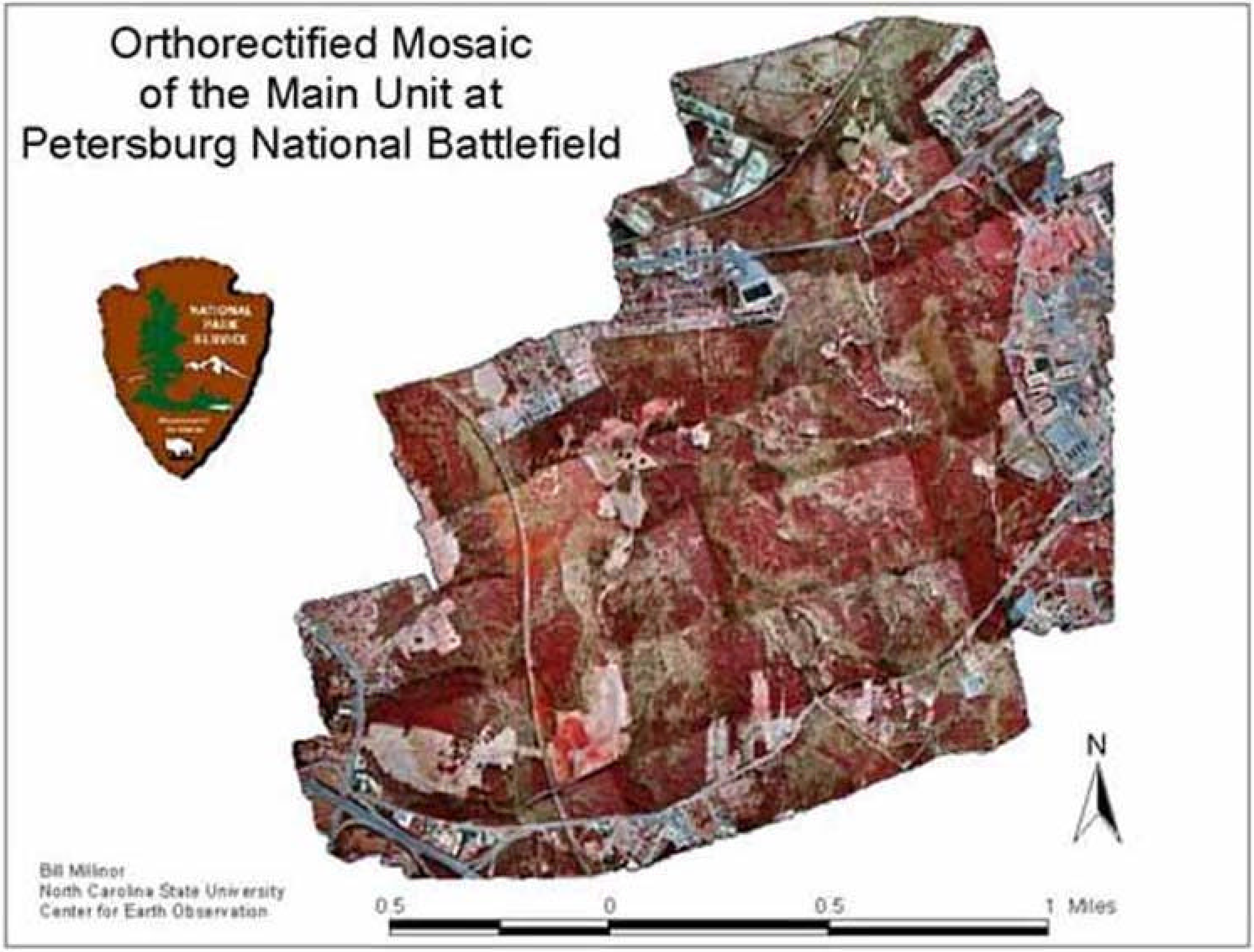
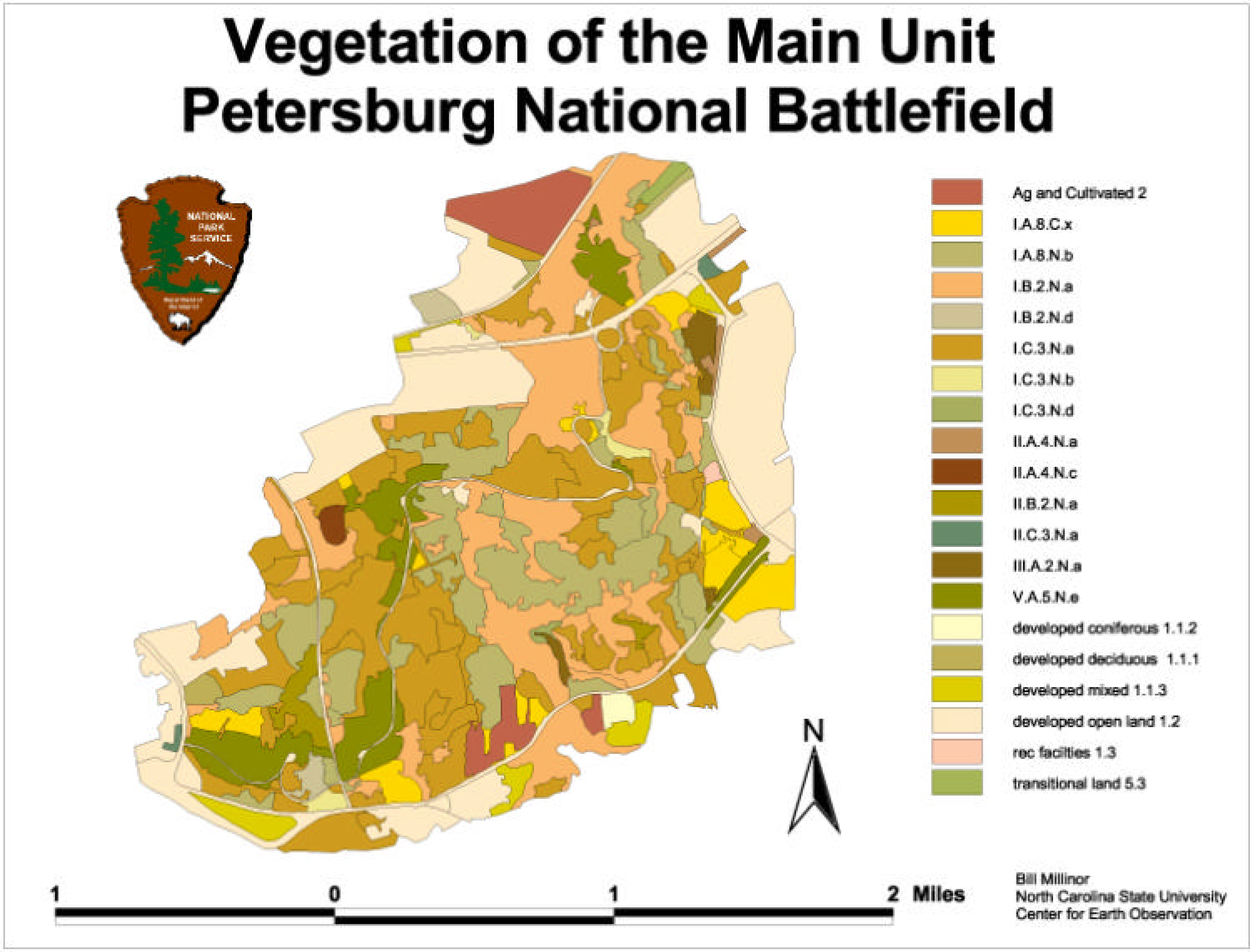


Figure 5. Vegetation of the Main Unit at Petersburg National Battlefield



An error matrix for the vegetation delineation was generated to show which classes contributed the most to errors in the vegetation mapping process (Table 3). The diagonal cells of the error matrix are the numbers of sites correctly classified in the image. The sum of the non-diagonal cells in a column indicates the omission error; the number of sites not identified as being in a certain class. The sum of the non-diagonal row cells indicates the commission error, the number of sites identified as being in a certain class when they belonged to a different class. There are actually 21 vegetation classes present in the error matrix. The saturated cold deciduous forest class (I.B.2.N.g) was incorrectly identified three times. It is included in the error matrix but was never correctly identified and is therefore not included in the final vegetation map.

