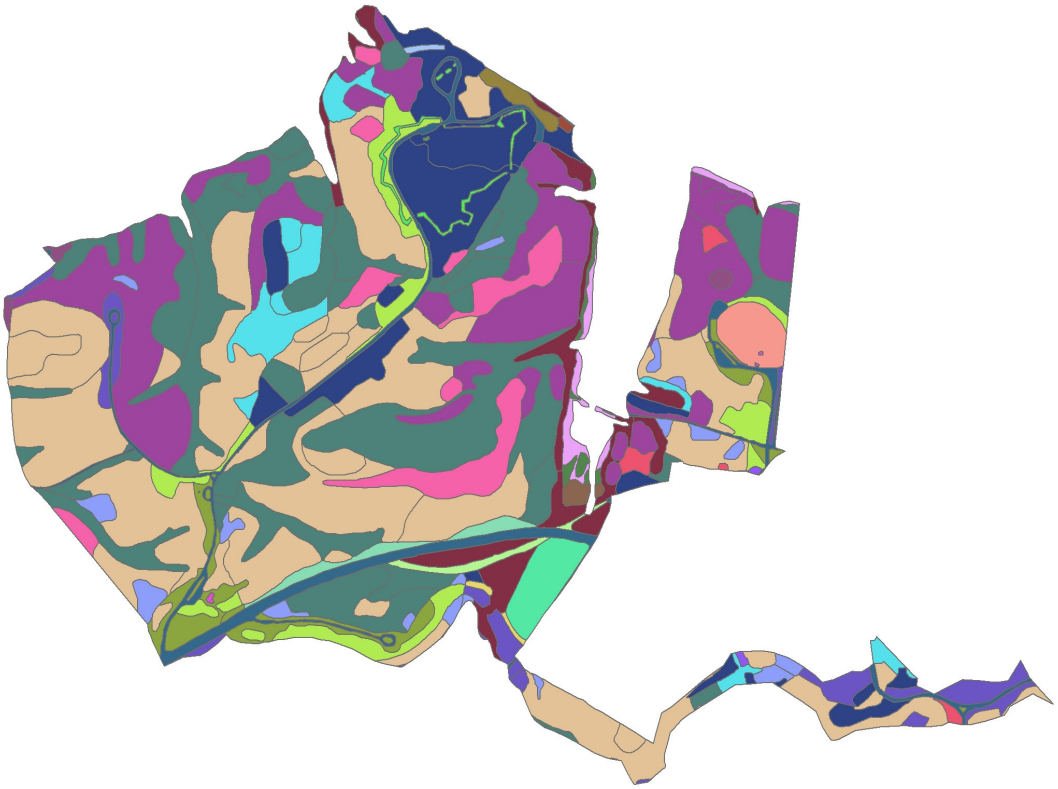
Accuracy Assessment:
Fort Donelson National Battlefield



Prepared for the National Park Service by NatureServe
Durham, NC
January 2009

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A NatureServe Technical Report
Prepared for the National Park Service under Cooperative Agreement H 5028 01 0435

Citation: Summer, H. and C. Nordman. 2009. *Accuracy Assessment: Fort Donelson National Battlefield*. NatureServe: Durham, North Carolina.

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Electronic files have been provided to the National Park Service in addition to hard copies. Current information on all vegetation communities mentioned in this report can be found on NatureServe Explorer at www.natureserve.org/explorer.

Acknowledgements

This report was prepared in cooperation with the Cumberland Piedmont Inventory and Monitoring Network, National Park Service, Department of the Interior. Network coordinator Teresa Leibfreid quickly responded and provided support whenever issues arose that needed to be addressed, as well as assisted with field data collection. Shepard McAninch, ecologist for the Cumberland Piedmont I & M Network, and Chad Desselle, NPS work-study intern, also assisted with field data collection.

Marguerite Madden, Director of the Center for Remote Sensing and Mapping Science (CRMS) at the University of Georgia (UGA), Tommy Jordan, the Associate Director of CRMS, and Phyllis Jackson, a photointerpreter/ecologist at CRMS, were actively involved in the creation of the vegetation map. We're grateful for their help in providing data and answering the questions that arose in the process of conducting the accuracy assessment.

Several other NatureServe Southeast staff assisted with various aspects of this accuracy assessment. We thank Regan Lyons Smyth, Milo Pyne, and Mary Russo for their assistance with assessment point selection, field data collection, data entry, and data analysis.

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Executive Summary

This report presents an accuracy assessment of the digital vegetation map of Fort Donelson National Battlefield (FODO). Vegetation at FODO was mapped by The University of Georgia Center for Remote Sensing and Mapping Science (Jordan and Madden 2008) with ecological consultation assistance from NatureServe. The mapping was conducted as part of the National Park Service Vegetation Mapping Program.

The map accuracy was assessed by comparing the mapped vegetation type to the field verified vegetation type at randomized evaluation points. The evaluation points were chosen prior to field work so as to represent the full range of map classes in the park in a statistically valid manner. Accuracy was calculated for each individual map class, as well as an overall accuracy for all map classes combined.

