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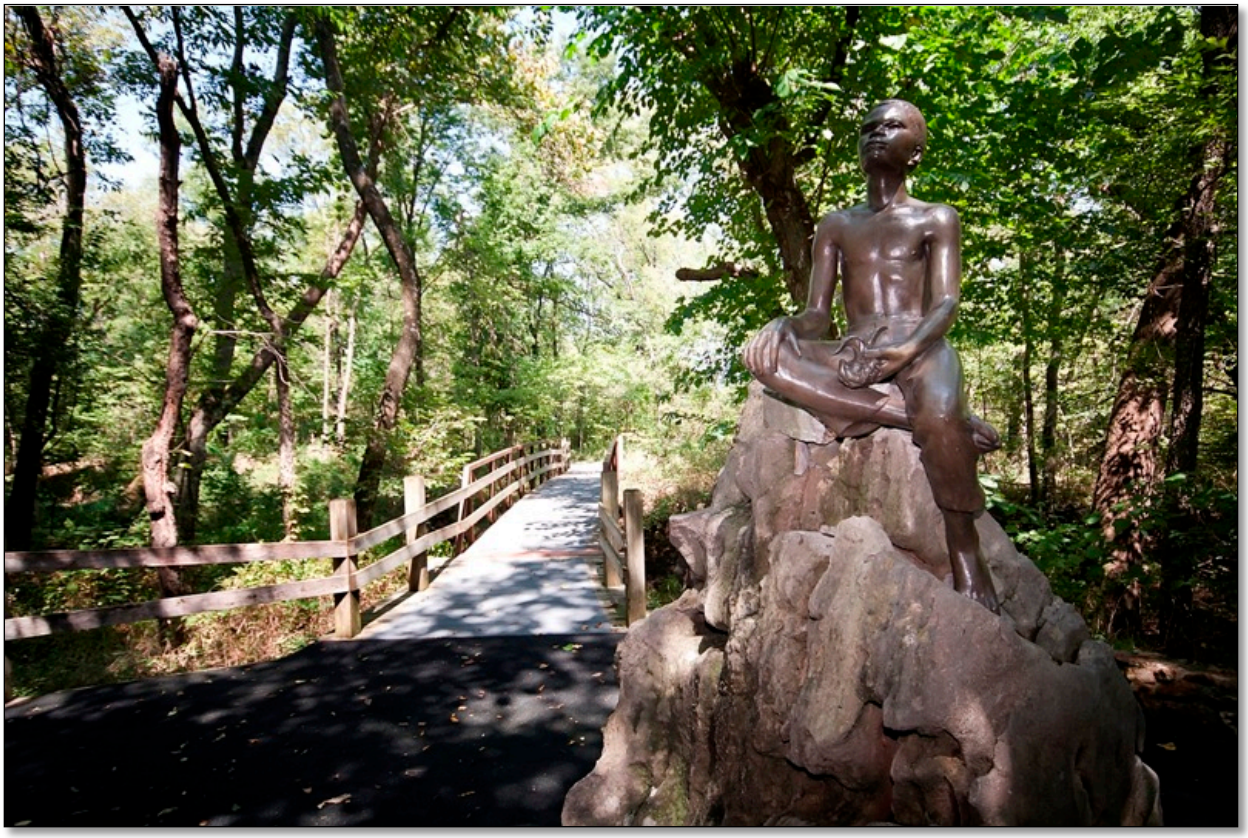
Natural Resource Stewardship and Science

Vegetation Classification and Mapping of George Washington Carver National Monument

Project Report

Natural Resource Report NPS/GWCA/NRR—2013/648



ON THE COVER
Boy Carver Statue
Photograph by: Robert Amendola, Courtesy of George Washington Carver National Monument

Vegetation Classification and Mapping of George Washington Carver National Monument

Project Report

Natural Resource Report NPS/GWCA/NRR—2013/648

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract/Executive Summary

George Washington Carver National Monument (GWCA) is situated on the original Moses Carver homestead, where George Washington Carver spent about ten years of his early life. Although the plant communities were almost certainly highly disturbed during that time, Carver was positively influenced by the beauty and variety of his natural surroundings.

A vegetation classification and mapping project was initiated in 2010 and completed in 2012. Protocols and products were produced following National Park Service Vegetation Mapping Program guidelines. Classification was based on sixteen quantitative field plots, which were placed across GWCA in a stratified random manner based on qualitative field observation points and viewing of air photos. Mapping was based on photo-interpretation of both leaf-on and leaf-off air photos. Accuracy assessment points obtained during 2012 verified that the map is nearly 100% accurate.

Restored tallgrass prairie covers 134 acres (54.1 ha), or 57% of the park. An additional 54 acres (21.7 ha), or 23% of GWCA, is in ruderal woodland and forest. This type includes a central area that shades an interpretive trail along Carver Creek and Williams Branch, two perennial, spring-fed streams between the visitor's center and a replicated house similar to the one Carver lived in during part of his stay at the homestead. The remainder of the park is in early successional grassland or shrubland (27 acres or 11 ha or 11%) or is developed (22 acres or 8.87 ha or 9%).

Introduction

George Washington Carver National Monument Vegetation Mapping Project

George Washington Carver National Monument (GWCA) Vegetation Mapping Inventory Project was a cooperative initiative involving the Missouri Resource Assessment Partnership (MoRAP) at the University of Missouri, the Heartland Inventory and Monitoring Program (HTLN) of the National Park Service (NPS), and park managers and resource specialists. MoRAP provided the classification and mapping and HTLN provided accuracy assessment and overall project coordination. All aspects of the project conform to overall requirements set forward by the National Park Service Vegetation Inventory Program (see http://science.nature.nps.gov/im/inventory/veg/index.cfm).

The project was initiated because accurate maps of existing vegetation facilitate natural and cultural resource management and interpretation. GWCA offers opportunities for restoration of tallgrass prairie communities over deep, tillable soils, which are rare on the modern landscape. The natural landscapes, including woodlands and prairies, also influenced George Washington Carver in his youth, and thus were significant in serving as the basis for his lifelong interest in the natural world.

Each NPS Vegetation Mapping Inventory Project has three major components: classification, mapping, and map accuracy assessment. This report provides details on each of these fundamental elements.

USGS-NPS Vegetation Mapping Program

The National Vegetation Inventory Program is an interagency initiative established to inventory, classify, describe, and map vegetation in National Park units and other areas across the United States. It is administered by the NPS Natural Resources Information Division, and provides baseline vegetation information to the NPS Inventory and Monitoring Program (I&M).

Vegetation Inventory Program scientists have developed procedures for classification, mapping, and accuracy assessment (Lea 2011; Lea and Curtis 2010). Use of the National Vegetation Classification System (NVCS) as the standard classification is central to fulfilling the goals of this national program. This system:

- is vegetation based;
- uses a systematic approach to classify a continuum;
- emphasizes natural and existing vegetation;
- uses a combined physiognomic-floristic hierarchy;
- identifies vegetation units based on both qualitative and quantitative data; and
- is appropriate for mapping at multiple scales.

The use of the NVCS and the standardized vegetation mapping protocols facilitates effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs. In addition they can be used to provide a structure for framing and answering

critical scientific questions about vegetation communities and their relationship to environmental conditions and ecological processes across the landscape.

Before 1994, NVCS development was led by The Nature Conservancy (TNC), and further development was then passed on to the newly formed NatureServe organization. A network of state and regional ecologists involving dozens of individuals worked on the classification (TNC and ESRI 1994; Grossman et al. 1998). The NVCS is currently supported and endorsed by multiple federal agencies, the Federal Geographic Data Committee (FGDC 2008), NatureServe, state heritage programs, and the Ecological Society of America. Refinements to the classification have occurred in fits and spurts over the past decade, with funding from various federal and state agencies. A formal process for review of proposed revisions is in place (see Jennings et al. 2009), and the most accessible source for the NVCS is provided by NatureServe Explorer (http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol).

Vegetation Mapping Program Standards

The NPS I&M Program established guidance and standards for all vegetation mapping projects in a series of documents.

Protocols

- documenting a National Vegetation Classification System (TNC and ESRI 1994)
- standards for field methods and mapping procedures (Jennings et al. 2009; Lea 2011)
- producing rigorous and consistent accuracy assessment procedures (Lea and Curtis 2010)
- establishing standards for using existing vegetation data (TNC 1996)

Standards

- National Vegetation Classification Standard (FGDC 2008)
- Spatial Data Transfer Standard (FGDC 1998)
- Content Standard for Digital Geospatial Metadata (FGDC 1998)
- United States National Map Accuracy Standards (USGS 1999)
- Integrated Taxonomic Information System (http://www.itis.gov/)
- program-defined standards for map attribute accuracy and minimum mapping unit

A 12-step guidance document provides details that cover the entire process with links to information extracted or summarized from publications described above (National Parks Service 2011, available at http://science.nature.nps.gov/im/inventory/veg/docs/Veg_Inv_12step_Guidance_v1.1.pdf). Product specifications are also provided in a document (National Park Service 2011a, available at http://science.nature.nps.gov/im/inventory/veg/docs/Product_Specifications.pdf).

George Washington Carver National Monument

The monument is located southwest of Joplin, MO (Figure 1) and consists of the original 237 acre Moses Carver homestead. The historic landscape probably consisted almost entirely of native grasslands or open savannas, with wetter grasslands along upland drainage ways (Annis et al. 2011). According to the Springs of Genius study (Harrington et al. 1999), by the 1860-1870s "the conversion of prairie to agricultural purposes would have been nearly complete…by the late 1870s there was probably very little uncompromised prairie left on the Carver farm. At least 100

acres had been developed as fields. The remaining open land was probably intensely grazed. … What prairie remained on the Carver farm would most likely have been restricted to fence rows, hedges and patches of marginal land used for pasture and hay production. These remnants would be significantly different from pre-settlement prairie, but because the composition of the pre-settlement prairie is unknown, the full extent of the changes cannot be determined."

In 1985, NPS began a restored tallgrass prairie program, and since then different methods have been used at different times to restore native grasses and forbs on former cropland areas. Management activities have included seeding, mowing, haying, and prescribed fire. Some areas purchased more recently have not yet been restored and consist of non-native grasses and forbs as well as successional woody species. Successional woodlands have also grown up adjacent to upland waterways. A man-made pond and small garden plot add diversity to the park. Invasive species, such as tall fescue (*Schedonorus phoenix*), smooth sumac (*Rhus glabra*), multiflora rose (*Rosa multiflora*), and Japanese honeysuckle (*Lonicera japonica*) are common (Annis et al. 2011). Several birds of continental concern are fairly common nesting species within the park, including the Dickcissel (*Spiza americana*), Indigo bunting (*Passerina cyanea*), and Carolina wren (*Thryothorus ludovicianus*) (Peitz et al. 2009). Streams also support high quality, diverse fish communities (Annis et al. 2011). A few significant prairie remnants remain in the general area of GWCA, and restored grasslands at the park may be valuable to a variety of native grassland flora and fauna.

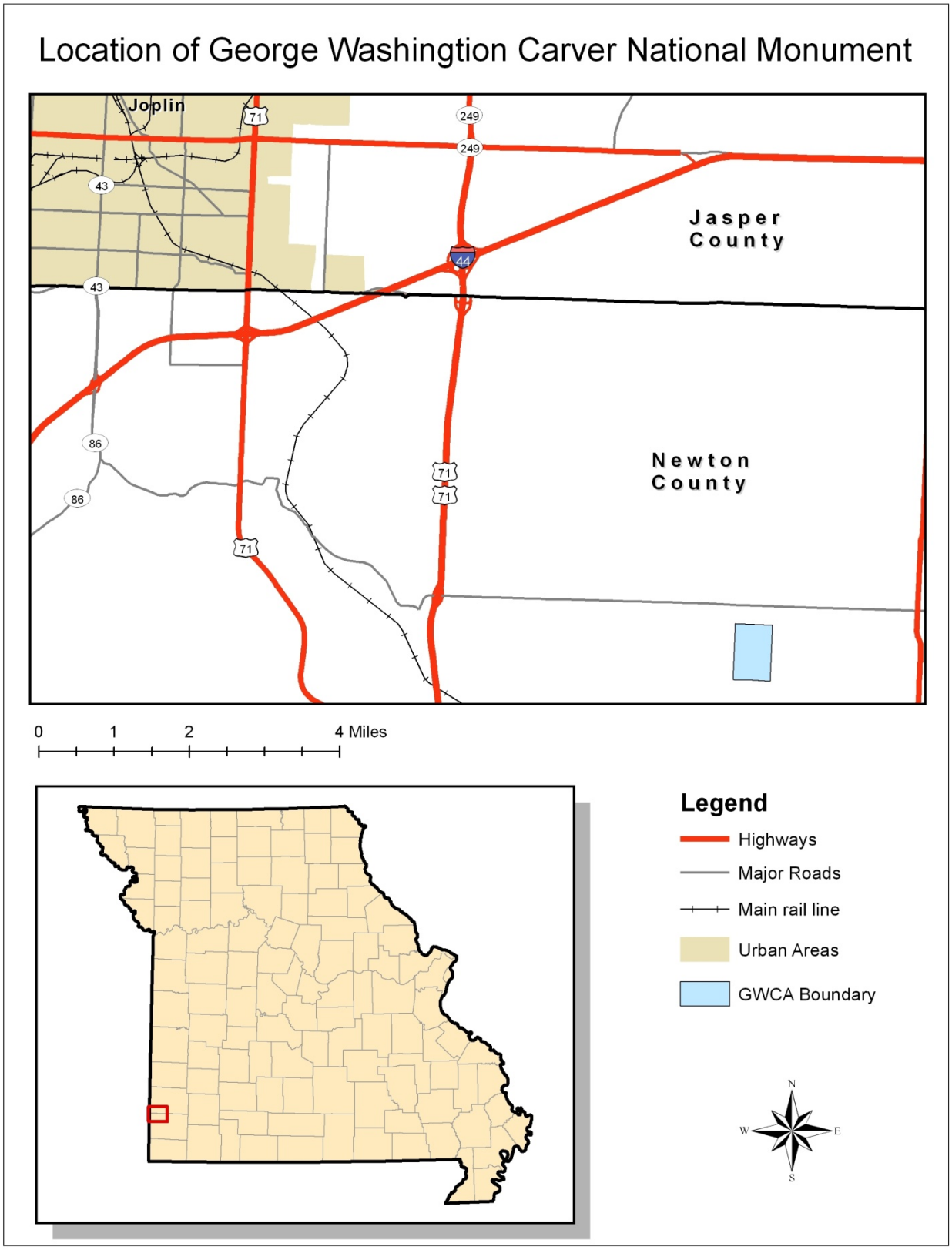


Figure 1. Location of George Washington Carver National Monument in Newton County, Missouri.