Table 4 shows Producer's and User's Accuracy for each vegetation class. Producer's accuracy is the probability that an area that is in a certain class has been correctly identified as being in that class. User's accuracy is the probability that an area that has been identified as a certain class actually is that class. The User's and Producer's accuracy's were very high. Only nine of these percentages were below 80%, which is what the USGS-NPS guidelines require for overall thematic accuracy. The lower accuracies were due to problems with delineating correct moisture regimes from the aerial photos or were due to the small sample sizes of those particular classes. Overall 139 out of 159 sampled polygons were correct to yield a total accuracy of 87.42%. The Kappa statistic was .8545 and was computed according to Jensen (1996). This coefficient measures the probability that this classification is more accurate than a random classification. Values close to zero are no better than a random classification and values close to one are much better than a random classification.

Table 3. Final Error Matrix

						Reference																			
	Class Name					Totals																		Total	Total
		#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	21	23	IC	CE
	Agriculture and Cultivated 2	1	2				1																	3	1
	developed coniferous 1.1.2	2		1																				1	0
	developed deciduous 1.1.1	3			1																			1	0
	developed mixed 1.1.3	4				4	1																	5	1
	developed open land 1.2	5					21																	21	0
	recreational facilities 1.3	6						1																1	0
	transitional land 5.3	7							1															1	0
	I.A.8.C.x	8								13														13	0
	I.A.8.N.b	9								3	34	1												38	4
	I.B.2.N.a	10										25		1										26	1
Classification	I.B.2.N.d	11										1	0	1										2	2
Totals	I.B.2.N.g	12												0										0	0
	I.C.3.N.a	13					1					1			16				2					20	4
	I.C.3.N.b	14										2		1		0								3	3
	I.C.3.N.d	15															1							1	0
	II.A.4.N.a	16									1							3						4	1
	II.B.2.N.a	17																	2					2	0
	II.C.3.N.a	18										1								1				2	1
	II.C.3.N.c	19																			0			0	0
	III.A.2.N.a	20																			1	0		1	1
	V.A.5.N.e	23					1																13	14	1
	Total GT		2	1	1	4	25	1	1	16	35	31	0	3	16	0	1	3	4	1	1	0	13	159	
	Total OE		0	0	0	0	4	0	0	3	1	6	0	3	0	0	0	0	2	0	1	0	0		

Table 4. User’s and Producer’s Accuracy

	Accuracy Totals				
	reference totals	classified totals	number correct	Producer's Accuracy	User's Accuracy
Agriculture and Cultivated 2	2	3	2	100.00%	66.67%
developed coniferous 1.1.2	1	1	1	100.00%	100.00%
developed deciduous 1.1.1	1	1	1	100.00%	100.00%
developed mixed 1.1.3	4	5	4	100.00%	80.00%
developed open land 1.2	25	21	21	84.00%	100.00%
recreational facilities 1.3	1	1	1	100.00%	100.00%
transitional land 5.3	1	1	1	100.00%	100.00%
I.A.8.C.x	16	13	13	81.25%	100.00%
I.A.8.N.b	35	38	34	97.14%	89.47%
I.B.2.N.a	31	26	25	80.65%	96.15%
I.B.2.N.d	0	2	0	100.00%	0.00%
I.B.2.N.g	3	0	0	0.00%	100.00%
I.C.3.N.a	16	20	16	100.00%	80.00%
I.C.3.N.b	0	3	0	100.00%	0.00%
I.C.3.N.d	1	1	1	100.00%	100.00%
II.A.4.N.a	3	4	3	100.00%	75.00%
II.B.2.N.a	4	2	2	50.00%	100.00%
II.C.3.N.a	1	2	1	100.00%	50.00%
II.C.3.N.c	1	0	0	0.00%	100.00%
III.A.2.N.a	0	1	0	100.00%	0.00%
V.A.5.N.e	13	14	13	100.00%	92.86%
Totals	159	159	139		
Overall Accuracy	139/159=87.42%				

Positional accuracy is reported as a standard error in each coordinate direction; it is a measure of variability that includes the effects of both bias and random error. It is computed as follows (Merchant 1985):

$$RMSE_x = \left[\frac{1}{N}\sum_{i=1}^{n}(\delta X_i - \delta X_c)^2\right]^{1/2}$$

where $RMSE_x$ is the standard error in the x-coordinate direction, N is the sample size, dX_i is the actual (measured) coordinate location, and dX_c is the true coordinate location as determined in the source of higher accuracy. Positional accuracy was very good with a RMSE of 1.62 meters in the x direction and 2.81 meters in the y direction. According to National Map Accuracy Standards this places the maps at Class 3 level (ASPRS, 1989) for the planimetric x accuracy but the planimetric y accuracy is less than Class 3 standards. Class 1 at 1:3000 scale requires a RMSE of .75 meters or less and Class 2 requires a RMSE of 1.5 meters or less. Appendix 7 shows the spreadsheet totals and derivations used to attain these figures. The accuracy can also be described another way using Euclidean geometry ($(A^2 + B^2)^{1/2} = C$). Using the average of the squared differences between the reference coordinates and the field coordinates and using the formula for Euclidean distance yielded an error of 3.06 meters.

Discussion

The methodology described here allowed me to create an orthorectified mosaic and a vegetation database more quickly than I could have using traditional methods. The final products were just as accurate as those produced using traditional methods.

Postional accuracy was very good at 1.62 meters in the x direction and 2.81 meters in the y direction. I found that most of the positional error in the mosaic was derived error that was also present in the reference DOQQ's. This is to be expected, because the DOQQ was the reference for the orthorectification process. However, the DEM cannot be discounted as a large source of error as well. The DEM was originally used to create the DOQQ. So, any error present in the DEM was also transferred to the DOQQ. The elevation value is very important in the orthorectification process and any error in the elevation values can greatly affect the finished product.

The positional accuracy could be greatly enhanced by using a higher quality reference such as ground control points taken throughout the park with a real time global positioning system (gps) unit. The points would have to be identifiable on the aerial photographs. These points could then be used as the control points to rectify the images. The Trimble Pro XR gps unit used in this project is rated to 1-meter accuracy using real time correction. This gps receiver has the ability to use carrier phase processing which increases the accuracy to less than 1 foot and would be ideal for taking control points for orthorectification. If performed correctly with more accurate ground control points and a higher quality DEM, the positional accuracy could be increased to at least Class 2 (1.5 meters) and maybe even Class 1 (0.75 meters) according to National Map Accuracy Standards.

Thematic accuracy was good at 87%. This compares favorably with results obtained using other methods such as a ZTS (thematic accuracy of anywhere from 46 to 88%) or Welch's method of using a ZTS and scanned line work (thematic accuracy of 83.4 to 95.2%) that were presented in the literature review.

