



Vegetation Inventory, Mapping, and Characterization Report, Saguaro National Park

Volume I, Main Report

Natural Resource Report NPS/SODN/NRR—2021/2233



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ON THE COVER

Clockwise from top left: *Populus tremuloides* Forest in the Rincon Mountain District; *Pinus ponderosa* (*Pinus strobiformis*) / *Muhlenbergia virescens* Woodland in the Rincon Mountain District; *Quercus emoryi* / *Nolina microcarpa* / *Muhlenbergia emersleyi* Wooded Shrub Savanna in the Rincon Mountain District; *Simmondsia chinensis* - Mixed Cacti / *Ambrosia deltoidea* Shrubland in the Tucson Mountain District. NPS photos.

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Acronyms

AA:	accuracy assessment
ac:	acres
CEGL:	community element global (NatureServe code)
CES:	community ecological system (NatureServe code)
CHM:	canopy-height model
CI:	confidence interval
cm:	centimeter
DOQQ:	digital orthophoto quarter quadrangle
ERDAS:	Earth Resources Data Analysis System
ESA:	Ecological Society of America
ESRI:	Environmental Systems Research Institute
FGDC:	Federal Geographic Data Committee
ft:	foot/feet
GCP:	ground control point
GIS:	geographic information system
GPS:	global positioning system
GRTS:	generalized random tessellation stratified
ha:	hectares
I&M:	inventory and monitoring
ITIS:	Integrated Taxonomic Information System
km:	kilometers
LiDAR:	Light Detection and Ranging
m:	meters
mi:	miles
MMU:	minimum mapping unit
n:	number
NA:	not applicable
NAD83:	North American Datum of 1983
NM:	national monument
NMAS:	National Map Accuracy Standards
NMDS:	non-metric multi-dimensional scaling
NP:	national park
NPS:	National Park Service
NS:	NatureServe
NVC:	National Vegetation Classification
NVCS:	National Vegetation Classification Standard (or System)
OALS:	Office of Arid Lands Studies
PAG:	Pima Association of Governments
PRIMER:	Plymouth Routines in Multivariate Ecological Research
RMD:	Rincon Mountain District
RMSE:	root mean square error
RRQRR:	Reversed Randomized Quadrant-Recursive Raster
SAGE:	Saguaro National Park, Rincon Mountain District (East Unit)
SAGU:	Saguaro National Park, both units
SAGW:	Saguaro National Park, Tucson Mountain District (West Unit)
SIMPER:	similarity percentages routine
SIMPROF:	similarity profile
SODN:	Sonoran Desert Network
sp.:	species
spp.:	species (plural)
subsp.:	subspecies
TM:	Thematic Mapper

TMD:	Tucson Mountain District
TNC:	The Nature Conservancy
UNESCO:	United Nations Education, Science, and Cultural Organization
USDA:	U.S. Department of Agriculture
USFS:	U.S. Forest Service
USGS:	U.S. Geological Survey
UTM:	Universal Transverse Mercator

Glossary

Alluvial/Alluvium: Clay, silt, sand, gravel, or similar detrital material deposited by running water ([Merriam-Webster](#)).

Association: The lowest floristic unit defined in this report based on the cover and consistency of dominant plant species.

Colluvial: Rock detritus and soil accumulated at the foot of a slope ([Merriam-Webster](#)).

Encinal: An oak grove or an area marked primarily by the growth of oaks ([Merriam-Webster](#)).

Floristic: Of or relating to flowers, a flora, or the phytogeographical study of plants and plant groups ([Merriam-Webster](#)).

Growth/Life form: Broad groupings of plants based upon broad characteristics (e.g. woody vs non-woody, single trunk vs multi-stem) of species, such as graminoid, shrub, subshrub, tree, vine, and forb.

Hydrologic distance (“hydro distance”): Distance to water and/or ephemeral waterways, such as washes and arroyos.

Madrean: A floristic region covering the southwestern US and northwestern Mexico.

Map class: A polygon or series of polygons that define the boundary of one to many different associations.

Microphyllous: Having small leaves.

Mesomorphic: Adapted to conditions of abundant water and relatively humid conditions ([Merriam-Webster](#)).

Montane: Of, relating to, growing in, or being the biogeographic zone of relatively moist cool upland slopes below timberline dominated by large coniferous trees ([Merriam-Webster](#)).

Pediment: A broad gently sloping bedrock surface with low relief that is situated at the base of a steeper slope and is usually thinly covered with alluvial gravel and sand ([Merriam-Webster](#)).

Polygon: A geometric figure that has three or more sides, though they are often irregular lines, and it lies on one plane. Polygons are used to represent the shape and location of different types of data, usually homogenous data.

Physiognomic: Physiognomy is a combination of the external appearance of vegetation, its vertical structure, and the growth forms of the dominant taxa. ([Brian McCarthy](#)).

Ruderal: Growing where the natural vegetational cover has been disturbed by humans ([Merriam-Webster](#)).

Shrub Savanna: A grass dominated community with absolute cover of shrub species at or above 10%, but not exceeding that of the grass species.

Supervised classification: A method of image classification that uses training data to delineate classes.

Topoedaphic: Describing regions that have a specific soil type ([Wiktionary](#)).

Topographic: The configuration of a surface including its relief and the position of its natural and man-made features ([Merriam-Webster](#)).

Tree Savanna: A grass dominated community with absolute cover of tree species at or above 10%, but not exceeding that of the grass species.

Xerophytic: A plant adapted for life and growth with a limited water supply ([Merriam-Webster](#)).

How to Use this Report

This is a large report. Readers with specific interests can focus on particular sections.

Just the highlights, please

- [Executive Summary](#)
- [Chapter 5](#) (Final map products)

Add background on project location

- [Section 1.7](#) (Project area description)
- [Section 1.8](#) (Factors influencing vegetation communities)

Add detail on final vegetation communities

- [Volume II](#) (Two-page summaries of community descriptions)
- [Section 6.4](#) (Distribution and importance of vegetation communities)

Add technical methodology and results

- [Chapter 2](#) (Vegetation classification)
- [Chapter 3](#) (Map creation)
- [Chapter 4](#) (Accuracy assessment)

Executive Summary

The Sonoran Desert Network (SODN) conducted a vegetation mapping and characterization effort at Saguaro National Park from 2010 to 2018. This project was completed under the National Park Service (NPS) Vegetation Mapping Inventory, which aims to complete base-line mapping and classification inventories at more than 270 NPS units. The vegetation map data were collected to provide park managers with a digital map product that meets national standards of spatial and thematic accuracy, while also placing the vegetation into a regional and national context. The data standard was designed to facilitate the production of uniform statistics about vegetation across the nation, enable the translation of data collected at various scales, and allow data sharing, aggregation, and comparison across regions.

Saguaro National Park consists of two units located at opposite ends of Tucson, Arizona. The Tucson Mountain District (TMD) spans the Tucson Mountains to the west of Tucson, while the Rincon Mountain District (RMD) spans the Rincon and Tanque Verde Mountains to the east. These units were completed as separate projects due to their large size and considerable differences in vegetation communities, elevational range, and geology. This report combines the projects from both units into one cohesive document.

Vegetation mapping and characterization comprised four major phases: (1) field-based data collection, (2) development of vegetation community types at the National Vegetation Classification (NVC) association level, (3) development of the vegetation map, and (4) accuracy assessment of the vegetation map. These phases began at the TMD in spring 2010 and at the RMD in spring 2013. The final phase, accuracy assessment, was completed at the TMD in fall 2016 and at the RMD in summer/fall 2018. Due to concurrent vegetation projects at other SODN parks, fieldwork at both units was sporadic throughout these time periods. Further detail can be found in the sections of this report detailing field effort.

A total of 97 distinct vegetation communities were described: 9 exclusively at the TMD, 83 exclusively at the RMD, and 5 occurring in both districts. These communities ranged from low-elevation creosote (*Larrea tridentata*) shrublands spanning broad alluvial fans to mountaintop Douglas fir (*Pseudotsuga menziesii*) forests on the slopes of Rincon Peak. All 97 communities were described at the association level, each with detailed narratives including lists of species found in each association, their abundance, landscape features, and overall community structural characteristics. These associations were attributed across 76 map classes in the final map: 13 at the TMD and 68 at the RMD (with 5 occurring at both districts).

The final project phase of accuracy assessment showed overall map accuracy for all classes was 78.4% (90% CI: 74.0, 83.0) at the TMD, and 76.3% (90% CI: 74.0, 79.0) at the RMD. Individual per-class accuracies ranged from 41.4% to 100%. Only 15 of the 97 vegetation types were existing “accepted” types within the NVC. The others are newly described and specific to Saguaro National Park (and will be proposed for formal status within the NVC).

The products are designed with the goal of facilitating ecologically-based natural resources management and research. The vector (polygon) map is in digital format within a geodatabase structure that allows for complex relationships to be established between spatial and tabular data, and allows much of the data to be accessed concurrently. Each map unit has multiple photo attachments viewable easily from within the geodatabase, linked to their actual location on the ground. The Geographic Information System (GIS) format of the map allows user flexibility and will also enable updates to be made as new information becomes available (such as revised NVC codes or vegetation type names) or in the event of major disturbance events that could impact the vegetation.

This document is Volume I of three volumes comprising the [Saguaro National Park Vegetation Mapping Inventory](#). Volume II provides summaries of the type descriptions for the 97 vegetation communities identified by the project, briefly describing the floristic and structural characteristics of the vegetation and showing representative photos of associations, their distribution, and an example of the satellite imagery for one polygon. Volume III comprises the full type descriptions.

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The authors would like to thank the staff of Saguaro National Park for their support of this project and assistance with logistics. We'd especially like to thank Tim Onstott for providing pack support for a number of high-elevation backcountry tours. Without his assistance, these tours would not have been feasible. Biologist Don Swann has championed this mapping effort and we are deeply grateful for his support, encouragement, and anticipated use of the data. Former Sonoran Desert Network data manager Kristen Bonebrake helped with database design and management. Many people collected and managed the field data, including Nicole Gonzalez, Ethan Sandoval, Katie Dahle, Sage Ragland, Connor Everly, Megan Kimball, Natalie Wilson, Shannon Henke, Beth Fallon, Dan Winkler, Greg Goodrum, and Daniel Stauning. Accuracy assessments were conducted by Ethan Sandoval, Nicole Gonzalez, Sage Ragland, and Connor Everly. Especially in the early phases of this project, we partnered with U.S. Geological Survey (USGS) research geographer and remote-sensing specialist Dr. Miguel Villarreal and USGS researcher Natalie Wilson, who helped us navigate some new methodologies. Finally, we would like to thank Dr. Jim Malusa (University of Arizona), Don Swann (Saguaro National Park), and Natalie Wilson (USGS) for their review and helpful comments, and Patty Valentine-Darby for her valuable editorial support.

1 Introduction

1.1 Project background

This report describes the methods and results of a multi-year project (2010–2018) to classify, describe, and map vegetation at the two districts of Saguaro National Park—the Tucson Mountain District and the Rincon Mountain District—located in Pima County, in southern Arizona. In 1999, the National Park Service’s Natural Resource Challenge provided funding for 12 baseline inventories to be completed in each of 270 park units that contain significant natural resources. The National Park Service Vegetation Mapping Inventory is one of those 12 baseline inventories.

The Sonoran Desert Network (SODN), part of the National Park Service (NPS) Inventory and Monitoring (I&M) Division, organized and coordinated the vegetation inventory at Saguaro National Park (NP), including the upfront classification of the vegetation and subsequent mapping. Vegetation is a primary resource of natural areas, and knowledge of vegetation composition, structure, and distribution is fundamental to effective land management. At Saguaro NP and other network parks, park managers need baseline data on park vegetation for planning new facilities (e.g., trails, campgrounds), conducting prescribed fire, predicting the behavior of wildfire, protecting rare plants, and restoring disturbed habitats. The term “vegetation” encompasses plants at multiple scales, from the most refined floristic levels (referred to as “plant communities” in this report) to the broadest physiognomic or lifeform levels, such as “tropical rainforest” or “savanna.”

The standards of the NPS Vegetation Mapping Inventory include a minimum mapping unit of 0.5 hectares, >80% thematic accuracy per class, and spatial accuracy meeting the U.S. National Map Accuracy Standards developed by the Federal Geographic Data Committee (FGDC). In addition to meeting the program standards, every effort is made to provide the mapping and classification data to park managers in a manner best suited to their specific management objectives and needs.

1.2 Goals, scope, and products

The aim of the Saguaro National Park project was to create a vegetation map at the National Vegetation Classification System (NVCS) association level for both districts of the park, a study area of about 37,281 hectares (92,123 acres). Products developed for the project include those listed below.

- A final report (this document) that:
 - Discusses classified vegetation communities in the broader context of the park as it relates to fire history, non-native invasive plants, and other types of disturbance.
 - Provides a detailed overview of the park to provide more context for the project and all its products.
 - Discusses the methodology, what worked, and what could have been done differently.
 - Discusses the previous vegetation map (Roseberry and Dole 1937) and how it was used to inform the current map.
- A classification report containing the full vegetation community-type descriptions set within the NVCS hierarchy framework.
- A dichotomous vegetation key to all classified associations.
- Digital reference photos of each vegetation plot.
- A geodatabase containing mapped vegetation data, plot data and location, permanent photo point locations, and satellite imagery.
- Printable digital graphics of final map polygons.
- Federal Geographic Data Committee-compliant metadata for all spatial database files and field data.
- A park-specific [field guide](#) to common plants with an annotated checklist and voucher-specimen list (not a program requirement; an additional product developed by SODN).

1.3 The NPS Vegetation Mapping Inventory

The NPS Vegetation Mapping Inventory classifies, describes, and maps vegetation communities in more than 270 national park units across the country. The NPS is the primary funding agency, providing parks support through Inventory and Monitoring Division base funds. The program serves the data products from the Vegetation Mapping Inventory website. They can also be accessed via the NPS Integrated Resource Management Applications (IRMA) portal.

The Vegetation Mapping Inventory supports consistent vegetation classification, mapping, and accuracy-assessment protocols and standards across all park vegetation-mapping projects. The program has established guidance in four documents:

- Vegetation classification guidelines: National Park Service Vegetation Inventory, version 2.0. (Natural Resource Report NPS/NRPC/NRR—2011/374).
- Methodology for assessing the utility of existing data for vegetation mapping (TNC and ESRI 1994a).
- Federal Geographic Data Committee National Vegetation Classification Standard, v. 2 (2008).
- Thematic accuracy assessment procedures: National Park Service Vegetation Inventory, version 2.0 (Natural Resource Report NPS/NRPC/NRR—2010/204).

In addition, the program has defined national standards for all park vegetation classification and mapping projects:

- Vegetation classification follows the FGDC standard for vegetation classification, the National Vegetation Classification Standard.
- Spatial data formatting follows FGDC standards for spatial data transfer.
- Metadata for each spatial dataset use the FGDC metadata standard.
- Spatial data are provided with a horizontal positional accuracy that meets National Map Accuracy Standards at the 1:24,000 scale. Each well-defined object within the spatial database is within 1/50

of an inch display scale, or 12.2 meters (40 ft) of its actual location.

- All plant names used in the classification are consistent with the Integrated Taxonomic Information System (ITIS).
- Each vegetated map class will try to meet or exceed 80% accuracy at the 90% confidence level.
- The minimum mapping unit (MMU) is 0.5 hectares (1.24 ac).

1.4 The National Vegetation Classification Standard

Patterns of vegetation vary continuously over landscapes. Classification systems attempt to categorize those patterns by identifying and describing assemblages of plants that repeat under similar environmental conditions. The National Vegetation Classification Standard provides a classification framework that is the standard for all NPS vegetation mapping projects (Comer et al. 2003; TNC and ESRI 1994). In 1997, the FGDC formally adopted the NVCS version 1 (FGDC 1997). It was recognized as incomplete at the time of its adoption, and work to refine and further develop it began immediately. In October 2007, the FGDC vegetation subcommittee released the NVCS Version 2 Working Draft (FGDC 1997), which was formally endorsed in February 2008.

The NVCS evolved from vegetation classification primarily conducted over more than two decades by The Nature Conservancy, NatureServe, and the Natural Heritage Program network (Grossman et al. 1998). It derives in part from earlier vegetation classification frameworks produced by the United Nations Educational, Cultural, and Scientific Organization (UNESCO 1973; Driscoll et al. 1984). Use of this standardized classification system helps ensure data compatibility throughout the National Park Service and other agencies. The NVCS was designed to facilitate the production of uniform statistics about vegetation across the nation, enable the translation of data collected at various scales, and allow data sharing, aggregation, and comparison across regions.

The NVCS is a hierarchical system that allows vegetation classification to occur at multiple scales. Existing vegetation is classified on the basis of both physiognomic and floristic criteria. The upper three levels are physiognomic, based primarily on growth form, structure, and cover, indicating characteristics that reflect geographically widespread (global) topoeclaphic factors, such as soils and physical properties of landscapes. The middle three levels focus on largely biogeographic and habitat factors along very broad, continental-to-regional topographic, edaphic, and disturbance gradients. The lower two levels are floristic,

based primarily on species composition and abundance. Tables 1-1 to 1-3 show the revised version 2, under which this project was conducted, and which NatureServe and the Ecological Society of America (ESA) vegetation panel are currently using to substantially update the structure and content of the NVCS.

The NVCS also distinguishes between natural and cultural vegetation, the former being determined primarily by ecological processes and the latter by regular human activity. Vegetated areas intermediate between the two, such as those influenced by both hu-

Table 1-1. Example of the National Vegetation Classification Standard hierarchical approach: Version 2.

Level	Level name	Criteria	Example
L1	Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and/or substrate or aquatic conditions.	Mesomorphic Shrub and Herb Vegetation (Shrubland and Grassland)
L2	Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position, or that reflect overriding substrate or aquatic conditions.	Temperate and Boreal Shrub and Herb Vegetation (Temperate and Boreal Shrubland & Grassland)
L3	Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic factors as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.	Temperate Shrub and Herb Vegetation (Temperate Shrubland & Grassland)

Table 1-2. Example of the National Vegetation Classification Standard (version 2) hierarchy: Mid levels.

Level	Level name	Criteria	Example
L4	Division	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.	<i>Andropogon gerardii</i> - <i>Stipa</i> - <i>Bouteloua</i> Grassland & Shrubland Division (North American Great Plains Grassland & Shrubland)
L5	Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and subcontinental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	<i>Andropogon gerardii</i> - <i>Schizachyrium scoparium</i> - <i>Sorghastrum nutans</i> Grassland & Shrubland Macrogroup (Great Plains Tall Grassland & Shrubland)
L6	Group	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 composition and subcontinental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	<i>Andropogon gerardii</i> - <i>Sporobolus heterolepis</i> Grassland Group (Great Plains Mesic Tallgrass Prairie)

Table 1-3. Example of the National Vegetation Classification Standard (version 2) hierarchy: Lower levels.