Project Statistics

Field Work Summer 2011:

Plot Sampling = 16

Plots sampled in June 2011 by MoRAP staff

Accuracy Assessment Points = 16

All collected in June 2012 by Heartland Inventory and Monitoring Network staff

Observation Points = 27

Collected between August 2009 and December 2010 by MoRAP staff

Classification:

1 NVC Plant Association
3 Park Special Vegetation Classes
1 Non-Vegetated Land-Use Class

GIS Database 2011 - 2012:

George Washington Carver National Monument = 237 acres (96 hectares)

Base Imagery used for mapping (acquired by MoRAP):

2009, Newton County, MO, leaf-on, true color, 1 m
2009, Newton County, MO, leaf-on, 3-band CIR, 1 m
2007-2009, Newton County, MO, true color, leaf-off, 2 foot

Additional Imagery acquired and viewed by MoRAP:

2007, Newton County, MO, leaf-on, true color, 1 m
2006, Newton County, MO, leaf-on, true color, 2 m
2005, Newton County, MO, leaf-on, true color, 2 m
2003, Newton County, MO, leaf-on, CIR, 1 m

Minimum Mapping Unit = 0.5 hectare
Minimum Patch Size=.007 hectares
Total Size = 38 Polygons
Average Polygon Size = 6.58 acres (2.66 hectares)
Overall Thematic Accuracy = 100%
Project Completion Date: 11/2012

Methods

George Washington Carver National Monument, at 237 acres, is a small park as defined by sampling design protocols (TNC and ESRI 1994), so most of the mapped vegetation polygons were visited for this study. Since access to private lands outside of the park was not ensured, the project boundary consisted of the boundary of the park itself (Figure 2). Five major tasks were identified and completed, including:

1. Plan, gather data, and coordinate tasks;

2. Survey GWCA to understand and sample the vegetation;

3. Classify the vegetation using the field data to NVC standard associations and alliances and crosswalk these to recognizable map units as far as possible;

4. Acquire current digital imagery and interpret the vegetation from these using the classification scheme and a map unit crosswalk; and

5. Assess the accuracy of the final map product.

All protocols for this project are outlined by NPS and important sections are summarized or linked at http://science.nature.nps.gov/im/inventory/veg/index.cfm). Drilling down to additional linked documents can be accomplished via the link to the National Park Service 12-step guidance document on that web site (National Park Service 2011). Important references include TNC and ESRI (1994), Jennings et al. (2009), Lea (2011), and Lea and Curtis (2010).

Planning, Data Gathering, and Coordination

A Natural Resource Condition Assessment (NRCA) was completed for GWCA and published in 2011 (Annis et al. 2011). During the course of that project, the current vegetation mapping project was discussed with appropriate park staff in coordination with Heartland Network staff and MoRAP staff. A proposal for vegetation mapping was subsequently completed and approved by National Park Service National Vegetation Mapping staff. Based on that proposal, MoRAP was responsible for classification, plot sampling, mapping, and development of digital databases. The Heartland Network was responsible for oversight of MoRAP activities in concert with NPS Mapping Program staff, and coordinated Accuracy Assessment tasks. GWCA staff provided logistical and technical support, and helped coordinate field activities.

Field Survey

The field methods used in sampling and classifying the vegetation followed the methodology outlined by the NPS Vegetation Mapping Program team (see Jennings 2009 et al., Lea 2011, National Park Service 2011). The application of these methods to GWCA is outlined below.

A generalized land cover classification was available from the GWCA NRCA (Annis et al. 2011), and this information together with NAIP air photos, digital soils information, and field-collected observation data were used to inform the design of field surveys and ultimately vegetation classification and mapping (Figure 3). Observation points consisted of brief visits

(fewer than 15 minute) by ecologists from MoRAP where general information on vegetation structure and composition was noted.

Vegetation data were collected at 16 plots by MoRAP staff in June of 2011 (Figure 4). In the lab, the locations of plots were randomly placed within the following general strata based on field observation points and viewing of air photos and digital soils surveys (available at http://soils.usda.gov/survey/geography/ssurgo/): woodland and forest over moist soils, woodland and forest over better-drained soils, shrubland and open woodland, restored prairie, and non-native fescue grassland. Plots were located >30 m from an obvious land cover edge, and for each point there was at least one alternate, should the original point be determined unusable in the field (e.g. close to an un-mapped trail or road, stand too small). The stratified random plot location information was loaded into a GPS and workers navigated to the plot in the field for field sampling.

Woodlands and forests were sampled with a 10 m x 40 m plot (400 sq m), shrublands and open woodlands with a 10 m x 20 m plot (200 sq m), and herbaceous vegetation with a 5 m x 20 m plot (100 sq m). Minimal flagging was used to mark the plot. Data were collected using a plot survey form (Appendix B). The survey form includes sections for plot location and description, as well as vegetation and environmental information about the plot.

Vegetation sampling included information about structure and physiognomy, with leaf phenology, leaf type and physiognomic class recorded for the dominant vegetative stratum. Cover data was collected for the following strata, where applicable.

T1 = Emergent Tree (overstory) >30 m
T2 = Tree Canopy (overstory) 20-30 m
T3 = Tree Subcanopy (midstory) 5-20 m
S1 = Tall Shrub (understory woody species, tree and shrub) 1-5 m
S2 = Short Shrub (woody species, tree and shrub) <1 m
H = Herbaceous species, does not include S2

Additionally, cover was recorded in modified Daubenmire (1959) cover classes for each species by strata (Table 1).

Table 1. Canopy cover classes used for quantitative vegetation sampling.

Cover Class Codes	Range of Cover (%)
7	95-100
6	75-95
5	50-75
4	25-50
3	5-25
2	1-5
1	0-0.99

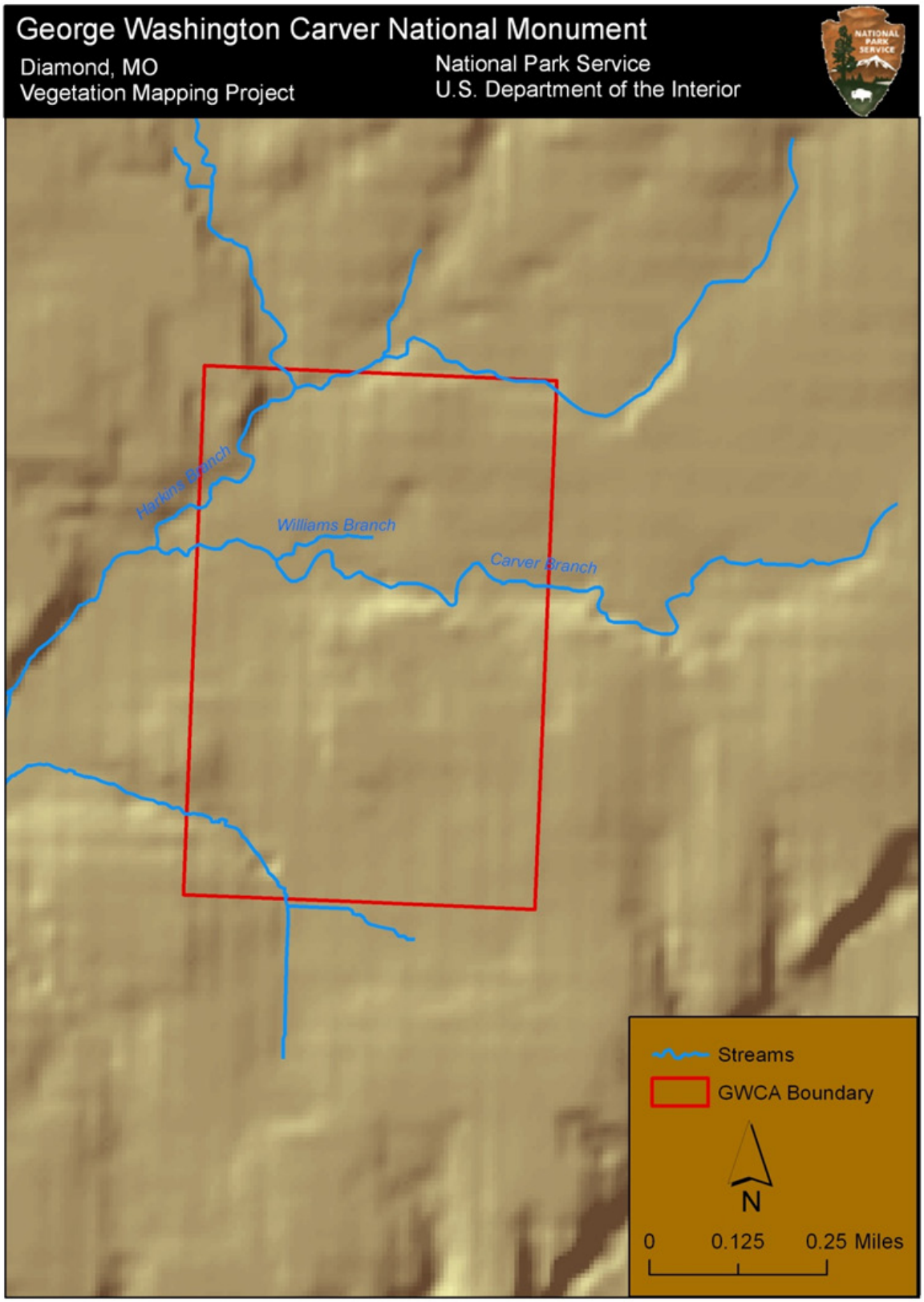


Figure 2. Map of the George Washington Carver National Monument.

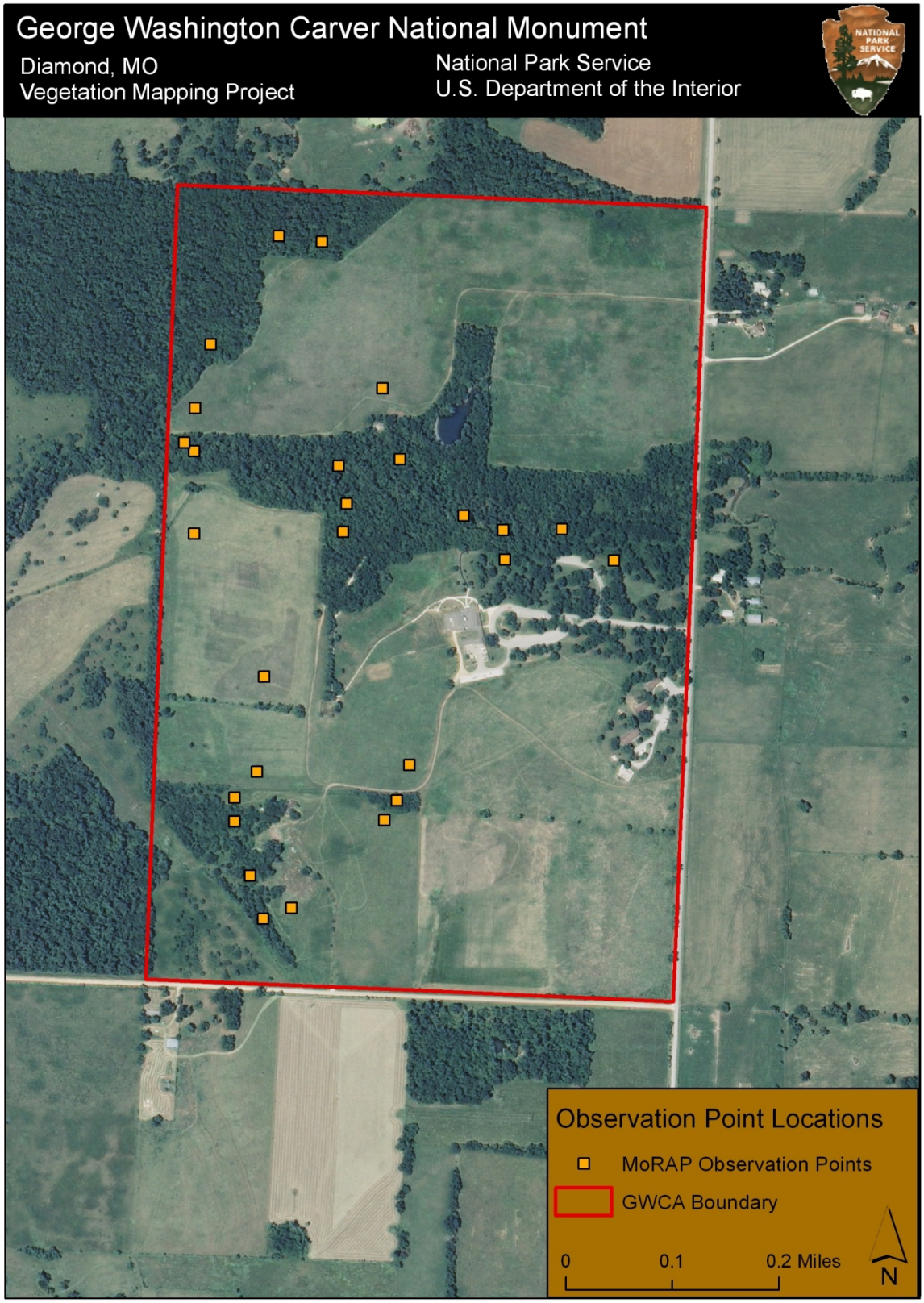


Figure 3. Location of 27 observation points collected in George Washington Carver National Monument.