Several adjustments were made to the original error matrix. Initially 21 polygons were corrected for photo age. Since the photos were 8 years old this caused some inconsistencies with what was seen in the field. This was especially noticeable in some of the woodland classes. The canopy of these areas increased to more than 60% in the 8 years since the photos were taken so are now classed as forests. Another issue caused by the age of the photographs was polygons that were initially classed one way that were later changed due to storm damage found in the field. For example, an area may have been called mixed forest, but when it was checked in the field there was obvious storm damage and the area's density had been decreased to a woodland class. All these polygons were changed accordingly in the error matrix and are shown in Appendix 8.

Additionally, 8 polygons were classified as mixed needle-leaved evergreen – cold deciduous forest (I.C.3.N.a) when they should have been classified as rounded crowned temperate or subpolar needle-leaved evergreen forest (I.A.8.N.b). The aerial photos were taken in leaf off conditions so the interpreter had to estimate deciduous crown cover. The interpreter overestimated deciduous crown cover and this caused areas that should have been classified as evergreen forests to be classified as mixed forests. These polygons were corrected in the final error matrix as well (Appendix 9) to leave 20 polygons that were misattributed.

Of the 20 polygons incorrectly identified, 6 were due to errors in classifying the moisture regime making moisture regime the largest contributing factor for incorrectly attributed polygons. The temporarily flooded and saturated areas are very hard to see in aerial photos. In fact, the areas found in the field to be saturated, or semi permanently flooded may not be correct. The only way to guarantee their accuracy is to check in the field at different times of the year as seasonal effects on water regimes vary greatly throughout the different seasons.

The other 14 mistakes were due to misinterpretation; 4 were physiognomic class errors (woodland vs forest), 3 were physiognomic subclass errors (deciduous vs evergreen), 3 more were physiognomic subgroup errors (natural vs planted). One polygon was misclassified due to the point falling within a pocket of storm damage within the polygon; another was due to similar classifications within the 2 classification systems. Mitchell's developed open land class is very similar to TNC's short sod temperate or subpolar grassland formation. This left one polygon that was grossly misclassified by the interpreter. Appendix 10 lists the number of polygons incorrectly identified for each reason.

The methodology presented here represents a large estimated savings in man-hours. Cheshire estimated that a project of this size performed using a zts would have taken 675 hours versus approximately 200 hours using this new method. The creation of this methodology required more than one year of research; much of which was spent in learning the software and upgrading the computer equipment. Computational and storage issues were a problem in the beginning with such large file sizes. Overall this project generated large quantities of data including all the original scanned TIFF images, all the converted Imagine images, and then all the orthorectified Imagine images that were used to create the 1.6 GB orthorectified mosaic. Each of the 75 aerial photographs was stored in three different formats throughout the process (each one was about 85 MB in each format), but with hard drives and computer equipment rapidly decreasing in price, storage issues were quickly dealt with using large hard drives or rewriteable compact disks. This process can now be learned and applied in only a few weeks and has already been applied in two other research areas yielding similar positive results. Once this process becomes more widely used the accuracy will likely increase. The use of a zts requires tracing the polygons and other delineated line work three times whereas this method requires only one. Not only is the workload decreased but the potential for human error in retracing is decreased as well.

The orthorectified mosaic and the vegetation map overlay very well with existing GIS data owned by Petersburg National Battlefield. This provides Petersburg National Battlefield with an inventory of their cover types and allows for better overall park management. The mosaiced image can be used as a backdrop for all future GIS work in the park similar to what black and white DOQQ's have been used for in the past. DOQQ's have long been used for control in various GPS projects. But a DOQQ only has a 30-meter pixel resolution, while the orthorectified mosaic has a pixel resolution of less than 1 meter. This will allow much greater detail work and therefore much greater accuracy and precision management strategies not to mention that the orthorectified basemap produced with this methodology is a color IR image as opposed to a black and white DOQQ. For example, PETE could use the vegetation data to manage for fire fuel loads on a per polygon basis. This would be much more effective than a broader system in that only the areas that really needed to be thinned or cleaned up could be handled instead of performing the same techniques on a larger area that didn't really need it.

Conclusions and Recommendations

This project produced a color infrared orthorectified basemap with a planimetric x accuracy of 1.62 meters and a planimetric y accuracy of 2.81 meters. At a scale of 1:3000 this corresponds to a Class 3 map in the planimetric x direction and close to a Class 3 in the planimetric y according to National Map Accuracy Standards. The positional accuracy could be greatly enhanced by using a higher quality reference such as ground control points taken throughout the park with a real time global positioning system (gps) unit at points that can be identified on the aerial photographs.

The vegetation database was created yielding a thematic accuracy of 87.42% with a Kappa of .8545, well within the standards of the USGS – NPS Vegetation Mapping Project. The methodology presented here represents a large estimated savings in man-hours of more than 200% for this project while achieving accuracy figures comparable to those using more traditional methods.

For a project like this to be repeated, up-to-date aerial photography is essential. If orthorectification of the photos is a goal, some steps can be taken to simplify the orthorectification process. The longest step was in finding suitably accurate ground control points from the black and white DOQQ's. The better method would be for control point markers to be laid on the ground while the plane flies the mission. This would allow for easy location of ground control points on the photos for rectification and the markers could then be positionally located with a high degree of accuracy. This would significantly enhance the accuracy of the final orthorectified mosaic and would speed up the process considerably. Future researchers could also return to the sampled polygons throughout the year to check the validity of their classifications. This should include visits to all the polygons and not just the ones classed in the water regimes since some of the dry areas could be wet at other times of the year thus changing their classifications as well.

Another option would be to fly the mission with a plane capable of airborne GPS while using an Inertial Measurement Unit (IMU) system. This process costs about twice as much to fly but it yields an overall cost savings for an orthorectification project. The airborne GPS can greatly reduce the number of control points needed for a project, which would in turn reduce the amount of post processing time needed. The IMU provides the exact orientation of the camera as the photographs are taken, eliminating the need for aerotriangulation.

As was used in this project color infrared photographs on leaf off conditions is recommended. Color infrared and leaf off properties helped substantially in the differentiation between deciduous and evergreen species as well as in locating ground control points for orthorectification.

Future research should compare this methodology to techniques that allow onscreen stereo viewing while digitizing using a fully digital methodology as well as to the old method of using a zoom transfer scope. Previous research has shown that stereoscopic planimetric extraction is more accurate than monoscopic methods, at least using remotely sensed data (Toutin, 1997). It would be worthwhile to see if that held true for vegetation delineation on small-scale aerial photographs. The software available for onscreen stereo viewing and digitizing in the past required long setup times before the images could be viewed onscreen. However, Erdas' Stereo Analyst and OrthoBase show promise in reducing the setup time and delivering better resolution stereo viewing.

Orthobase helps in automating the aerotriangulation step by automatically generating tie points, and it greatly decreases the amount of time required to set up a block file. But, until these new packages are out and working well, I believe the methodology I used represents a substantive improvement over current monoscopic methods.