It is very important to understand that the accuracy assessment process is not meant to exclusively judge the performance of the mapper or the ecologists on the project since error can be caused at any point in the process, from remote sensing to ecological classification to the accuracy assessment exercise itself. In addition, even the best mappers cannot tell the difference between certain species of oaks or pines from a remotely sensed image. Sources of error for the mapping project include not just "remote sensing error" but also "ecologist error" caused by poor interpretation of the vegetation community concept, "field worker error" caused by mistakes made by fieldworkers while collecting the data (including misreading of the key), and temporal error when conditions on the ground change between the mapping and assessment processes. It is not possible to tease apart which of these errors is causing accuracy issues without more research. *The accuracy assessment, therefore, should be used more as a tool to discern usability of map classes rather than a way to judge the performance of the mapmakers.*

In an attempt to provide the most useful information possible to NPS, the University of Georgia (UGA) Team has made a strong effort to pull out the highest level of detail possible when mapping vegetation of parks. As a consequence, assessment of the finished project requires a two step approach: assessing the overall accuracy of the finest scale map produced and then combining the most "confused" map classes and determining the accuracy of the coarser scale but higher accuracy map. In this way, we are able to report our best approximation of how accurate each individual map class is but also suggest a way to combine certain map classes to produce a more reliable map at a coarser scale.

For FODO, the overall accuracy of the final map, which includes several grouped map classes, is 80%, with a kappa statistic of 0.73 (73%). This version of the map is the most appropriate for use by the standard user; what it misses in fine-scale detail, it makes up for in the relatively high level of accuracy of map classes. Vegetation associations displayed as grouped map classes on the coarse-scale map include:

a. Cultivated meadows (CEGL004048) and Successional Broom-sedge Vegetation (CEGL004044)
b. White Oak – Mixed Oak Dry-Mesic Alkaline Forest (CEGL002070) and Central Interior Upland Cherrybark Oak Forest (CEGL003871)

c. Successional Sweetgum Floodplain Forest (CEGL007330) and Sycamore-Silver Maple Calcareous Floodplain Forest (CEGL007334)

The accuracy assessment for this version of the map considered points as a match if the vegetation observed on the ground matched any of the dominant, secondary, or tertiary vegetation types attributed to the map by the mapmaking team.

The strictest analysis of the data (before any combining of map classes or NVC associations occurred and considering a point a match only if the vegetation observed on the ground matched the dominant vegetation type attributed by the mappers) showed an overall accuracy of the map of 46% with a kappa statistic of 0.36 (36%). This lower accuracy reflects the difficulty in differentiating the vegetation associations that were combined in the final analysis and that are similar in their composition on the ground and/or in their appearance on aerial photography. The lower accuracy may also indicate successional changes may have occurred between the time of the mapping effort and the accuracy assessment.

Key findings:

For users interested in preserving the full detail of the map for the purpose of highly detailed studies or management of the landscape, we recommend use of the fine-scale map as published by UGA. For all other users, we recommend combining map classes as specified above to allow for an overall map accuracy of 80%. These actions will allow for a map that is useful for the widest audience possible while not losing potentially important fine scale detail.

Introduction

In an effort to catalog and map the biodiversity of the United States, in 1994 the National Park Service (NPS) and the U.S. Geological Survey (USGS) embarked on a collaborative vegetative mapping project with the goal of mapping 230+ National Park units (ESRI et al. 1994). As part of this national mapping initiative, a digital vegetation map of Fort Donelson National Battlefield (FODO) was created in 2004 by the University of Georgia Center for Remote Sensing and Mapping Science (Jordan and Madden 2008), in consultation with NatureServe. The mapping effort included collection of field data, aerial photograph interpretation, and polygon attribution to GIS maps.

Fort Donelson National Battlefield is located in Stewart County, Tennessee (just west of downtown Dover), on bluffs overlooking what was once the main channel of the Cumberland River and is now the impounded Lake Barkley. The park's approximately 226 hectares (559 acres) are composed primarily of second growth forests and old fields, and many of the forested stands are young and currently recovering from past disturbances such as cultivation and logging (White 2005). Fort Donelson National Battlefield occurs in the Interior Low Plateau ecoregion (Bailey 1994, Keys et al. 1995). Vegetation at Fort Donelson was mapped and classified to the association level using the United States National Vegetation Classification (Grossman et al. 1998, White 2005), following NPS guidelines. The minimum mapping unit (MMU) was 0.5 hectare.

The accuracy assessment assigns a measure of validity to the map product and allows users to understand the reliability with which the mapped vegetation classes capture conditions on the ground. Knowing the accuracy of the map will enable potential users to determine the suitability of the map for any particular application (ESRI et al. 1994). This report describes the methods used in the accuracy assessment and the results for each map class.

Methods

The thematic accuracy of the map was assessed by comparing the vegetation type shown on the map to the vegetation type identified on the ground for a representative sample of evaluation points. When polygons representing vegetation types are mapped and labeled with the correct community types, then the map has high thematic accuracy.

