

Vegetation Mapping

Overview

Vegetation reflects the environmental characteristics of an area, as well as current and historical land use. Vegetation is a primary resource of the landscape; it forms habitat for animal species and background for human activities. In the early days of development of the modern study of ecology in North America, Clements (1916) described plant communities as distinct units of interacting species. Gleason (1926), on the other hand, believed that plant communities are simply aggregations of species, where individual species' distributions are determined by environmental and topographic factors such as temperature, soil type, and elevation. Current views of plant communities or vegetation types allow for consideration of both views; while species distribution may be determined by environmental factors, there are aggregations of plant species that occur in more-or-less distinct patterns (sometimes with species influencing each other) (Riklefs 1982); these patterns can be described and analyzed, and the studies provide clues to ecosystem processes and management techniques (Grossman et al. 1998).

Frameworks developed for vegetation description include those based on plant form (for example, structural characteristics - tree, shrub, herbaceous; leaf characteristics - evergreen or deciduous, needle-shaped or broadleaved) (Kuechler 1949, Raunkiaer 1934). Daubenmire (1968) believed that vegetation types are most usefully described by their plant species composition. A descriptive, hierarchical system, based on plant form at the higher levels, and species composition at the lower levels, forms the basis of the National Vegetation Classification (NVC) in use today by many federal agencies and conservation groups (Grossman et al. 1998).

The description and classification of vegetation types has been accompanied by attempts to understand and to map their distribution (Grossman et al. 1998). Daubenmire (1974) suggested that since plant communities integrate all impinging environmental conditions, the classification and description of plant associations provides a framework for understanding the ecological composition and structure of a given landscape. Accordingly, plant associations can be used to define map units, or spatial representations of the distribution of vegetation. Plant associations provide the information linkage between a vegetation type's spatial distribution and its ecology. By grouping land areas based on the ability to support similar associations, general management observations and

OVERVIEW



Mesa Verde NP with La Plata Mountains in the background.

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recommendations can be made for each grouping. In addition, resource managers have found that the classification of vegetation into plant associations has provided insight and the ability to predict vegetation changes in response to various disturbance processes (Muldavin et al. 2010). Understanding the characteristics of the vegetation enhances the potential for successful monitoring, management, restoration, and protection of natural resources (Cogan and Salas 2006).

The U.S. Geological Survey (USGS) and the National Park Service (NPS) formed the USGS-NPS Vegetation Mapping Program in 1994 (now called the USGS-NPS Vegetation Characterization Program) to cooperatively inventory and map vegetation in more than 280 national parks across the United States. The program's goals are to provide baseline ecological data for park resource managers, obtain data that can be examined in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities. It is a NPS goal to have the majority of the parks mapped. Member parks are currently developing and implementing vegetation mapping projects to produce detailed maps of vegetation types across park sites (e.g., see Figure 1). As of October 2009, 65 NPS units had completed vegetation mapping projects (because this may change rapidly, please consult <http://biology.usgs.gov/npsveg> for current information). More mapping projects are ongoing, and additional projects are in the planning stage. A number of parks in the NPS Inventory and Monitoring (I&M) Networks of the American Southwest have been mapped to date. For example, maps are complete for all