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Appendices

Appendix 1. Anderson Land Cover / Land Use Codes

Level 1	Level 2
1 Urban or built-up land	
	11 Residental
	12 Commercial and services
	13 Industrial
	14 Transportation, communication, utilities
	15 Industrial and commercial complexes
	16 Mixed urban or built-up land
	17 Other urban or built-up land
2 Agricultural land	
	21 Cropland and pasture
	22 Orchards, groves, vineyards, nurseries, and ornamental horticultural
	23 Confined feeeding operations
	24 Other agricultural land
3 Rangeland	
	31 Herbaceous rangeland
	32 Shrub and brush rangeland
	33 Mixed rangeland
4 Forest land	
	41 Deciduous forest land
	42 Evergreen forest land
	43 Mixed forest land
5 Water	
	51 Streams and canals
	52 Lakes
	53 Reservoirs
	54 Bays and estuaries
6 Wetland	
	61 Forested wetland
	62 Nonforested wetland
7 Barren land	
	71 Dry salt flats
	72 Beaches
	73 Sandy areas not beaches
	74 Bare exposed rock
	75 Strip mines, quarries, gravel pits
	76 Transitional areas
8 Tundra	
	81 Shrub and brush tundra
	82 Herbaceous tundra
	83 Bare ground

84 Wet tundra
85 Mixed tundra

9 Perennial snow or ice

91 Perennial snowfields
92 Glaciers

Appendix 2. National Vegetation Classification System and Mitchell Classification System Descriptions

Vegetation Class	Description
I.A.8.C.x	Planted/Cultivated temperate or subpolar needle-leaved evergreen forest
I.A.8.N.b	Rounded-crowned temperate or subpolar needle-leaved evergreen forest
I.B.2.N.a	Lowland or submontane cold-deciduous forest
I.B.2.N.d	Temporarily flooded cold-deciduous forest
I.C.3.N.a	Mixed needle-leaved evergreen - cold deciduous forest
I.C.3.N.b	Temporarily flooded mixed needle-leaved evergreen - cold deciduous forest
I.C.3.N.d	Saturated mixed needle-leaved evergreen - cold deciduous forest
II.A.4.N.a	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland
II.B.2.N.a	Cold-deciduous woodland
II.C.3.N.a	Mixed needle-leaved evergreen - cold deciduous woodland
III.A.2.N.a	Temperate broad-leaved evergreen shrubland
V.A.5.N.e	Short sod temperate or subpolar grassland
Ag and Cultivated 2	Distinguishable agricultural areas
Developed Coniferous 1.1.2	Area with sign of human habitation and more than 80% basal area in *Pinus* spp.
Developed Deciduous 1.1.1	Area with sign of human habitation and less than 20% basal area in *Pinus* spp
Developed Mixed 1.1.3	Area with sign of human habitation and 21% to 79% basal area in *Pinus* spp
Developed Open Land 1.2	Area with sign of human habitation and less than 10% canopy closure
Recreational Facilities 1.3	Area with sign of human habitation and identifiable recreation areas i.e. playing fields
Transitional Land 5.3	Area undergoing development or construction

Appendix 3. Arc commands

The text in red is the actual arc command lines.

Import DEM's: IMPORT grid interchange_file output

Merge DEM's: outgrid = merge(ingrid1, ingrid2)

Clip DEM'S: GRIDCLIP ingrid newgrid COVER clipcover

Resample DEM's from 30 meters to 10meters:

outputgrid = resample (inputgrid, 10, cubic)

Appendix 4. Sampling Stratification Guidelines

Scenario A: The class is abundant. It covers more than 50 hectares of the total area and consists of at least 30 polygons. In this case, the recommended sample size is 30.

Scenario B: The class is relatively abundant. It covers more than 50 hectares of the total area but consists of fewer than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size for this type of class is that sample sites are more difficult to find because of the lower frequency of the class.

Scenario C: The class is relatively rare. It covers less than 50 hectares of the total area but consists of more than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size is that the class occupies a small area. At the same time, however, the class consists of a considerable number of distinct polygons that are possibly widely distributed. The number of samples therefore remains relatively high because of the high frequency of the class.

Scenario D: The class is rare. It has more than 5 but fewer than 30 polygons and covers less than 50 hectares of the area. In this case, the recommended number of samples is 5. The rationale for reducing the sample size is that the class consists of small polygons and the frequency of the polygons is low. Specifying more than 5 sample sites will therefore probably result in multiple sample sites within the same (small) polygon. Collecting 5 sample sites will allow an accuracy estimate to be computed, although it will not be very precise.

Scenario E: The class is very rare. It has fewer than 5 polygons and occupies less than 50_hectares of the total area. In this case, it is recommended that the existence of the class be confirmed by a visit to each sample site. The rationale for the recommendation is that with fewer than 5 sample sites (assuming 1 site per polygon), no estimate of level of confidence can be established for the sample (the existence of the class can only be confirmed through field checking).

Appendix 5. Field Accuracy Assessment Form
USGS-NPS Vegetation Mapping Program

1. Plot Number ______________ 2. Park Code ______________ 3. Date ______________

4. Observer(s) ______________________________ 5. Datum __________ 6. Accuracy __________

7. UTM Coordinates: Easting _ _ _, _ _ _ Northing _, _ _ _, _ _ _

8. UTM Zone __________ 9. Offset from Point: Easting __________ m Northing __________ m

10. Topographic Description ______________________________

11. Elevation ______________ m 12. Aspect ______________

13. Veg Assoc. at Site ______________________________

14. Veg Assoc 2 within 50m of Site ______________________________

15. Veg Assoc 3 within 50m of Site ______________________________

16. Major Species Present (by strata) ______________________________

____

____

17. Canopy Closure of Top Layer ______________

18. Rationale for Classification ______________________________

____

____

____

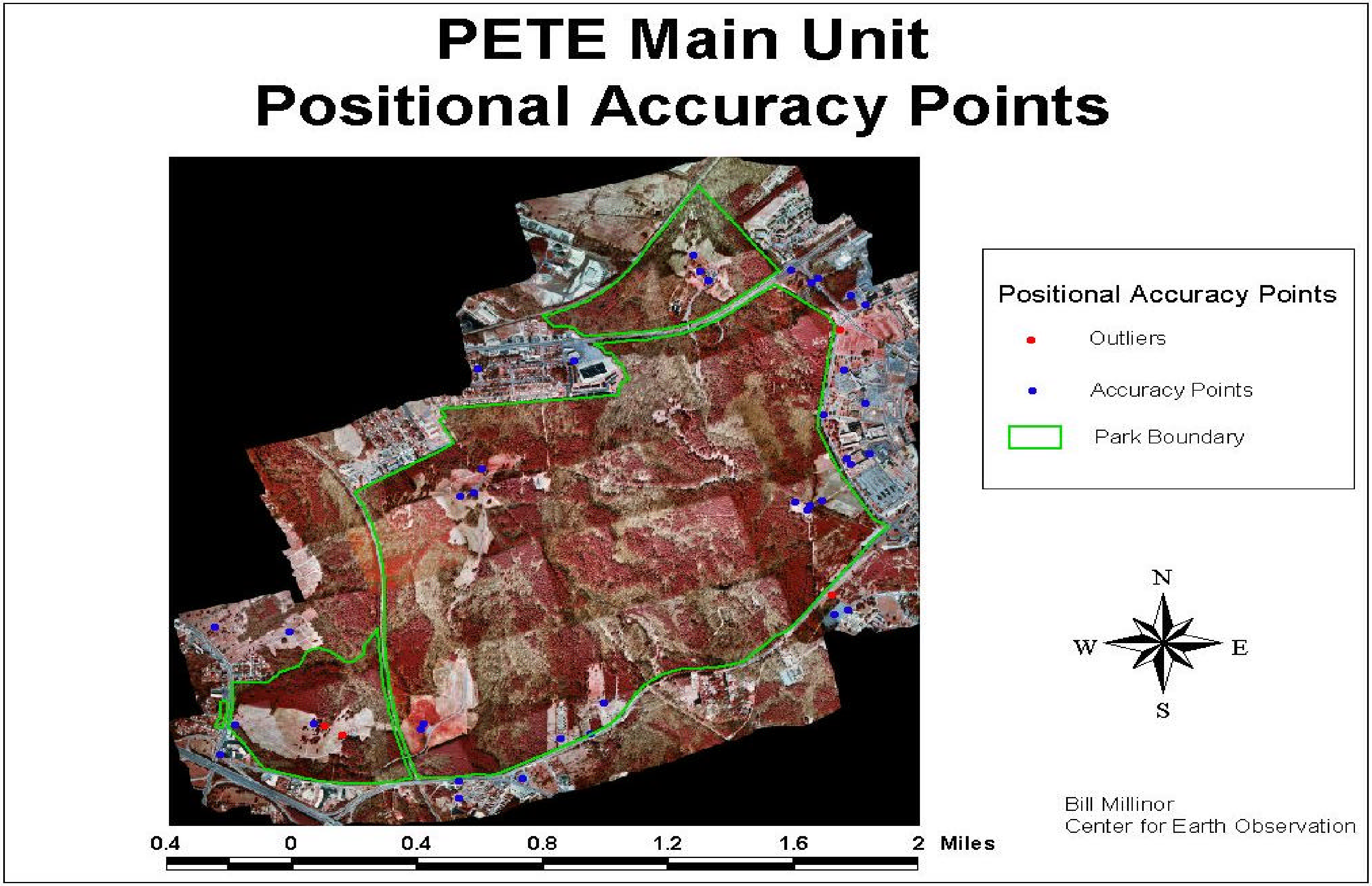
19. Comments ______________________________