For each map class, both producer's and user's accuracy are evaluated. User's accuracy is a prediction of the percentage of points mapped as a certain type, which are confirmed to belong to that mapped vegetation type when visited in the field. In other words, user's accuracy is a measure of the reliability of the map to predict what is found on the ground (i.e. how likely the map user is to encounter correct information while using the map). Producer's accuracy is the percentage of points observed to be of a given vegetation type in the field that are correctly mapped to that type. In other words, producer's accuracy is a measure of the reliability of the aerial photo interpretation to distinguish the vegetation types (i.e. how well the map maker was able to represent the ground features). In addition to the user's and producer's accuracy, measures of the overall map accuracy are calculated, and contingency tables showing the frequency of confusion (i.e. misclassification) between associations are presented.

Point Selection

A point-based approach was used to assess the accuracy of the map classes, with one or more evaluation points representing each map class. The map represents vegetation types using one or more polygons per type. Points were selected from within those polygons using a stratified random sampling design, so that points were distributed across all map classes with a higher number of points placed within map classes with large areas. Because representative points, not entire polygons, were evaluated, the assessment results should be interpreted as a measure of the accuracy of the overall map class, rather than an assessment of whether whole polygons were classified correctly. For the FODO accuracy assessment, 111 points representing 12 vegetation types were evaluated.

In the mapping process, UGA assigned a dominant vegetation association based on the U.S. National Vegetation Classification (NVC) for each polygon. Many polygons were also assigned secondary and/or tertiary associations where ecotones, inclusions smaller than the minimum mapping unit, active succession, or blended vegetation types made assignment to one association unrepresentative of the situation on the ground. For the selection of evaluation points, only the dominant vegetation type was considered. The number of required points for each dominant vegetation type was determined based on the area of each vegetation association at the park (ESRI et al. 1994, NatureServe 2007). The locations of the evaluation points were then selected using the Generate Random Points tool in the GIS extension "Hawth's Analysis Tools for ArcGIS" (Beyer 2004). Points were excluded from a 12 meter internal buffer around the boundary of each vegetation polygon to ensure that points were within polygons and to avoid misclassification due to GPS error in the field; however, in some instances the size and shape of the vegetation polygons prevented selection of an adequate number of points outside the buffered area. Likewise, points were randomly placed but polygons smaller than 0.045 hectares (452 square meters) were excluded because of the potential that GPS error could lead field crews to record data for an area outside the polygon of the mapped class. A distance of at least 80 meters was maintained between adjacent points to prevent overlap in the area evaluated around each point.

Field Data Collection

Field crews located each evaluation point using a WAAS-enabled Garmin 5 GPS unit. Wide Area Augmentation System (WAAS) is a form of Differential GPS, which provides enhanced positional accuracy. At each point, the field crew recorded new coordinates, GPS positional accuracy, and collected limited vegetation data. When collecting the data for the accuracy points, the vegetation was considered in an area approximately 0.5 hectare, within a 40 meter radius circle around each point. Only the dominant and diagnostic species were recorded for each stratum. The primary association type at that point was determined by the field crew using an existing key to the ecological and human influenced communities at FODO (found in White 2005), and a "fit" value of this type of high, medium, or low was also selected. During the accuracy assessment data collection, it became evident that the vegetation key required some modification, and the modified key is included in this report as Attachment A. At some more confusing points, a secondary or alternate association was also recorded, and notes were taken on

any difficulties keying out the point. A total of 112 data points with field data were collected, however one of those points fell outside of the mapped boundary area and was deleted prior to analysis. Therefore, only 111 points were used for the assessment of thematic accuracy.

Data Analysis

Data analysis for the accuracy assessment consisted of creation of contingency tables which summarize misclassification rates for each vegetation type, calculation of user's and producer's accuracy for each vegetation type, and evaluation of the overall accuracy of the map using the kappa statistic (Cohen 1960). The data was analyzed for three scenarios. The first scenario was a strict interpretation of map accuracy at the finest scale. An evaluation point was considered correctly classified only if the dominant vegetation type assigned on the map matched the observed value on the ground. The second scenario considered a point a match if the dominant, secondary, or tertiary vegetation type assigned to the mapped polygon matched the observed type. The third scenario was similar to the second in that it used dominant, secondary, or tertiary vegetation, but in addition, this scenario combined several map classes into broader groups where evaluation of the first scenario results indicated they were difficult to differentiate. If questions arose with regard to the proper assignment of a point to a map class, the supplemental notes recorded by the field crew were also considered. In addition, any points that fell within the 12 meter polygon edge buffer that were observed to have the same type as that of an adjacent mapped polygon were regarded as correct in the third scenario. This accounts for any GPS error that may have occurred during data collection.

A contingency matrix was constructed for each scenario. This table lists sample data (i.e. mapped values) as rows and reference data (i.e. the type observed in the field) as columns. An example of a contingency matrix is presented below (Table 1). Cell values equal the number of points mapped or field-verified as belonging to that type, with numbers along the diagonal representing correctly classified points and all others cells representing misclassifications. In this example, four of the five evaluation points mapped as belonging to Class B were mapped correctly, while the fifth point was found to belong to Class D in the field. In addition, the field crew identified two evaluation points that were mapped as Class C but were shown to belong in Class B in the field. Examining the contingency table in this manner allows the users to discern patterns in misclassifications between classes.