Level	Level name	Criteria	Example
L7	Alliance	Diagnostic species, including some from the dominant growth form or layer, and moderately similar composition that reflect regional to subregional climate substrates, hydrology, moisture/nutrient factors, and disturbance regimes.	<i>Andropogon gerardii</i> - (<i>Calamagrostis canadensis</i> - <i>Panicum virgatum</i>) Herbaceous Alliance (Wet-mesic Tallgrass Prairie)
L8	Association	Diagnostic species, usually from multiple growth forms or layers, and more narrowly similar composition that reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.	<i>Andropogon gerardii</i> - <i>Panicum virgatum</i> - <i>Helianthus grosseserratus</i> Herbaceous Vegetation (Central Wet-mesic Tallgrass Prairie)

man activity (e.g., logging, fire, and grazing) and ecological processes, are defined as semi-natural. The guidelines for NPS vegetation mapping projects require the classification and mapping of communities as they are at the time of mapping. In areas of recent disturbance, communities are described in their current condition, not as what they once were or what they are likely to become in the future. Understanding the succession of disturbed communities is vital for the management of wildlands. Sections 1.8.5 and 6.2 of this report attempt to address the effects of large-scale disturbance, primarily wildfire, on the vegetation communities throughout the park. The authors do not have the necessary expertise or information to predict future community structure of these areas.

1.5 The National Vegetation Classification

The NVCS provides a framework for levels of classification but does not provide descriptions of all existing vegetation types at all levels. Those descriptions comprise the National Vegetation Classification (NVC), which is being populated by data from various completed vegetation inventory projects (such as the present one) and many other sources. The NVC, which is predominantly maintained by NatureServe and used by many federal agencies, including the NPS, includes the plant communities (associations and alliances) defined for the United States.

NatureServe manages a database of NVC plant-community entities. Their online database, NatureServe Explorer, provides public access to regularly updated versions of NVC

plant-community listings and descriptions. However, the plant-community listings within the NVC are incomplete; many are still in development and/or undergoing revisions. A newer website, usnvc.org, posts all new descriptions as well as information on the changes to the hierarchy, and displays these vegetation type descriptions in the new hierarchy (see Tables 1-1 to 1-3).

Most vegetation associations listed on this site link to a full and updated description on the NatureServe explorer site. However, as the NatureServe/ESA vegetation panel review progresses, new alliance concepts are slowly being added, as are associations from recent mapping efforts. The alliance level of the system was incomplete during our project, with few alliances formally accepted for our area in southern Arizona. Therefore, all classes have been developed and reported here at the association level, with group and/or alliance membership noted when known. This project used information available through usnvc.org and NatureServe to describe and classify the vegetation types within the broader system of known types. Where information was lacking or incomplete, classification of vegetation sampled at Saguaro NP was based solely on data collected during this effort, and naming conventions were developed as fitting.

For more information on the NVC, see the NPS Vegetation Mapping Inventory [website](#) or Grossman and others (1998).

1.6 Terminology and naming conventions

Alliances and associations are based on

both the dominant (greatest-canopy-cover) species in the upper stratum of a contiguous vegetation unit and on diagnostic species (those consistently found in some land-cover types but not others). Associations, which describe and identify the two or three dominant species of a community, are the most specific classification, and are hierarchically subsumed in alliances. Typically, each association is included in only one alliance, while each alliance may include many associations.

Associations define distinct plant compositions that repeat across the landscape. They are generally named using both the dominant species in the uppermost stratum of the vegetation and one or more dominant species in lower strata (or a diagnostic species in any stratum). Associations are defined as having consistent species composition, uniform physiognomy, and similar habitat conditions.

Map classes are spatial components that define the area covered by associations. When mapping efforts are fully successful, there is a 1:1 relationship between association and map class, meaning associations were distinct enough from one another that the model was able to accurately define their boundaries. When this is not the case, map classes are created with a 1:many relationship between map class and association. This occurred at two points during this project. Prior to and during map creation, we identified a number of associations that either lacked sufficient data or were so intermingled with adjacent associations that we combined them into map classes. After the accuracy assessment, we identified additional groups of associations that were consistently misidentified as one another or were too similar (floristically) to differentiate. In most cases, these became 1:many map classes. More on terminology can be found in the Glossary section of this report.

Naming conventions and syntax for all NVC names are as follows:

- A hyphen with a space on either side (-) separates names of species occurring in the same stratum.
- A slash with a space on either side (/)

separates names of species occurring in different strata.

- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.
- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value. (Indicator species are those that are restricted to certain environments, so while not dominant, they are indicative of, or can represent, certain communities.)
- Parentheses () around a species name indicate the species is less consistently found either in all associations of an alliance, or in all occurrences of an association.
- Square brackets [] around two species names indicate the species are co-dominant, with either being dominant in a given stand.
- Association names include the dominant species of the significant strata, followed by the structural class in which they are classified (e.g., Forest, Woodland, or Herbaceous).
- Alliance names also include the structural class in which they are classified (e.g., Forest, Woodland, or Herbaceous), but are followed by the word “Alliance” to distinguish them from associations (alliances are not used in this report).
- A “(P)” at the end of an alliance or association name implies the type is proposed only and is not yet a formally accepted vegetation type within the NVC. These proposed types are reviewed on an ongoing basis and are added to the NVCS when sufficient data have been collected to support their addition.
- A “(PS)” at the end of an association name implies that the type is a “park special,” meaning it has been described as a unique community only found in the given park unit to date. This typically occurs when an area has a unique disturbance or management history.

The species nomenclature for all associations follows Kartesz (1999). Examples of association names from Saguaro NP include the following:

- *Pinus ponderosa* / *Quercus hypoleucoides* Woodland Association
- *Pinus discolor* / *Quercus rugosa* Woodland Association
- *Parkinsonia microphylla* / *Encelia farinosa* - *Hibiscus denudatus* Shrubland Association

1.7 Project area description

1.7.1 Location and setting

Saguaro National Park is located in southern Arizona, in the northeastern portion of Pima County, around the city of Tucson (Figure 1-1). The park comprises two districts, the Tucson Mountain District (TMD) (Figure 1-2) and the Rincon Mountain District (RMD) (Figure 1-3). The districts are separated by 32 kilometers (20 mi), with the TMD positioned to the west of Tucson and the RMD to the east (see Figure 1-1). Combined, these districts encompass a total of 37,390 hectares (92,392 ac), the majority of which (73%) is within the RMD.

The TMD covers 10,049 hectares (24,830 ac) of Sonoran Desert scrub, at elevations

ranging from 665 meters (2,182 ft) along the district's western boundary to 1,429 meters (4,690 ft) at the summit of Wasson Peak, the high point of the Tucson Mountains. This district spans the northern portion of the Tucson Mountains and is contiguous with Pima County's Tucson Mountain Park to the south. State trust and private lands surround the district in all other directions.

The RMD covers 27,346 hectares (67,575 ac) of the Rincon Mountains, at elevations ranging from 812 meters (2,666 ft) near the northwest boundary to 2,642 meters (8,668 ft) at the summit of Mica Mountain. This district encompasses saguaro (*Carnegiea gigantea*) "forests" along the west boundary, as well as the majority of the Rincon Mountains. The eastern half of the district is surrounded by U.S. Forest Service (USFS) lands of the Coronado National Forest's Santa Catalina ranger district. Portions adjacent to the other park boundaries are privately owned, with a mixture of low- and high-density housing.



Figure 1-1. Overview of both districts of Saguaro National Park, including the Tucson metropolitan area.

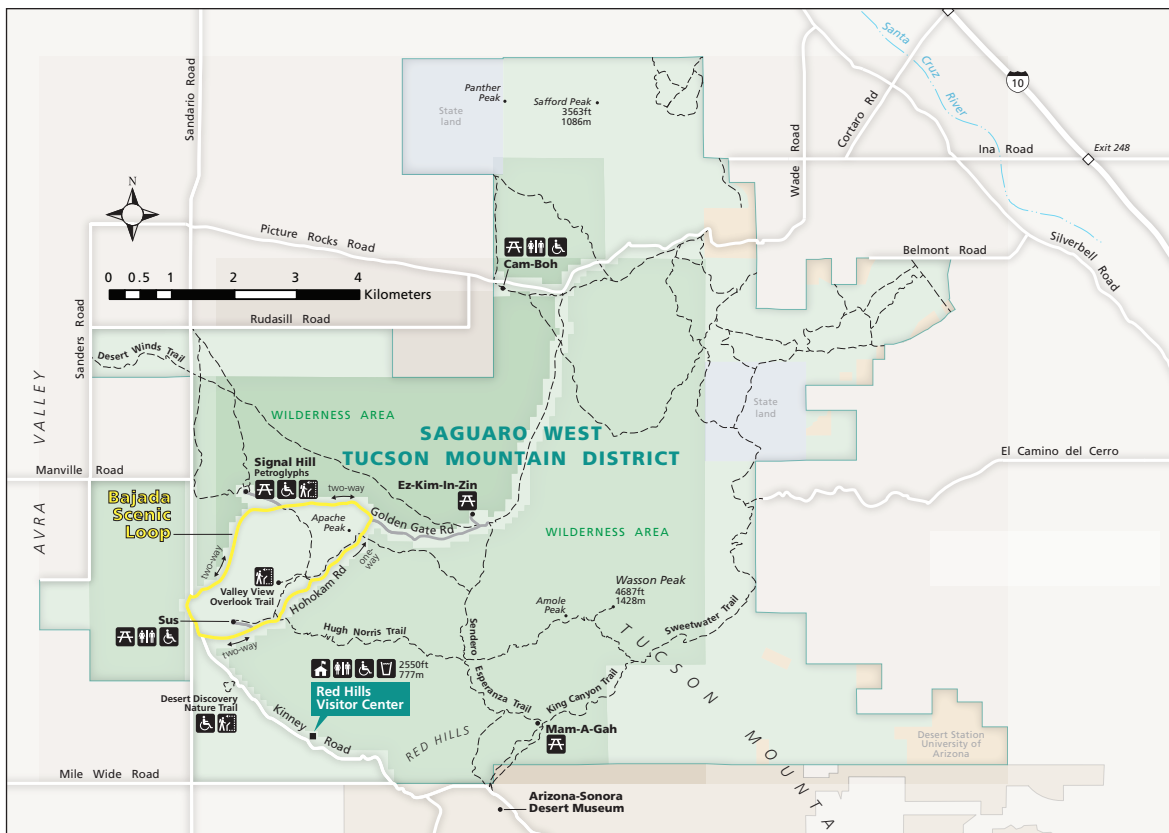


Figure 1-2. General map of the Tucson Mountain District, Saguaro National Park.

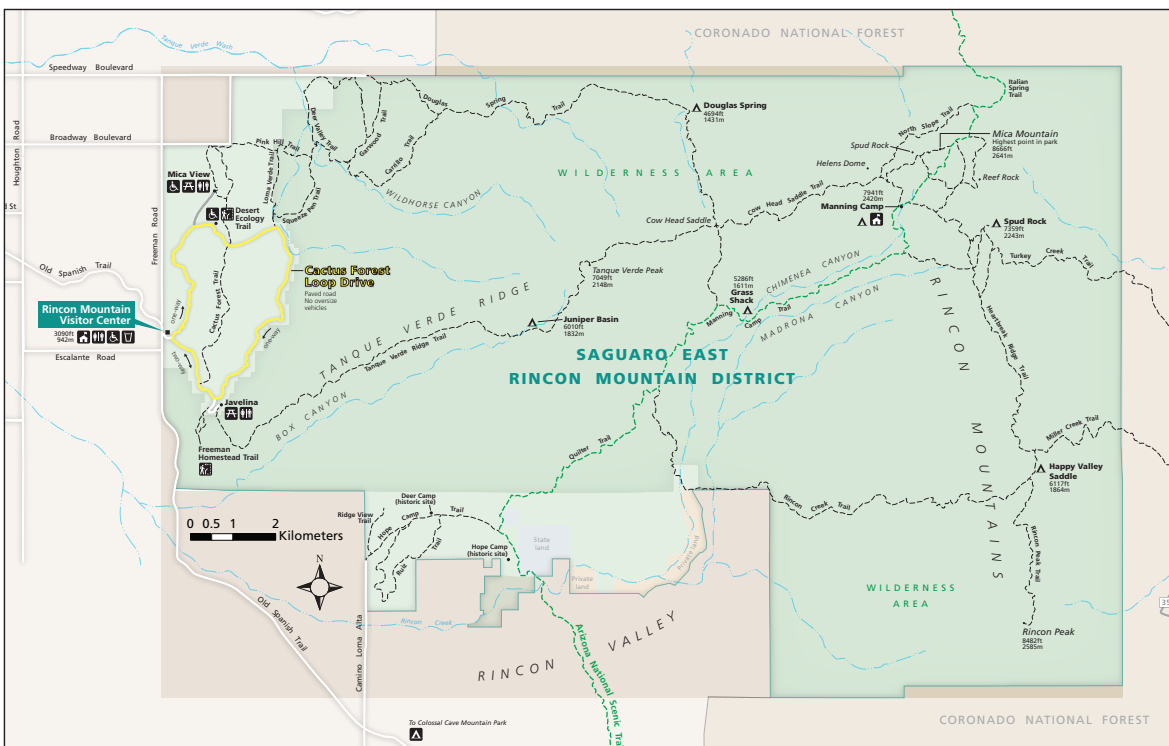


Figure 1-3. General map of the Rincon Mountain District, Saguaro National Park.

1.7.2 Park establishment and purpose

Saguaro National Park was established as Saguaro National Monument in 1933, to preserve and protect lands “of outstanding scientific interest because of the exceptional growth thereon of various species of cacti, including the so-called giant cactus” (saguaro) (Presidential Proclamation No. 2032, 47 Stat. 2557). At time of establishment, the monument included only 25,000 hectares (61,776 ac) of what is currently in the Rincon Mountain District, and was administered by the U.S. Forest Service. Within a few months of the monument’s creation, the lands were transferred to National Park Service jurisdiction. In 1961, concerns over the potential loss of Sonoran Desert habitat in the Tucson Mountains, due to mining, led to the addition of 6,215 hectares (15,360 ac) to the monument (Beckwith 2016). This addition, disjunct from the original lands, became known as the Tucson Mountain District, and the original portion of the monument became known as the Rincon Mountain District. Additional lands were added to the TMD in 1976 (2,176 ha/5,378 ac) and 1994 (1,508 ha/3,726 ac). The RMD received an additional 1,416 hectares (3,500 ac) in 1991 and 108 hectares (267 ac) in 2019. Congress elevated the monument to national park status in 1994 (NPS 2014).

1.7.3 Previous vegetation studies

In the spring of 1937, two junior foresters with the USFS, R. D. Roseberry and N. E. Dole, completed fieldwork for a basic vegetation survey and map of Saguaro National Monument (Roseberry and Dole 1939a, 1939b). Travelling on horseback and with the aid of topographic maps, the foresters hand-drew the boundaries of 14 broad vegetation types. In addition, an unknown number of vegetation plots were sampled across the Rincon Mountains. Roseberry and Dole defined most types by the presence/absence of diagnostic species, cover by lifeform (e.g., shrub, grass), and presence/absence of commercial timber trees. For example, the pine type is defined as “areas that contain 20% or more commercial pines, to the exclusion of Douglas fir and white fir.”

Roseberry and Dole’s final map was referenced for the current project but not used to inform it, due to methodological differences and their coarse level of classification. Roseberry and Dole’s map, and more detail about their project, can be found in Section 6.3 of this report.

Beginning prior to the establishment of the monument and continuing to the present day, various projects have been implemented to study and monitor saguaros (*Carnegiea gigantea*) within the park. The history of these projects is best summarized in Ahnmark and Swann (2008).

Starting in the early 1990s, Saguaro NP’s fire effects program began establishing long-term monitoring plots in high-elevation areas of the RMD, following protocols outlined in the NPS fire-monitoring handbook. As per these protocols, plots are sampled pre-fire and immediately post-fire, then at 1, 2, 5, and 10 years post-fire. Data collected at each plot have varied since establishment, but at a minimum include density of trees, saplings, and seedlings; and assessments of canopy cover, dominant herbaceous species, and burn severity. As of 2011 (the most recent year of plot establishment), a total of 58 plots were established, starting south of Devils Bathtub and continuing north to the North Slope Trail. These data were referenced as the current vegetation classification was developed for high-elevation reaches of the RMD.

In fall 2008, the Sonoran Desert Network began establishing long-term vegetation-and-soils monitoring plots throughout the RMD. The project was expanded to the TMD the following year. These plots are sampled on five-year cycles, with a subset of plots sampled every year. Data are collected in an effort to monitor change in species cover and composition over time. At time of writing, the third five-year sampling cycle had begun at both units of the park. Data from the initial two rounds of sampling are discussed in Hubbard and others (in prep). These plots ($n = 72$) were referenced as the current vegetation classification was developed.

1.8 Factors influencing vegetation communities

1.8.1 Urban pressures

The Southwest is one of the fastest-growing regions in the United States. The population of Pima County increased from approximately 351,667 in 1970 to 980,263 in 2010. The number of housing units has greatly increased as well, growing from 118,623 to 440,909 over the same timespan. This rapidly expanding population has led to numerous current and potential future resource management challenges.

The destruction and/or alteration of riparian corridors and the increasing urbanization of the Tucson Valley have increased the isolation of the two districts from each other and from other nearby sky islands, such as the Santa Rita Mountains, to the south, and Santa Catalina Mountains, to the north. This is problematic for many wildlife species (e.g., mountain lion, American black bear, desert bighorn, desert tortoise, fox, skunk) that rely on sizable home ranges for hunting and foraging, predator/competitor avoidance, and maintaining gene flow between populations (Murphy et al. 1999). The decrease in free movement between the sky islands and other intact protected lands, and the increased chance of human interaction, may

be detrimental to the long-term survival of these and many other native wildlife species.

Concurrent with rising human population, increased groundwater pumping for agriculture, industry, and drinking water has caused the water table to drop. Studies in desert ecosystems have determined that depth-to-groundwater is one of the most important variables influencing vegetation composition (Stromberg et al. 1996; Bryan 1928). This may be especially problematic for riparian communities that require groundwater to survive periods of drought and are unable to cope with periods of repeated stress.