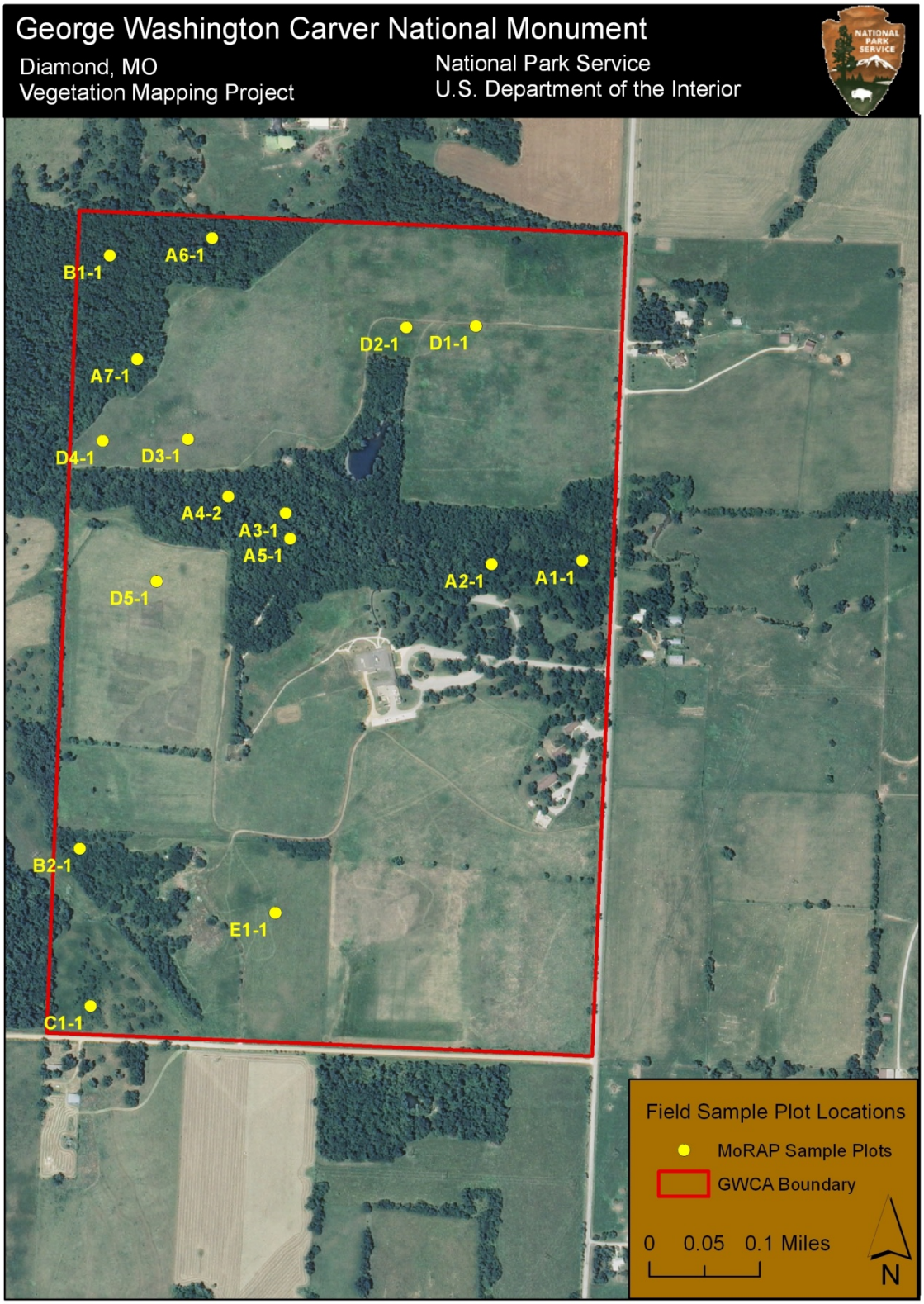


Figure 4. Location of 16 sampled plots within George Washington Carver National Monument.

Vegetation Classification

All recorded data were entered into the NPS PLOTS v3 database (available at http://science.nature.nps.gov/im/inventory/veg/plots.cfm), a Microsoft Access-derived program. The PLOTS database was developed for the NPS National Vegetation Mapping Program so that data entry fields mirror the standard field form. Data entry was facilitated by assigning each plant taxon a unique, standardized code and name based on the PLANTS database developed by Natural Resources Conservation Service in cooperation with the Biota of North America Program (USDA and NRCS 2009, available at http://plants.usda.gov/java/). Data were thoroughly proofed after entry to minimize errors.

Plot data were subject to cluster analysis and ordination in order to help inform classification. Species-specific data were collected in multiple strata using cover classes, but for the purpose of analysis, the cover values for each species were combined into a single value using the midpoint of the cover class. The formula for percent overlap used to combine the strata cover values for each species was

$$1 - \prod \left(1 - \frac{\%cover}{100}\right)$$

.

Use of this formula reduces the effects of overlapping cover in various strata. We used a log transformation to standardize cover values using the formula log(cover + 1). Bray-Curtis dissimilarity was used as the distance metric for the cluster and ordination analyses (Legendre & Legendre 1998). Clustering was performed using the hierarchical clustering algorithm known as flexible Beta with a $\beta = -0.25$ (Lance & Williams 1966, Maechler et al. 2011). Non-metric multidimensional scaling was used to develop the ordination (Legendre & Legendre 1998, Roberts 2010).

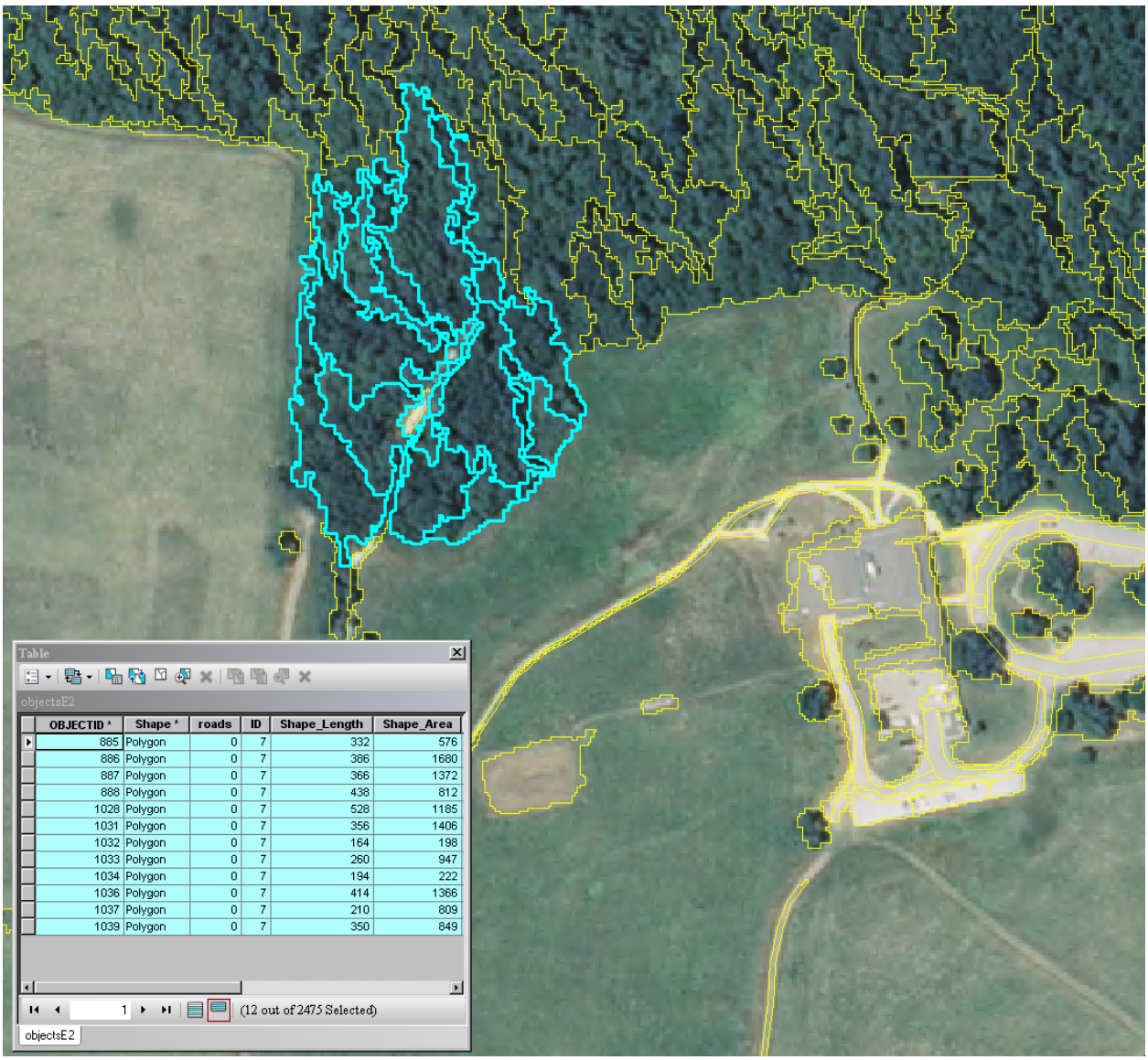
Descriptive information on NVC community composition concepts and classification were obtained from the NatureServe Explorer (2012) website available at http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol. Where the observed GWCA vegetation did not fit descriptions of natural associations described for Missouri, ruderal types were assigned.

Once the classification was finalized, a dichotomous key was developed by MoRAP for use during the Accuracy Assessment (Appendix C). For types with an NVC assignment, the full NVC hierarchical classification and global descriptions are available in the results section. In addition, the final described types were linked to map classes for use in the photo-interpretation and mapping portions of the project.

In the future, GWCA classification plot data may be used by NatureServe to update and improve world-wide (i.e., global) descriptions of the NVC plant associations, especially for ruderal types which are generally lacking for the Midwest. GWCA specific (i.e., local) descriptions were written based on GWCA plot, observation, and accuracy assessment data.

Digital Imagery and Interpretation

The mapping component was produced by identifying land cover in a three-step process: (1) image objects were generated at 1 m resolution using e-Cognition applied to stacked leaf-on and leaf-off air photos, (2) image objects were coded with land cover classes on-screen, and (3) image objects were cut and corrected via heads-up digitizing at a display scale of not more than 1:1,000 against a back-drop of air photos. Imagery was the most recent available from the National Agriculture Imagery Program (NAIP; see http://www.fsa.usda.gov/Internet/FSA_File/naip_2009_info_final.pdf). This included 2009 leaf-on true color and 4-band Color infrared (CIR) 1 m resolution photos, and 2007-2009 leaf-off true color 2 foot resolution photos. All images were stacked before image objects were generated (Figure 5).



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886	Polygon	0	7	386	1680
887	Polygon	0	7	366	1372
888	Polygon	0	7	438	812
1028	Polygon	0	7	528	1185
1031	Polygon	0	7	356	1406
1032	Polygon	0	7	164	198
1033	Polygon	0	7	260	947
1034	Polygon	0	7	194	222
1036	Polygon	0	7	414	1366
1037	Polygon	0	7	210	809
1039	Polygon	0	7	350	849

Figure 5. Example of polygon digitization process.