____

____

____

Appendix 6. Positional Accuracy Point Distribution



Appendix 7. RMSE for Positional Accuracy Points

Xi - Xc	$(Xi-Xc)^2$	Yi - Yc	$(Yi-Yc)^2$	Euclidean Distances
-1.93	3.72	-0.82	0.68	2.10
-2.00	4.02	-1.07	1.14	2.27
-1.65	2.71	-0.89	0.79	1.87
-0.76	0.57	-2.66	7.09	2.77
-1.65	2.71	-1.60	2.57	2.30
-1.29	1.66	-2.67	7.11	2.96
-1.38	1.90	0.18	0.03	1.39
-0.76	0.58	-4.00	15.97	4.07
-0.48	0.23	-4.80	23.06	4.83
-2.18	4.75	-2.75	7.56	3.51
-0.49	0.24	-1.69	2.85	1.76
-1.11	1.23	-2.57	6.63	2.80
-1.91	3.64	-3.47	12.02	3.96
-0.57	0.33	-2.93	8.58	2.99
-0.94	0.88	-2.31	5.35	2.50
-0.75	0.57	-2.84	8.07	2.94
-1.91	3.66	-2.05	4.19	2.80
-1.11	1.24	-3.64	13.24	3.81
-1.20	1.45	-3.11	9.65	3.33
-2.45	5.99	-4.63	21.39	5.23
0.22	0.05	-3.91	15.29	3.92
-3.24	10.50	-1.77	3.14	3.70
-1.99	3.98	-3.82	14.62	4.31
3.07	9.42	-3.20	10.24	4.43
1.74	3.02	-4.71	22.18	5.02
0.67	0.45	-1.42	2.02	1.57
2.62	6.89	-1.43	2.03	2.99
1.47	2.16	1.52	2.30	2.11
-1.38	1.90	1.15	1.33	1.80
1.11	1.23	-1.60	2.55	1.94
-1.47	2.16	-3.73	13.92	4.01
-1.03	1.05	-0.89	0.80	1.36
-1.11	1.22	-3.82	14.57	3.97
-2.18	4.76	-4.26	18.16	4.79
-2.36	5.55	-0.54	0.29	2.42
-1.20	1.44	-3.20	10.25	3.42
-0.49	0.24	-1.06	1.13	1.17
1.47	2.15	-2.76	7.61	3.12
Sum	100.24		300.40	116.21
N	38		38	38
RMSE	1.6241		2.8116	
				3.06
				Average Euclidean Difference

Appendix 8: Polygons Changed Due to Time Difference in Aerial Photographs

	MYPOLYID	VEGETATION
1	18	I.C.3.N.a
2	19	I.C.3.N.a
3	31	I.A.8.C.x
4	35	I.A.8.C.x
5	57	I.B.2.N.a
6	59	I.B.2.N.a
7	64	I.A.8.C.x
8	65	I.B.2.N.a
9	74	I.A.8.C.x
10	94	I.A.8.C.x
11	105	I.B.2.N.a
12	118	I.A.8.C.x
13	123	I.A.8.C.x
14	131	I.A.C.N.x
15	144	I.B.2.N.a
16	145	I.B.2.N.a
17	156	II.B.2.N.a
18	160	I.C.3.N.d
19	170	II.B.2.N.a
20	188	I.B.2.N.a
21	214	1.2 developed open land

Appendix 9. Polygons Changed Due to Over Estimation of Crown Cover

	MYPOLYID	VEGETATION
1	25	I.A.8.N.b
2	51	I.A.8.N.b
3	72	I.A.8.N.b
4	85	I.A.8.N.b
5	135	I.A.8.N.b
6	151	I.A.8.N.b
7	217	I.A.8.N.b
8	225	I.A.8.N.b

Appendix 10. Reasons for Polygon Disagreements

Reasons for Incorrectly Identified Polygons	Number
Physiognomic Class (woodland vs forest)	4
Physiognomic Subclass (deciduous vs evergreen)	3
Physiognomic Class and Physiognomic Subclass	1
Moisture Regime	6
point location within the polygon	1
Physiognomic Subgroup (natural vs planted)	3
Similar classes between the 2 classification systems	1
wrong id	1
total	20

Appendix 11. Mosaiced Imagine Image Metadata

Identification_Information:
  Citation:
    Citation_Information:
      Originator:
        North Carolina State University, Center for Earth Observation
      Publication_Date: 20000801
      Title: Imagine .img file color infrared image of the Main Unit at Petersburg National Battlefield
      Edition: first
      Geospatial_Data_Presentation_Form: map
  Description:
    Abstract: Orthorectified color infrared Imagine image of the Main Unit at Petersburg National Battlefield. Produced from 75 color infrared photos taken March, 1992 in leaf off conditions.
    Purpose: The dataset was developed for use by Petersburg National Battlefield to allow better resource management.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 199203
        Time_of_Day: 1300
    Currentness_Reference: ground condition
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: Unknown
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -77.386448
      East_Bounding_Coordinate: -77.344182
      North_Bounding_Coordinate: 37.250275
      South_Bounding_Coordinate: 37.212912
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus: none
      Theme_Keyword: Imagine
      Theme_Keyword: Color Infrared
      Theme_Keyword: mosaic
      Theme_Keyword: aerial photo
    Place:
      Place_Keyword_Thesaurus: none
      Place_Keyword: Virginia
      Place_Keyword: National Battlefield

Place_Keyword: National Park
Place_Keyword: Petersburg
Temporal:
Temporal_Keyword_Thesaurus: none
Temporal_Keyword: 1992
Temporal_Keyword: leaf-off
Temporal_Keyword: March
Access_Constraints: none
Use_Constraints: none
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Richard Easterbrook
Contact_Organization: Petersburg National Battlefield
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing address
Address:
Richard Easterbrook
Petersburg National Battlefield
1539 Hickory Hill Rd
City: Petersburg
State_or_Province: Virginia
Postal_Code: 23803
Country: USA
Contact_Voice_Telephone: (804) 732-0171
Contact_Facsimile_Telephone: (804) 862-7943
Contact_Electronic_Mail_Address: Richard _Easterbrook@nps.gov
Data_Set_Credit: Bill Millinor
Native_Data_Set_Environment: Windows NT Version 4.0 (Build 1381) Service Pack 6; ESRI ArcInfo 8.0.345