1.8.2 Climate, geology, and hydrology

1.8.2.1 Climate

Saguaro NP experiences climate typical of the Sonoran Desert and Apache Highlands ecoregions: highly variable, bimodal precipitation with a considerable range in daily and seasonal air temperature, and relatively high potential evapotranspiration rates (TNC 1999). Lower elevations of both districts receive approximately half their annual precipitation during summer thunderstorms (Figure 1-4), with maximum air temperatures often exceeding 40°C (104°F). Higher elevations in the Rincon Mountains receive nearly twice the annual precipitation

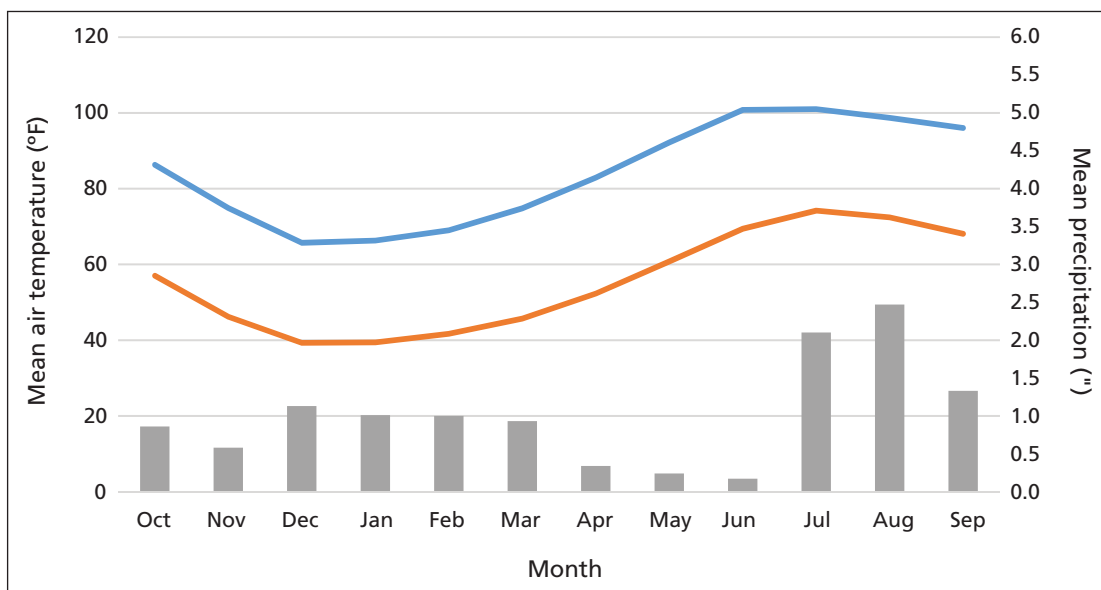


Figure 1-4. Maximum and minimum mean monthly air temperatures and precipitation, Tucson Mountain District, Saguaro National Park (Tucson 17NW), 1981–2010. Conditions at lower elevations of the Rincon Mountain District are similar. Average annual precipitation is 12.2". Data from www.climateanalyzer.org.

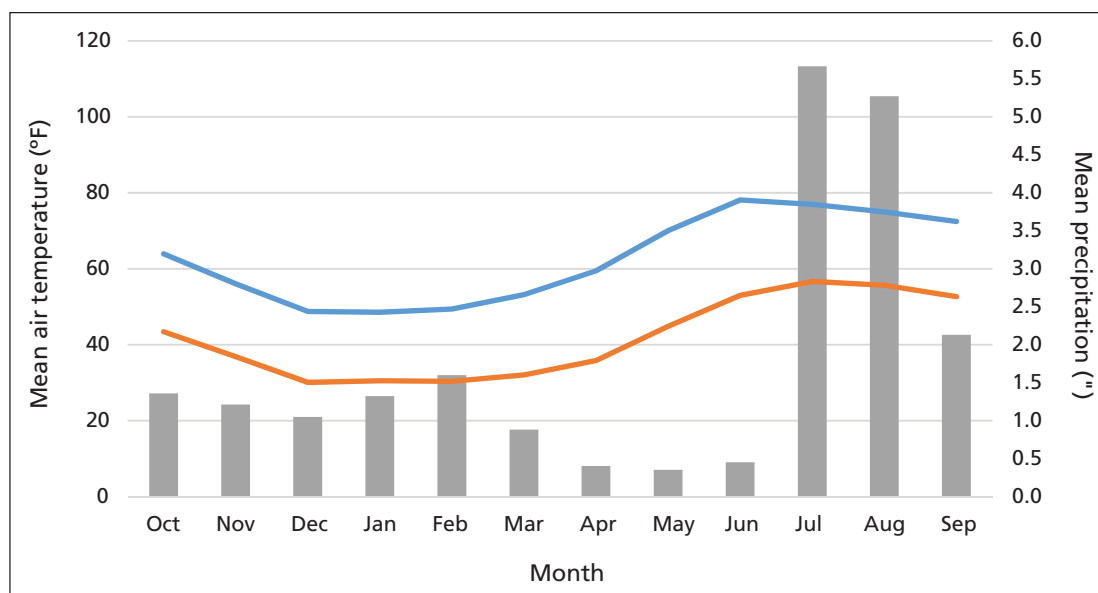


Figure 1-5. Maximum and minimum mean monthly air temperatures and precipitation atop Mica Mountain in the Rincon Mountain District, Saguaro National Park (QHVA3 RAWs), 1994–2010. Precipitation is only measured via tipping-bucket rain gauge, which often fails to accurately measure precipitation as snow. Winter and overall precipitation are therefore likely underestimated. Average annual precipitation is 21.7". Data from www.climateanalyzer.org.

of lower sites, with the increase occurring mostly during summer months (Figure 1-5). The bulk of the remaining annual precipitation falls in relatively gentle, cool-season events of broad extent, often as snow at higher elevations (Davey et al. 2007).

1.8.2.2 Geology

The Rincon Mountain District contains one of the best exposures of a metamorphic core complex in western North America, exhibiting features that provide important clues about how these complexes developed (Graham 2010). By contrast, the Tucson Mountain District is volcanic in nature, and displays examples of the Tucson Mountains Caldera found along the western extent of the Tucson Basin (Graham 2010).

These divergent geologies, including the age of the dominant parent material (much younger for the RMD) have important consequences for soil development and characteristics. Unfortunately, the thematic and spatial scale of soil mapping at Saguaro NP is among the most imprecise in the Sonoran Desert Network, and the NPS has not provided resources to support an adequate survey effort. The current park surveys are merely “clipped” from the Pima County (Arizona) soil survey, which generally lumps

foothills and mountain soils into broad categories.

Despite the lack of detailed soils information, we can conclude that soils of both districts are generally shallow and rocky. Across the entire park, rock fragments make up 35–90% of surface soils by volume (NRCS 2020). Known exceptions are the relatively less-rocky soils of the RMD Cactus Forest area, and small portions of the valley bottoms in the Tucson Mountain District.

1.8.2.3 Hydrology

The TMD spans five watersheds (HUC12) that converge near the summit of Wasson Peak (Figure 1-6). In general, these watersheds flow into Brawley Wash in Avra Valley to the west, or into the Santa Cruz River Valley to the east. Within the district, the primary watercourses are dry, desert washes, typically lined with xerophytic shrubs and trees, such as velvet mesquite (*Prosopis velutina*), whitethorn acacia (*Vachellia constricta*), and catclaw acacia (*Senegalia greggii*) (Figure 1-7). These ephemeral watercourses are fed by occasional summer thunderstorms and winter rains and appear as broad, sandy washes in the lower elevations and rocky drainages in the higher areas. In the absence of recent precipitation events, these features

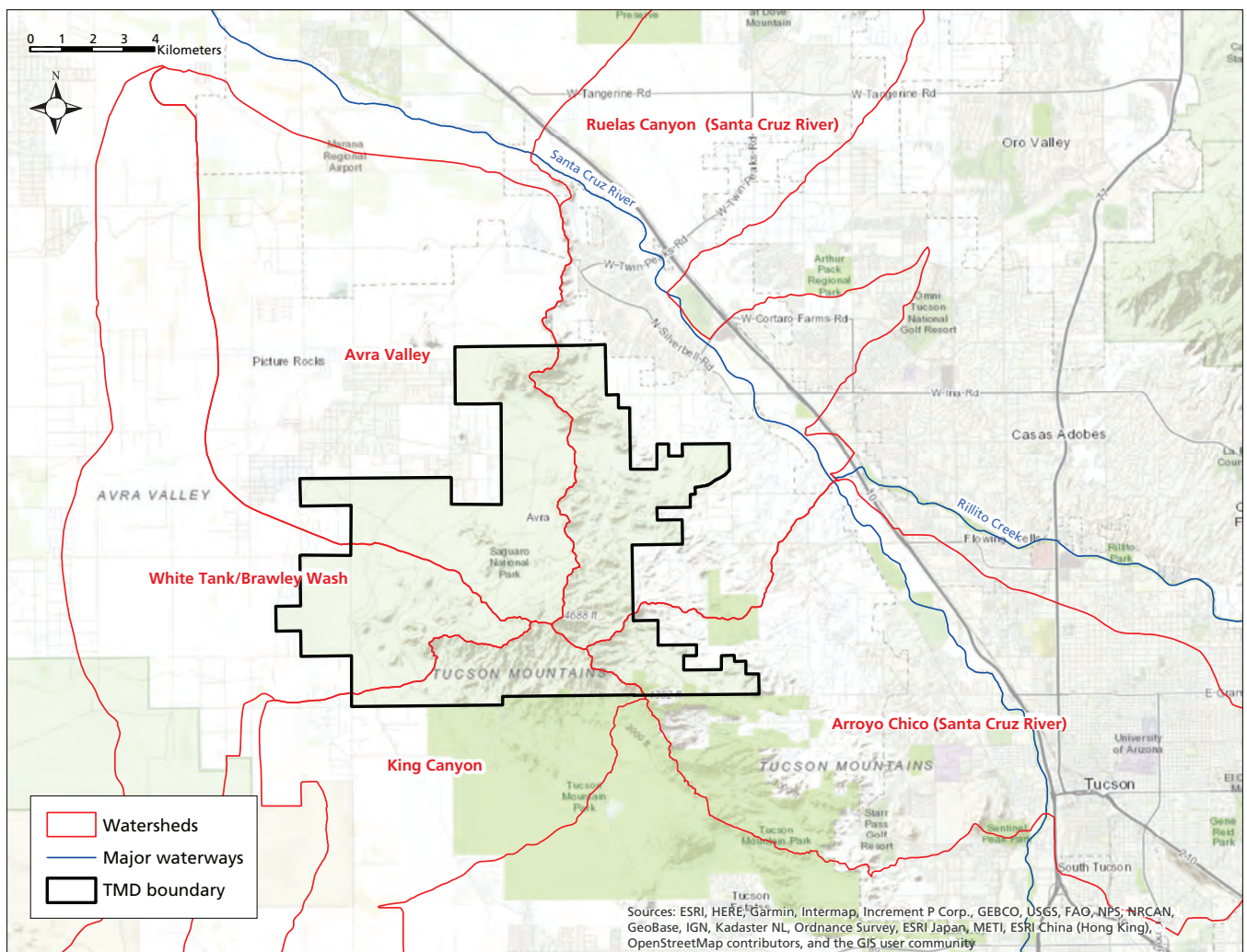


Figure 1-6. Overview of HUC12 watersheds (USGS 2014) included within the Tucson Mountain District. Major named watercourses within and adjacent to the district are depicted.



Figure 1-7. Dry desert wash community at the Tucson Mountain District.

are dry. No perennial springs or seeps have been documented within this district.

The Rincon Mountain District spans nine watersheds (HUC12) that converge along Tanque Verde and Heartbreak ridges. The watersheds west of Heartbreak Ridge predominately flow into either Rincon Creek, to the south, or Tanque Verde Creek, to the north (Figure 1-8). Both of these flow into Rillito Creek and eventually the Santa Cruz River. The eastern flank of the range flows to the San Pedro River via Ash Creek, Paige Creek, and Soza Canyon. Running from its headwaters on the northern slopes of Rincon Peak and flowing west along the district's southern boundary, Rincon Creek is the most prominent riparian habitat within the park. Along its course, numerous major named drainages converge, including Chiminea, Madrona, and Box canyons.

Within the district, watercourses range from dry desert washes similar to those at the TMD, to deep, rocky mountain drainages dotted with spring-fed tinajas.

At lower elevations, vegetation communities include xerophytic shrublands and woodlands similar to those in the TMD, as well as riparian woodlands dominated by Arizona sycamore (*Platanus wrightii*), velvet ash (*Fraxinus velutina*), and willow (*Salix* spp.) (Figure 1-9). At the park's upper reaches, communities begin to include Arizona alder (*Alnus oblongifolia*) and/or boxelder (*Acer negundo*). Spring-fed tinaja systems occur throughout the numerous rocky drainages bisecting the range. These provide critical access to scarce water for the park's fauna, such as the lowland leopard frog (*Rana yavapensis*) (Swann et al. 2013). In addition, these pools provide habitat for numerous

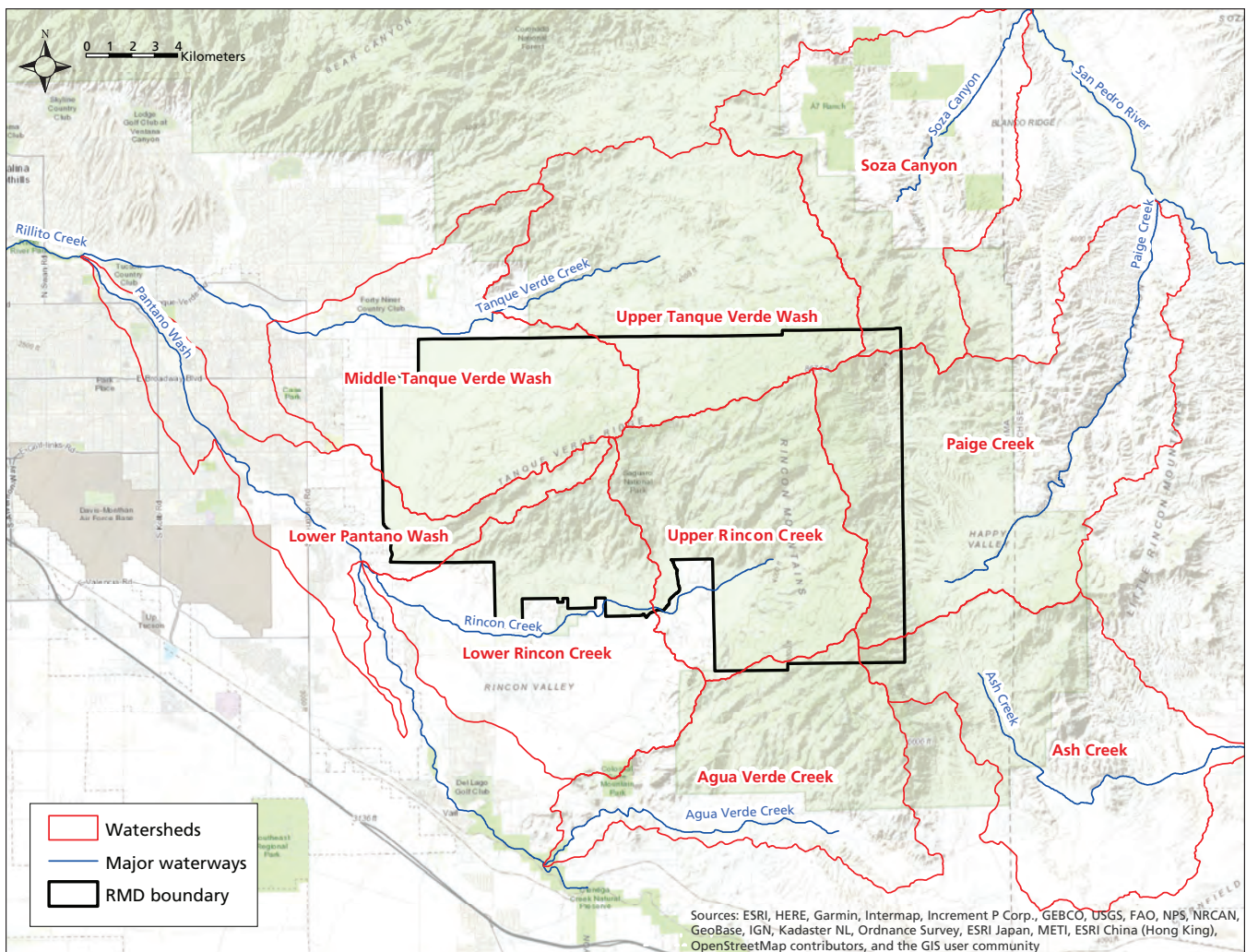


Figure 1-8. Overview of HUC12 watersheds (USGS 2014) included within the Rincon Mountain District. Major named watercourses within and adjacent to the district are depicted.

obligate wetland species only found in these locations, including southern cat-tail (*Typha domingensis*), rush (*Juncus* spp.), bulrush (*Scirpus* spp.), sedge (*Carex* spp.), and the imperiled (S2) Chiricahua Mountain brookweed (*Samolus vagans*).

1.8.3 Vegetation

1.8.3.1 Vegetation communities

Saguaro NP sits along the eastern edge of the Sonoran Desert, within the Arizona upland subdivision, as described by Brown (1982). This subdivision is the cooler and higher-elevation portion of the Sonoran Desert. The TMD falls entirely within the Sonoran Desert, while the RMD encompasses additional, higher-elevation biomes, including semidesert grassland, Madrean evergreen woodlands, interior chaparral, and montane coniferous forests. East of the Rincon Mountain District, vegetation begins its transition to the Chihuahuan Desert.

The Sonoran Desert portions of the park (Figure 1-10) are characterized by the presence of saguaro (*Carnegiea gigantea*), with an open canopy of yellow paloverde (*Parinsonia microphylla*) and/or velvet mesquite (*Prosopis velutina*). The diverse understory contains a mix of micro-sclerophyllous shrubs, such as creosote (*Larrea tridentata*); drought-deciduous legumes, including whitethorn acacia (*Vachellia constricta*) and catclaw acacia (*Senegalia greggii*); and low succulents, such as cactus apple (*Opuntia engelmannii*). Within this biome, the two districts differ due to the dominance of triangle bur ragweed (*Ambrosia deltoidea*) at the TMD (it is rare to absent at the RMD), and desert ironwood (*Olneya tesota*), which grows exclusively at the TMD.

As described by Brown (1994), semi-desert grassland (Figure 1-11) is a perennial-grass/scrub-dominated system that sits between the low-elevation Sonoran Desert and the evergreen woodland and chaparral found above. Regionally, these grassland systems extend into southeastern Arizona from Mexico, New Mexico, and Texas, existing primarily as a Chihuahuan grassland type. Local examples show the Sonoran influence. A very small area atop Wasson Peak (TMD) begins to transition to this type, whereas



Figure 1-9. *Platanus wrightii* - *Fraxinus velutina* Intermittently Flooded Woodland along Rincon Creek, within the Rincon Mountain District.



Figure 1-10. Example of Sonoran Desert communities at Saguaro National Park.



Figure 1-11. Example of semi-desert grassland communities at Saguaro National Park.



Figure 1-12. Example of Madrean encinal communities at Saguaro National Park.



Figure 1-13. Example of Madrean evergreen woodland communities at Saguaro National Park.