Table 1. A sample contingency matrix with shaded cells representing correctly classified points.

		Observed as:				Row Totals
		A	B	C	D	
Mapped as:	A	5	0	0	0	5
	B	0	4	0	1	5
	C	0	2	8	0	10
	D	0	0	3	2	5
Column Totals		5	6	11	3	25

User's and producer's accuracy were derived from the values in the contingency table. Producer's accuracy, or (1 - errors of omission), is calculated by dividing the number of correctly classified points for a map class by the total number of points determined to belong to that class in the field (i.e. the column total). In our example, the producer's accuracy for Class B is 4 divided by 6, or 67%. User's accuracy (1 - errors or commission) is determined by dividing the number of correctly classified points in one map class by the total number of evaluation points originally generated for that class (i.e. the row total). In our example, the users' accuracy for Class B is 4 divided by 5, or 80%.

Overall map accuracy was determined by dividing the number of correct points by the total number of points assessed. A kappa index, which takes into account that some polygons are correctly classified by chance (Cohen 1960, ESRI et al. 1994, Foody 1992), was also calculated. The overall accuracy and kappa index were calculated based on all map classes for all three analysis scenarios.

Results

The overall accuracy of the final FODO vegetation map, which considered dominant, secondary, or tertiary vegetation types as well as several combined map classes, is 80% with a kappa statistic of 0.73 (73%). The contingency matrix for this scenario, along with a tabulation of user's and producer's accuracy for each map class, is provided in Appendix B, Tables 2a-b. Groupings were created based on a review of the contingency matrix for the fine-scale analysis. Grouped associations included:

a. Cultivated meadows (CEGL004048) and Successional Broom-sedge Vegetation (CEGL004044)

b. White Oak - Mixed Oak Dry-Mesic Alkaline Forest (CEGL002070) and Central Interior Upland Cherrybark Oak Forest (CEGL003871)

c. Successional Sweetgum Floodplain Forest (CEGL007330) and Sycamore-Silver Maple Calcareous Floodplain Forest (CEGL7334)

A stricter analysis, which considered dominant, secondary, or tertiary vegetation types but no combined map classes, produced an overall accuracy of 64% with a kappa statistic of 0.58 (58%) (Appendix B, Tables 3a-b). The strictest analysis of the FODO map at its finest scale, which considered only the dominant mapped vegetation, resulted in an accuracy of 46% with a kappa statistic of 0.36 (36%) (Appendix B, Tables 4a-b).

Confidence intervals for user's and producer's accuracy were not calculated for FODO because the generally small number of assessment points per map class inflates the size of the confidence interval and thus limits its usefulness for meaningful interpretation.

It is apparent from the comparison of Tables 2-4 that overall map accuracy is considerably higher when classes are grouped and secondary and tertiary mapped vegetation is considered.

The fine-scale detail that is available to users of the ungrouped map classes will be invaluable to researchers and managers interested in distinct vegetation associations. However, due to the error inherent in mapping at such fine-scale, it is important that the user take into account the misclassification rates shown on the contingency tables in Appendix B when using this version of the map. Because much higher accuracies are achieved when vegetation types are grouped, we recommend that users who are less inclined to explore the accuracy assessment in depth be guided to use the coarser scale, higher accuracy version of the map.

Discussion

Overall, the vegetation map for Fort Donelson National Battlefield provides an accurate representation of vegetation types within the park and meets the NPS 80% accuracy standard. A few of the vegetation classes had low user's or producer's accuracy, and thus users should be very cautious in interpreting areas mapped or identified in the field as belonging to those classes. It should be noted however, that these classes occupied a very small portion of the total park area, and the low accuracy recorded may be an artifact of the small sample size for these map classes.

In addition, small fragmented parks with active ecosystem management, such as Fort Donelson, are by their nature difficult candidates for accurate mapping to the NVC association level for all map classes. Disturbed and/or successional vegetation types do not lend themselves easily to being mapped at the association level. Unlike larger and more intact landscapes, Fort Donelson National Battlefield is composed of a patchwork of late successional forest types, managed cultural vegetation, small patch types, and early successional shrub, grassland and forest types resulting in a continuum of spatial and temporal vegetation patterns. Due to floristic similarity in dominant strata, late and early successional upland and palustrine (wetland) forests were often mistaken for one another in the field and on the map. When visiting a polygon, the surveyors were obligated to choose a map class among successional types which often form an aggregation of several classes rather than a homogenous type. In addition, occasionally the field assessment point did not fit well into any community description so the surveyors chose the closest one, which may not have been a perfect fit.