Accuracy Assessment

Thematic accuracy assessment (AA) was conducted by the Heartland Inventory and Monitoring Network (HTLN). Methods and analysis for the accuracy assessment of vegetation mapping at George Washington Carver National Monument (GWCA) were based on National Park Service standards (Lea and Curtis 2010). Thematic or attribute accuracy of mapped vegetation classes were assessed independently following the completion of the vegetation mapping inventory by the lead authors. Representative sites were identified and visited in the field to determine if interpreted mapped classes were correctly assigned by field observers using the dichotomous key to mapped current vegetation types (Appendix C). Identifying the degree of correspondence between field observations and mapped attributes provides a measure of the maps suitability for different applications.

Accuracy assessment consisted of first evaluating the spatial pattern (total area and number of polygons) of each mapped vegetation class. The number of samples in each class was selected from five possible scenarios (Table 2). Accuracy assessment was restricted to natural vegetation map classes, thus omitting developed areas and standing water. Once the appropriate sampling scenario for each map class was determined, site selection was performed using a geographical information system (ArcGIS 10.0).

Table 2. Target number of Accuracy Assessment samples per map class based on number of polygons and area.

Scenario	Description	Polygons in class	Area occupied by class	Recommended number of samples in class
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.	>30	>50 ha	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.	<30	>50 ha	20
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.	>30	<50 ha	20

Table 2. Target number of Accuracy Assessment samples per map class based on number of polygons and area (continued).

Scenario	Description	Polygons in class	Area occupied by class	Recommended number of samples in 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.	5 - 30	<50 ha	5
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).	<5	<50 ha	Visit all and confirm

Random sample points were generated in ArcGIS. Points were buffered 40 meters from the park boundary and 80 meters from another point. The minimum mapping unit used in delineating vegetation polygons was 0.5 hectare. All random points were selected within the park boundary to avoid any private land issues.

Randomly selected site locations were loaded onto a Garmin GPS unit for field navigation (Figure 6). All accuracy assessment field work was completed on June 26, 2012. Field staff was provided with a GPS unit, dichotomous key for mapping vegetation map classes and vegetation class definitions.

Plot shape and size varied according the extent of the vegetation class patch containing the sample point. Circular 0.25 hectare (28 m radius) plots were used for larger patches while circular 0.1 hectare plots were used for small patches approaching the minimum mapping unit. A circular plot size of 0.5 hectare (40 m radius) was used to capture information for a single large homogenous patch. In all cases, plot size exceeded the minimum patch size for GWCA.

Field staff recorded plot size and shape, positional accuracy and vegetation classification at each point (Accuracy assessment field form, Appendix D). In addition, comments regarding the plot location, plot size and vegetation were recorded on the field form. Field data from the 16 points

were entered into to the PLOTS database and underwent quality assurance/quality control (QA/QC) verification. In addition, the associated project geodatabase was updated in ArcGIS to reflect any changes to the point location due to offsets made in the field. All classification and spatial field observations were compared with the vegetation map and AA point locations for any differences.

Upon completion of QA/QC, the accuracy assessment analysis was performed. All analysis and evaluation of producer and user accuracy was conducted using the AA Contingency Table Calculation Spreadsheet (http://science.nature.nps.gov/im/inventory/veg/guidance.cfm). Statistics and calculations performed in the spreadsheet are presented in Table 3.

Table 3. Summary of the Accuracy Assessment statistics used at George Washington Carver National Monument.

Statistic	**Description**
User's Accuracy	The fraction of the accuracy assessment observations in a map class that were found to have the correct vegetation class in the field.
Producer's Accuracy	The fraction of the accuracy assessment observations in a vegetation class in the field that were found to be mapped correctly.
Overall Accuracy	The fraction of accuracy assessment observations within all map classes that were correctly mapped.
Kappa Index	Another measure of overall accuracy, which takes into account the probability that mapped polygons will be correct due to random chance.

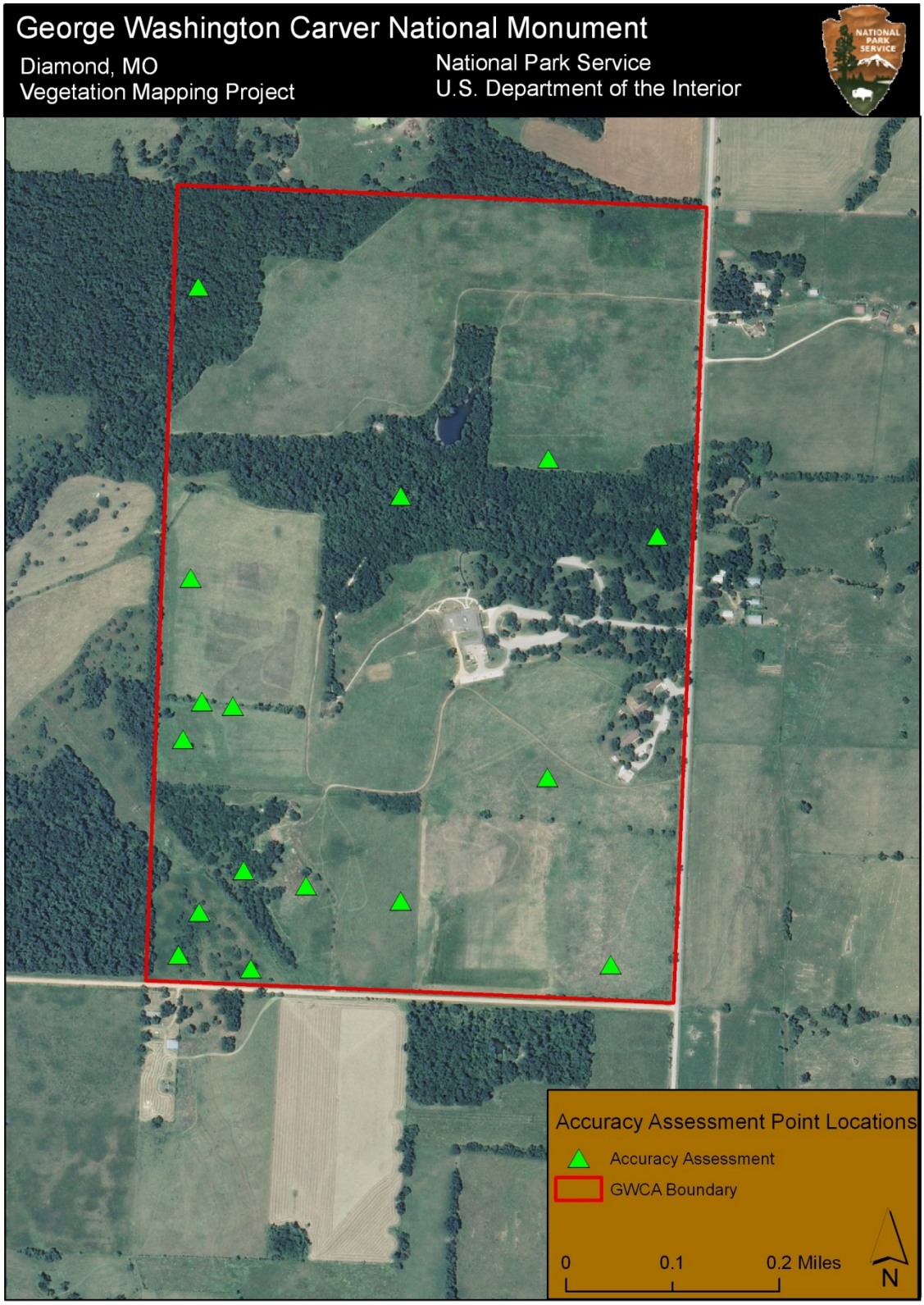
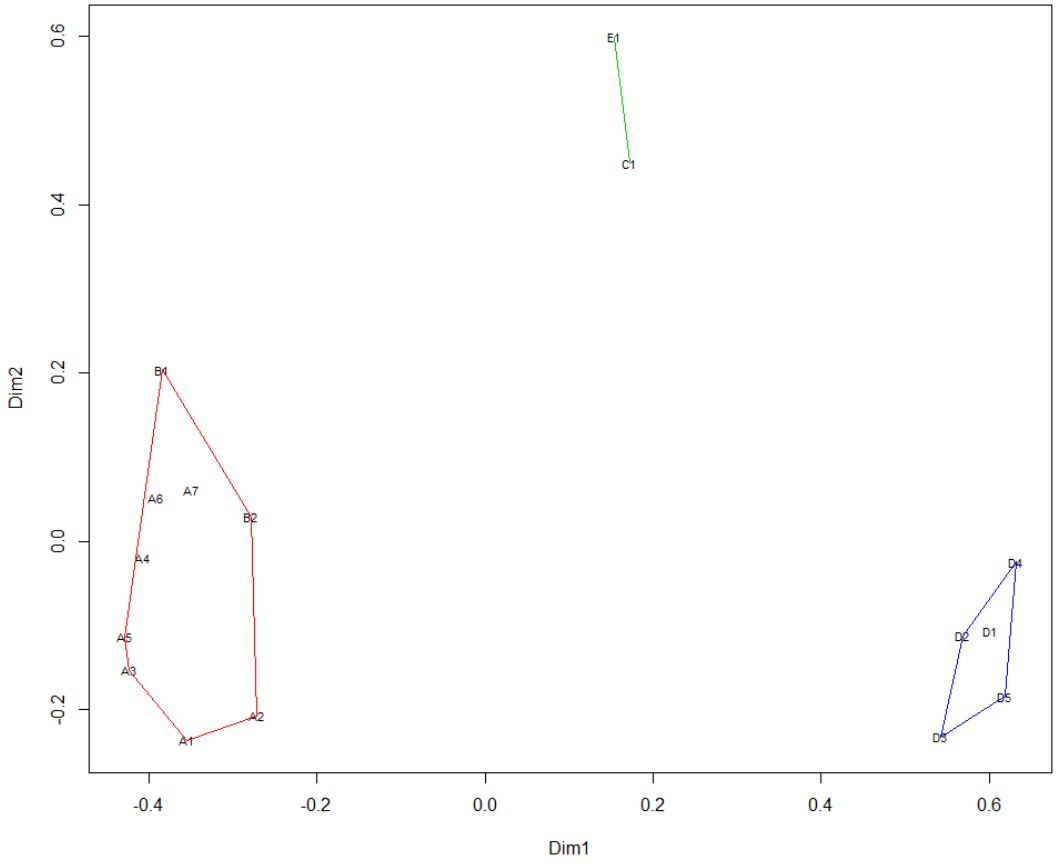


Figure 6. Accuracy Assessment points for George Washington Carver National Monument.

Results

Vegetation Classification

Four vegetation types were identified at GWCA based on ordination and cluster analysis results (**Figure 7**). Developed land, undivided by type, made up a fifth class. These results are generally in line with previous evaluations of the park (Annis et al. 2011, Jones 2004). Neither qualitative observation points nor quantitative plot data analysis supported the separation of a mesic prairie type from a drier type, as tentatively suggested by Jones (2004) and repeated by Annis et al. (2011). Sycamore (*Platanus occidentalis*) is a visually striking forest tree species with relatively large individuals adjacent to Carver Branch and to a lesser extent Harkins Branch. However, more mesic areas are usually not wider than 5 m from water's edge, and did not warrant sampling as a potentially separate forest type. During the sampling efforts a total of 171 taxa were recorded (Appendix E). A plant list provided by Jones (2004) listed 645 taxa, including 114 introduced species.



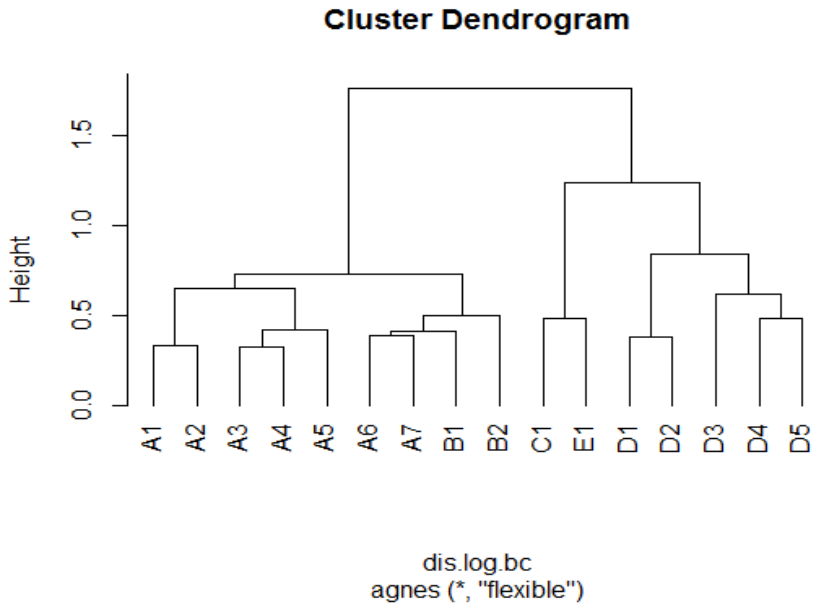


Figure 7. Ordination and cluster dendrogram for 16 plots sampled in George Washington Carver National Monument. Plots labeled A and B were assigned to a ruderal woodland and forest class, C was

in a ruderal shrubland class, D was restored tallgrass prairie plots, and E was a non-native ruderal grassland.