Figure 1-14. Example of warm interior chaparral communities at Saguaro National Park.

vast expanses at the RMD support this biome. Characteristic graminoids include sideoats grama (*Bouteloua curtipendula*), tanglehead (*Heteropogon contortus*), Lehmann lovegrass (*Eragrostis lehmanniana*), and bullgrass (*Muhlenbergia emersleyi*). Characteristic shrubs, succulents, and trees include Schott's century plant (*Agave schottii*), cactus apple (*Opuntia engelmannii*), turpentine bush (*Ericameria laricifolia*), velvet mesquite (*Prosopis velutina*), beargrass (*Nolina microcarpa*), common sotol (*Dasylirion wheeleri*), yucca (*Yucca madrensis*), and Arizona rosewood (*Vauquelinia californica*).

As elevation increases at the RMD, oak species (*Quercus* spp.) begin to appear and become consistent canopy trees. This marks the transition to the Madrean encinal woodlands (Figure 1-12). This biome spans open tree savannas with a dominant understory of perennial bunch grasses. At the RMD, this biome is defined by a mixed-oak canopy of Emory oak (*Quercus emoryi*) and Mexican blue oak (*Quercus oblongifolia*), with an herbaceous understory of bullgrass (*Muhlenbergia emersleyi*), pointleaf manzanita (*Arctostaphylos pungens*), beargrass (*Nolina microcarpa*), and Schott's century plant (*Agave schottii*). In many examples, these communities are a result of historical fire disturbance.

As elevation increases further in the RMD, pinyon pines begin to appear. This marks the transition to the Madrean pinyon/juniper woodlands (Figure 1-13). This biome spans open tree savannas with a dominant understory of perennial bunch grasses at the lower elevational range, to dense woodlands at the upper. It is defined by a canopy of border pinyon (*Pinus discolor*) and alligator juniper (*Juniperus deppeana*), with a mix of evergreen oaks, such as Emory oak (*Quercus emoryi*), Mexican blue oak (*Quercus oblongifolia*), Arizona white oak (*Quercus arizonica*), silverleaf oak (*Quercus hypoleucoides*), and netleaf oak (*Quercus rugosa*).

Interspersed with the Madrean encinal and pinyon-juniper communities are expanses of warm interior chaparral (Figure 1-14). This biome is defined by a dense shrub layer of pointleaf manzanita (*Arctostaphylos pungens*) at lower elevations and Pringle's manzanita

(*Arctostaphylos pringlei*) at higher elevations. Spread throughout these shrublands are numerous oak species, including Emory oak (*Quercus emoryi*), Arizona white oak (*Quercus arizonica*), and silverleaf oak (*Quercus hypoleucoides*). In many cases, this community is the result of historical fire disturbance.

Above the Madrean pinyon-juniper woodlands, large conifers begin to appear as the emergent canopy tree. This marks the transition to Madrean montane forest (Figure 1-15). This biome is characterized by a canopy of large conifers with an understory of mixed oak species. The large conifers include Chihuahuan pine (*Pinus leiophylla*), ponderosa pine (*Pinus ponderosa*), and Arizona pine (*Pinus arizonica*). The oaks include silverleaf oak (*Quercus hypoleucoides*), Arizona white oak (*Quercus arizonica*), and netleaf oak (*Quercus rugosa*).

Interspersed with the Madrean montane forest, typically in areas of historical fire disturbance, a number of dense oak communities occur that are devoid of both large conifers and pinyon pine (Figure 1-16). Depending upon fire severity and the number of years since the fire event, these communities present as either woodlands or shrublands. Oak composition typically includes a mix of silverleaf oak (*Quercus hypoleucoides*), netleaf oak (*Quercus rugosa*), Arizona white oak (*Quercus arizonica*), and canyon live oak (*Quercus chrysolepis*).

At the upper elevational range of the RMD sit the montane coniferous forests (Figure 1-17), defined by a canopy of ponderosa pine (*Pinus ponderosa*), Arizona pine (*Pinus arizonica*), southwestern white pine (*Pinus strobiformis*), and/or Douglas fir (*Pseudotsuga menziesii*), with a sparse understory that is typically devoid of the trees that define the Madrean evergreen woodlands.

1.8.3.2 Flora

Saguaro is a floristically diverse park with more than 1,300 species, subspecies, and varieties documented across both districts. With 1,179 taxa (compared to the TMD's 605), the RMD is more floristically diverse, because of its larger size and broader elevation range (SEINet 2020a, 2020b). The flora contains species that appear in various



Figure 1-15. Example of Madrean montane forest communities at Saguaro National Park.



Figure 1-16. Example of oak woodland communities at Saguaro National Park.



Figure 1-17. Example of montane coniferous forest communities at Saguaro National Park.

floristic provinces throughout the western United States and Mexico. Mexican blue oak (*Quercus oblongifolia*), a species common to the Madrean floristic province, sits at the northern end of its range in the Rincon Mountains. Quaking aspen (*Populus tremuloides*), a species more prevalent in the intermountain floristic province, appears toward the southern end of its range in the Rincon Mountains.

1.8.4 Non-native plants

Biological invasions into new regions, whether accidental or deliberate, have increased at unprecedented rates in the past few hundred years (D'Antonio and Vitousek 1992). Once established, these species can alter ecosystem processes, leading to functional as well as compositional change. Several studies have implicated environmental and climatic variables as potential drivers for sustaining or accelerating non-native plant dominance in semi-arid ecosystems (Shinneman and Baker 2009). In the American Southwest, historical and current land-use practices, such as livestock grazing and fire suppression, are thought to have made arid lands more susceptible to invasion, caused the loss of native species, and decreased biodiversity (Brown and Archer 1999).

At Saguaro NP, buffelgrass (*Cenchrus ciliaris*) and, to a lesser extent, red brome (*Bromus rubens*), are effective colonizers of Sonoran Desert plant communities (Esque et al. 2007). These two non-native grasses can provide sufficient fine fuels to carry wildfire into plant communities composed of native species highly susceptible to mortality from fire damage. Unlike most species present throughout the park's desert communities, buffelgrass is well-adapted to frequent, intense fire events, re-establishing quickly. As a result, buffelgrass control efforts are a major focus of operations at Saguaro NP. Mechanical pulling of buffelgrass began in 1993, with herbicide spraying starting in 2005. Starting in summer 2010, park resource managers began to experiment with the aerial application of herbicide on steep and less-accessible locations with the aid of helicopters. Initial treatments were successful and aerial herbicide applications continue through the present time (Perry Grissom, pers. comm.).

While buffelgrass commands the bulk of the park's treatment and restoration activities, many other non-native invasive species have been documented and removed by park staff. SODN vegetation-mapping crews recorded these species whenever possible. The most widespread and/or problematic of these species included tamarisk (*Tamarix* spp.), rose natal grass (*Melinis repens*), fountain grass (*Cenchrus setaceus*), Lehmann lovegrass (*Eragrostis lehmanniana*), and newer threats from African lovegrass (*Eragrostis echinochloidea*) and stock (*Matthiola* spp.).

1.8.5 Disturbance history

Saguaro NP has been subjected to significant recent and historical disturbance across both districts, including mining (e.g., lead, zinc, and copper), livestock grazing, wood harvest, saguaro poaching, and wildfire. Currently, no mining or livestock are permitted within the park. However, their historical impacts are still evident.

Cattle grazing on the lands now contained within Saguaro NP began in the late 19th century, primarily in what is now the Rincon Mountain District. Grazing continued across much of the monument until 1958, when, responding to concerns about the potential impacts of grazing on saguaro cacti (*Carnegiea gigantea*), the NPS removed cattle from the Cactus Forest area of the RMD. Cattle continued to graze in other areas of the RMD until 1978, when all grazing allotments were eliminated. The long and complex grazing history of these lands is best summarized in a report by Robin Pinto (2013).

Numerous historical mines are spread throughout the park. They are mainly within the TMD, which contains around 129 unnamed prospects and 35 named sites. These sites and prospects are a mix of shafts, adits (horizontal mine entrances), and declines ranging in size from shallow (5-ft) adits to relatively deep (50-ft) shafts. At the TMD, the majority of claims targeted the extraction of copper, silver, gold, and, to a lesser extent, lead. The largest of these named sites are the Yuma Mine, located north of the Coyote Pass Trail; the Gila Monster Mine,

located along the Thunderbird Trail; the Copper King (Mile Wide) Mine, located south of Amole Peak; and Gould Mine, located along the Sendero Esperanza Trail. Of these, the Gould Mine is the most conspicuous; it can be clearly seen from the King Canyon Trailhead. Mining on these lands was halted in 1961, with the creation of the TMD. Currently, mining sites that pose a safety hazard are closed off with cages and fencing. At time of writing, Saguaro NP was embarking on a comprehensive adit-closure program for many abandoned mines in the TMD (Jeff Conn, pers. comm.).

Saguaro NP's fire history has been best summarized, by former park fire ecologist Perry Grissom, as "too much fire down below, and too little up above." Tree-ring research by Baisan and Swetnam (1989) and Farris and others (2010) indicates that pre-settlement surface fires in high-elevation woodlands, forests, and savannas of Mica Mountain were relatively frequent (6–10 year intervals) and extensive (generally >200 ha). By contrast, pre-settlement fires on Rincon Peak were much less frequent and more likely to occur as crown fires, perhaps due to the relatively low rates of natural ignition and spread in this steep landscape with large inclusions of exposed bedrock (Iniguez et al. 2009; Hunter et al. 2014).

At mid- to high elevations, active fire suppression and fine-fuel reduction via livestock grazing in the 19th and early 20th centuries resulted in a period of reduced fire frequency and size, consistent with patterns observed throughout the region (Baisan and Swetnam 1989). However, steep topography and lack of road access into the Rincon Mountains, coupled with an active fire-use policy since the 1980s, appear to have locally limited the more-extreme consequences of human fire suppression in the American Southwest (NPS 2007).

Due to the rocky terrain, sparse vegetation, and accessibility of the TMD, wildfires are largely absent there. But a number of large (>1,000-ha) wildfires have burned across the RMD in recent history (1980–2020), causing considerable and varied changes to vegetation communities. These include the Helen's 2 Fire (2003), Box Canyon Fire (1999), Chiva

Fire (1989), Rincon Fire (1994), Mother's Day Fire (1994), and Cabin Fire (1988) (Figure 1-18).

Depending upon severity and individual species' adaptations to fire, certain vegetation communities fared better than others. Detailed data on fire severity and related impacts to specific vegetation communities is not a standard post-fire product, particularly in the case of wildfire incidents such as these. However, some impacts from these larger and more severe fire events can still be seen on the ground today.

An experienced observer can estimate the extent of community resilience or recovery by noting presence and age of snags, and making comparisons to nearby unburned stands. Communities dominated by herbaceous species, such as sideoats grama (*Bouteloua curtipendula*), tend to rebound quickly and, in the absence of exotic species invasion, remain relatively unchanged. However, communities dominated by species poorly adapted to high-severity fires, such as border pinyon (*Pinus discolor*), may be significantly altered.

Fire impacts that can still be easily seen in the vegetation communities today were reflected in the classification of communities during this project, and are described below. The spatial information (acreage and locations) in the following section was derived from historical fire-boundary data from Saguaro NP. Species and community-level impacts were derived from first-hand observations made by SODN ecologists during this inventory project.

The Helen's 2 Fire (2003) burned 736 hectares (1,820 ac) within the RMD, accounting for 52% of the total area covered by this fire. It burned predominantly in montane conifer forest along the north-trending slopes of Mica Mountain, running from Helen's Dome to the eastern boundary. Vast areas of snags and downed trees without living canopy trees indicated that areas covered by Helen's 2 experienced high-severity fire with extremely high tree mortality. Areas previously dominated by Douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) are now herbaceous communities of

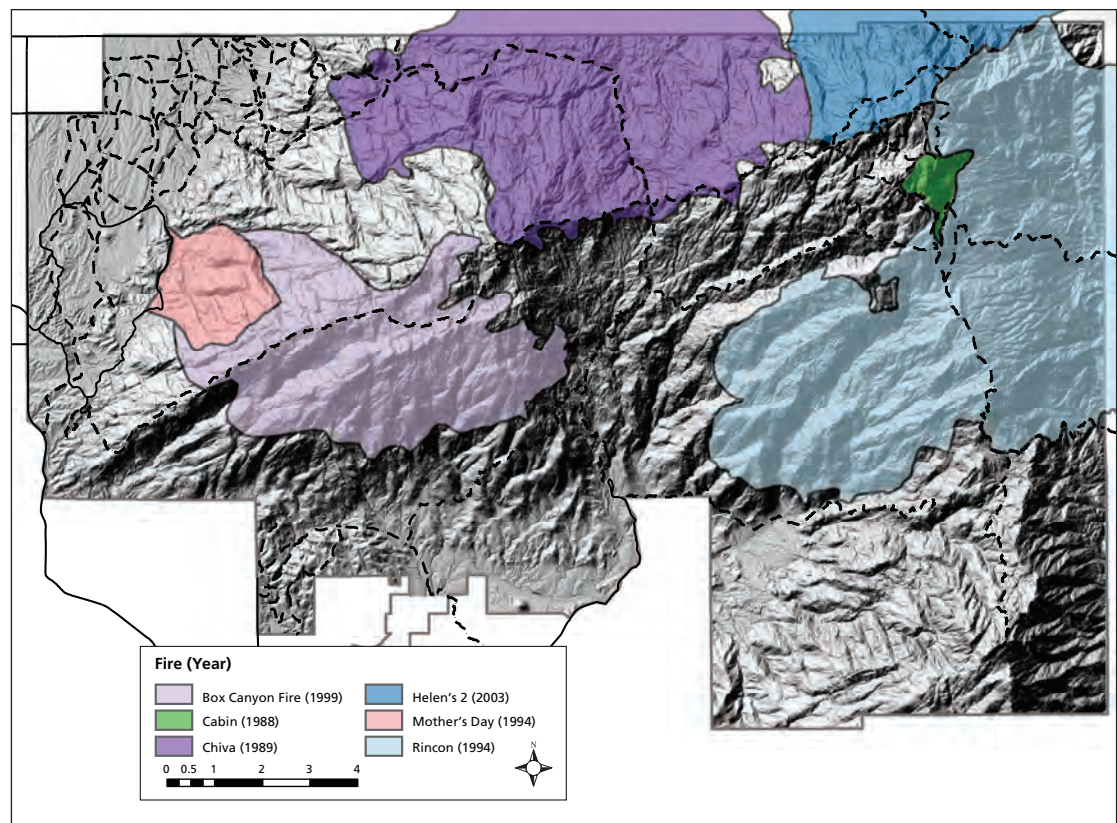


Figure 1-18. Map showing the location of major burns (>100 ha) in the Rincon Mountain District, Saguaro National Park, 1980–2011. Boundaries show the extent of each fire but do not indicate complete coverage or severity within each polygon.

western brackenfern (*Pteridium aquilinum*) and/or screwleaf muhly (*Muhlenbergia virescens*) (Figure 1-19).

The Box Canyon Fire was fully contained within the RMD and burned across 2,621 hectares (6,476 ac) of Tanque Verde Ridge, predominantly in semi-desert grasslands, oak savannas, and mixed pine-oak woodlands. Currently, many areas previously characterized by pinyon pine and juniper dominance contain only charred snags of these species. While pockets of unburned border pinyon (*Pinus discolor*) exist, they are vastly outcompeted by large expanses of oak savanna created by the Box Canyon Fire (Figure 1-20).

The Chiva Fire burned 3,060 hectares (7,561 ac) within the RMD, accounting for 79% of the total area covered by this fire. It burned along the north-trending slopes of Tanque Verde Ridge and Mica Mountain, from Helen's Dome east to Tanque Verde Peak. Like the Box Canyon Fire, it burned primarily in semi-desert grasslands, oak savannas,

and mixed pine-oak woodlands (Figure 1-21). Toward Helen's Dome, it reached up into areas of montane conifer forest. Mortality of border pinyon (*Pinus discolor*) and alligator juniper (*Juniperus deppeana*) was high, causing the conversion of many communities to oak savanna or oak - manzanita chaparral. While oaks (*Quercus* spp.) exhibit low resistance to fire, they are very resilient and are quick to re-sprout and/or regenerate post-fire (Barton 1999).

The Rincon Fire (1994) burned 4,973 hectares (12,288 ac) within the RMD, accounting for 56% of the total area covered by this fire. It burned along the eastern slopes of the Rincon Mountains, from the northeast corner south to Miller Creek; and west of Heartbreak Ridge, from Madrona Canyon south to Rincon Creek. This widespread fire burned through most mid-to-high elevation communities from semi-desert grassland up to montane conifer forests. Changes to burned communities include all those outlined in the other three fires (Figure 1-22).



Figure 1-19. *Left:* Conifer forest burned by the Helen's 2 Fire (2003). *Right:* Conifer forest not burned by the Helen's 2 Fire.



Figure 1-20. *Left:* Oak savanna in Juniper Basin burned in the Box Canyon Fire (1999). *Right:* Unburned pinyon, juniper, and oak woodland in Juniper Basin.



Figure 1-21. *Left:* Pinyon-juniper-oak woodland burned by the Chiva Fire (1989), currently oak - manzanita chaparral. *Right:* Pinyon-juniper - oak woodland not burned by the Chiva Fire.



Figure 1-22. *Left:* Conifer - oak forest burned by the Rincon Fire (1994), currently an oak shrubland. *Right:* Conifer - oak forest not burned by the Rincon Fire.

2 Vegetation Classification

2.1 Tucson Mountain District

2.1.1 Planning and scoping

A scoping meeting for the vegetation mapping project took place at Saguaro National Park on April 24, 2009. Key park staff attended, including the superintendent, fire ecologist, chief of natural resources, restoration ecologist, lead biologist, and GIS specialist. SODN staff were joined by project partners from the University of Arizona's Office of Arid Lands Studies (OALS; now merged into the School of Natural Resources and the Environment)—image-analysis experts who had worked on prior mapping projects.

Meeting participants identified multiple existing datasets available for use in classification and mapping. These included plot data from short- and long-term studies, fire-effects monitoring data/photos, and spatial base layers. Other data already acquired by SODN were discussed. Free imagery available from the Pima Association of Governments (PAG) was determined to meet project needs.

The park requested additional data collection, where possible, to advance their knowledge of park resources and exotic plants. Specifically, they asked that we map any area over the minimum mapping unit of one half-hectare dominated by buffelgrass (*Cenchrus ciliare*) as “Buffelgrass Herbaceous” alliances, and that we take GPS points at any springs, seeps, or other standing water not already mapped. The project team met these requests to their best ability.