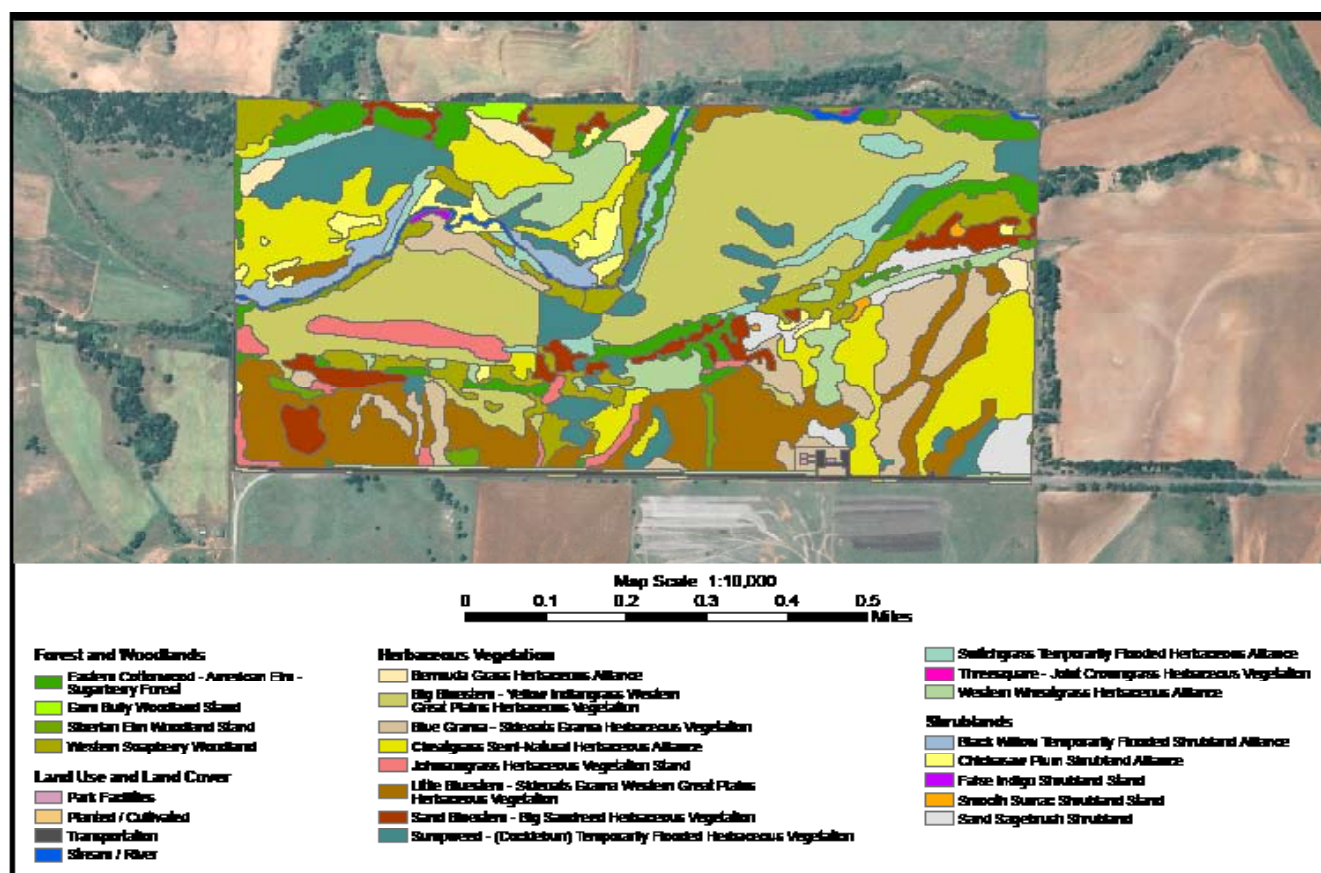


Figure 1. Map of Washita Battlefield NHS, SOPN (Cogan and Salas 2006).

but three parks in the Southern Plains Network (SOPN). In the Southern Colorado Plateau Network (SCPN), five parks are complete and thirteen will be completed and made available in 2009 and 2010. In the Sonoran Desert Network (SODN), one map is complete, and in the Chihuahuan Desert Network (CHDN), four maps are in progress and two are planned. The vegetation maps provide valuable data in an easily accessible format, and they are invaluable tools for park managers in a broad array of applications. Example applications are discussed in the last section of this overview.