Digital Imagery and Interpretation

Five map units that corresponded directly with the classified vegetation plus developed land were defined (Table 4). The developed land map class was a catch-all that included all areas without semi-natural vegetation.

Vegetation Map

A total of 237 acres (96 hectares) are within the accepted boundaries of GWCA (Figure 8). The standard minimum mapping unit for NPS vegetation mapping projects is defined as 0.5 hectare, although several mapped polygons were smaller for GWCA. Restored tallgrass prairie made up most of the current vegetation of the park, and accounted for 134 acres (54.1 ha) in eight polygons, or 56.5% of the total area. Ruderal woodland and forest was the next most abundant with 53.6 acres in eight polygons, or 22.6% of the park. Non-native ruderal grassland and ruderal shrubland accounted for 25 acres (10.1 ha or 10.5%) and 2.2 acres (0.9 ha or <1%) of the area of the park, respectively. Developed land accounts for 21.9 acres (8.9 ha), or 9.2% of the park. A total of 36 polygons were mapped, with an average area of 15.2 acres (6.1 ha).

Accuracy Assessment

The 2012 accuracy assessment for GWCA was limited to the 237 acres (96 hectares) within the park boundary. A total of 16 points were required to accurately evaluate the four natural vegetation map classes identified in the park.

Navigational error (positional accuracy) of the GPS unit ranged from 2 – 4 meters for the 16 accuracy assessment points. Only a single original point required a spatial offset to ensure the entire plot was composed of a homogenous map class. The new GPS coordinates for the offset were updated in both the project geodatabase as well as the tabular database.

Table 4. Mapped types identified at George Washington Carver National Monument.

NVC Identifier	Mapped Type Name	Scientific Name / Description	Number of Polygons	Acres	Hectares
Forest and Woodlands					
None assigned	Ruderal Woodland and Forest	*Juglans nigra-Celtis occidentalis* Woodland and Forest	8	53.63	21.7
Shrubland Vegetation					
None assigned	Ruderal Shrubland	Early successional shrubs and small trees with non-native grasses	7	2.2	0.89
Herbaceous Vegetation					
CEGL004048	Non-native Ruderal Grassland	*Schedonorus phoenix* Herbaceous Vegetation	8	25.02	10.12

Table 5. Mapped types identified at George Washington Carver National Monument (continued).

NVC Identifier	Mapped Type Name	Scientific Name / Description	Number of Polygons	Acres	Hectares
None assigned	Restored Tallgrass Prairie	*Andropogon gerardii* - *Sorghastrum nutans* Herbaceous Vegetation	8	133.68	54.1
Land Use/Land Cover					
None assigned	Developed Land	buildings, parking lots, picnic areas, roads, cemetery, garden, sewage application field	4	21.92	8.87
None assigned	Water	man-made, spring-fed pond	1	0.54	0.22
Total Land Use/Land Cover			5	22.46	9.09
Total Natural Vegetation			31	214.53	86.81
Totals			**36**	**236.99**	**95.9**

Overall accuracy of the final error matrix was 100% for the natural vegetation map classes at GWCA (Appendix A). All four natural vegetation map classes fell into sampling scenario E, thus occurring both in low frequency and low abundance on the park. Each type was readily discernible in the field using the dichotomous key.

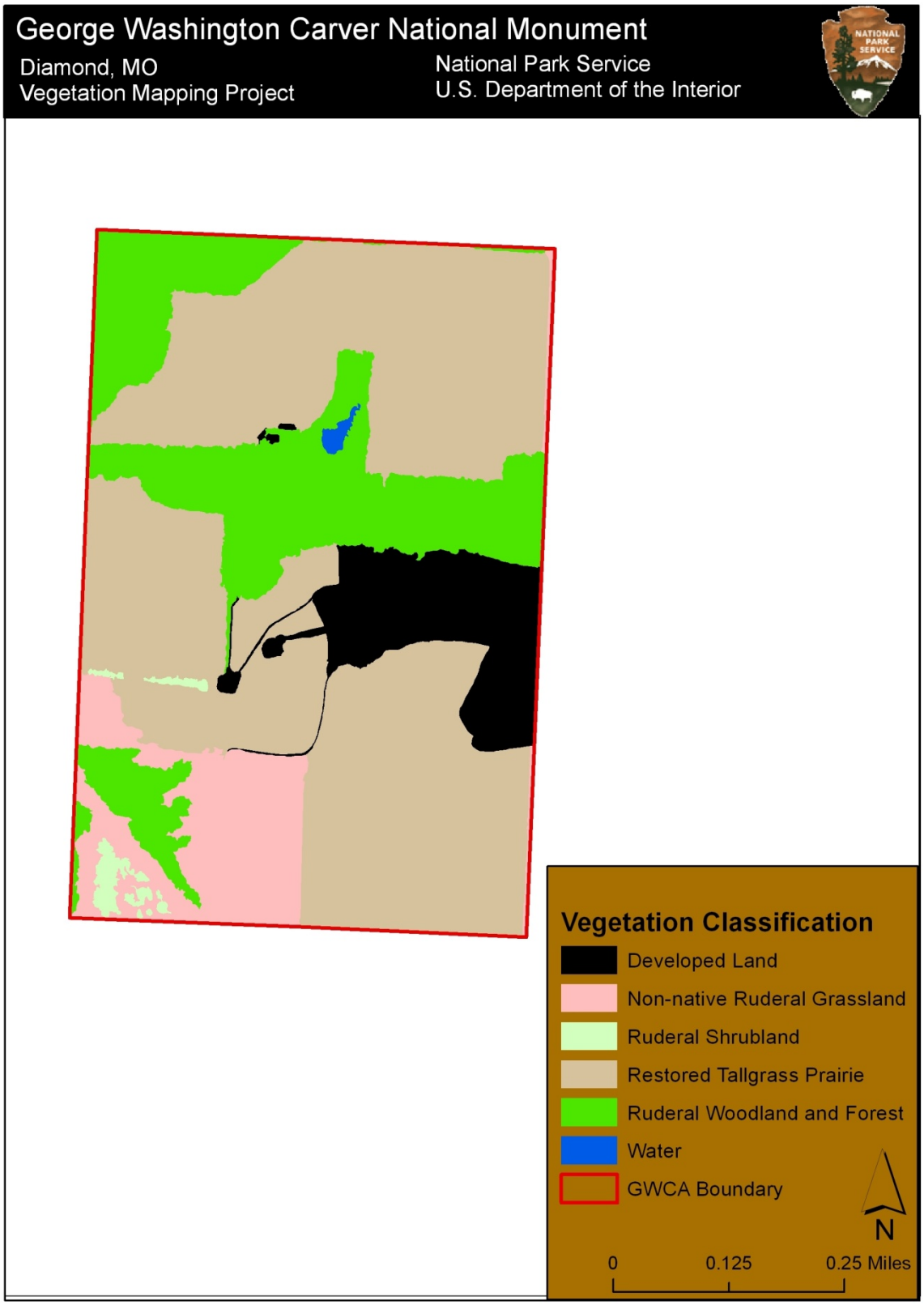


Figure 8. Vegetation map of George Washington Carver National Monument.

Vegetation Associations

Mapped Type Name: Ruderal Woodland and Forest
Macrogroup: Eastern North American Ruderal Forest and Plantation (MG013)
Group: North & Central Hardwood & Conifer Ruderal Forest Group (G030)
Association: None assigned
Type Common Name: BlackWalnut-Common Hackberry Woodland and Forest
Type Scientific Name: *Juglans nigra –Celtis occidentalis* Woodland and Forest

Figure 9. Ruderal Woodland and Forest at George Washington Carver National Monument.

Global Summary: Ruderal woodlands and forests of moist soils in the Midwest often contain black walnut (*Juglans nigra*) and common hackberry (*Celtis occidentalis*) among the dominant species. However, these types of successional communities have not been well-described within the National Vegetation Classification. Other species common on disturbed bottomlands include red mulberry (*Morus rubra*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), and slippery elm (*Ulmus rubra*) (Figure 9).

Environmental Description: At GWCA, this type was mainly on soils of headwater or spring-fed drainages, although they are generally only temporarily, rather than seasonally flooded.

These areas have mainly been plowed for row crop production or at least cleared for grazing or other land uses in the past. A small area in the far northwestern side of the park has better-drained soils according to county soil surveys.

Vegetation Description: Early successional and invasive species were characteristic of this type. Black walnut (*Juglans nigra*), common hackberry (*Celtis occidentalis*), slippery elm (*Ulmus rubra*), American ash (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), Osage orange (M*aclura pomifera*), and honeylocust (*Gleditsia triacanthos*) were often important. Coralberry (*Symphoricarpos orbiculatus*) and multiflora rose (*Rosa multiflora*) were common shrubs, and Virginia creeper (*Pathenocissu quinquefolia*) and poison ivy (*Toxicodendron radicans*) were common vines. Japanese honeysuckle (*Lonicera japonica*) formed a mat on the forest floor in some locations, and other non-native invasive species such as winter creeper (*Euonymus fortunei*), bromes (*Bromus tectorum, B. arvensis*), ground ivy (*Glechoma hederacea*), and tall fescue (*Schedonorus phoenix*) were locally dominant ground flora. Communities along Carver Creek and Williams Branch in the central part of the park had more large trees versus other areas, and sycamore (*Platanus occidentalis*) formed an aesthetically pleasing gallery of large trees at water's edge in some places. Succession in this area may lead to more mature forests that fit within the NVC *Fraxinus pennsylvanica – Celtis* spp.-*Quercus* spp.-*Platanus occidentalis* Bottomland Forest (CEGL002410) over the next few decades. Communities in the southwest portion of GWCA appear more disturbed with fewer large trees and a more open canopy versus other woodlands, and eastern redcedar (*Juniperus virginiana*) was more common (Table 6).

Most Abundant Species:

Table 6. Average cover (for plots where the species occurred) and frequency by layer and species for nine plots taken within Ruderal Woodland and Forest. Only species with at least 0.5% cover in at least two plots are shown.

Ruderal Woodland and Forest			
Scientific Name	**Common Name**	**%Cover**	**Frequency**
Tree			
Juglans nigra	black walnut	40.46	88.9%
Celtis occidentalis	common hackberry	36.65	100.0%
Maclura pomifera	Osage orange	20.41	55.6%
Platanus occidentalis	sycamore	9.00	22.2%
Ulmus rubra	slippery elm	4.59	88.9%
Gleditsia triacanthos	honey locust	4.32	66.7%
Quercus muehlenbergii	chinkapin oak	4.23	44.4%
Quercus macrocarpa	bur oak	2.33	33.3%
Morus rubra	red mulberry	1.57	77.8%
Prunus serotina	black cherry	1.50	66.7%
Fraxinus pennsylvanica	green ash	1.50	33.3%
Juniperus virginiana	eastern redcedar	1.13	44.4%
Robinia pseudoacacia	black locust	1.00	11.1%
Ulmus americana	American elm	0.60	55.6%
Acer negundo	boxelder	0.50	33.3%

Table 5. Average cover (for plots where the species occurred) and frequency by layer and species for nine plots taken within Ruderal Woodland and Forest. Only species with at least 0.5% cover in at least two plots are shown (continued).

Scientific Name	Common Name	%Cover	Frequency
Shrub			
Symphoricarpos orbiculatus	coralberry	24.56	88.9%
Euonymus fortunei	winter creeper	10.38	44.4%
Pathenocissus quinquefolia	Virginia creeper	8.78	100.0%
Rosa multiflora	multiflora rose	6.56	88.9%
Toxicodendron radicans	poison ivy	5.73	77.8%
Smilax bona-nox	saw greenbrier	4.42	77.8%
Prunus hortulana	hortulan plum	3.49	11.1%
Vitis vulpina	frost grape	3.11	88.9%
Ribes missouriense	Missouri gooseberry	2.29	77.8%
Smilax tamnoides	bristly greenbrier	1.39	100.0%
Vitis aestivalis	summer grape	0.50	55.6%
Cercis canadensis	eastern redbud	0.50	33.3%
Sideroxylon lanuginosum	gum bully	0.50	33.3%
Viburnum rufidulum	rusty blackhaw	0.50	22.2%
Herbaceous			
Bromus tectorum	cheatgrass	53.33	33.3%
Lonicera japonica	Japanese honeysuckle	33.50	55.6%
Elymus virginicus	Virginia wildrye	23.25	88.9%
Sanicula canadensis	Canadian blacksnakeroot	15.00	11.1%
Chasmanthium latifolium	Indian woodoats	12.00	44.4%
Bromus arvensis	field brome	6.17	33.3%
Carex jamesii	James' sedge	3.00	22.2%
Silphium perfoliatum	cup plant	3.00	22.2%
Glechoma hederacea	ground ivy	3.00	11.1%
Muhlenbergia sobolifera	rock muhly	3.00	11.1%
Schedonorus phoenix	tall fescue	3.00	11.1%
Solidago gigantea	giant goldenrod	3.00	11.1%
Dichanthelium clandestinum	deertongue	2.94	100.0%
Elephantopus carolinianus	Carolina elephantsfoot	1.75	88.9%
Asplenium platyneuron	ebony spleenwort	1.75	22.2%
Festuca subverticillata	nodding fescue	1.50	55.6%
Desmodium perplexum	perplexed ticktrefoil	1.33	33.3%
Polygonum virginianum	jumpseed	1.13	44.4%
Ageratina altissima	white snakeroot	0.92	66.7%

Table 5. Average cover (for plots where the species occurred) and frequency by layer and species for nine plots taken within Ruderal Woodland and Forest. Only species with at least 0.5% cover in at least two plots are shown (continued).