Data_Quality_Information:
Logical_Consistency_Report: none
Completeness_Report: Petersburg National Battlefield - Main Unit
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Overall positional accuracy of 2.365 meters
1.88 meters in the x direction
2.85 meters in the y direction
Class 3 map accuracy
Horizontal accuracy was found by assessing 41 points in the field spread throughout the orthorectified image area. These points were identified on the basemap and then were found in the field where their coordinates were taken using a Trimble Pro XR

with real time correction. The field coordinates were then
compared to the coordinates from the basemap using ArcView.
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Air Photographics, Inc
Publication_Date: Unpublished Material
Title: Aerial photographs of the Main Unit at Petersburg
National Battlefield
Edition: first
Geospatial_Data_Presentation_Form: remote-sensing image
Source_Scale_Denominator: 3000
Type_of_Source_Media: color ir aerial photographs
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 19920316
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: aerial photos
Source_Contribution: Aerial view of Petersburg National Battlefield
Process_Step:
Process_Description:
The aerial photos (75 total) were used to create an orthorectified mosaic using Erdas Imagine. The photos were scanned at 600 dpi and imported into Imagine. They were then orthorectofied using USGS DOQQ's and USGS DEM's as reference. The DEM'S were resampled from 30 meters to 10 meters. Each photo had at least 6 ground control points with a total RMS of less than 1 meter. The orthorectified images were then mosaiced within Imagine to form one seamless basemap image for the Main Unit at Petersburg National Battlefield.
Process_Date: 200005
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: NCSU, Center for Earth Observation
Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106
City: Raleigh
State_or_Province: NC
Postal_Code: 27695-7106
Country: USA

Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Hours_of_Service: 8:30 am - 5:30 pm
Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Raster
Raster_Object_Information:
Raster_Object_Type: Pixel
Row_Count: 23366
Column_Count: 22221
Vertical_Count: 1

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 18
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -75.000000
Latitude_of_Projection_Origin:
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: row and column
Coordinate_Representation:
Abscissa_Resolution: 0.173425
Ordinate_Resolution: 0.173425
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: Band_1
Attribute:
Attribute_Label: Order_ID
Attribute:
Attribute_Label: Value
Attribute:
Attribute_Label: Count

Detailed_Description:
Entity_Type:
Entity_Type_Label: Band_2
Attribute:
Attribute_Label: Order_ID
Attribute:
Attribute_Label: Value
Attribute:
Attribute_Label: Count
Detailed_Description:
Entity_Type:
Entity_Type_Label: Band_3
Attribute:
Attribute_Label: Order_ID
Attribute:
Attribute_Label: Value
Attribute:
Attribute_Label: Count
Overview_Description:
Entity_and_Attribute_Overview: Dataset consists of a raster 3 band color image.
Entity_and_Attribute_Detail_Citation: none

Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Richard Easterbrook
Contact_Organization: Petersburg National Battlefield
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing address
Address:
Petersburg National Battlefield
1539 Hickory Hill Rd
City: Petersburg
State_or_Province: Virginia
Postal_Code: 23803
Country: USA
Contact_Voice_Telephone: (804) 732-0171
Contact_Facsimile_Telephone: Fax: (804) 862-7943
Contact_Electronic_Mail_Address: Richard _Easterbrook@nps.gov
Resource_Description: Orthorectified 3 band color raster image of the Main Unit at Petersburg National Battlefield.
Distribution_Liability:
The National Park Service shall not be held liable for improper or

incorrect use of the data described and/or contained herein. These data and related graphics ("GIF" format files) are not legal documents and are not intended to be used as such. The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data in particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data. The National Park Service gives no warranty, expressed or implied, as to the accuracy, reliability, or completeness of these data. It is strongly recommended that these data are directly acquired from an NPS server and not indirectly through other sources which may have changed the data in some way. Although these data have been processed successfully on a computer system at the National Park Service, no warranty expressed or implied is made regarding the utility of the data on another system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data.

Custom_Order_Process: Contact
Richard Easterbrook
Petersburg National Battlefield
1539 Hickory Hill Rd
Petersburg, VA 23803
(804) 732-0171
Richard_Easterbrook@nps.gov

Metadata_Reference_Information:
Metadata_Date: 20000725
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Center for Earth Observation
Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106, 5112 Jordan Hall
City: Raleigh
State_or_Province: NC
Postal_Code: 27695-7106
Country: USA
Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Contact_Instructions: phone
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time

Appendix 12. MR SID Mosaic Metadata

Identification_Information:
  Citation:
    Citation_Information:
      Originator:
        North Carolina State University, Center for Earth Observation
      Publication_Date: 20000801
      Title: Compressed Mr SID color infrared image of Petersburg National
          Battlefield - Main Unit
      Edition: first
      Geospatial_Data_Presentation_Form: remote-sensing image
  Description:
    Abstract: Orthorectified color infrared Mr SID image of the Main Unit at
      Petersburg National Battlefield. Produced from 75 color infrared photos taken
      March, 1992 in leaf off conditions.
    Purpose: The dataset was developed for use by Petersburg National Battlefield
      to allow better resource management.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 199203
        Time_of_Day: 1300
    Currentness_Reference: ground condition
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: Unknown
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -77.386448
      East_Bounding_Coordinate: -77.344182
      North_Bounding_Coordinate: 37.250275
      South_Bounding_Coordinate: 37.212912
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus: none
      Theme_Keyword: Imagine
      Theme_Keyword: Color Infrared
      Theme_Keyword: mosaic
      Theme_Keyword: image
      Theme_Keyword: aerial photos
    Place:
      Place_Keyword_Thesaurus: none
      Place_Keyword: Virginia
      Place_Keyword: National Battlefield
      Place_Keyword: National Park

Place_Keyword: Petersburg
Temporal:
Temporal_Keyword_Thesaurus: none
Temporal_Keyword: 1992
Temporal_Keyword: leaf-off
Temporal_Keyword: March
Access_Constraints: none
Use_Constraints: none
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Richard Easterbrook
Contact_Organization: Petersburg National Battlefield
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing adddress
Address:
Richard Easterbrook
Petersburg National Battlefield
1539 Hickory Hill Rd
City: Petersburg
State_or_Province: Virginia
Postal_Code: 23803
Country: USA
Contact_Voice_Telephone: (804) 732-0171
Contact_Facsimile_Telephone: (804) 862-7943
Contact_Electronic_Mail_Address: Richard _Easterbrook@nps.gov
Data_Set_Credit: Bill Millinor
Native_Data_Set_Environment: Mr. SID

Data_Quality_Information:
Logical_Consistency_Report: none
Completeness_Report: Petersburg National Battlefield - Main Unit
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Overall positional accuracy of 2.365 meters
1.88 meters in the x direction
2.85 meters in the y direction
Class 3 map accuracy
Horizontal accuracy was found by assessing 41 points in the field spread throughout the orthorectified image. These points were identified on the basemap and then were found in the field where their coordinates were taken using a Trimble Pro XR with real time correction. The field coordinates were then compared to the coordinates from the basemap using ArcView.
Lineage:

Source_Information:
  Source_Citation:
    Citation_Information:
      Originator:
        Air Photographics, Inc
      Publication_Date: Unpublished Material
      Title: Aerial photographs of the Main Unit at Petersburg National
        Battlefield
      Edition: first
      Geospatial_Data_Presentation_Form: remote-sensing image
  Source_Scale_Denominator: 3000
  Type_of_Source_Media: color ir aerial photographs
  Source_Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 19920316
    Source_Currentness_Reference: ground condition
  Source_Citation_Abbreviation: aerial photos
  Source_Contribution: Aerial view of Petersburg National Battlefield
Process_Step:
  Process_Description:
    The aerial photos (75 total) were used to create an orthorectified mosaic using Erdas Imagine. The photos were scanned at 600 dpi and imported into Imagine. They were then orthorectofied using USGS DOQQ's and USGS DEM's as reference. The DEM'S were resampled from 30 meters to 10 meters. Each photo had at least 6 ground control points with a total RMS of less than 1 meter. The orthorectified images were then mosaiced within Imagine to form one seamless basemap image for the Main Unit at Petersburg National Battlefield.
  Process_Date: 200006
  Source Produced Citation Abbreviation: Orthorectified Imagine image of the
    Main Unit at Petersburg National Battlefield.
  Process_Contact:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: NCSU, Center for Earth Observation
      Contact_Address:
        Address_Type: mailing address
        Address:
          NCSU, Center For Earth Observation
          NCSU Campus Box 7106
        City: Raleigh
        State_or_Province: NC
        Postal_Code: 27695-7106
        Country: USA
      Contact_Voice_Telephone: 919-515-3430

Contact_Facsimile_Telephone: 919-515-3439
Hours_of_Service: 8:30 am - 5:30 pm
Source_Information:
Source_Citation:
Citation_Information:
Originator:
NCSU, Center for Earth Observation
Publication_Date: 200008
Title: Orthorectified Imagine image of the Main Unit at Petersburg National Battlefield.
Edition: first
Geospatial_Data_Presentation_Form: map
Source_Scale_Denominator: 3000
Type_of_Source_Media: remote-sensing image
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 19920316
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: original Imagine photomosaic
Source_Contribution: The original uncompressed Imagine photomosaic.
Process_Step:
Process_Description:
The Imagine file was exported to a geotiff using Imagine.
A geotiff world file was then created in notepad. Mr SID was then used at a 20:1 compression ratio to compress the image from 1.6gb to 56 mb.
Process_Date: 200005
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: NCSU, Center for Earth Observation
Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106
City: Raleigh
State_or_Province: NC
Postal_Code: 27695-7106
Country: USA
Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Hours_of_Service: 8:30 am - 5:30 pm
Contact_Instructions: phone

Spatial_Data_Organization_Information:

Direct_Spatial_Reference_Method: Raster
Raster_Object_Information:
Raster_Object_Type: Pixel
Row_Count: 23366
Column_Count: 22221
Vertical_Count: 1

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 18
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -75.000000
Latitude_of_Projection_Origin:
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: row and column
Coordinate_Representation:
Abscissa_Resolution: 0.173425
Ordinate_Resolution: 0.173425
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: Band_1
Attribute:
Attribute_Label: Order_ID
Attribute:
Attribute_Label: Value
Attribute:
Attribute_Label: Count
Detailed_Description:
Entity_Type:
Entity_Type_Label: Band_2
Attribute:
Attribute_Label: Order_ID

Attribute:
Attribute_Label: Value
Attribute:
Attribute_Label: Count
Detailed_Description:
Entity_Type:
Entity_Type_Label: Band_3
Attribute:
Attribute_Label: Order_ID
Attribute:
Attribute_Label: Value
Attribute:
Attribute_Label: Count
Overview_Description:
Entity_and_Attribute_Overview: Dataset consists of a compressed 3 band raster color image.
Entity_and_Attribute_Detail_Citation: none
Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Richard Easterbrook
Contact_Organization: Petersburg National Battlefield
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing address
Address:
Petersburg National Battlefield
1539 Hickory Hill Rd
City: Petersburg
State_or_Province: Virginia
Postal_Code: 23803
Country: USA
Contact_Voice_Telephone: (804) 732-0171
Contact_Facsimile_Telephone: Fax: (804) 862-7943
Contact_Electronic_Mail_Address: Richard _Easterbrook@nps.gov
Resource_Description:
Mr. SID image of Imagine .img file color infrared image of the Main Unit at Petersburg National Battlefield
Distribution_Liability:
The National Park Service shall not be held liable for improper or incorrect use of the data described and/or contained herein. These data and related graphics ("GIF" format files) are not legal documents and are not intended to be used as such.

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Custom_Order_Process: Contact
Richard Easterbrook
Petersburg National Battlefield
1539 Hickory Hill Rd
Petersburg, VA 23803
(804) 732-0171
Richard_Easterbrook@nps.gov

Metadata_Reference_Information:
Metadata_Date: 20000725
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Center for Earth Observation
Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106
City: Raleigh
State_or_Province: NC
Postal_Code: 27695-7106
Country: USA
Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Contact_Instructions: phone
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998

Appendix 13. Vegetation Coverage Metadata

Identification_Information:
  Citation:
    Citation_Information:
      Originator:
        North Carolina State University, Center for Earth Observation
      Publication_Date: 20000801
      Title: Petersburg National Battlefield - Main Unit Vegetation
      Edition: first
      Geospatial_Data_Presentation_Form: map
  Description:
    Abstract: Vegetation classification of the Petersburg National Battlefield, Main Unit. Vegetation was delineated to formation level using the Nature Conservancy's National Vegetaton Classification System with a minimum mapping unit of .5 acre. The data was created following general guidelines set forth by the USGS-NPS Vegetation Mapping Program. The data meets National Map Accuracy Standards for a Class 3 map.
    Purpose: This data set was created for use by Petersburg National Battlefield to allow better resource management.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 19920316
        Time_of_Day: 1300
    Currentness_Reference: Time and data of source photography.
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: Unknown
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -77.386064
      East_Bounding_Coordinate: -77.344309
      North_Bounding_Coordinate: 37.250185
      South_Bounding_Coordinate: 37.213023
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus: none
      Theme_Keyword: nature conservancy
      Theme_Keyword: classification
      Theme_Keyword: USGS
      Theme_Keyword: NPS
      Theme_Keyword: color ir
      Theme_Keyword: color infrared
      Theme_Keyword: vegetation

Theme_Keyword: landcover
Place:
Place_Keyword_Thesaurus: none
Place_Keyword: Virginia
Place_Keyword: National Park
Place_Keyword: Petersburg National Battlefield
Temporal:
Temporal_Keyword_Thesaurus: none
Temporal_Keyword: 1992
Temporal_Keyword: leaf-off
Temporal_Keyword: March
Access_Constraints: none
Use_Constraints: none
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Richard Easterbrook
Contact_Organization: Petersburg National Battlefield
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing address
Address:
Richard Easterbrook
GIS Specialist
Petersburg National Battlefield
1539 Hickory Hill Rd
City: Petersburg
State_or_Province: Virginia
Postal_Code: 23803
Country: USA
Contact_Voice_Telephone: (804) 732-0171
Contact_Facsimile_Telephone: 804) 862-7943
Contact_Electronic_Mail_Address: Richard _Easterbrook@nps.gov
Data_Set_Credit: Bill Millinor, NCSU-CEO
Native_Data_Set_Environment: Windows NT Version 5.0 (Build 2195) ; ESRI ArcInfo 8.0.345

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Classified to formation level of the Nature Conservancy's National Vegetation Classification System 87% overall thematic accuracy. Thematic accuracy was tested using a stratified random sample based on number of polygons per class and total area per class. 159 of 228 polygons were visted in the field for accuracy assesment. The accuracy assesment followed guidelines of the USGS-NPS Vegetation Mapping Program.