The National Vegetation Classification (NVC) System

In order to create accurate and useful vegetation maps, park managers must share a common, comprehensive system for classifying different vegetation communities. The Vegetation Mapping Program uses the NVC as the standard vegetation classification system. This system:

- is vegetation based;
- uses a systematic approach to classify a continuum;
- emphasizes natural and existing vegetation;

- uses a combined physiognomic-floristic hierarchy (Table 1);
- identifies vegetation units based on both qualitative and quantitative data; and
- is appropriate for mapping at multiple scales.

The use of the NVC system and the USGS-NPS vegetation mapping protocols facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS, as well as by other federal and state agencies (Cogan and Salas 2006). The vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs. They can also 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.

Over the past twenty years, the NVC has been developed and implemented primarily by The Nature Conservancy (TNC) and the network of State Natural Heritage Programs. It is currently maintained and updated by NatureServe. Additional support has come from federal agencies, the Federal Geo-

Table 1. The National Vegetation Classification Standard, version 2, with definitions and examples (FGDC 2008, Thomas et al. 2009).

Level	Level Name	Primary Basis for Classification	Example
Upper Level 1	Formation Class	Defined by broad combinations of dominant general growth forms adapted to basic moisture, temperature, and/or substrate or aquatic conditions.	Shrubland and grassland
Upper Level 2	Formation Subclass	Defined by combination of general dominant & diagnostic growth forms that reflect global macroclimatic factors driven mainly by latitude and continental position, or that reflect overriding substrate or aquatic conditions.	Temperate and boreal shrubland and grassland
Upper Level 3	Formation	Defined by combinations of dominant and diagnostic growth forms that reflect global macroclimatic conditions as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.	Temperate shrubland and grassland
Mid Level 4	Division	Defined by combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant taxa that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	North American Great Plains grassland and shrubland
Mid Level 5	Macrogroup	Defined by combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	Great Plains tall grassland and shrubland
Mid Level 6	Group	Defined by combinations of relatively narrow sets of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect biogeographic differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	Great Plains mesic tallgrass prairie
Lower Level 7	Alliance	Defined by characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation. They reflect regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes.	Wet-mesic tallgrass prairie
Lower Level 8	Association	Defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions and physiognomy. They reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.	Central wet-mesic tallgrass prairie



Ground photo of *Juniperus ashei* (Ashe Juniper) Woodland Alliance at Lyndon B. Johnson NHP (from Cogan 2007).



Photo signature of *Juniperus ashei* (Ashe Juniper) Woodland Alliance (in yellow) at Lyndon B. Johnson NHP (from Cogan 2007).

graphic Data Committee (FGDC), and the Ecological Society of America. In the process of applying the classification, refinements are made and revisions suggested, leading to ongoing proposed revisions that are reviewed both locally and nationally. TNC and NatureServe have made available a two-volume publication presenting the standardized classification, providing a thorough introduction to the classification, its structure, and the list of vegetation types found across the U.S. as of April 1997. The *International Classification of Ecological Communities: Terrestrial Vegetation of the United States. Volume I: The National Vegetation Classification System* (Grossman et al. 1998) can be found on the Internet (at <http://www.natureserve.org/publications/library.jsp>). NatureServe has since superseded Volume II of the publication (the classification listing), providing regular updates to ecological communities in the U.S. and Canada. This online database server, NatureServe Explorer®, can also be found on the Internet (at <http://www.natureserve.org/explorer>).

Stages of a Vegetation Mapping Project

In order to ensure consistency between vegetation maps from numerous parks, the NPS and USGS have established a standard mapping methodology. The steps are described here.

Plan, Gather Data, and Coordinate Tasks

To begin the mapping process, park managers bring together all of the parties who will be working on the mapping project and outline the tasks ahead. If a park has special management issues or concerns that a vegetation map might address, those concerns are integrated into the planning process. Because the vegetation mapping process relies on effective coordination between different agencies and organizations, a thorough plan that accounts for all tasks and assigns responsibility for each one is essential. Also at this stage, park managers determine the boundary of the area to be mapped, and they begin gathering the imagery that will provide the basis for the final map.