For example, 6 assessment points were identified in the field as Interior Successional Sweetgum - Oak Forest (CEGL007217); however, only 1 of these points fell within a polygon mapped as such. The other 5 assessment points were mapped as either Central Interior Upland Cherrybark Oak Forest (CEGL003871), Successional Tuliptree/Redbud Forest (CEGL007220), or Red-cedar Successional Forest (CEGL007124). Interestingly enough, the field notes for these 5 assessment points indicate a mix of other species such as tuliptree, red cedar, and Cherrybark oak as also being present or co-dominant within both the canopy and subcanopy layers. This could potentially indicate patchy successional forests and does not necessarily mean that these areas were mapped incorrectly. Conversely, there were 4 polygons mapped as Interior Successional Sweetgum - Oak Forest (CEGL007217), however only 1 of these polygons contained an assessment point observed in the field to be such (i.e. the point mentioned above). The other polygons contained assessment points that were identified in the field as either White Oak - Mixed Oak Dry-Mesic Alkaline Forest (CEGL002070) or Successional Tuliptree/Redbud Forest

(CEGL007220), however the field forms for these assessment points noted sweetgum as an important species in either the canopy or subcanopy, thus explaining why these areas may have been mapped as Interior Successional Sweetgum - Oak Forest (CEGL007217).

While the accuracy assessment is intended to provide a measure of the reliability of the map classes, the reader should be aware that error is also inherent in the field assessment of evaluation points. The overall accuracy of the Fort Donelson vegetation map was relatively low before grouping map classes. At any park, the overall accuracy and user's and producer's accuracy of individual map classes may be affected by the fragmented state and severe changes in management practices, GPS error, data collection error by the field crew, poorly written and/or untested classification keys, poor ecological community concepts, inconsistent interpretation of the classification key, and potential lag times between photointerpretation and accuracy assessment. Two or more community types could be similar enough such that one assessment point could be mistakenly assigned to a particular community type by the field crew when another community type was assigned to the same area by the map producers (Townsend 2000). Points may fall into ecotones or into inclusions within the larger community type and the resulting classification in the field may not be the same as that on the map. While measures were taken to reduce these errors, they are not altogether avoidable and it is not within the scope of this project to discern what mistakes led to errors. However, it is important to note that mapping error is but one of many types of error that combine to create accuracy issues with any given map.

Users of the FODO digital vegetation map should familiarize themselves with the results of this accuracy assessment, potential sources of classification error, and the contingency tables provided in Appendix B. When interested in using the map to locate a particular association, it is useful to know what other map classes have been shown to contain points matching that association, and what other vegetation types the mapped association of interest is likely to contain. We recommend that natural resource managers consider combining some commonly confused map classes together for display or other purposes. The results of the accuracy assessment indicate that Cultivated meadows (CEGL004048) and Successional Broom-sedge Vegetation (CEGL004044) cannot be consistently distinguished from each other on aerial imagery and may be best displayed as a combined map class. Likewise, White Oak - Mixed Oak Dry-Mesic Alkaline Forest (CEGL002070) and Central Interior Upland Cherrybark Oak Forest (CEGL003871) were difficult for the mappers to distinguish from one another and also may best be displayed as a combined class. Additionally, assessment points that were identified in the field as Successional Sweetgum Floodplain Forest (CEGL007330) fell within polygons that were mapped as Sycamore-Silver Maple Calcareous Floodplain Forest (CEGL007334) due to a co-dominance of sycamore in the canopy and subcanopy layers, indicating that these classes may also be best displayed as a combined class.

For casual map users and general display purposes, use of the higher-accuracy map, which includes these lumped classes, will be most useful. For researchers and managers interested in fine-scale detail and rare vegetation types, a version of the map that preserves the full detail as published by UGA should be maintained. This more detailed version of the map, while less accurate for some map classes, contains valuable information for those interested in locating vegetation types that are inherently difficult to map. Used in conjunction with the results of this

accuracy assessment, the original map provides the best tool available for understanding the spatial distribution of vegetation types at FODO.

Key Findings:

For users interested in preserving the full detail of the map for the purpose of highly detailed studies or management of the landscape, we recommend use of the fine-scale FODO map as published by UGA. For all other users, we recommend combining map classes as specified above to allow for an overall map accuracy of 80%. These actions will allow for a map that is useful for the widest audience possible while not losing potentially important fine scale detail.

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Appendix A: Revised Vegetation Classification Key

Key to Ecological Communities of Fort Donelson National Battlefield

This key was developed for Fort Donelson National Battlefield and is intended to allow field workers and naturalists to quickly identify community types while in the field. Due to the small size of the park and the limited habitat types available within the park boundary, this key does not cover all of the ecosystems of the adjacent region. However, within the boundary, we believe this key represents the range of variation of existing vegetation.

This document is a dichotomous key. The user must make a series of choices based on the structure, composition, and environment of the vegetation to arrive at the correct association. If the key leads to a choice that is not reasonable, consider returning to the beginning of the key and reviewing your decisions to confirm that you are confident in all your choices. It may be useful to walk around the area in question to get a feel for the composition of the area. This exercise may help you arrive at the correct place in the key since small-scale variations within a matrix community may be misleading. In addition, ecotones between ecological communities may have traits of both communities and so may need to be classified as both communities if they cannot be assigned with confidence to one or the other.