2.1.2 Data collection overview

The methods used to map and classify vegetation generally followed the guidelines outlined in NPS technical guidance and support documents. However, the lack of existing NVC classes for southern Arizona required additional steps. No polygon map units were created prior to classification work, in part because our partners at OALS had inaccurate results from object-based

segmentation trials using Definiens software. Therefore, the team decided to adopt a hybrid method at the TMD, in which the crew collected detailed species-cover data at plots and also delineated (i.e., sketched onto paper maps and later digitized) a large area around the plot of the same floristic and structural composition as the sampled plot. These were originally envisioned as serving as the basis for final map units, but it soon became clear we could not adequately map at the scale/size needed for that purpose. Instead, these polygons were used as training data for the supervised classification (see Section 3.1.1).

2.1.3 Digital imagery acquisition and processing

PAG imagery was acquired, at no cost, in the form of natural-color, 1-foot resolution aerial photos. Although these did not contain a near-infrared (NIR) band, which can be useful for visually identifying vegetation in certain environments, the resolution was such that individual shrub canopies and cacti shadows were visible, which proved far more useful in the park's sparsely vegetated desert areas.

2.1.4 Field-data collection

2.1.4.1 Classification plots

Jennings and others (2009) identified the need for vegetation units to be sampled and described through the use of plot data. They recommended plots be distributed in homogenous areas, because minimizing sampling in areas with high physiognomic, floristic, and environmental variation simplifies interpretation of plot data. Plot locations can be determined via subjective or objective means, but the former method necessitates prior knowledge of the various types to be sampled. The latter can provide a less-biased set of plots, but may miss rare or unusual types. We decided to sample primarily by objectively locating plots, adding a smaller number of plots subjectively to account for any under- or un-sampled areas or vegetation types.

Prior to the start of fieldwork, plot locations were preselected using the spatially balanced RRQRR (Reversed Randomized Quadrant-Recursive Raster) algorithm, to provide an objective, parkwide sampling basis for vegetation classification (Theobald et al. 2007). Using this method, 200 non-stratified points were distributed across the entirety of the TMD (Figure 2-1). The authors determined the number of plots distributed and sampled using their best judgment and knowledge of the park's vegetation diversity and estimate of potential vegetation types.

An NPS crew of 4–6 people, typically working in pairs, collected all data. Crew leads had several months' experience in vegetation mapping at other SODN parks (e.g., Chiricahua and Tonto national monuments) prior to this field effort, and were proficient in all SODN mapping and classification

methodologies. Data collection at classification plots occurred over two seasons (fall 2010 and winter 2011), spanning a total of 38 field days. Working in teams of two or more to facilitate a multiple-observer, consensus-based approach, the field crew visited each of the distributed points and sampled 195 objectively placed plots.

In the field, these generated points served as one corner of a 1,000-m² classification plot. Ideally, the plot location represented the surrounding vegetation community. When it did not, the classification protocol allowed crews to evaluate the surrounding vegetation and move the point up to 50 meters into more representative vegetation. Crews laid out the plots so as to best capture the orientation and shape of the sampled community. Various shapes were employed to capture the targeted community, but the

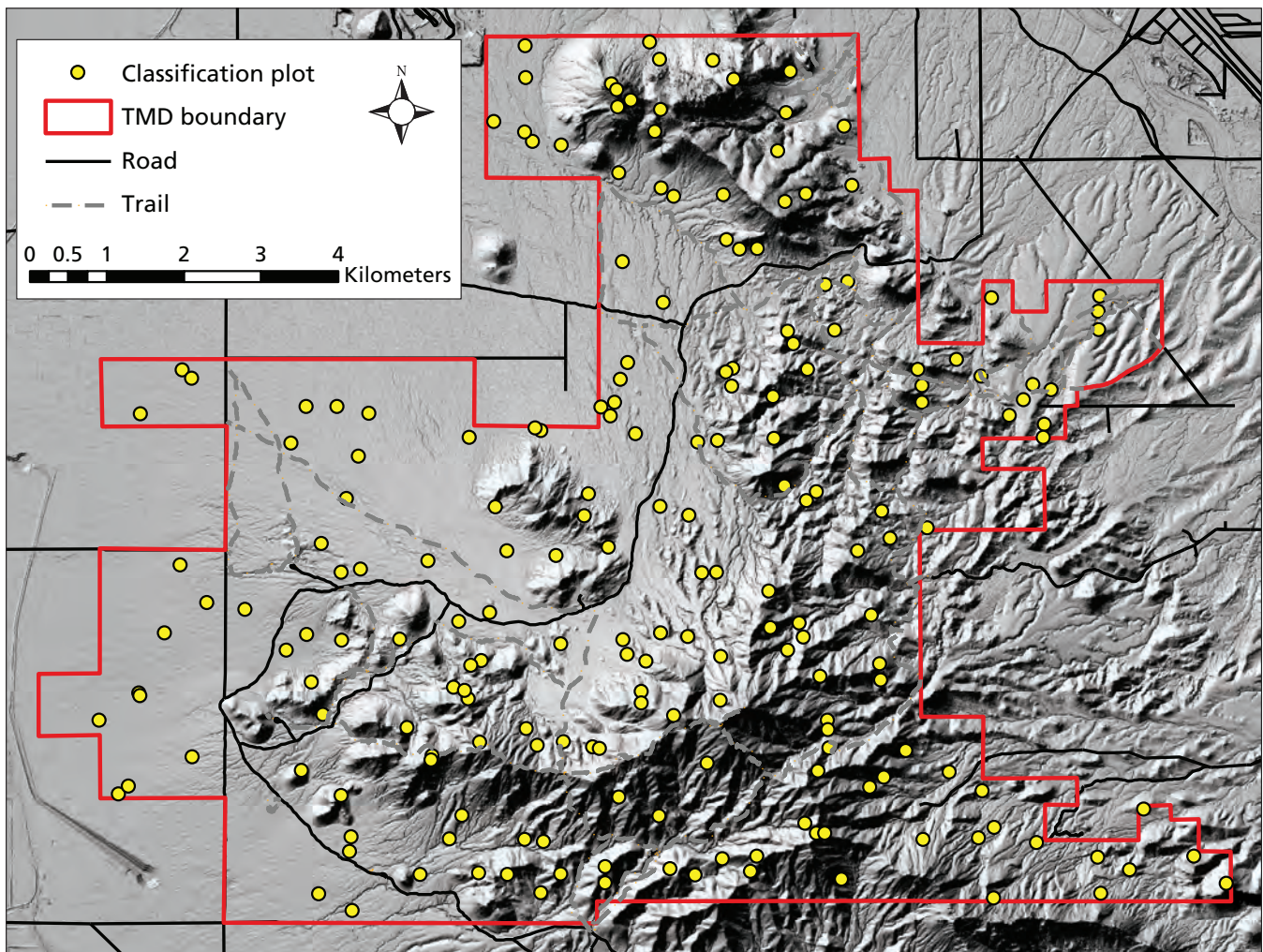


Figure 2-1. Distribution of classification plots in the Tucson Mountain District.

preponderance of plots were square, with sides measuring 31.6 meters. For more linear communities, typically associated with washes and drainages, plots ranged in shape from 25 × 40 meters to 10 × 100 meters, but always covered 1,000 m².

Within these plots, the crews collected semi-quantitative data on absolute canopy cover for all vascular plant species in four height strata: field (0–0.5 m), subcanopy (0.5–2 m), lower canopy (2–5 m), and upper canopy (>5 m). In each stratum, crewmembers placed each documented species into one of nine broad cover classes: 1 (<1%), 2 (1–5%), 3 (6–10%), 4 (11–25%), 5 (26–33%), 6 (34–50%), 7 (51–75%), 8 (76–95%), and 9 (96–100%). In general, crews only included perennial and non-native annual species. Native annuals were occasionally documented when they provided a noteworthy amount of cover or were diagnostic of the community.

Up to three species per stratum were assigned a dominance rank based on their cover class and/or importance to the sampled vegetation community. Additionally, crews recorded the average plant height (lower and upper canopy only), lifeform (excluding the field stratum), disturbance types (using the NVC-constrained vocabulary), total absolute cover by stratum, and a range of soil and landscape characteristics (see Table 2-1 and Appendix A). A single photograph was taken at a 45-degree angle into the plot from one of the corners. Two brief narratives were written to describe the tentative association type of the polygon, noting the ways in which this association/area differed from the adjacent areas, and any topographic features contributing to the divisions of floristic similarities.

2.1.4.2 Training polygons

Concurrent with plot-based data collection, crews (assisted by hardcopy prints of imagery and GPS-linked handheld mapping units) created polygons to define the extent of each vegetation association. Additional polygon-scale data collection was completed in 2012, following the sampling of classification plots. Crews walked the boundary and interior of each proposed polygon while hand-drawing its extent onto the printed im-

agery. Within each of these polygons, crews collected qualitative data (ocular cover estimates) on the dominant and commonly associated species that defined the captured association. In addition, they drafted brief narratives to describe the vegetation community, including a tentative association name, differences from the surrounding vegetation, defining landscape features, and features used to bound the polygon (see Appendix B). A sequence of four representative photographs in the four cardinal directions was taken from near the center of the polygon. Each was marked with a GPS point for future repeat photography.

At the end of each field day, crews transferred all field-map edits onto a set of master paper maps that did not go into the field. These will be archived with the datasheets. Upon completion of the mapping effort, polygon boundaries were transferred from the master maps into a digital format using ArcMap GIS software (ESRI 2011). The dataset is housed in a file geodatabase structure (.gdb), enabling establishment of topology rules and relationships. Strict nomenclature was enforced for polygons, such that unique names were assigned to each polygon. These names reflected the verified physiognomic formation type with a prefix of representative letters (e.g., W = Woodland, SS = Shrub Savanna), followed by a number.

This dataset was originally intended to serve as the basis for the final map, with additional mapping planned to fill in the area of the entire district. Prior to the Saguaro NP mapping project, all SODN vegetation mapping efforts employed a field-based, census approach in which crewmembers visited and hand-drew all polygon boundaries. This was a feasible methodology at some SODN parks, due to their small size (Tumacácori National Historical Park and Casa Grande Ruins National Monument) or relatively straightforward vegetation composition (Gila Cliff Dwellings National Monument and Fort Bowie National Historic Site). In contrast, the sheer size of Saguaro NP, and its highly diverse vegetation, made a field-based, census approach logistically challenging. Instead, we opted for a remote-sensing

Table 2-1. Types of information and items noted on classification-plot datasheets.

Type of information	Items noted
Plot metadata	Date, time, observer name(s), recorder name(s), park code, sub-map number, protocol version
Polygon documentation	Plot ID, keyed formation, plot dimension, plot orientation
Environmental description	Topographic position, landform type, parent material, slope class, erosion features, aspect
Surface cover (% cover classes)	Bare soil, gravel, rock, bedrock outcrops, physical crust, biological crust, down wood, litter
Vegetation description	Qualitative narrative: community structure, notable inclusions, leaf phenology, community structure
Vegetation strata data	Lifeform, dominance rank, cover class and height in each of four height classes (0–0.5 m, 0.5–2 m, 2–5 m, >5 m). Associated species.
Plant species	Scientific name (ITIS codes)
Other vegetation characteristics	Homogeneity, stand maturity, similarity to other types, mortality, disturbance

approach, in which the mapped polygons were used in a supervised classification. Detailed information about this phase of the project can be found in Section 3.1.1. Some of the polygon-scale data were used to help classify vegetation at the TMD, as described in Section 2.1.6.

2.1.5 Data management

All classification-plot data were entered into a Microsoft Access (2007) database created by the SODN data manager (later transferred into the PLOTS database during creation of final products and deliverables). The digital data were subsequently quality-checked for accuracy against the original datasheets, and any transcription errors were rectified prior to analysis. An alternate mapping-team member also validated the data for logical errors or unusual species entries. These processes followed the quality standards outlined in the global operating procedures written by the SODN data-management program. All datasheets were copied and stored separately from the original set.

Each training-area polygon was reviewed for complete data attribution. Hardcopy maps were archived at SODN. Photographs were verified to be present for each polygon and plot, and for correct naming conventions. Photopoint locations (shapefiles) were similarly quality-checked for spatial accuracy

and attribute completeness. After all data checks were completed, the entire project team reviewed and analyzed the field data.

2.1.6 Preliminary vegetation classification analysis

2.1.6.1 Classification-plot analysis

Using the program Plymouth Routines in Multivariate Ecological Research (PRIMER), version 7 (Clarke and Gorley 2006), we employed a multivariate approach to delineate vegetation communities using our sampled classification plots ($n = 195$). For all analyses, we used the midpoint of the selected cover class. For example, the value used from the cover class that spans 11–25% was changed to a value of 18.

These values for all species, at all plot locations, were exported from the Access database post-quality assessment and imported into PRIMER for analysis (Clarke and Warwick 2001). This data matrix had species as variables (rows), plots as samples (columns), and midpoint cover values as the matrix values. These data were square-root transformed to balance the contributions from common and rare species in the measure of similarity between two samples (Clarke and Warwick 2001).

Then, using the resemblance tool in PRIMER, the transformed values were converted into a similarity matrix using the Bray-Curtis

similarity coefficient (Bray and Curtis 1957). This matrix contains values comparing the similarity of every combination of samples (plots) with values ranging from 0, indicating no similarity, to 100, indicating identical samples. Using this matrix, we employed a group-average cluster analysis with an associated dendrogram to aid in assigning plots to groups based on the similarity/dissimilarity of documented species and their associated cover values.

In addition, a SIMPROF (similarity profile) test was performed in conjunction with the cluster analysis. SIMPROF is a permutation test of the null hypothesis such that “a specified set of samples, which are not a priori divided into groups, do not differ from one another in a multivariate structure” (Clarke and Gorley 2006).

The dendrogram and associated SIMPROF test split the data into 38 small groups containing as few as one and up to 20 plots. The SIMPROF identified these small groupings

at high levels of similarity, ranging between 40% and 50%. This similarity value is useful for exploring the data but is often too high to use for vegetation-classification efforts. Initially, we evaluated the results at a subjective similarity of 37% (Group C was evaluated at 32%), where plots fell within five broad clusters (A–E) (Figure 2-2). These clusters were further analyzed using the similarity percentages routine (SIMPER). Tabular output from PRIMER showed the average similarity of members within each cluster, as well as the contribution of each species to that similarity. Based on this information, we determined that each group was defined by the presence or absence of certain diagnostic species and the major landform types found at the TMD.

- Cluster A (52% similarity): A small cluster ($n = 4$) of plots located on the small, upper-elevation section of Wasson Peak, where vegetation has strong semi-desert grassland affinities lacking elsewhere in

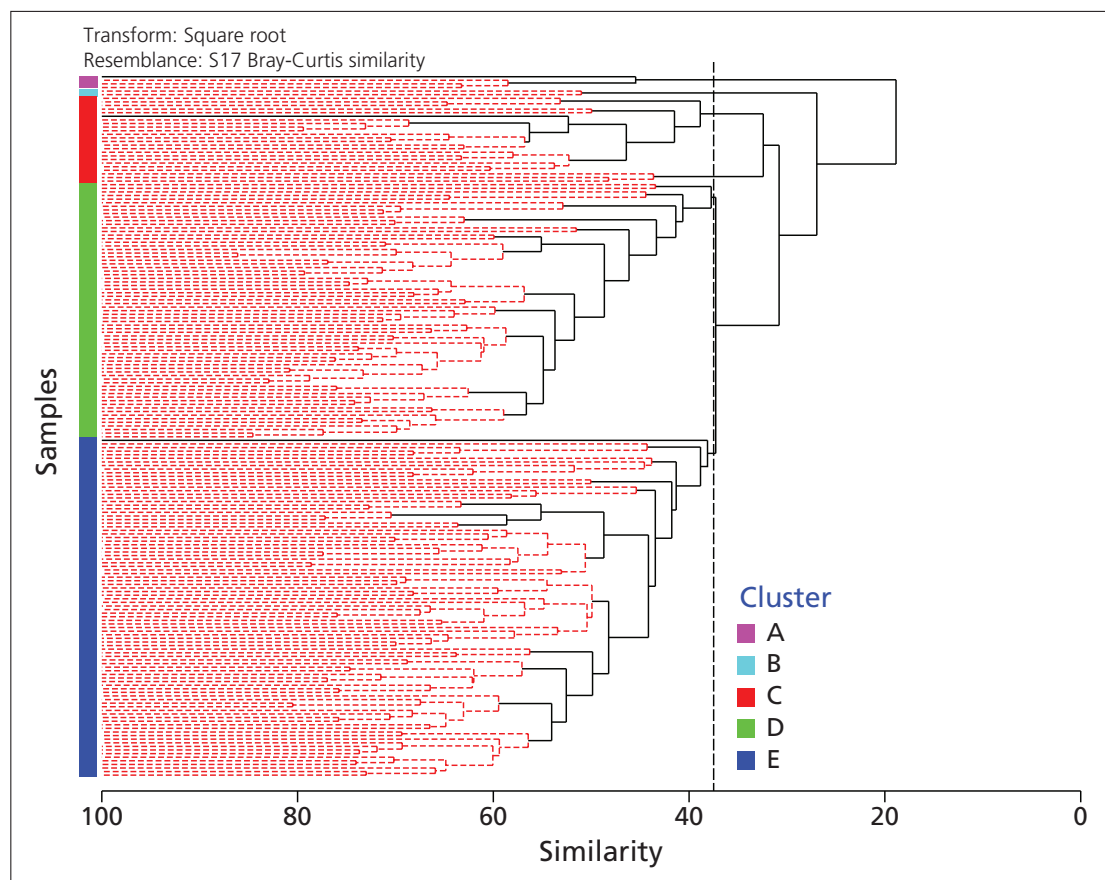


Figure 2-2. Dendrogram from the cluster analysis, showing five distinct macro groups (A–E) defined at a 37% similarity level, as indicated by the vertical dashed line (Group E, on the far right, was evaluated at 32% similarity). Data are from Saguaro National Park’s Tucson Mountain District, 2010–2011.

the unit. These plots were defined by the presence and abundance of bush muhly (*Muhlenbergia porteri*), Wright's beebrush (*Aloysia wrightii*), sideoats grama (*Bouteloua curtipendula*), sotol (*Dasylirion wheeleri*), ocotillo (*Fouquieria splendens*), banana yucca (*Yucca baccata*), and cliff brake fern (*Pellaea truncata*), among others.