Scientific Name	Common Name	%Cover	Frequency
Sanicula odorata	clustered blacksnakeroot	0.86	77.8%
Carex blanda	eastern woodland sedge	0.50	100.0%
Phryma leptostachya	American lopseed	0.50	88.9%
Geum canadense	white avens	0.50	77.8%
Viola sororia	common blue violet	0.50	77.8%
Ambrosia trifida	great ragweed	0.50	66.7%
Geum vernum	spring avens	0.50	66.7%
Leersia virginica	whitegrass	0.50	66.7%
Ruellia strepens	limestone wild petunia	0.50	66.7%
Conyza canadensis	Canadian horseweed	0.50	55.6%
Carex amphibola	eastern narrowleaf sedge	0.50	4.4%
Poa sylvestris	woodland bluegrass	0.50	44.4%
Verbesina virginica	white crownbeard	0.50	44.4%
Impatiens spp.	touch-me-not	0.50	33.3%
Phytolacca americana	American pokeweed	0.50	33.3%
Silene stellata	widowsfrill	0.50	33.3%
Verbesina alternifolia	wingstem	0.50	33.3%
Arisaema dracontium	green dragon	0.50	22.2%
Bromus pubescens	hairy woodland brome	0.50	22.2%
Cryptotaenia canadensis	Canadian honewort	0.50	22.2%
Dactylis glomerata	orchardgrass	0.50	22.2%
Desmodium paniculatum	panicledleaf ticktrefoil	0.50	22.2%
Erigeron strigosus	prairie fleabane	0.50	22.2%
Galium aparine	stickywilly	0.50	22.2%
Lactuca floridana	woodland lettuce	0.50	22.2%
Osmorhiza claytonii	Clayton's sweetroot	0.50	22.2%
Pilea pumila	Canadian clearweed	0.50	22.2%
Trillium sessile	toadshade	0.50	22.2%
Vernonia baldwinii	Baldwin's ironweed	0.50	22.2%
Viola pubescens var. *pubescens*	downy yellow violet	0.50	22.2%

Mapped Type Name: Ruderal Shrubland
Macrogroup: Eastern Ruderal Shrubland and Grassland (MG123)
Group: Eastern Ruderal Shrubland and Grassland (G059)
Association: None assigned
Type Common Name: Ruderal Shrubland
Type Scientific Name: Early Successional shrubs and small trees with non-native grasses

Figure 10. Ruderal Shrubland at George Washington Carver National Monument.

Global Summary: Ruderal shrublands occur throughout the Midwest, but have not been described and included within the National Vegetation Classification. The extent of this type on the landscape is not clear. Open lands in the region are largely used for pasture, and efforts are made to suppress woody species. Thus, this type could be relatively uncommon in the modern landscape.

Environmental Description: At George Washington Carver National Monument these areas were former cropland that were converted to pasture with subsequent invasion of woody species, or may represent re-vegetation of soils disturbed by past small-scale mining. This type occurs on former prairie soils (Figure 10).

Vegetation Description: This shrubland was dominated by weedy and early successional species such as Osage orange (*Maclura pomifera*), honeylocust (*Gleditsia triacanthos*), hortulan plum species (*Prunus hortulana*), and Pennsylvania blackberry (*Rubus pensilvanicus*). Non-native tall fescue (*Schedonorus phoenix*) together with annual and short-lived perennial grasses and forbs such as field brome (*Bromus arvensis*) and Canada germander (*Teucrium canadense*) were common (Table 7).

Most Abundant Species:

Table 7. Percent cover for species found in one plot sampled for Ruderal Shrubland.

Ruderal Shrubland		
Scientific Name	**Common Name**	**%Cover**
Shrub		
Maclura pomifera	Osage orange	39.375
Gleditsia triacanthos	honey locust	3.485
Symphoricarpos orbiculatus	coralberry	15
Prunus hortulana	hortulan plum	15
Rubus pensilvanicus	Pennsylvania blackberry	15
Herbaceous		
Schedonorus phoenix	tall fescue	37.5
Bromus arvensis	field brome	3
Teucrium canadense	Canada germander	3
Vernonia baldwinii	Baldwin's ironweed	0.5
Lactuca floridana	woodland lettuce	0.5
Achillea millefolium	common yarrow	0.5
Allium vineale	wild garlic	0.5
Andropogon virginicus	broomsedge bluestem	0.5
Carex bushii	Bush's sedge	0.5
Cirsium altissimum	tall thistle	0.5
Conyza canadensis	Canadian horseweed	0.5
Dactylis glomerata	orchardgrass	0.5
Dianthus armeria	Deptford pink	0.5
Dichanthelium clandestinum	deertongue	0.5
Erigeron strigosus	prairie fleabane	0.5
Trifolium pratense	red clover	0.5
Verbascum blattaria	moth mullein	0.5
Ambrosia artemisiifolia	annual ragweed	0.5
Galium virgatum	limestone bedstraw	0.5
Trifolium campestre	field clover	0.5
Solanum carolinense	Carolina horsenettle	0.5
Tridens flavus	purpletop tridens	0.5

Mapped Type Name: Non-native Ruderal Grassland
Macrogroup: Eastern Ruderal Shrubland and Grassland (MG123)
Group: Eastern Ruderal Shrubland and Grassland (G059)
Association: CEGL004048
NVC Common Name: (Tall Fescue, Meadow Fescue) Herbaceous Vegetation
NVC Scientific Name: *Schedonorus (phoenix, pratensis)* Herbaceous Vegetation

Figure 11. Non-native Ruderal Grassland at George Washington Carver National Monument.

Global Summary: This association (Figure 11) includes grassland pastures and hayfields, more-or-less cultural, though sometimes no longer actively maintained. The dominant species in this type are the European "tall or meadow fescues" of uncertain and controversial generic placement. Several other exotic grasses (redtop (*Agrostis gigantea),* orchardgrass *(Dactylis glomerata),* common velvetgrass (*Holcus lanatus),* timothy (*Phleum pretense)*, and Kentucky bluegrass (*Poa pratensis)*, for example) are common associates. These communities are sometimes nearly monospecific but can also be very diverse and contain many native as well as exotic species of grasses, sedges, and forbs. Exotic forbs include the legumes sericea lespedeza (*Lespedeza cuneata),* field clover (*Trifolium campestre),* alsike clover (*Trifolium hybridum),* red clover (*Trifolium pretense)*, and white clover (*Trifolium repens)*, as well as common yarrow (*Achillea millefolium),* hedge false bindweed (*Calystegia sepium),* Queen Anne's lace *(Daucus*

carota), oxeye daisy (*Leucanthemum vulgare),* common yellow oxalis (*Oxalis stricta)*, and narrowleaf plantain (*Plantago lanceolata)*. Common native herbs include Indianhemp (*Apocynum cannabinum),* hoary ticktrefoil (*Desmodium canescens),* deertongue (*Dichanthelium clandestinum),* eastern daisy fleabane (*Erigeron annuus),* Virginia strawberry (*Fragaria virginiana),* common cinquefoil (*Potentilla simplex),* Carolina horsenettle (*Solanum carolinense),* Canada goldenrod (*Solidago canadensis)*, and yellow crownbeard (*Verbesina occidentalis*). This vegetation is currently defined for the central and southern Appalachians, Ozarks, Ouachita Mountains, and parts of the Piedmont and Interior Low Plateau, but it is possible throughout much of the eastern United States and southern Canada.

Environmental Description: This association at GWCA includes former grassland pastures and hayfields, more-or-less cultural, though no longer actively maintained. It occurred in areas that have been cleared in the past, including abandoned farmlands, small scale mines and associated tailings, and other areas disturbed by human activities.

Vegetation Description: This mapped vegetation type was dominated by tall fescue (*Schedonorus phoenix*), which was often the overwhelming dominant, and other successional grasses and forbs. Ruderal shrubs and small trees were often present, including Pennsylvania blackberry (*Rubus pensilvanicus*), hortulan plum (*Prunus hortulana*), multiflora rose (*Rosa multiflora*), honeylocust (*Gleditsia triacanthos*), and Osage orange (*Maclura pomifera*) (Table 8).

Most Abundant Species:

Table 8. Percent cover for species found in one plot sampled for Non-native Ruderal Grassland.

Non-native Ruderal Grassland		
Scientific Name	**Common Name**	**%Cover**
Tree		
Gleditsia triacanthos	honey locust	3
Shrub		
Symphoricarpos orbiculatus	coralberry	3
Rubus pensilvanicus	Pennsylvania blackberry	0.5
Prunus hortulana	hortulan plum	0.5
Maclura pomifera	Osage orange	0.5
Rosa multiflora	multiflora rose	0.5
Herbaceous		
Schedonorus phoenix	tall fescue	85
Vernonia baldwinii	Baldwin's ironweed	0.5
Vicia sativa	garden vetch	0.5
Vernonia arkansana	Arkansas ironweed	0.5
Trifolium pretense	red clover	0.5
Tridens flavus	purpletop tridens	0.5

Table 9. Percent cover for species found in one plot sampled for Non-native Ruderal Grassland. (continued)

Non-native Ruderal Grassland		
Scientific Name	**Common Name**	**%Cover**
Teucrium canadense	Canada germander	0.5
Solanum carolinense	Carolina horsenettle	0.5
Scientific Name	**Common Name**	**%Cover**
Andropogon virginicus	broomsedge bluestem	0.5
Erechtites hieraciifolia	American burnweed	0.5
Desmodium paniculatum	panicleleaf tickrefoil	0.5
Desmodium glabellum	Dillenius' ticktrefoil	0.5
Croton monanthogynus	prairie tea	0.5
Cirsium altissimum	tall thistle	0.5

Mapped Type Name: Restored Tallgrass Prairie
Macrogroup: Planted to replicate – Great Plains Tallgrass Prairie, Savanna & Shrubland (MG054)
Group: Planted to replicate – Central Great Plains Tallgrass Prairie Group (G333)
Association: None assigned
Type Common Name: Big Bluestem – Indiangrass Herbaceous Vegetation
Type Scientific Name: *Andropogon gerardii – Sorghastrum nutans* Herbaceous Vegetation

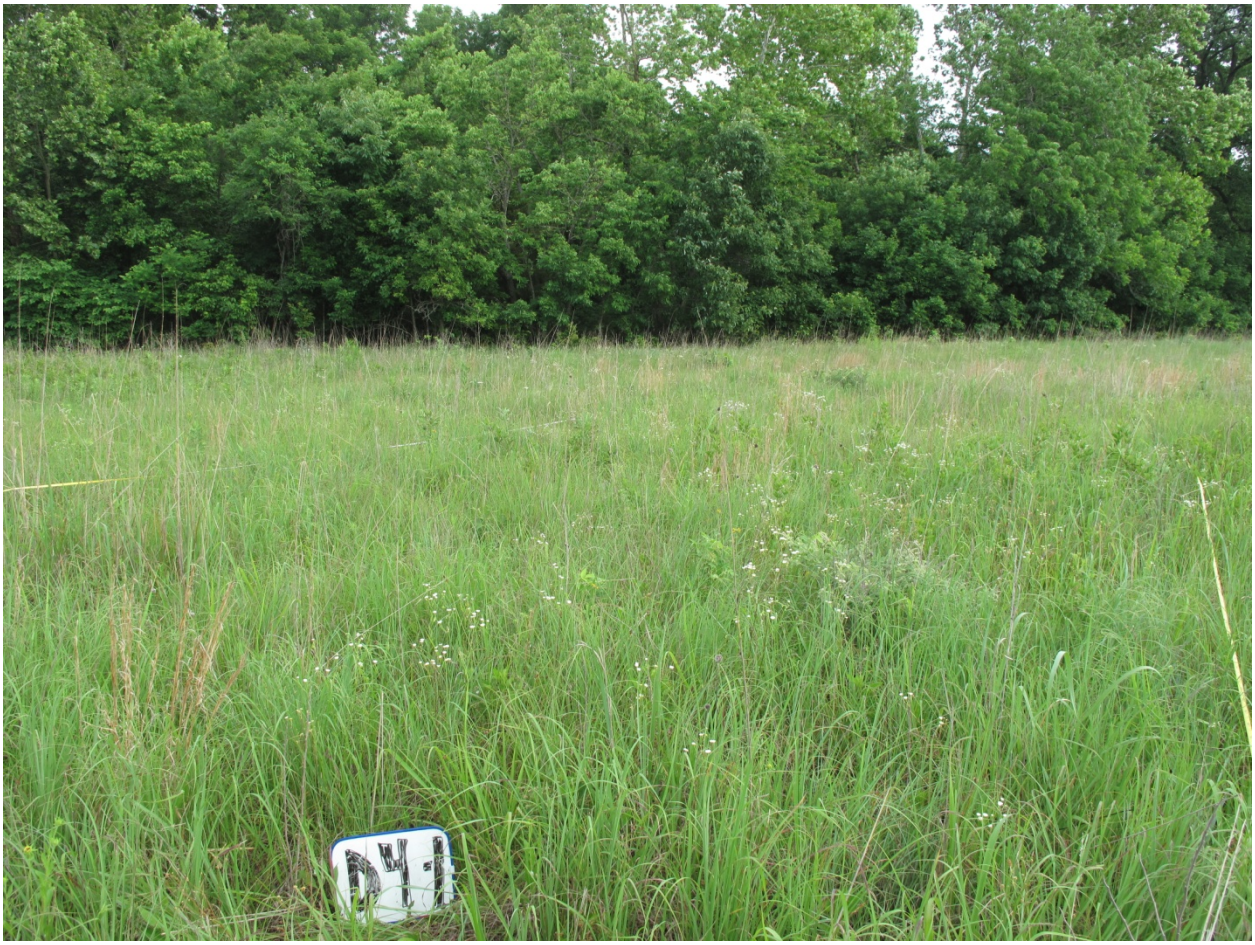


Figure 12. Restored Tallgrass Prairie at George Washington Carver National Monument.