Where appropriate, the name of the NatureServe Ecological Group appears in [brackets]. The EcoGroup is a broader concept than the association level, so similar communities may fall out in one ecogroup. The full association name and code (e.g. CEGL002591) appears alongside an underlined title of the type. The CEGL code may be used to refer back to the document or to look association names and information up in other references that use the National Vegetation Classification. The "common name" of the community also appears with the scientific name of the association.

[ALL CAPS AND BRACKETS] signifies an ecological system
Bold faced words signify an NVC ecological community type
Italics signify a community type that hasn't been documented with a plot, but that we suspect is in the park based on past studies.

1.Successional upland communities regenerating after heavy human disturbance (usually clearcutting or mowing or flooding from lake impoundment) 1-50 years ago.
[HUMAN MODIFIED/SUCCESSIONAL]

A.Upland

1.Old field (<20% canopy cover)

a.Old field mostly dominated by broomsedge (*Andropogon virginicus*) and other native plants (<50% cover of non-natives such as fescue. Caution: broomsedge is more visible in late fall and early spring before mowing and less visible during the summer growing season.
Successional Broomsedge Vegetation (CEGL004044)

b.Old field mostly dominated by non native plants, esp. fescue (*Lolium/Festuca spp.*) (usually at least 50% non-native plants).
Cultivated Meadow (CEGL004048)

2.Young upland forest or shrubland or woodland succeeding into forest vegetation and dominated by usually even aged stands of eastern red-cedar (*Juniperus virginiana var. virginiana*), tuliptree (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), pine (*Pinus spp.*), or other species considered early successional.

a. Forest canopy dominated by tuliptree or occasionally black walnut (*Juglans nigra*), hackberry/sugarberry (*Celtis spp.*), or elm (*Ulmus spp.*).
Successional Tuliptree/Redbud Forest (CEGL007220)

b.Canopy dominated by conifers or sweetgum instead of tuliptree.

1. Forest or shrubland dominated by conifers (at least 50% of canopy)

a. Canopy dominated by eastern red-cedar (>50% of canopy)
Eastern Red-cedar Successional Forest (CEGL007124)

b. Canopy dominated by pine (>50% pine in canopy)

1. Canopy dominated by loblolly pine (*Pinus taeda*) (>50% pine in canopy)
Loblolly Pine / Tuliptree – Sugar Maple Successional Forest (CEGL007105)

2. Canopy dominated by Shortleaf Pine (*Pinus echinata*) (>50% of canopy)
Shortleaf Pine Early-Successional Forest (CEGL006327)

2. Canopy dominated by a combination of sweetgum and oak (*Quercus spp.*) (usually sweetgum is at least 50% of canopy) – don't confuse with lowland successional sweetgum in floodplains!
Interior Successional Sweetgum - Oak Forest (CEGL007217)

B. Wetland

1. Herbaceous dominated mudflat (<20% woody cover) inundated by fluctuating levels of the impoundment for much of the year.
[HUMAN MODIFIED/SUCCESSIONAL]
Tennessee Valley Authority Mudflat (CEGL004049)

2. Shrubland/forest (>20% woody cover) only inundated for short periods of time each year.

a.Dominated by black willow (*Salix nigra*) shrubs/trees (>50% cover of willow trees/shrubs combined)
[SOUTH-CENTRAL INTERIOR LARGE FLOODPLAIN]
Black Willow Riparian Forest (CEGL002103)

b. Canopy dominated by trees other than black willow (<50% canopy cover)

1. Dominated by sweetgum (>50% cover of sweetgum in canopy/shrub layer) but sometimes also with high cover of tuliptree (up to 50% of canopy)
[SOUTH-CENTRAL INTERIOR SMALL STREAM AND RIPARIAN]
Successional Sweetgum Floodplain Forest (CEGL007330)

2. Canopy not dominated by sweetgum or tuliptree. Young bottomland hardwood forest usually with a diverse canopy that may be dominated or co-dominated by sycamore (*Platanus occidentalis*), boxelder (*Acer negundo*), elm, ash (*Fraxinus spp.*), hackberry. Usually >10% sycamore and >10% boxelder. Silver maple (*Acer saccharinum*) may or may not be present.
[SOUTH-CENTRAL INTERIOR LARGE FLOODPLAIN]
Sycamore-Silver Maple Calcareous Floodplain Forest (CEGL007334)

2. Upland and wetland communities not subjected to human caused cutting or mowing over the last 50 years (although possibly were cultivated >50 years ago and are second growth stands). Either oak-hickory-beech forests or stands influenced by flooding.