Survey Park to Understand and Sample the Vegetation

Prior to beginning the fieldwork, project members gather a preliminary list of vegetation associations and alliances from the NVC based on previous studies and local knowledge. This list is used to set targets for data collection, with each association marked for 3-5 plots. Botanists also use this list in the field when they survey the entire site for representative stands of vegetation. Once a stand of vegetation is located that appears to be representative of the plant communities in the area, a study plot is laid out to capture its characteristics. Pertinent information includes:

elevation, slope, aspect, landform, topographic position, soil texture and drainage, hydrologic (flooding) regime, and evidence of disturbance or wildlife use. Vegetation structure and species composition are sampled using plots that vary in size, depending on the dominant physiognomy of the vegetation. Within each plot, botanists visually divide the vegetation into strata, and the height and canopy cover of vegetation is estimated for each stratum. Physiognomic class, leaf phenology, and type of dominant stratum are recorded. The species of each stratum are then listed and percent canopy cover estimated using a cover scale (<1%, 1-5%, >5-15%, etc.). Additional species within the vegetation unit that occur outside of sampled plots are listed separately.

Researchers use a Global Positioning System (GPS) unit to record the plot location. Universal Transverse Mercator (UTM) X-Y coordinates and elevation are recorded both manually and stored as waypoints in the GPS unit. Finally, four representative photos in each cardinal direction are taken of the plot to maintain a visual record and for potential monitoring purposes.

Classify the Vegetation in the NVC using the Field Data

After gathering field data from plots distributed throughout the park, researchers input the data into a national database. The data are checked for consistency, and obvious errors are corrected. In some cases, statistical analyses, including descriptive statistics, ordination, cluster analysis, and other analyses, are used to determine appropriate groupings of plots and vegetation type designations. After analyses are complete, the database is used to match each plot with a corresponding vegetation association. Any plots that do not have a clear association are analyzed further and may be used to identify new associations. All data are used to further refine and improve the vegetation classifications used by the NVC. Ultimately, a final set of associations is identified in each park. A consistent, ecologically based vegetation classification forms the foundation for the development of an information-rich vegetation map (Muldavin et al. 2010).

Acquire Current Digital or Aerial Imagery and Translate Vegetation Types into Recognizable Map Units

If necessary, NPS acquires new imagery or aerial photography that is current and has high resolution and accurate color. This imagery is entered into an ArcGIS, a Geographic Information System (GIS) program, and merged to form a continuous image of the park and surrounding area. Using standard photo-

interpretation (9x9 inch photos with stereoscope) or computer analysis (sometimes a combination of the two), the imagery is analyzed and distinctive patterns and textures are identified. The imagery is segmented according to these distinct patterns, creating a map that is a mosaic of interlocking sections. Before they are matched with vegetation associations, each pattern type is “ground-truthed” by botanists working in the field. During this process, photointerpreters often collect “observation point” data, abbreviated samples of vegetation and environmental characteristics, to assist in the determination of vegetation types and their distribution across the landscape in map units. Finally, the map unit associated with each vegetation type is used to code the appropriate sections of the map. Sometimes, when it is not possible to distinguish certain plant associations on the imagery, more than one plant association will comprise a map unit. The resulting map clearly displays the location and distribution of each map unit present in the park (see figures 2 and 3).



Figure 2. Post-fire Mixed Herbaceous Vegetation, Mesa Verde NP (ground photo [top] and photosignature [bottom] (from Thomas et al. 2009).