- Cluster B (51% similarity): A very small cluster ($n = 2$), characterized by a unique composition of creosote (*Larrea tridentata*), rough joint-fir (*Ephedra aspera*), mariola (*Parthenium incanum*), slender janusia (*Cottisia gracilis*), wolfberry (*Lycium exsertum*), rough menodora (*Menodora scabra*) and bush muhly (*Muhlenbergia porteri*).
- Cluster C (43.7% similarity): A medium-sized cluster ($n = 24$) of plots occupying the park's mountain and hilly terrain. Important species in this grouping included Arizona spikemoss (*Selaginella arizonica*), jojoba (*Simmondsia chinensis*), slender janusia (*Cottisia gracilis*), fairy duster (*Calliandra eriophylla*), ocotillo (*Fouquieria splendens*), Berlandier's wolfberry (*Lycium berlandieri*), saguaro (*Carnegiea gigantea*), buckhorn cholla (*Cylindropuntia acanthocarpa*), and candy barrelcactus (*Ferocactus wislizenii*).
- Cluster D (49% similarity): A large cluster ($n = 71$) of plots representing communities that occupy lower alluvial fans with low-gradient slopes. In these plots, the most important species were triangle bur ragweed (*Ambrosia deltoidea*), yellow paloverde (*Parkinsonia microphylla*), saguaro (*Carnegiea gigantea*), buckhorn cholla (*Cylindropuntia acanthocarpa*), creosote (*Larrea tridentata*), chainfruit cholla (*Cylindropuntia fulgida*), candy barrelcactus (*Ferocactus wislizenii*), Engelmann pricklypear (*Opuntia engelmannii*) and ironwood (*Oleaya tesota*).
- Cluster E (46% similarity): A large cluster ($n = 94$) of plots occupying the upper alluvial-fan systems and low hills, dominated by yellow paloverde (*Parkinsonia microphylla*), saguaro (*Carnegiea gigantea*), brittlebush (*Encelia farinosa*),

Berlandier's wolfberry (*Lycium berlandieri*), slender janusia (*Cottisia gracilis*), fairy duster (*Calliandra eriophylla*), buckhorn cholla (*Cylindropuntia acanthocarpa*), triangle bur ragweed (*Ambrosia deltoidea*), whitethorn acacia (*Vachellia constricta*) and candy barrelcactus (*Ferocactus wislizenii*).

With the data split into broad clusters, we further analyzed them by employing non-metric multidimensional scaling (NMDS). In the resulting diagram (Figure 2-3), similarity/dissimilarity can be assessed based on the distance between points (samples). Using the NMDS, SIMPROF groups, and SIMPER profiles, we further explored the finer grouping within each cluster. As is evident in Figure 2-3, the three bigger groups (D, E, C) were not well separated but rather occurred along a well-defined gradient (more or less from left to right). This was not entirely surprising given the small size and relatively narrow elevation range of the TMD. By considering the data on landform position for each plot, we began to understand the gradient to represent the strong ecotones between the valley-bottom, low alluvial-fan outflows, to upper-alluvial and, eventually, mountain-slope associations.

Species dominance, defined by abundance values, shifted between groups, but most groups shared many of the same species. Put another way, most of the species common at the TMD were widespread and occurred on most landforms and most aspects, albeit with varying abundances. We also discovered that ecotones (the area between two adjacent communities that shares characteristics of both) were often quite wide, and diagnostic species often did not appear or disappear abruptly. Our ability to successfully classify them often depended on several variables. For these reasons, we undertook further data exploration to identify which combination of species shifts correlated to recognizable and ecologically meaningful separate communities. We used a variety of methods, including manual sorting of data sheets and looking at photographs.

Visual exploration (Figure 2-4) of species-level data showed a sub-grouping of plots within groups D and E that separated, in

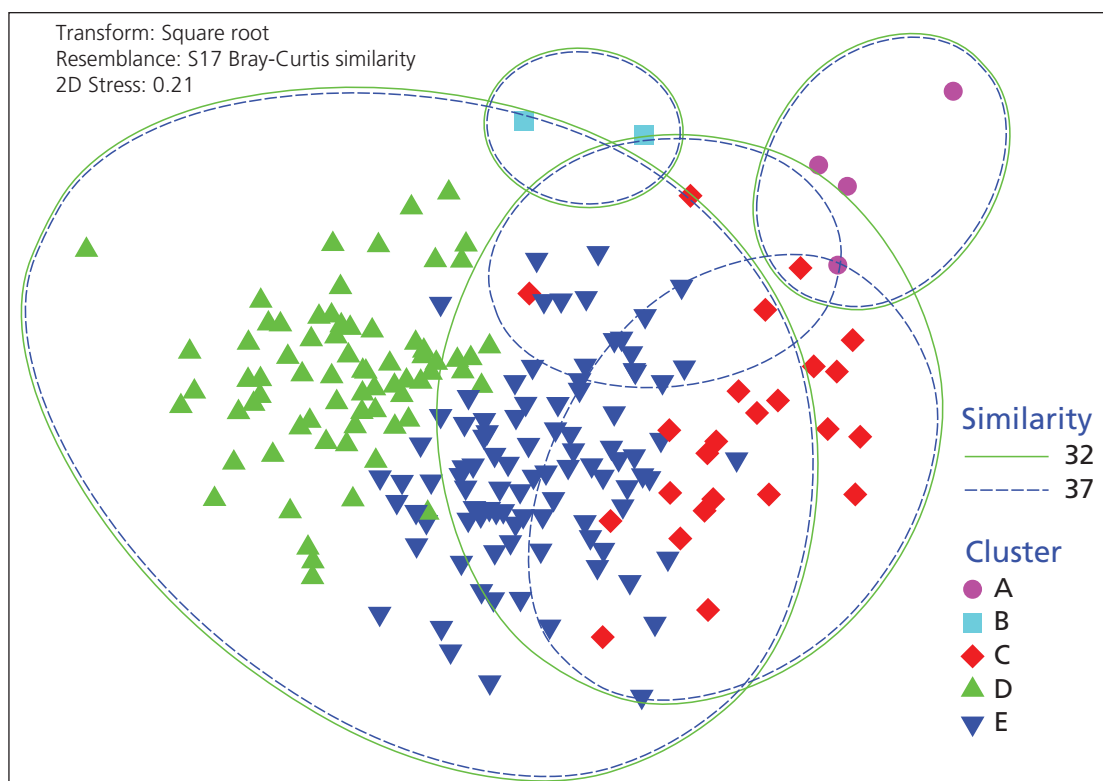


Figure 2-3. Non-metric multidimensional scaling of classification plots, Tucson Mountain District, Saguaro National Park, 2010–2011.

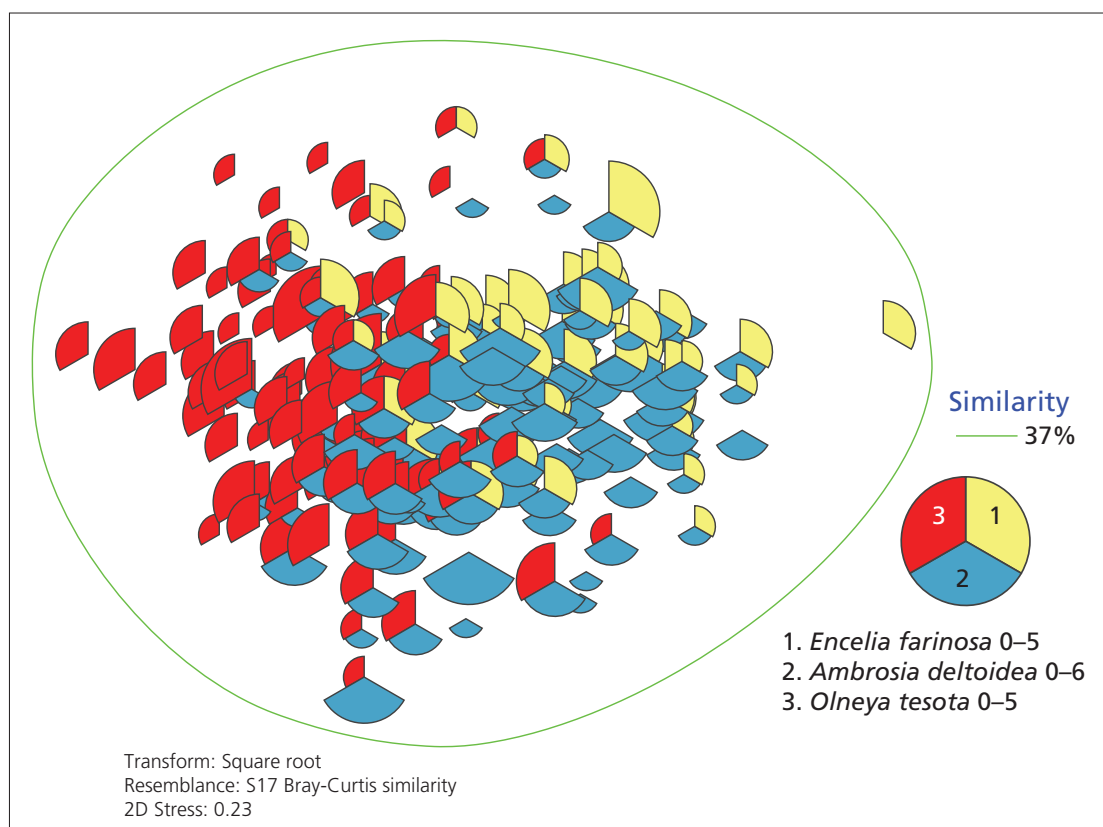


Figure 2-4. Non-metric multidimensional scaling symbolized to show which of three species are present in each plot: brittlebush (*Encelia farinosa*), triangle bur ragweed (*Ambrosia deltoidea*), and/or desert ironwood (*Olneya tesota*). The colored pie pieces indicate the species is present. Size represents abundance. Data are from Saguaro National Park's Tucson Mountain District, 2010–2011.

part, on the basis of the dominant field species, being either triangle bur ragweed (*Ambrosia deltoidea*, shown in blue) on the lower-elevation, flatter sites, or brittlebush (*Encelia farinosa*, shown in yellow) on slightly higher and steeper slopes, or those sites that contained both (the ecotonal area). In addition, ironwood tree (*Olneya tesota*, shown in red) occupied a very restricted range at the TMD, and helped to further define some of the subgroupings we explored during the classification phase. Figure 2-4 illustrates one example of the ecotonal overlap common at the park. It is in the same orientation as Figure 2-3, but only shows groups D and E. Each plot has been symbolized with a multi-colored bubble showing species presence/absence in the plot. The size of the bubble indicates abundance.

Additional data available from the training-polygon observations ($n = 76$; see Section 2.1.4.2) were evaluated using the same cluster, NMDS, and SIMPER routines as the plots. These data showed similar patterns of overlap between the Level 1 groupings (47% simi-

larity in the cluster, Figure 2-5) and correlated well to the landform data (alluvial sites versus hill and mountain sites) when viewed in the NMDS. These data helped us to better describe several tentative associations and also included data from several dry wash sites and drainages that were underrepresented in the plot data, enabling us to draft two associations restricted to those environments.

Within the polygon data, we explored the subgroupings for each Level 1 group with further analyses. An example (Figure 2-6) from polygon Group D shows how the data separated into two groups (C and D), with two single plots lying further apart. The bigger group (C) represented the *Carnegiea gigantea* / *Parkinsonia microphylla* (*Olneya tesota*) / *Ambrosia deltoidea* Shrubland Association. The smaller group (D) represented the similar (*Parkinsonia microphylla*) / *Larrea tridentata* - Mixed Cacti / *Ambrosia deltoidea* Shrubland Association. These associations both occupied the low-gradient alluvial outflows at the TMD, differing primarily in that the former had consistent

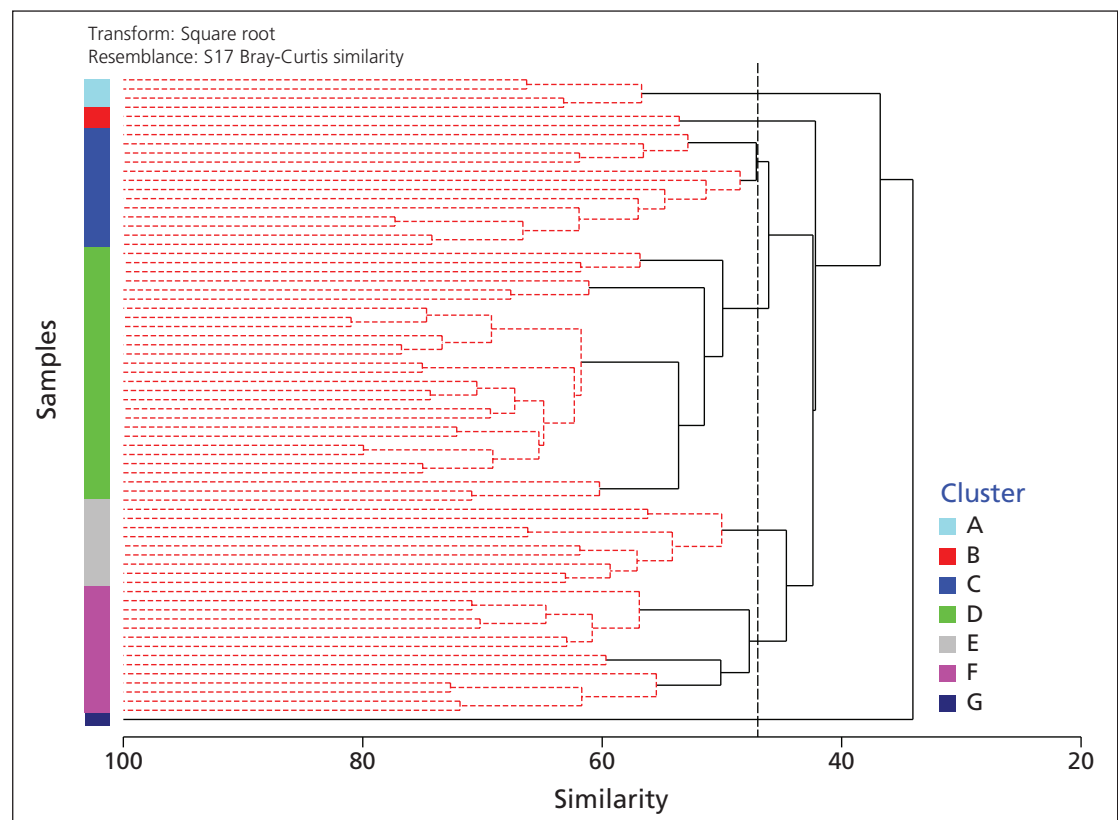


Figure 2-5. Cluster-analysis diagram of the 76 polygon-scale classification datasets. Level 1 groupings are indicated by a cut in the cluster tree at 47% similarity, as indicated by the vertical dashed line. Data are from Saguaro National Park's Tucson Mountain District, 2010–2011.

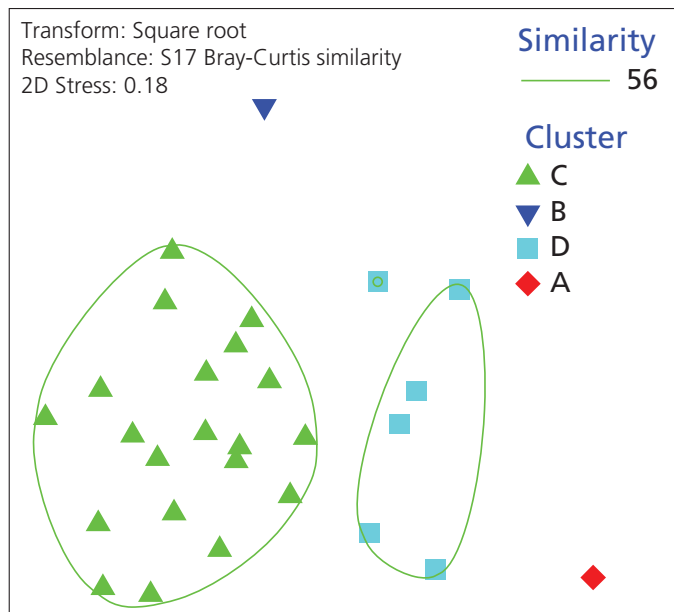


Figure 2-6. Non-metric multidimensional scaling graph of Level 1, Group D, illustrating two main subdivisions within the data. Data are from Saguaro National Park's Tucson Mountain District, 2010–2011.

2–3% cover of *Olneya tesota* and low cover of *Larrea tridentata*, while the latter had dominant *L. tridentata* cover and occasional-to-absent *O. tesota* (with many other shared species in varying amounts).

Combined, these analyses led to the identification of 15 vegetation communities described at the association level (see Section 2.1.6.2). The classification team returned to multiple field sites to evaluate the drafted type descriptions on the ground. During that time, additional notes and photographs were taken and some minor adjustments were made to better clarify distinctions between similar areas.

2.1.6.2 Preliminary classification results

During this initial round of classification, we identified a total of 15 vegetation groups at the association level (see below). Of these, five associations were shown to occur in both districts of the park. More detail on where final associations were distributed can be found in Chapter 5-1.

1. (*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Vachellia constricta* - *Larrea tridentata* / *Krameria bicolor* Wooded Shrubland
2. (*Parkinsonia microphylla* - *Fouquieria splendens*) / *Encelia farinosa* (*Cottisia gracilis*) Shrubland
3. (*Parkinsonia microphylla*) / *Larrea tridentata* - Mixed Cacti / *Ambrosia deltoidea* Shrubland
4. (*Prosopis velutina*) / *Vachellia constricta* (*Larrea tridentata* - *Senegalia greggii*) Intermittently Flooded Shrubland
5. *Carnegiea gigantea* / *Parkinsonia microphylla* (*Olneya tesota*) / *Ambrosia deltoidea* Shrubland
6. *Cylindropuntia acanthocarpa* - *Vachellia constricta* / *Calliandra eriophylla* - *Cottisia gracilis* Shrubland
7. *Larrea tridentata* / [*Ephedra aspera* - *Parthenium incanum*] Shrubland
8. *Opuntia engelmannii* (*Calliandra eriophylla* - *Agave schottii*) / *Selaginella arizonica* Shrubland
9. *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland
10. *Parkinsonia microphylla* / *Lycium berlandieri* (Mixed Shrub) Rocky Shrubland
11. *Parkinsonia microphylla* / *Opuntia* spp. - *Ambrosia salsola* / *Muhlenbergia porteri* Shrubland
12. *Simmondsia chinensis* - Mixed Cacti / *Ambrosia deltoidea* Shrubland
13. *Simmondsia chinensis* (Mixed Cacti) Shrubland
14. *Simmondsia chinensis* / *Encelia farinosa* Shrubland
15. *Yucca baccata* - *Dasyllirion wheeleri* / *Muhlenbergia porteri* Shrubland

2.2 Rincon Mountain District

2.2.1 Planning and scoping

Planning and scoping were completed for both units of Saguaro NP during the meeting on April 24, 2009 (see Section 2.1.1). However, classification fieldwork at the RMD occurred later than at the TMD, in 2013.

2.2.2 Data collection overview

The methods used to classify vegetation at the RMD followed the guidelines outlined in NPS [technical guidance](#) and support documents.