A.Wetland
Bottomland hardwood forest usually with a diverse canopy that may be dominated or co-dominated by sycamore, boxelder, elm, ash, hackberry/sugarberry. Usually >10% sycamore and >10% boxelder. Silver maple may or may not be present.
[SOUTH-CENTRAL INTERIOR LARGE FLOODPLAIN]
Sycamore-Silver Maple Calcareous Floodplain Forest (CEGL007334)

B. Upland forest

1. Forest dominated by Beech (*Fagus grandifolia*) and/or white oak (*Quercus alba* (beech at least 25% of canopy).
[SOUTH-CENTRAL INTERIOR MESOPHYTIC FOREST]
Central Interior Beech - White Oak Forest (CEGL007881)

2. Oak forest with <25% beech in canopy.

a. Forest on upland ridges and southwest-facing slopes, dominated by post oak (*Quercus stellata)* or southern red oak (*Quercus falcata)* and post oak (*Quercus stellata)*, usually with less white oak (*Quercus alba*). In addition, mockernut hickory (*Carya alba)* or sand hickory (*Carya pallida)* may be important components of the canopy
Dry Acidic Eastern Coastal Plain Oak - Hickory Forest (CEGL007246)

b. Forest not dominated of codominated by post oak (*Quercus stellata*), but rather dominated by white oak (*Quercus alba*), cherrybark oak (*Quercus pagoda*), red hickory (*Carya ovalis*), shagbark hickory (*Carya ovata*), southern red oak (*Quercus falcata*) or northern red oak (*Quercus rubra*)
[SOUTHERN INTERIOR LOW PLATEAU DRY OAK FOREST]

1. Canopy dominated by white oak and sometimes northern red oak (>50% white oak and/or northern red oak, <25% southern red oak)
Mesic/dry-mesic side slopes up to and sometimes including ridge tops with white oak (>50% white oak) and shagbark hickory (*Carya ovata*). Shrub layer and herbaceous layer is sparse to rich and generally has a circumneutral component. >25% cover of redbud (*Cercis canadensis*) and/or pawpaw (*Asimina triloba*) and/or spicebush (*Lindera benzoin*) in shrub layer. Beech can often dominate understory.
White Oak - Mixed Oak Dry-Mesic Alkaline Forest (2070)

2. Dry-mesic forest of slopes and only occassionally ridgetops. Canopy usually with >50% cherrybark oak (*Quercus pagoda*) plus red hickory (*Carya ovalis*) combined (and occasionally with >50% coverage of southern red oak (*Quercus falcata*). Other trees often present in high amounts include shingle oak (*Quercus imbricaria*), northern red oak (*Quercus rubra*), Shumard oak (*Quercus shumardii*), and chinquapin oak (*Quercus muehlenbergii*). Shrub layer often has a significant component of ironwood (*Carpinus caroliniana*).
Central Interior Upland Cherrybark Oak Forest (CEGL003871)

Appendix B: Contingency Matrices and Accuracy Tables

Table 2a
Contingency Matrix Using Mapped Dominant, Secondary, or Tertiary Vegetation (Best Match), plus Combined Map Classes (4044/4048, 2070/3871, and 7330/7334), and accounting for GPS error

Fort Donelson National Battlefield

		Observed as:										Grand Total	User's Accuracy:
		2070/3871	2103	4044/4048	4049	7105	7124	7217	7220	7330/7334	7881		
Mapped as:	2070/3871	40	0	0	0	0	1	3	2	0	3	49	82%
	2103	0	1	0	0	0	0	0	0	0	0	1	100%
	4044/4048	1	0	14	0	0	0	0	0	0	0	15	93%
	4049	0	0	0	1	0	0	0	0	0	0	1	100%
	7105	1	0	0	0	1	1	0	0	0	0	3	33%
	7124	0	0	1	0	0	4	1	1	0	0	7	57%
	7217	1	0	0	0	0	0	1	1	0	0	3	33%
	7220	2	0	0	0	0	0	1	20	1	0	24	83%
	7330/7334	0	1	0	0	0	0	0	0	4	0	5	80%
	7881	0	0	0	0	0	0	0	0	0	3	3	100%
Grand Total		45	2	15	1	1	6	6	24	5	6	111	
Producer's Accuracy:		89%	50%	93%	100%	100%	67%	17%	83%	80%	50%		

Overall accuracy= 80.18%
Kappa statistic= 73.47%

Table 2b
Accuracy Calculations Using Mapped Dominant, Secondary, or Tertiary Vegetation (Best Match), plus Combined Map Classes (2070/2871, 4044/4048, and 7330/7334), and accounting for GPS error
Fort Donelson National Battlefield

Map Class	Producer's Accuracy		User's Accuracy	
	Accuracy	n	Accuracy	n
2070/3871	89%	45	82%	49
2103	50%	2	100%	1
4044/4048	93%	15	93%	15
4049	100%	1	100%	1
7105	100%	1	33%	3
7124	67%	6	57%	7
7217	17%	6	33%	3
7220	83%	24	83%	24
7330/7334	80%	5	80%	5
7881	50%	6	100%	3

n	The sample size. For user's accuracy, this is the number of points mapped in this class. For producer's accuracy, it is the number of points assigned to that class in the field.
n/a	Not applicable. For user's accuracy, no evaluation points were mapped in this class. For producer's accuracy, no evaluation points were assigned to this class in the field.
--	A confidence interval could not be calculated due to the small sample size.