Global Summary: This community (Figure 12) is typical of restored tallgrass prairie plots throughout the Midwest. Both native and non-native grasses and forbs may volunteer in. Efforts are often on-going and uneven, with managers adding native forbs or grasses in an ad hoc fashion. The general aspect or restorations is of a tallgrass prairie with the flowering culms of visual dominants often reaching 2 m tall, but prairie forbs are often lacking or may be present in novel proportions (**Error! Reference source not found.**). Weedy shrubs and vines such as blackberry (*Rubus* spp.) and sumac (*Rhus* spp.) are nearly always present in prairie restorations.

Environmental Description: This community at GWCA occurs on old cropland. Some areas are more moist than others, though differences apparent in the field were subtle.

Vegetation Description: This grassland community was usually dominated by native tallgrass prairie species such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and little bluestem (*Schizachyrium scoparium*). Restoration efforts have not been uniformly successful, and in some patches, usually <500 square meters, shrubs and annual grasses were among the dominants. Field brome (*Bromus arvensis*) was commonly important in these patches. Shrubs, including Pennsylvania blackberry (*Rubus pensilvanicus*) and sumac (*Rhus copallinum* and *Rhus glabra*) were common components, and were among the visual dominants in some patches after one or more years of rest following mowing or prescribed fire. A wide variety of other herbaceous species were present, including rush (*Juncus* spp.) and sedge (*Carex* spp.) species, composite dropseed (*Sporobolus compositus*), and blackeyed Susan (*Rudbeckia hirta*). The herbaceous flora varied based on soil characteristics and, apparently, on past restoration history, which was not perfectly documented (Table 10).

Most Abundant Species:

Table 10. Average cover (for plots where the species occurred) and frequency by layer and species for five plots taken within Restored Tallgrass Prairie. Only species with at least 0.5% cover in at least two plots are shown.

Restored Tallgrass Prarie			
Scientific Name	**Common Name**	**%Cover**	**Frequency**
Tree			
Fraxinus pennsylvanica	green ash	17.55	20%
Shrub			
Rhus copallinum	winged sumac	13.67	60%
Rubus pensilvanicus	Pennsylvania blackberry	2.50	100%
Prunus americana	American plum	0.50	40%
Herbaceous			
Bromus arvensis	field brome	37.50	40%
Andropogon gerardii	big bluestem	31.10	100%
Sporobolus compositus var. *compositus*	composite dropseed	26.25	40%
Trifolium campestre	field clover	11.00	60%
Sorghastrum nutans	Indian grass	9.70	100%
Schizachyrium scoparium	little bluestem	8.40	100%
Agrostis hyemalis	winter bentgrass	5.33	60%
Juncus tenuis	poverty rush	4.13	80%
Andropogon virginicus	broomsedge bluestem	3.00	20%
Poa annua	annual bluegrass	3.00	20%
Solidago altissima	Canada goldenrod	3.00	20%
Tridens flavus	purpletop tridens	2.17	60%
Ambrosia artemisiifolia	annual ragweed	1.75	40%

Table 8. Average cover (for plots where the species occurred) and frequency by layer and species for five plots taken within Restored Tallgrass Prairie. Only species with at least 0.5% cover in at least two plots are shown (continued).

Restored Tallgrass Prarie			
Scientific Name	**Common Name**	**%Cover**	**Frequency**
Carex bushii	Bush's sedge	1.75	40%
Bouteloua curtipendula	sideoats grama	1.33	60%
Panicum virgatum	switchgrass	1.33	60%
Symphyotrichum pilosum var. *pilosum*	hairy white oldfield aster	1.33	60%
Carex annectens	yellowfruit sedge	1.13	80%
Erigeron annuus	eastern daisy fleabane	0.50	80%
Potentilla recta	sulphur cinquefoil	0.50	80%
Rudbeckia hirta	blackeyed Susan	0.50	80%
Achillea millefolium	common yarrow	0.50	60%
Conyza canadensis	Canadian horseweed	0.50	60%
Desmodium paniculatum	panicleleaf tickrefoil	0.50	60%
Elymus virginicus	Virginia wildrye	0.50	60%
Galium virgatum	limestone bedstraw	0.50	60%
Lactuca canadensis	Canada lettuce	0.50	60%
Oxalis dillenii	slender yellow woodsorrel	0.50	60%
Triodanis perfoliata	clasping Venus' looking-glass	0.50	60%
Vulpia octoflora	sixweeks fescue	0.50	60%
Apocynum cannabinum	Indian hemp	0.50	40%
Carex scoparia	broom sedge	0.50	40%
Cirsium altissimum	tall thistle	0.50	40%
Dichanthelium acuminatum var. *lindheimeri*	Lindheimer panicgrass	0.50	40%
Lespedeza capitata	roundhead lespedeza	0.50	40%
Lespedeza cuneata	sericea lespedeza	0.50	40%
Plantago virginica	Virginia plantain	0.50	40%
Sphenopholis obtusata	prairie wedgescale	0.50	40%
Symphyotrichum ericoides var. *ericoides*	white heath aster	0.50	40%
Tragopogon dubius	yellow salsify	0.50	40%

Discussion

George Washington Carver National Monument currently has significant restored prairie and successional, but maturing woodlands and forests. Given that the surrounding landscape is used intensively for agricultural purposes, the vegetation of the park has real value for prairie and woodland wildlife species. Even though most of the park was at one time in row crop production, native grasses and forbs have been restored to a substantial area, and remnant mima mounds are still apparent on some of the landscape. This restored tallgrass prairie is probably the most significant plant community on the park.

Field Survey
The plant communities of GWCA will be quite dynamic over time because many are relatively early successional types. Documentation of change via repeated sampling will be highly desirable. Sampling of the general landscape around the park (e.g. interpretation of general vegetation types such as urban, grassland, and woodland/forest) will help to document context and provide early signs of urban encroachment on the boundaries, should that occur.

NVC Classification
Quantitative data from the park may help in the description of ruderal vegetation types for the Midwest. Currently, no ruderal type descriptions that correspond with the woodlands, forests, and shrublands exist. Some of these types are quite likely widespread on the landscape and provide the matrix habitats for native fauna and flora in the region (e.g. ruderal woodland and forest). Other ruderal types, such as the shrubland type, may actually be fairly uncommon or rare on the landscape, and valuable for native fauna. Forest, grassland, and especially shrubland birds of continental concern all nest within the park, which attests to the area's regional importance (Peitz 2009). Upland woodlands also provide shade and nutrient input for perennial streams that traverse the park, and harbor significant aquatic resources (Bowles 2009, Peitz 2005).

Digital Imagery and Interpretation
Multiple years of both leaf-on and leaf-off imagery were available for the park and were used to develop map polygons. The use of leaf-on and leaf-off data helped ensure high quality results. Because the park was small, heads up corrections to initial image objects were made at fine resolution. Small mapped polygons were retained in the final results, again due to the small size of the park.

Accuracy Assessment
The high degree of thematic accuracy was made possible in part by the small size of GWCA and the limited number of natural vegetation classes identified within the park. The overall accuracy assessment, as well as the accuracy assessment of each mapped class exceeded the 80% level required by the NPS Vegetation Mapping Inventory program. Further, the lower limit of the 90% confidence interval exceeded the programmatic requirement of 80% for each individual map class accuracy assessment.

Future Recommendations
The vegetation at GWCA consists mainly of early successional woodland and forest communities and restored prairie and thus will be quite dynamic over short time frames. For

example, woodlands and forest along Carver Creek, Williams Branch, and Harkin Creek may through succession become recognizable examples of a NCV Bottomland Forest type (e.g. *Fraxinus pennsylvanica – Celtis* spp.-*Quercus* spp.-*Platanus occidentalis* Bottomland Forest, CEGL002410). Monitoring of native flora and fauna by the Heartland Inventory and Monitoring Network will provide information on change. Efforts have already documented the status of the primary plant communities, species of concern, and invasive species (Annis et al. 2011, see also http:// science.nature.nps.gov/im/units/HTLN). The plant communities are quite simple and common in the landscape, yet these ruderal types are not described within the NVC. Data from this study should be made available to help facilitate possible NVC additions. Jones (2004) suggested that distinct wet prairie habitats may exist within the park, and areas circumscribed by him may warrant further monitoring. Likewise, woodlands and forests in the far northwestern section of the park have better drained soils than in other areas according to county soil surveys, and these areas may warrant further consideration and monitoring.

Research Opportunities

Restoration of tallgrass prairie will be one of the most important on-going activities with regard to natural resources at GWCA. These activities may afford the opportunity for research on the effectiveness of various techniques (e.g. seeding, prescribed fire, mowing) on restoration efforts. Invasive Japanese honeysuckle (*Lonicera japonica*) and several additional non-native species are abundant in some of the ruderal woodlands and forests, and research on the effectiveness of various methods to control these species might be possible. Nesting birds and fish of regional and national significance are present in the park, and documentation of the impacts of management on those species may also be possible, especially if park staff decide to do away with the small, man-made lake in the central part of the park. Finally, a few mounds of mine tailings exist on the southwestern side of the park, and these are currently covered by ruderal woodland and forest, ruderal shrubland, or non-native ruderal grassland. The response of these areas, particularly of the mine tailing mounds themselves, may warrant future research.

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Appendix A: Contingency Table for Vegetation Mapping at George Washington Carver National Monument

		Reference Data (Accuracy Assessment Field Data)					User's Error		
Sample Data (Polygon Map Data)	Map Units	Ruderal woodland and forest	Ruderal shrubland	Non-native ruderal grassland	Restored tallgrass prairie	Totals	Commission Accuracy	90% Conf. Interval	
								-	+
	Ruderal woodland and forest	**3**	0	0	0	3	100%	83.3%	100%
	Ruderal shrubland	0	**4**	0	0	4	100%	87.5%	100%
	Non-native ruderal grassland	0	0	**5**	0	5	100%	90.0%	100%
	Restored tallgrass prairie	0	0	0	**4**	4	100%	87.5%	100%
	Totals	3	4	5	4				
Producer's Error	Omission Accuracy	100%	100%	100%	100%	**16 Total Correct Points**			
	90% Conf. -	100%	100%	100%	100%	**16 Total Points**			
	Level +	100%	100%	100%	100%				
Overall Total Accuracy = 100% **Overall Kappa Index = 100%** **Overall 90% Upper and Lower Confidence Interval = 100% and 100%**									

Accuracy Assessment Contingency Table:
The contingency table combines the sample contingency and population contingency tables in which rows represent the map classes from the vegetation map and columns are the map classes determined in the field. The shaded areas display the number of accuracy assessment points where the field determination of the map class agrees with the vegetation map. Disagreement between field data (columns) and map data result in producer's error (omission error). Conversely, disagreement between map data (rows) and field data reflect user's error (errors of commission). Both types of error are reported in terms of accuracy (100% indicates no errors) and a corresponding 90% confidence interval. The total number of correct points out of the total number of accuracy assessment points (shaded diagonal values) provides the degree to which map classes were interpreted correctly. The Kappa Index is an index that accounts for chance agreement in the contingency table.