2.2.3 Field data collection

Prior to the start of fieldwork, plot locations were pre-selected using the spatially balanced RRQRR (Reversed Randomized Quadrant-Recursive Raster) algorithm, to provide an objective, parkwide sampling basis for vegetation classification (Theobald et al. 2007). Plots were stratified across four elevational bands that roughly aligned with broad changes in vegetation formation and composition (Table 2-2). Within each band, plots were stratified based on proximity to hydrologic features, typically washes and drainages. A 50-meter buffer around hydrologic features was used to differentiate upland plots from those potentially influenced by a hydrologic feature. This second stratification was done to capture the often-linear vegetation communities associated with washes and drainages. Plots were distributed across eight strata: one upland and one hydrologic stratum for each of the four elevational bands. For most upland

strata, a total of 200 points were distributed, of which 80 were designated as priority and 120 were set aside as an oversample. Due to its smaller size, the 300 stratum received only 100 points (60 priority and 40 oversample). Fifty plots were distributed within each of the hydrologic strata, with the ratio of priority to oversample dependent on the area covered by each stratum.

All data were collected by an NPS crew of 4–6 people, typically working in pairs. Crew leads had several months’ experience in vegetation mapping at other SODN parks (e.g., Gila Cliff Dwellings National Monument, Saguaro NP TMD) prior to this field effort, and were proficient in all mapping and classification methodologies. Initially, classification-plot data collection occurred over two field seasons (spring/summer 2013 and 2014), spanning a total of 65 field days. Over this time frame, crews sampled a total of 228 of the distributed classification plots plus an additional 17 subjectively placed plots (Figure 2-7). Subjectively placed plots were employed to capture communities un- or underrepresented by the distributed plots. Working in teams of two or more to facilitate a multiple-observer, consensus-based approach, the field crew visited each of the distributed points. Plots were sampled using the same methodology used in the TMD (see Section 2.1.4.1).

2.2.4 Data management

Data management for RMD classification datasets followed the same procedures used for the TMD portion of the project (see Section 2.1.5).

Table 2-2. Elevation strata and distributed classification plots, Rincon Mountain District.

Biome(s)	Stratum	Elevation (ft)	Elevation (m)	Uplands plots		Hydrologic plots	
				Priority	Oversample	Priority	Oversample
Thornscrub	200	2,501–3,700	762–1,128	120	80	36	14
Semi-desert Grassland	300	3,701–4,500	1,128–1,372	60	40	16	34
Madrean Woodland & Interior Chaparral	400	4,501–6,000	1,372–1,829	120	80	41	9
Temperate Forest	500	>6,000	>1,829	120	80	26	24

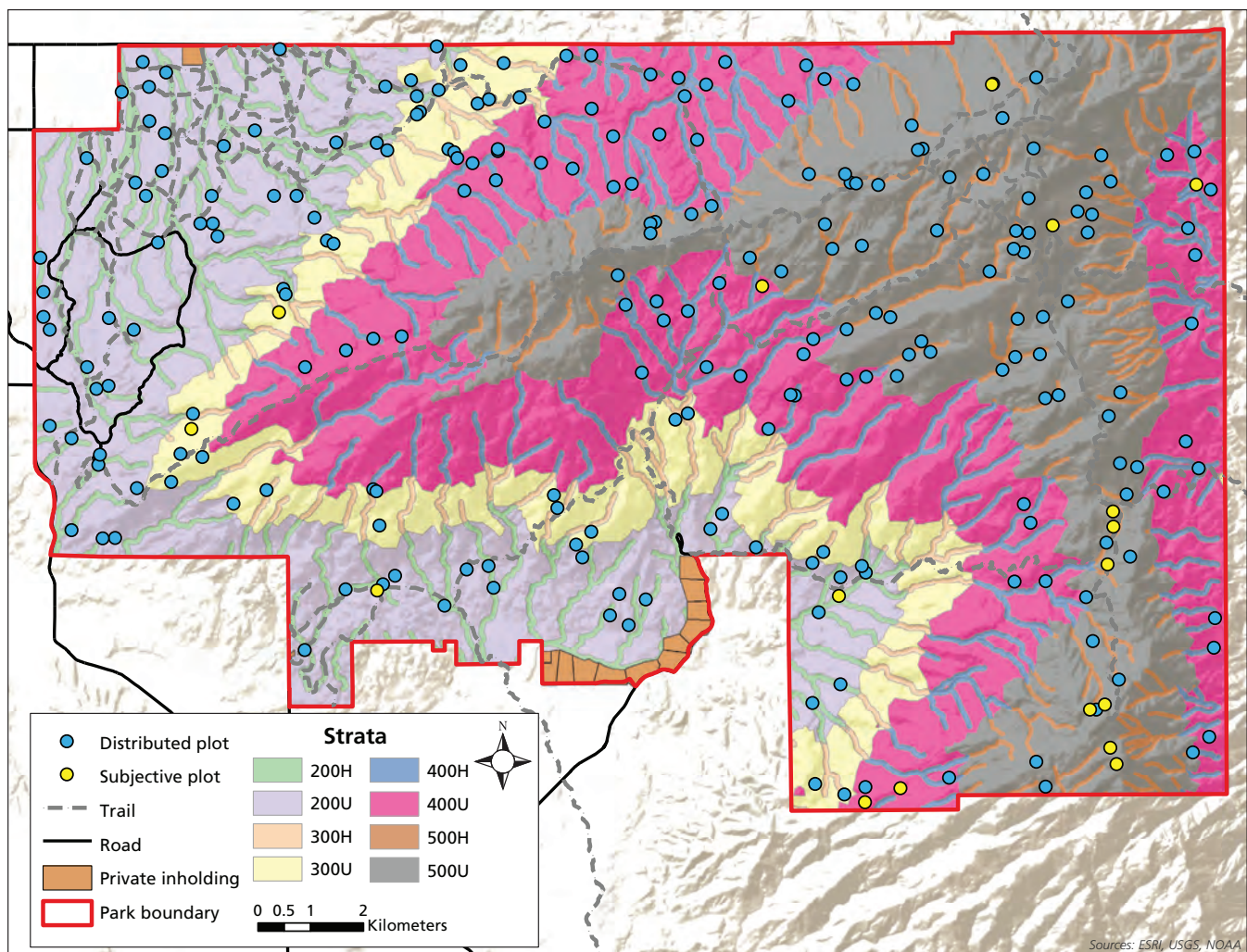


Figure 2-7. Distribution of classification plots in the Rincon Mountain District. Plots were distributed within upland (U) and hydrologic (H) strata among four elevational bands (200, 300, 400, 500).

2.2.5 Vegetation classification analysis

2.2.5.1 Classification plot analysis

RMD vegetation classification analysis used the same methodology employed for the TMD classification (see Section 2.1.6.1). At the RMD, the classification was an iterative process that occurred following multiple phases of the project. The first classification was created after initial plot sampling (2013–2014), with a dataset consisting of 244 classification plots. One plot was not included because it was assessed from a distance due to safety concerns.

The dendrogram and associated SIMPROF test split the data into 47 groups, of which 7 were represented by one plot and 40 were represented by two or more plots. Initially,

we evaluated the results at a subjective similarity of 10%, in which plots were lumped into three clusters (A, B, and C; Figure 2-8). These clusters were further analyzed using similarity percentages (SIMPER). This is a tabular output from PRIMER that shows the average similarity of members within each cluster, as well as the contribution of each species to that similarity. Based on this information, we determined that these three groups were each defined by the presence or absence of 5–15 diagnostic species and roughly aligned with NVC macrogroups (usnvc.org/data-standard) and the elevational gradient of the district. Codes in parentheses, such as M011, are the NVC database codes for the macrogroup level of the hierarchy.

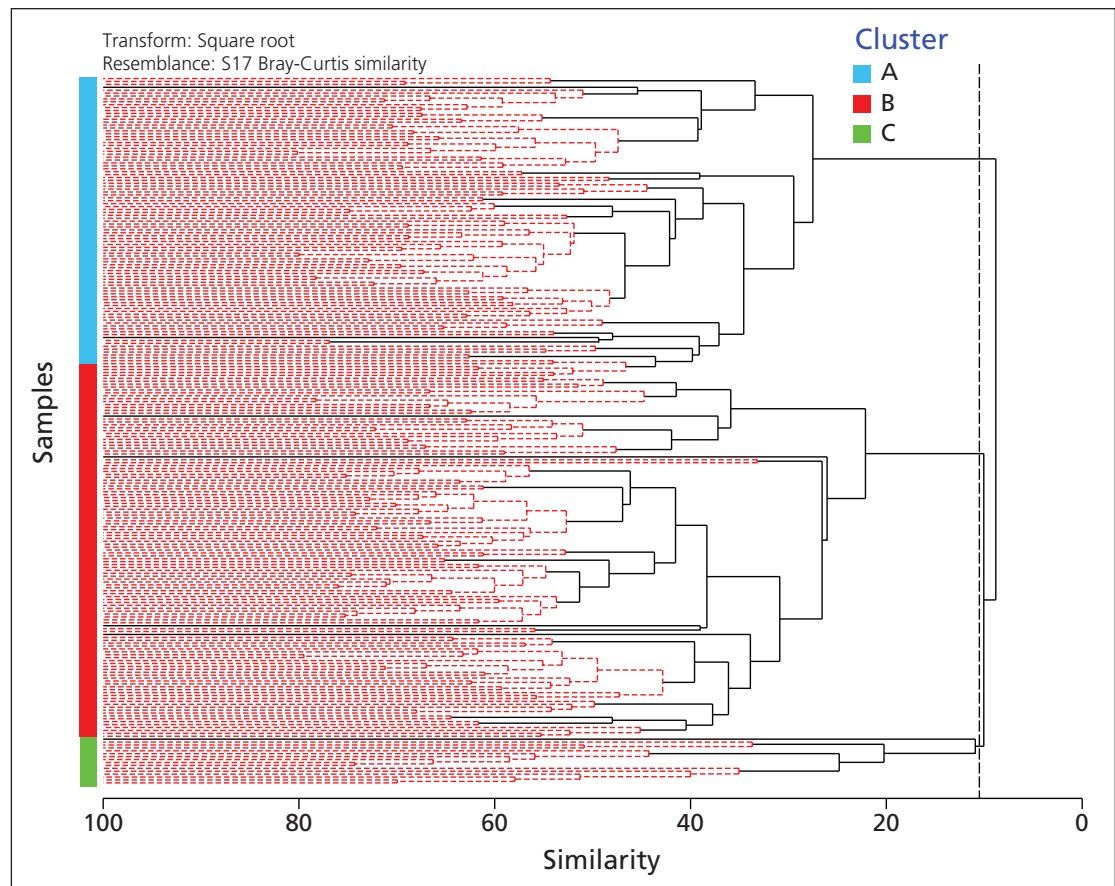


Figure 2-8. Dendrogram from the cluster analysis showing three distinct macrogroups (A–C) defined at a 10% similarity level, as indicated by the vertical dashed line. Data are from Saguaro National Park’s Rincon Mountain District, 2013–2014.

- **Cluster A (35% similarity):** A large cluster ($n = 103$) defined by the presence of cactus apple (*Opuntia engelmannii*), velvet mesquite (*Prosopis velutina*), buckhorn cholla (*Cylindropuntia versicolor*), yellow paloverde (*Parkinsonia microphylla*), catclaw acacia (*Senegalia greggii*), brittlebush (*Encelia farinosa*), candy barrelcactus (*Ferocactus wislizenii*), ocotillo (*Fouquieria splendens*), creosote (*Larrea tridentata*), and saguaro (*Carnegiea gigantea*). This cluster roughly aligned with the Mojave–Sonoran Semi-Desert Scrub Macrogroup (M088).
- **Cluster B (32% similarity):** A large cluster ($n = 124$) split into 22 SIMPROF groups, of which four contained one plot. The 22 groups were defined by the presence of Arizona white oak (*Quercus arizonica*), border pinyon (*Pinus discolor*), silverleaf oak (*Quercus hypoleucoides*), alligator juniper (*Juniperus deppeana*), manzanita (*Arctostaphylos* spp.), bullgrass (*Muhlenbergia emersleyi*), beargrass (*Nolina microcarpa*), Wright’s silktassel (*Garrya wrightii*), Emory oak (*Quercus emoryi*), Arizona pine (*Pinus arizonica*), ponderosa pine (*Pinus ponderosa*), and/or yucca (*Yucca madrensis*). This cluster was a mix of the Madrean Lowland Evergreen Woodland Macrogroup (M010) and Madrean Montane Forest & Woodland Macrogroup (M011).
- **Cluster C (31% similarity):** A small cluster ($n = 15$) split into 3 SIMPROF groups defined by the presence of ponderosa pine (*Pinus ponderosa*), Arizona pine (*Pinus arizonica*), southwestern white pine (*Pinus strobiformis*), Douglas fir (*Pseudotsuga menziesii*), screwleaf muhly (*Muhlenbergia virescens*), and/or Gambel oak (*Quercus gambelii*). This cluster roughly aligned with the Southern Rocky Mountain Lower Montane Forest Macrogroup (M022).

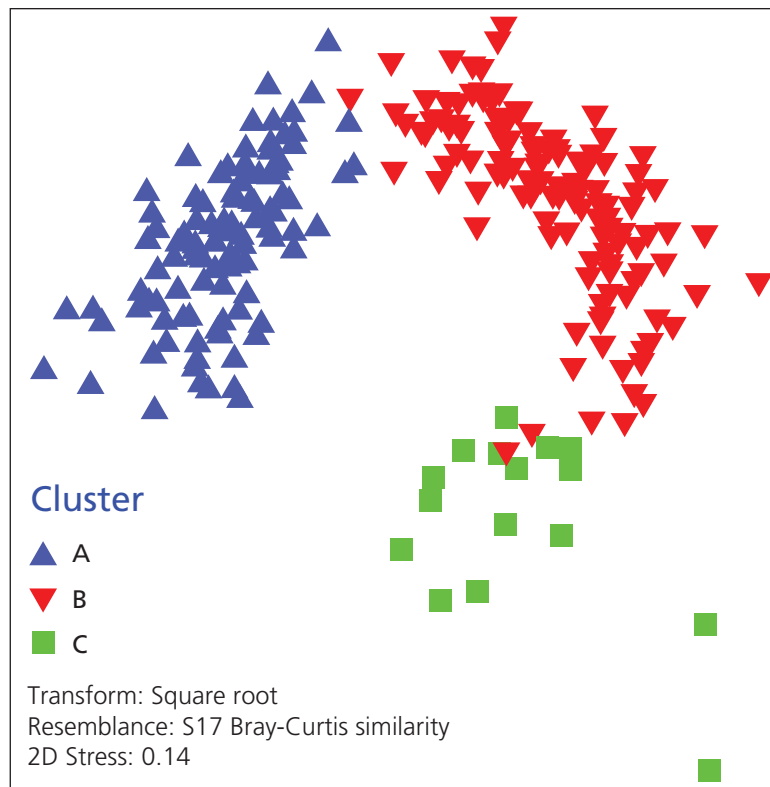


Figure 2-9. Non-metric multidimensional scaling of entire dataset. Data are from Saguaro National Park's Rincon Mountain District, 2013–2014.

With the data split into broad clusters, we further analyzed them by employing non-metric multidimensional scaling. In the resulting diagram (Figure 2-9), similarity/dissimilarity can be assessed based on the distance between points (samples). Using the NMDS, SIMPROF groups, and SIMPER profiles, we further explored the finer grouping within each cluster. Due to the large number of groups/vegetation associations identified during this process, we deemed it too cumbersome to fully detail within this report. Instead, a few examples associated with Cluster B are examined in further detail.

The first split in the dendrogram for Cluster B separated the Madrean Montane Forest & Woodland Macrogroup (M011) from the Madrean Lowland Evergreen Woodland Macrogroup (M010), based on the presence/absence of emergent large conifers, such as ponderosa pine (*Pinus ponderosa*)

and Arizona pine (*Pinus arizonica*), and the density of silverleaf oak (*Quercus hypoleucoides*). Under the M011 branch, we identified five associations that roughly aligned with the SIMPROF groupings (Figure 2-10). Under the M010 branch, the dendrogram split around 32% similarity, based on the presence/absence of border pinyon (*Pinus discolor*) (Figure 2-11). Under this split, the bottom branch contained the lower-elevation oak-savanna communities that were either too low in elevation for border pinyon (*Pinus discolor*) or subjected to severe, historical fire disturbance. This branch roughly aligned with an NVC-accepted group, Madrean Encinal (G201). We split these plots into four associations that roughly aligned with the SIMPROF groupings (Figure 2-12). The top branch, plots dominated by border pinyon (*Pinus discolor*), aligned with an NVC Group, Madrean Pinyon-juniper Woodland (G200).

Figure 2-10. Non-metric multidimensional scaling of M011 branch. Data are from Saguaro National Park's Rincon Mountain District, 2013–2014.