Table 3a
Contingency Matrix Using Mapped Dominant, Secondary, or Tertiary Vegetation (Best Match)
Fort Donelson National Battlefield

		Observed as:													Grand Total	User's Accuracy:
		2070	2103	3871	4044	4048	4049	7105	7124	7217	7220	7330	7334	7881		
Mapped as:	2070	22	0	2	0	0	0	0	0	0	1	0	0	3	28	79%
	2103	0	1	0	0	0	0	0	0	0	0	0	0	0	1	100%
	3871	0	0	13	0	0	0	0	1	3	1	0	0	0	18	72%
	4044	0	0	0	1	8	0	0	0	0	0	0	0	0	9	11%
	4048	1	0	0	2	3	0	0	0	0	0	0	0	0	6	50%
	4049	0	0	0	0	0	1	0	0	0	0	0	0	0	1	100%
	7105	1	0	1	0	0	0	1	1	0	1	0	0	0	5	20%
	7124	0	0	1	1	0	0	0	4	1	1	0	0	0	8	50%
	7217	2	0	0	0	0	0	0	0	1	1	0	0	0	4	25%
	7220	2	0	0	0	0	0	0	0	1	19	1	0	0	23	83%
	7330	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
	7334	0	1	0	0	0	0	0	0	0	0	2	2	0	5	40%
	7881	0	0	0	0	0	0	0	0	0	0	0	0	3	3	100%
Grand Total		28	2	17	4	11	1	1	6	6	24	3	2	6	111	
Producer's Accuracy:		79%	50%	76%	25%	27%	100%	100%	67%	17%	79%	0%	100%	50%		

Overall accuracy= 63.96%
Kappa statistic= 57.59%

Table 3b
Accuracy Calculations Using Mapped Dominant, Secondary, or Tertiary Vegetation (Best Match)
Fort Donelson National Battlefield

Map Class	Producer's Accuracy		User's Accuracy	
	Accuracy	n	Accuracy	n
2070	79%	28	79%	28
2103	50%	2	100%	1
3871	76%	17	72%	18
4044	25%	4	11%	9
4048	27%	11	50%	6
4049	100%	1	100%	1
7105	100%	1	20%	5
7124	67%	6	50%	8
7217	17%	6	25%	4
7220	79%	24	83%	23
7330	0%	3	n/a	0
7334	100%	2	40%	5
7881	50%	6	100%	3

n	The sample size. For user's accuracy, this is the number of points mapped in this class. For producer's accuracy, it is the number of points assigned to that class in the field.
n/a	Not applicable. For user's accuracy, no evaluation points were mapped in this class. For producer's accuracy, no evaluation points were assigned to this class in the field.
--	A confidence interval could not be calculated due to the small sample size.

Table 4a
Contingency Matrix Using Mapped Dominant Vegetation Only
Fort Donelson National Battlefield

		Observed as:													Grand Total	User's Accuracy:
		2070	2103	3871	4044	4048	4049	7105	7124	7217	7220	7330	7334	7881		
Mapped as:	2070	16	0	5	0	0	0	0	0	0	4	0	0	4	29	55%
	2103	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0%
	3871	4	0	8	0	0	0	0	1	3	2	0	0	0	18	44%
	4044	0	0	0	1	8	0	0	0	0	1	0	0	0	10	10%
	4048	1	0	0	2	2	0	0	0	0	0	0	0	0	5	40%
	4049	0	0	0	0	0	1	0	0	0	0	0	0	0	1	100%
	7105	1	0	1	0	0	0	1	2	0	1	0	0	0	6	17%
	7124	0	0	1	1	0	0	0	2	1	1	0	0	0	6	33%
	7217	2	0	0	0	0	0	0	1	1	1	0	0	0	5	20%
	7220	3	0	2	0	0	0	0	0	1	16	1	0	1	24	67%
	7330	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
	7334	0	1	0	0	0	0	0	0	0	0	2	2	0	5	40%
	7881	0	0	0	0	0	0	0	0	0	0	0	0	1	1	100%
Grand Total		27	1	17	4	10	1	1	6	6	26	3	3	6	111	
Producer's Accuracy:		59%	0%	47%	25%	20%	100%	100%	33%	17%	62%	0%	67%	17%		

Overall accuracy= 45.95%
Kappa statistic= 36.10%

Table 4b
Accuracy Calculations Using Mapped Dominant Vegetation Only
Fort Donelson National Battlefield

Map Class	Producer's Accuracy		User's Accuracy	
	Accuracy	n	Accuracy	n
2070	59%	27	55%	29
2103	0%	1	0%	1
3871	47%	17	44%	18
4044	25%	4	10%	10
4048	20%	10	40%	5
4049	100%	1	100%	1
7105	100%	1	17%	6
7124	33%	6	33%	6
7217	17%	6	20%	5
7220	62%	26	67%	24
7330	0%	3	n/a	0
7334	67%	3	40%	5
7881	17%	6	100%	1

n	The sample size. For user's accuracy, this is the number of points mapped in this class. For producer's accuracy, it is the number of points assigned to that class in the field.
n/a	Not applicable. For user's accuracy, no evaluation points were mapped in this class. For producer's accuracy, no evaluation points were assigned to this class in the field.
--	A confidence interval could not be calculated due to the small sample size.