Assess the Accuracy of the Final Map Product

Once the map is completed and finalized, an accuracy assessment (AA) is conducted. This is a four-step process consisting of a sample design, sample site selection, data collection, and data analysis. The design of the AA process selects random points placed in each map unit based on respective map unit frequency and area. Once the target locations are selected, field technicians are provided with draft field maps, overview maps, map unit definitions, the key to the associations, and digital GPS files containing the location of the target AA sites. Field technicians travel to the AA target sites and, using the key, determine the vegetation association. At each target, they record the primary and secondary associations that occur within a roughly 50-meter radius. They also record dominant stand stratum (herbaceous, shrub, woodland, forest), environmental data, and percent canopy cover of the major species, as well as other nearby vegetation types outside the 50-meter radius. Data from this survey are cross-checked with the vegetation map to determine the accuracy of the map. The NPS has a minimum standard of 80% accuracy for all vegetation mapping projects.

Vegetation Map Applications

Vegetation maps provide enormous amounts of data on plant species abundance and distribution, as well as associated data on topography and environment, in formats that readily inform planning decisions, assist research projects, and improve resource management. After initial data collection and baseline maps, monitoring of vegetation communities will help park managers and researchers better understand the dynamic nature of ecosystems and the processes that control them. Completed vegetation maps are currently being put to use in national parks around the country, such as in the uses discussed below (see additional applications from USGS, <http://biology.usgs.gov/npsveg/apps/index.html>).

Research

Vegetation maps are proving a valuable tool in ecological and resource management research. In the monitoring phase of the NPS I&M Program, networks have developed plans to monitor various aspects of the environment to assist NPS in understanding ecosystem processes and the development of appropriate management plans for park units. For the SCPN, vegetation maps and the data associated with them played a role in the development of monitoring plans and protocols for upland vegetation at Aztec Ruins National Monument, and Mesa Verde and Petrified Forest national parks (Thomas et al. 2006, <http://science.nature.nps.gov/im/units/scpn>). The veg-