Appendix B: Example of Plot Survey Form

NPS VEGETATION MAPPING PROGRAM – PLOT SURVEY FORM
PLOT LOCATION AND DESCRIPTION

Plot Code _____ Surveyors _____
Date _____

Plot Directions

_____

Plot Dimensions _____ by _____m Photos (y/n) _____
Provisional Community Name

_____

Relative Stand Size extensive (>100x plot), large (>10-100x plot), small (3-10x plot), very small (1-3x plot), unknown
Representativeness

_____
_____
_____

Landform (circle) interfluve, gap/saddle, side slope, terrace/bench flat plain

Topographic Position (circle) crest, upper slope, middle slope, lower slope, toe slope, plain/level/bottom, basin/depression

Hydrologic Regime ___Upland ___Permanently flooded ___Semipermanently flooded ___Seasonally/Temporarily flooded ___Unknown

Plot Shape (circle) concave convex flat irregular
General Comments

_____
_____
_____

Plot Code _____

NPS VEGETATION MAPPING PROGRAM – PLOT SURVEY FORM

VEGETATION SAMPLING

Leaf Phenology	Leaf type	Physiognomic Class
____Deciduous (<25% evergreen)	____Broadleaf	____Forest
____Evergreen (<25% deciduous)	____Needleleaf	____Woodland
____Mixed deciduous/evergreen	____Mixed	____Sparse woodland
____Perennial graminoid	____Graminoid	____Shrubland
____Perennial forb	____Forb	____Sparse shrubland
____Perennial mixed	____Pteridophyte	____Herbaceous
____Annual herbaceous	____Non-vascular	____Sparse vegetation

Strata	%Cover (1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%, 6=75-95%, 7=95-100%)
T1 Emergent >30m	_____
T2 Tree Canopy 20-30m	_____
T3 Tree Subcanopy 5-20m	_____
S1 Tall Shrub 1-5m	_____
S2 Short Shrub <1m	_____
H Herbaceous	_____

SPECIES COMPOSITION AND COVER CLASS BY STRATUM

%Cover (1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%, 6=75-95%, 7=95-100%)

T1	T2	T3	S1	S2	H	Species	Comments

Plot Code ___________

T1	T2	T3	S1	S2	H	Species	Comments

Appendix C: George Washington Carver National Monument Dichotomous Key to Mapped Current Vegetation Types

1a. Vegetation dominated by herbaceous species with absolute cover of woody species <30% except in patches <500 square meters (small patches of shrublands may be included here) ……... 2

2a. Native tallgrass prairie species such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and composite dropseed (*Sporobolus compositus* var. *compositus*) among the dominants…….Restored Tallgrass Prairie

2b. Native tallgrass prairie species not among the dominants. Non-native and ruderal grasses such as tall fescue (*Schedonorus phoenix*) among the dominants …….. …….Non-native Ruderal Grassland

1b. Vegetation dominated by woody species with absolute cover of all trees and shrubs combined greater than 30% except in patches <500 square meters …….……..3

3a. Vegetation dominated by trees >5 m tall with total absolute woody canopy cover greater than 70%. Species such as black walnut (*Juglans nigra*), hackberry (*Celtis occidentalis*), and slippery elm (*Ulmus rubra*) important in the canopy and/or sub-canopy .....Ruderal Woodland and Forest

3b. Vegetation dominated by shrubs or small trees with absolute total woody canopy less than 70%. Species such as Osage orange (*Maclura pomifera*) and honey locust (*Gleditsia triacanthos*) among the woody dominants and non-native or annual grasses such as tall fescue (*Schedonorus phoenix*) among the herbaceous dominants……...Ruderal Shrubland

Appendix D: Example of Accuracy Assessment Form

Accuracy Assessment Form

NPS Vegetation Inventory

1. PLOT (WAYPOINT) #:_____ 2. DATE:_____

3. OBSERVER (DETERMING ASSOCIATION) _____

4. Observer (assisting) _____

5. ACCURACY OF NAVIGATION (METERS) _____

6. How Determined: _____

7. UTM EASTING: _____ 8. UTM: _____

9. UTM Zone: _____ 10. Datum: _____

11. If GPS Position is an intentional offset from the waypoint, circle the explanation:

a.) Mosaicing scenario (too heterogeneous to key because of two or more clearly distinct types within observation area)

b.) Physical constraints in reaching waypoint

c.) Other (explain as needed):_____

_____

_____

12. VEGETATION ASSOCIATION (Primary call): _____

_____

13. Other possible associations (complexing scenario) (if applicable): _____

_____

14. Explanation for # 13 (if applicable): _____

_____

Appendix E: Species List for George Washington Carver National Monument

Family	Scientific Name	Common Name
Acanthaceae	*Ruellia strepens*	limestone wild petunia
Aceraceae	*Acer negundo*	boxelder
Anacardiaceae	*Rhus copallinum*	winged sumac
	Rhus glabra	smooth sumac
	Toxicodendron radicans	eastern poison ivy
Apiaceae	*Cryptotaenia canadensis*	Canadian honewort
	Osmorhiza claytonii	Clayton's sweetroot
	Sanicula canadensis	Canadian blacksnakeroot
	Sanicula odorata	clustered blacksnakeroot
	Torilis arvensis	spreading hedgeparsley
Apocynaceae	*Apocynum cannabinum*	Indianhemp
Araceae	*Arisaema dracontium*	green dragon
Aspleniaceae	*Asplenium platyneuron*	ebony spleenwort
Asteraceae	*Achillea millefolium*	common yarrow
	Ageratina altissima var. *altissima*	white snakeroot
	Ambrosia artemisiifolia	annual ragweed
	Ambrosia trifida	great ragweed
	Cirsium altissimum	tall thistle
	Conyza canadensis	Canadian horseweed
	Elephantopus carolinianus	Carolina elephantsfoot
	Erechtites hieraciifolia	American burnweed
	Erigeron annuus	eastern daisy fleabane
	Erigeron strigosus	prairie fleabane
	Gamochaeta purpurea	spoonleaf purple everlasting
	Hieracium gronovii	queendevil
	Krigia biflora	twoflower dwarfdandelion
	Lactuca canadensis	Canada lettuce
	Lactuca floridana	woodland lettuce
	Prenanthes altissima	tall rattlesnakeroot
	Rudbeckia hirta	blackeyed Susan
	Silphium perfoliatum	cup plant
	Solidago altissima	Canada goldenrod
	Solidago gigantea	giant goldenrod
	Symphyotrichum ericoides var. *ericoides*	white heath aster
	Symphyotrichum oolentangiense var. *oolentangiense*	skyblue aster
	Symphyotrichum patens var. *patens*	late purple aster

Appendix E: Species List for George Washington Carver National Monument

Family	Scientific Name	Common Name
Asteraceae	*Symphyotrichum pilosum* var. *pilosum*	hairy white oldfield aster
	Symphyotrichum turbinellum	smooth violet prairie aster
	Tragopogon dubius	yellow salsify
	Verbesina alternifolia	wingstem
	Verbesina virginica	white crownbeard
	Vernonia arkansana	Arkansas ironweed
	Vernonia baldwinii	Baldwin's ironweed
Balsaminaceae	*Impatiens*	touch-me-not
Boraginaceae	*Hackelia virginiana*	beggarslice
Campanulaceae	*Triodanis perfoliata*	clasping Venus' looking-glass
Caprifoliaceae	*Lonicera flava*	yellow honeysuckle
	Lonicera japonica	Japanese honeysuckle
	Sambucus nigra ssp. *canadensis*	American black elderberry
	Symphoricarpos orbiculatus	coralberry
	Viburnum rufidulum	rusty blackhaw
	Dianthus armeria	Deptford pink
Caryophyllaceae	*Silene stellata*	widowsfrill
Celastraceae	*Euonymus fortunei*	winter creeper
Cupressaceae	*Juniperus virginiana*	eastern redcedar
Cyperaceae	*Carex amphibola*	eastern narrowleaf sedge
	Carex annectens	yellowfruit sedge
	Carex blanda	eastern woodland sedge
	Carex bushii	Bush's sedge
	Carex jamesii	James' sedge
	Carex nigromarginata	black edge sedge
	Carex retroflexa	reflexed sedge
	Carex scoparia	broom sedge
Dryopteridaceae	*Woodsia obtusa*	bluntlobe cliff fern
Euphorbiaceae	*Acalypha virginica*	Virginia threeseed mercury
	Croton monanthogynus	prairie tea
	Tragia betonicifolia	betonyleaf noseburn
Fabaceae	*Amorpha canescens*	leadplant
	Cercis canadensis	eastern redbud
	Desmodium marilandicum	smooth small-leaf ticktrefoil
	Desmodium paniculatum	panicledleaf ticktrefoil
	Desmodium perplexum	perplexed ticktrefoil

Appendix E: Species List for George Washington Carver National Monument

Family	Scientific Name	Common Name
Fabaceae	*Gleditsia triacanthos*	honeylocust
	Lespedeza capitata	roundhead lespedeza
	Lespedeza cuneata	sericea lespedeza
	Lespedeza violacea	violet lespedeza
	Robinia pseudoacacia	black locust
	Strophostyles helvola	amberique-bean
	Trifolium campestre	field clover
	Trifolium pratense	red clover
	Vicia sativa	garden vetch
Fagacaea	*Quercus alba*	white oak
	Quercus macrocarpa	bur oak
	Quercus muehlenbergii	chinkapin oak
	Quercus velutina	black oak
Grossulariaceae	*Ribes missouriense*	Missouri gooseberry
Juglandaceae	*Juglans nigra*	black walnut
Juncaceae	*Juncus tenuis*	poverty rush
Lamiaceae	*Glechoma hederacea*	ground ivy
	Physostegia virginiana	obedient plant
	Prunella vulgaris	common selfheal
	Scutellaria incana	hoary skullcap
	Teucrium canadense	Canada germander
Liliaceae	*Allium vineale*	wild garlic
	Trillium sessile	toadshade
Moraceae	*Maclura pomifera*	Osage orange
	Morus rubra	red mulberry
Oleaceae	*Fraxinus americana*	white ash
	Fraxinus pennsylvanica	green ash
	Ligustrum vulgare	European privet
Ophioglossaceae	*Botrychium virginianum*	rattlesnake fern
Oxalidaceae	*Oxalis dillenii*	slender yellow woodsorrel
	Oxalis stricta	common yellow oxalis
Passifloraceae	*Passiflora lutea*	yellow passionflower
Phytolaccaceae	*Phytolacca americana*	American pokeweed
Plantaginaceae	*Plantago virginica*	Virginia plantain
Platanaceae	*Platanus occidentalis*	American sycamore

Appendix E: Species List for George Washington Carver National Monument

Family	Scientific Name	Common Name
Poaceae	*Agrostis hyemalis*	winter bentgrass
	Andropogon gerardii	big bluestem
	Andropogon virginicus	broomsedge bluestem
	Bouteloua curtipendula	sideoats grama
	Bromus arvensis	field brome
	Bromus pubescens	hairy woodland brome
	Bromus tectorum	cheatgrass
	Chasmanthium latifolium	Indian woodoats
	Dactylis glomerata	orchardgrass
	Dichanthelium acuminatum var. *fasciculatum*	western panicgrass
	Dichanthelium acuminatum var. *lindheimeri*	Lindheimer panicgrass
	Dichanthelium clandestinum	deertongue
	Dichanthelium commutatum	variable panicgrass
	Dichanthelium malacophyllum	softleaf rosette grass
	Elymus virginicus	Virginia wildrye
	Festuca subverticillata	nodding fescue
	Leersia virginica	whitegrass
	Muhlenbergia sobolifera	rock muhly
	Panicum virgatum	switchgrass
	Poa annua	annual bluegrass
	Poa chapmaniana	Chapman's bluegrass
	Poa compressa	Canada bluegrass
	Poa sylvestris	woodland bluegrass
	Schedonorus phoenix	tall fescue
	Schedonorus pratensis	meadow fescue
	Schizachyrium scoparium	little bluestem
	Sorghastrum nutans	Indiangrass
	Sphenopholis obtusata	prairie wedgescale
	Sporobolus compositus var. *compositus*	composite dropseed
	Tridens flavus	purpletop tridens
	Vulpia octoflora	sixweeks fescue
	Vulpia octoflora var. *octoflora*	sixweeks fescue
Polygonaceae	*Polygonum sp.*	knotweed species
	Polygonum virginianum	jumpseed

Appendix E: Species List for George Washington Carver National Monument

Family	Scientific Name	Common Name
Rosaceae	*Geum canadense*	white avens
	Geum vernum	spring avens
	Potentilla recta	sulphur cinquefoil
	Prunus americana	American plum
	Prunus hortulana	hortulan plum
	Prunus serotina	black cherry
	Rosa multiflora	multiflora rose
	Rubus pensilvanicus	Pennsylvania blackberry
Rubiaceae	*Galium aparine*	stickywilly
	Galium virgatum	southwestern bedstraw
Sapotaceae	*Sideroxylon lanuginosum*	gum bully
Scrophulariaceae	*Agalinis tenuifolia*	slenderleaf false foxglove
	Verbascum blattaria	moth mullein
Smilacaceae	*Smilax bona-nox*	saw greenbrier
	Smilax tamnoides	bristly greenbrier
Solanaceae	*Solanum carolinense*	Carolina horsenettle
Ulmaceae	*Celtis laevigata*	sugarberry
	Celtis occidentalis	common hackberry
	Ulmus alata	winged elm
	Ulmus americana	American elm
	Ulmus rubra	slippery elm
Urticaceae	*Pilea pumila*	Canadian clearweed
Valerianaceae	*Valerianella radiata*	beaked cornsalad
Verbenaceae	*Phryma leptostachya*	American lopseed
Violaceae	*Viola pubescens* var. *pubescens*	downy yellow violet
	Viola sagittata	arrowleaf violet
	Viola sororia	common blue violet
Vitaceae	*Parthenocissus quinquefolia*	Virginia creeper
	Vitis aestivalis	summer grape
	Vitis vulpina	frost grape

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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