Logical_Consistency_Report: arc and polygon topology exists.
Completeness_Report: Areas >= 0.5 acres were delineated and classified
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Class 3 positional accuracy according to national map accuracy standards
Overall positional accuracy of 2.365 meters
1.88 meters in the x direction
2.85 meters in the y direction
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Air Photographics, Inc
Publication_Date: Unpublished Material
Title: Aerial photographs of the Main Unit at Petersburg National Battlefield
Edition: first
Geospatial_Data_Presentation_Form: remote-sensing image
Source_Scale_Denominator: 3000
Type_of_Source_Media: color ir aerial photographs
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 19920316
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: aerial photos
Source_Contribution: Aerial view of Petersburg National Battlefield
Process_Step:
Process_Description:
The aerial photos (75 total) were used to create an orthorectified mosaic using Erdas Imagine. The photos were scanned at 600 dpi and imported into Imagine. They were then orthorectofied using USGS DOQQ's and USGS DEM's as reference. The DEM'S were resampled from 30 meters to 10 meters. Each photo had at least 6 ground control points with a total RMS of less than 1 meter. The orthorectified images were then mosaiced within Imagine to form one seamless basemap image for the Main Unit at Petersburg National Battlefield.
Process_Date: 200005
Source Produced Citation Abbreviation: Orthorectified Imagine image of the Main Unit at Petersburg National Battlefield.
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: NCSU, Center for Earth Observation

Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106
City: Raleigh
State_or_Province: NC
Postal_Code: 27695-7106
Country: USA
Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Hours_of_Service: 8:30 am - 5:30 pm
Source_Information:
Source_Citation:
Citation_Information:
Originator:
NCSU, Center for Earth Observation
Publication_Date: 200008
Title: Orthorectified Imagine image of the Main Unit at Petersburg National Battlefield.
Edition: first
Geospatial_Data_Presentation_Form: map
Source_Scale_Denominator: 3000
Type_of_Source_Media: remote-sensing image
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 19920316
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: original Imagine photomosaic
Source_Contribution: Mosaiced aerial view of Petersburg National Battlefield, Main Unit.

Process_Step:
Process_Description:
The vegetation polygons were delineated onscreen in ArcMap using the photomosaic as a basemap. The Nature Conservancy's Southeastern Vegetation Classification System was used to classify the polygons to formation level with a minimum mapping unit of .5 acres. The aerial photographs were used with a stereoscope for reference.
Process_Date: 200006
Source Produced Citation Abbreviation: vegetation polygons
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: NCSU, Center for Earth Observation

Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106
City: Raleigh
State_or_Province: NC
Postal_Code: 27695-7106
Country: USA
Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Hours_of_Service: 8:30 am - 5:30 pm
Contact_Instructions: phone

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Complete chain
Point_and_Vector_Object_Count: 672
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Entity point
Point_and_Vector_Object_Count: 228
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: GT-polygon composed of chains
Point_and_Vector_Object_Count: 228
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Point
Point_and_Vector_Object_Count: 4
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Label point
Point_and_Vector_Object_Count: 228

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Transverse Mercator
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -75.000000
Latitude_of_Projection_Origin:
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: row and column

Coordinate_Representation:
Abscissa_Resolution: 0.000002
Ordinate_Resolution: 0.000002
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: mainveg.pat
Entity_Type_Definition: none
Entity_Type_Definition_Source: none
Attribute:
Attribute_Label: FID
Attribute:
Attribute_Label: SHAPE
Attribute:
Attribute_Label: AREA
Attribute:
Attribute_Label: PERIMETER
Attribute:
Attribute_Label: MAINVEG#
Attribute:
Attribute_Label: MAINVEG-ID
Attribute:
Attribute_Label: VEGCLASS
Attribute_Definition: vegetation formation using TNC terrestrial vegetation of the SE United States
Attribute:
Attribute_Label: ACREAGE
Attribute_Definition: polygon area in acres
Attribute:
Attribute_Label: HECTARES
Attribute_Definition: polygon area in hectares
Attribute:
Attribute_Label: X_COORD
Attribute_Definition: polygon label x coordinate
Attribute:
Attribute_Label: Y_COORD
Attribute_Definition: polygon label y coordinate
Attribute:
Attribute_Label: WAYPT_ID

Attribute_Definition: waypoint id number corresponding to that polygon and is only entered if that polygon was visited in the field for accuracy. Also ties field sheets to each polygon.
Attribute:
Attribute_Label: MYPOLYID
Attribute_Definition: generic polygon number that would not change, used for referencing polygons
Attribute:
Attribute_Label: CROWNCOV_PERCENT
Attribute_Definition: polygon percent crown cover only entered if the polygon was visited in the field
Overview_Description:
Entity_and_Attribute_Overview:
Dataset includes: formation level vegetation class for each polygon, coordinates for each label point, whether the polygon was visited as part of the accuracy assesment, and the percent crown cover of each polygon visited.
Entity_and_Attribute_Detail_Citation: none

Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Richard Easterbrook
Contact_Organization: Petersburg National Battlefield
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing address
Address:
Petersburg National Battlefield
1539 Hickory Hill Rd
City: Petersburg
State_or_Province: Virginia
Postal_Code: 23803
Country: USA
Contact_Voice_Telephone: (804) 732-0171
Contact_Facsimile_Telephone: (804) 862-7943
Contact_Electronic_Mail_Address: Richard _Easterbrook@nps.gov
Resource_Description:
Vector polygon coverage of the Petersburg National Battlefield - Main Unit Vegetaiton.
Distribution_Liability:
The National Park Service shall not be held liable for improper or incorrect use of the data described and/or contained herein. These data and related graphics ("GIF" format files) are not legal documents and are not intended to be used as such.

The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data in particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data.

The National Park Service gives no warranty, expressed or implied, as to the accuracy, reliability, or completeness of these data. It is strongly recommended that these data are directly acquired from an NPS server and not indirectly through other sources which may have changed the data in some way. Although these data have been processed successfully on a computer system at the National Park Service, no warranty expressed or implied is made regarding the utility of the data on another system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data.

Standard_Order_Process:
  Digital_Form:
    Digital_Transfer_Information:
      Format_Name: ARCE
    Digital_Transfer_Option:
      Online_Option:
        Computer_Contact_Information:
          Network_Address:
            Network_Resource_Name: Available via ftp from
              http:\\www.nps.gov\gis
  Fees: none if ftp
  Ordering_Instructions:
    contact Richard Easterbrook
    (804) 732-0171
    Fax: (804) 862-7943
    Richard _Easterbrook@nps.gov
Custom_Order_Process:
  contact Richard Easterbrook
  (804) 732-0171
  Fax: (804) 862-7943
  Richard _Easterbrook@nps.gov

Metadata_Reference_Information:
  Metadata_Date: 20000726
  Metadata_Contact:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: NCSU - Center for Earth Observation

Contact_Address:
Address_Type: mailing address
Address:
NCSU, Center For Earth Observation
NCSU Campus Box 7106
City: Raleigh
State_or_Province: North Carolina
Postal_Code: 27695-7106
Country: USA
Contact_Voice_Telephone: 919-515-3430
Contact_Facsimile_Telephone: 919-515-3439
Contact_Instructions: phone
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time