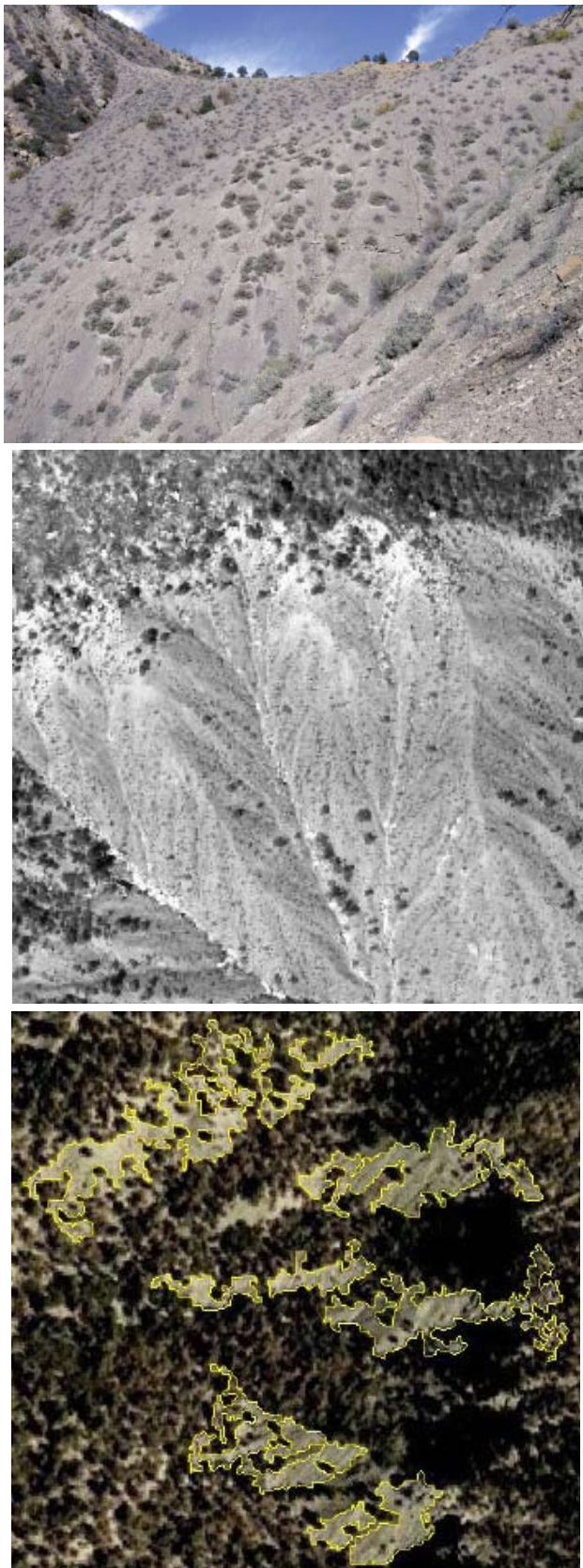


Figure 3. Crispleaf Wild Buckwheat Mancos Shale Sparse Vegetation, Mesa Verde NP (ground photo [top], aerial photo [center], and photosignature [bottom] (Thomas et al. 2009).

etation map completed for Theodore Roosevelt National Park, in North Dakota, is contributing to advanced remote sensing research for mapping an exotic, invasive plant species. A team of scientists from the NPS, USGS, and the University of California, Davis, have been analyzing NASA AVIRIS (Airborne Visible and Infrared Imaging Spectrometer) imagery to study the feasibility of detecting and mapping leafy spurge (*Euphorbia esula*) in and adjacent to the park. The recently completed vegetation map has proven extremely useful in this research.

Fire Management

Fire management includes both prescribed and wildfire management. Prescribed fires are conducted for several reasons, including fuel reduction for human safety and encouraging ecological processes. Vegetation mapping data are included in many park fire management models to optimize the use of funds and staff, prioritize areas for prescribed fire, and better predict wildfire and prescribed fire behavior. Vegetation map data are being used in fire management at Zion National Park, Utah, and Walnut Canyon National Monument, Arizona. At Mesa Verde National Park, Colorado, the vegetation map was used to develop a more detailed map of herbaceous vegetation that grew up in areas of the park that were burned in recent years (Hanna et al. 2008; see Figure 2); this more detailed mapping will help park staff to predict the outcome of different management practices in burned areas.

Planning

The maintenance and planning of park facilities can be facilitated using data from vegetation maps. For example, park staff can overlay existing trail systems on the vegetation map to analyze the percentage of trails in various vegetation types. This information can be included in the decision making process for determining the closure of existing trails and/or reopening of former trail sections. Such an analysis without the vegetation maps would require park staff to hike entire trail systems and make extensive written observations. Managers at Acadia National Park, in Maine, have used their vegetation map for such trail management and planning.

Natural Resource Management

Vegetation maps can also be used in managing and controlling exotic species of animals and plants. For example, nutria (*Myocastor coypus*) can prove to be a major problem wherever they invade. They disturb the root mat of marsh plants while swimming and foraging, which kills marsh plants and can severely impact salt marsh habitat. In Assateague Island National Seashore, Virginia, vegetation mapping data has been used to create a potential nutria habitat map for use in eradication efforts.

Conclusion

The USGS-NPS Vegetation Mapping Program seeks to provide baseline ecological data for park resource managers, obtain data that can be examined in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities. The use of the NVCS and the USGS-NPS vegetation mapping protocols facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS, as well as by other federal and state agencies. A comprehensive set of vegetation maps for our national parks, including those in the American Southwest, will be an invaluable tool for researchers, park managers, and anyone who hopes to deepen their understanding of the scope and diversity of our natural heritage.

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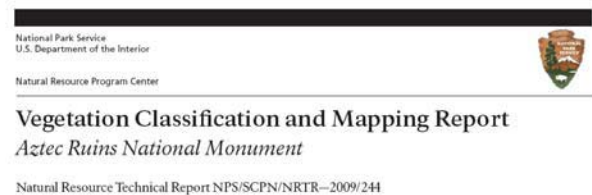


PHOTO: J. BEREN

Cover of Vegetation Classification and Mapping Report for Aztec Ruins NM.