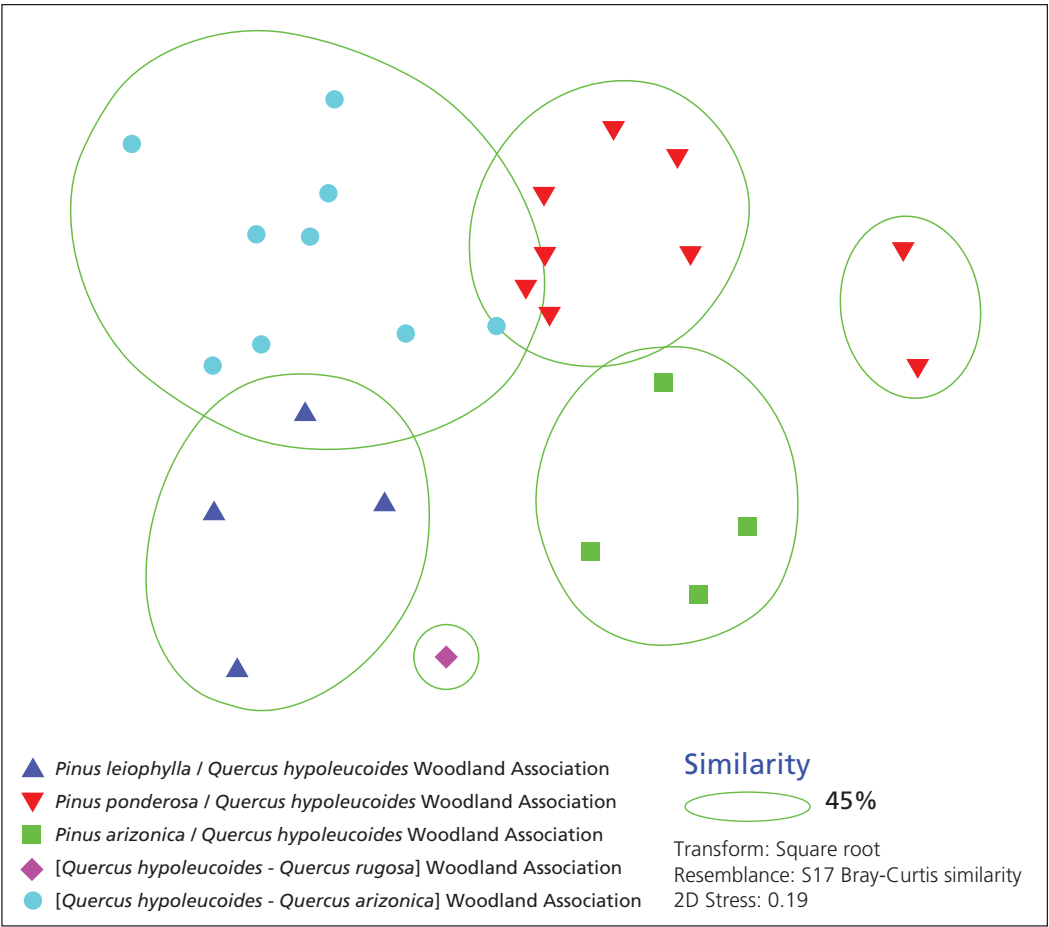
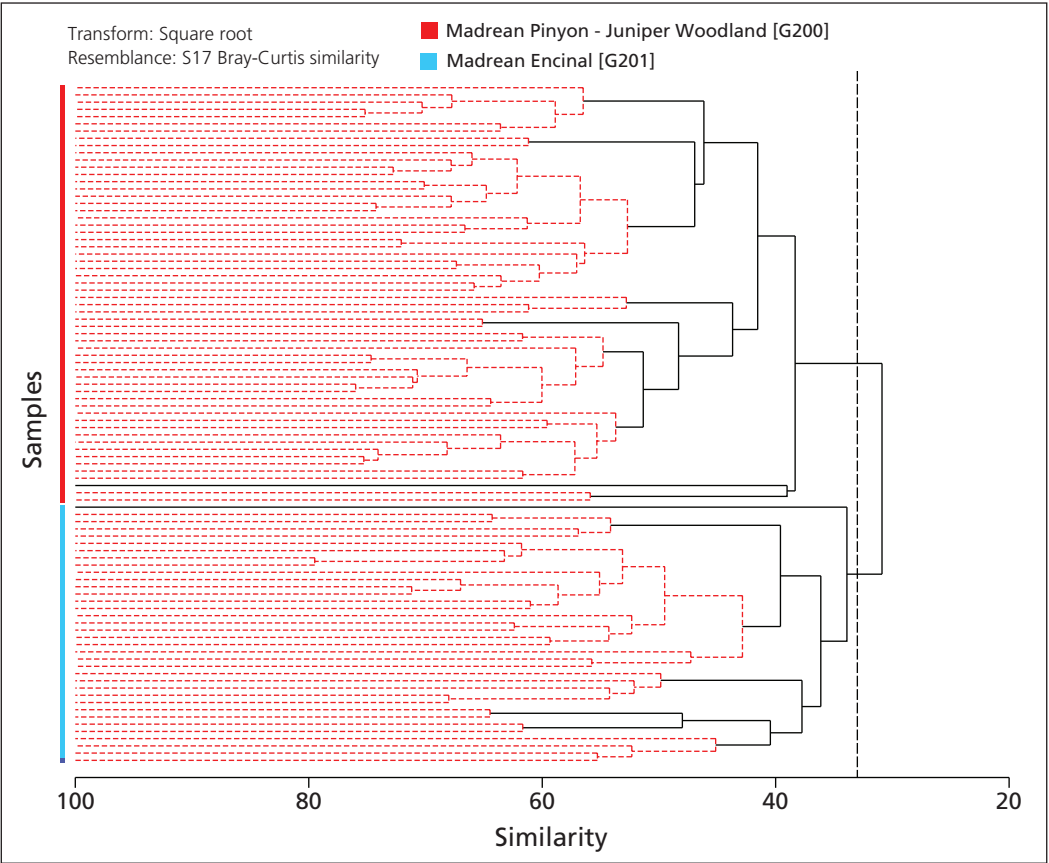


Figure 2-11. Dendrogram of the M010 branch, showing the split between G200 and G201 defined at a 32% similarity level, as indicated by the vertical dashed line. Data are from Saguaro National Park's Rincon Mountain District, 2013–2014.



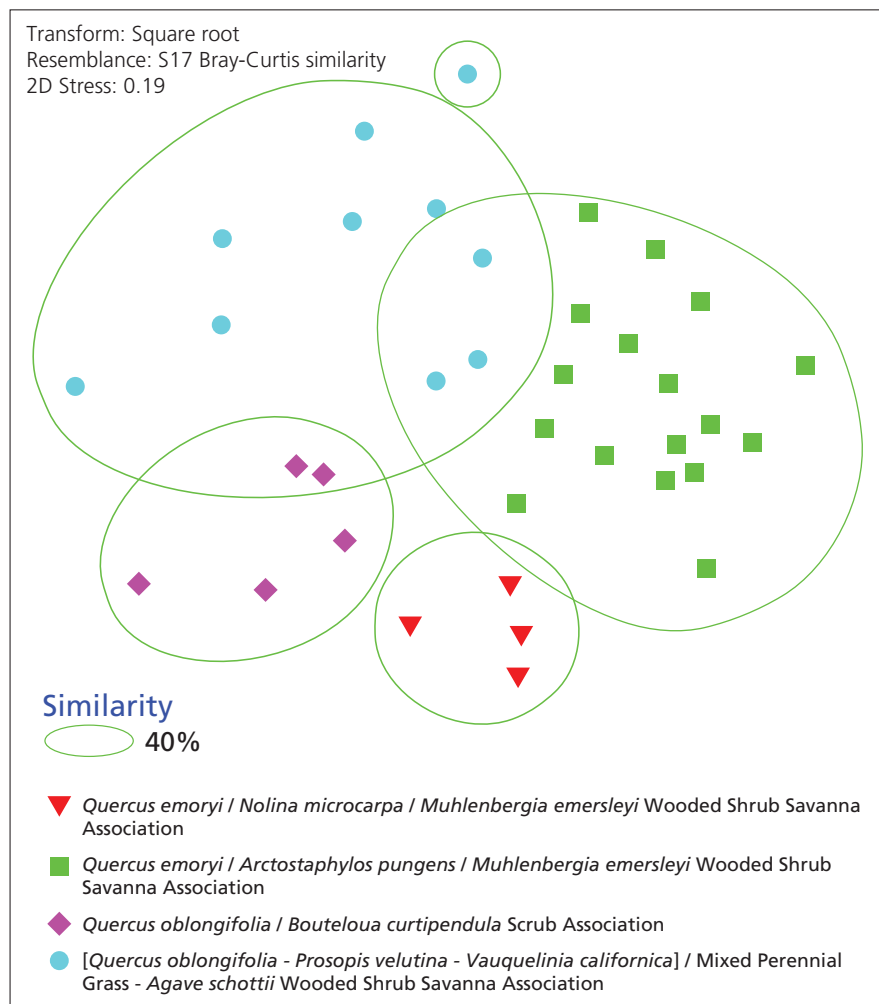


Figure 2-12. Non-metric multidimensional scaling of G201 branch. Green line denotes 40% similarity. Data are from Saguaro National Park's Rincon Mountain District, 2013–2014.

2.2.5.2 Classification validation

Following this initial round of sampling, we analyzed the plot data and drafted preliminary vegetation-type descriptions. Based on these results, we determined additional fieldwork was necessary to further describe undersampled communities and assess areas not sampled during the initial round. While our original intent was to sample all priority plots, we determined that focusing on subjective placement of plots would be a more efficient way to increase the dataset for undersampled communities.

The second round of sampling started in spring 2016, with the bulk of the fieldwork occurring throughout 2017. Crews sampled a total of 483 subjectively placed plots across an additional 74 field days (Figure 2-13). The protocol used to sample these

plots varied slightly from the one used in the initial round of sampling. To decrease the per-plot time commitment, we primarily sampled circular plots with an 18-meter radius (1,000 m²), delineated with the aid of rangefinders. This dataset helped to fill in some undersampled areas (i.e., Juniper Basin, Turkey Creek, and the eastern slopes of Rincon Peak), increase plots in previously undersampled communities, and describe communities undocumented in the initial round of sampling.

In addition to the classification plots, the second phase of sampling included the opportunistic collection of photopoints, which are akin to the observation/occurrence plots described in Lea (2011). Four photographs were taken at each point, typically one in each cardinal direction. Supporting infor-

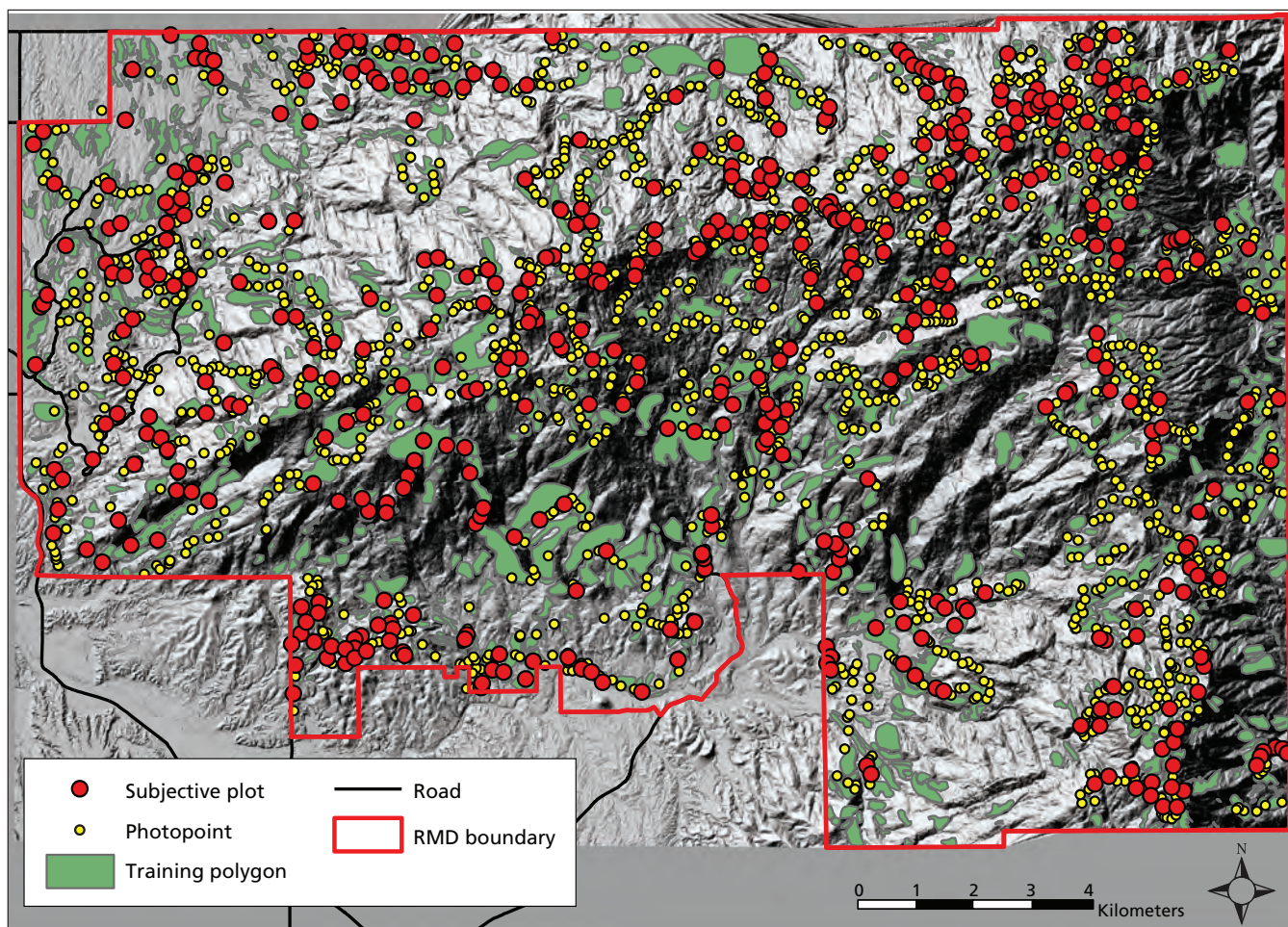


Figure 2-13. Locations of selectively placed classification plots, photopoints, and training polygons, Rincon Mountain District, Saguaro National Park, 2016–2017.

mation included GPS location, date, placement in a described vegetation type, and brief notes describing the captured vegetation community. These points were often used to capture broad vegetation gradients. Overall, crews collected 1,461 photopoints across the mountain (see Figure 2-13). These data were mainly used to fine-tune the training polygons (see Section 2.2.5.4) and final map (see Section 3.2).

2.2.5.3 Additional datasets

To enlarge the dataset used for classification, we acquired vegetation data from other projects. Starting in 2008, SODN began sampling plots for long-term upland vegetation and soils monitoring at the RMD. A subset of plots are sampled yearly, with all distributed plots sampled across a five-year sampling cycle. Prior to the start of this mapping project, one cycle was completed, providing an additional 57 plots to our da-

taset. These data were reformatted to align with the cover classes used for the classification plots.

High-elevation plots for Saguaro NP's fire-effects monitoring were also referenced for this phase of the project. The dataset included 57 plots distributed above 2,150 meters (7,053 ft), mainly in the Mica Bowl and around the northern end of Heartbreak Ridge. These data were primarily used to increase the training-polygon sample size (see Section 2.2.5.4) and fine-tune some of the upper-elevation associations.

2.2.5.4 Training polygons

Concurrent with the second round of classification-plot sampling, field crews collected a robust set of data from training polygons (see Figure 2-13). The methodology was similar to that employed at the TMD (see Section 2.1.4.2). However, the

RMD data were always intended for use in a remote-sensing supervised classification. In addition, survey locations were not dictated by plot distribution. Instead, they were intended to represent the range of variability in the rasters used to classify the final map (see Section 3.2 for more detail). Prior to fieldwork, project leads identified specific areas where crews could capture numerous aspects, slopes, canopy heights, canopy densities, and any oddities found in the raster datasets (Appendix C). In total, crews created around 1,500 training polygons covering around 15% of the park (4,246 ha/10,492 ac), with individual polygons ranging in size from >1 to 50 hectares. Crews hand-drew these polygons on 11 × 17" printouts of the imagery (PAG 2011), using topography, conspicuous landmarks, and GPS coordinates to delineate the boundaries. Upon completion of the field effort, these polygons were digitized and attributed in ArcMap (ESRI 2017). Additional training polygons were created based upon the initial classification plots, uplands monitoring plots, and high-elevation fire-effects plots described in Section 2.2.5.3.

2.2.5.5 Preliminary classification results

A total of 91 associations were identified from field observations, classification plots, and mapped polygons (see below). Of these, five associations were shown to occur in both districts of the park. More detail on where final associations were distributed can be found in Chapter 5-1.

1. (*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Opuntia engelmannii* (*Vachellia constricta* - *Larrea tridentata*) / *Ambrosia deltoidea* Wooded Shrubland
2. (*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Opuntia engelmannii* (*Vachellia constricta* - *Larrea tridentata*) Wooded Shrubland
3. (*Fouquieria splendens*) / *Prosopis velutina* / *Opuntia engelmannii* / *Cottsia gracilis* Shrubland
4. (*Parkinsonia microphylla* - *Fouquieria splendens*) / *Encelia farinosa* (*Cottsia gracilis*) Shrubland
5. (*Parkinsonia microphylla*) / *Aloysia wrightii* Shrubland
6. (*Parkinsonia microphylla*) / *Cylindropuntia bigelovii* / *Encelia farinosa* Shrubland
7. (*Parkinsonia microphylla*) / *Larrea tridentata* Shrubland
8. (*Prosopis velutina*) / *Aloysia wrightii* Shrubland
9. (*Prosopis velutina*) / *Larrea tridentata* Shrubland
10. (*Prosopis velutina*) / *Vachellia constricta* - *Opuntia engelmannii* Shrubland
11. (*Prosopis velutina*) / *Vachellia constricta* (*Larrea tridentata* - *Senegalia greggii*) Intermittently Flooded Shrubland
12. (*Quercus arizonica* - *Quercus emoryi*) / *Arctostaphylos pungens* Shrubland
13. (*Quercus emoryi* - *Quercus oblongifolia*) / *Eragrostis lehmanniana* Herbaceous
14. (*Quercus hypoleucoides* - *Quercus arizonica*) / *Arctostaphylos (pringlei - pungens)* Shrubland
15. (*Quercus hypoleucoides* - *Quercus arizonica*) / *Ceanothus fendleri* Wooded Shrubland
16. (*Quercus hypoleucoides* - *Quercus rugosa*) / *Arctostaphylos pringlei* Shrubland
17. (*Symphoricarpos oreophilus*) / *Ageratina herbacea* Shrubland
18. [*Quercus arizonica* - *Quercus emoryi*] / *Arctostaphylos pungens* Woodland
19. [*Quercus arizonica* - *Quercus hypoleucoides*] Intermittently Flooded Woodland
20. [*Quercus chrysolepis* - *Quercus rugosa* - *Holodiscus dumosa*] Shrubland
21. [*Quercus hypoleucoides* - *Quercus arizonica*] / *Arctostaphylos (pringlei - pungens)* Woodland
22. [*Quercus hypoleucoides* - *Quercus arizonica*] Shrubland
23. [*Quercus hypoleucoides* - *Quercus arizonica*] Woodland
24. [*Quercus hypoleucoides* - *Quercus rugosa*] / *Arctostaphylos pringlei* Woodland
25. [*Quercus hypoleucoides* - *Quercus rugosa*] Intermittently Flooded Woodland
26. [*Quercus hypoleucoides* - *Quercus rugosa*] Shrubland

27. [*Quercus oblongifolia* - *Prosopis velutina* - *Vauquelinia californica*] / Mixed Perennial Grass - *Agave schottii* Wooded Shrub Savanna
28. [*Quercus rugosa* - *Quercus hypoleucoides*] Woodland
29. *Alnus oblongifolia* / *Acer negundo* / *Rosa woodsii* Intermittently Flooded Woodland
30. *Cupressus arizonica* / *Quercus hypoleucoides* Forest
31. *Dalea pulchra* / Mixed Perennial Grass Shrub Savanna
32. *Fouquieria splendens* - *Prosopis velutina* / *Dodonaea viscosa* Shrubland
33. *Fouquieria splendens* (*Prosopis velutina*) / *Opuntia engelmannii* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna
34. *Fouquieria splendens* / (*Opuntia engelmannii*) / *Selaginella rupincola* Sparse Rock Outcrop
35. *Mimosa aculeaticarpa* Shrubland
36. *Muhlenbergia virescens* - *Pteridium aquilinum* - *Ceanothus fendleri* Herbaceous
37. *Nolina microcarpa* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna
38. *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland
39. *Parkinsonia microphylla* / *Encelia farinosa* - *Hibiscus denudatus* Shrubland
40. *Parkinsonia microphylla* / *Encelia farinosa* - *Zinnia acerosa* Shrubland
41. *Parkinsonia microphylla* / *Opuntia engelmannii* / *Encelia farinosa* Shrubland
42. *Parkinsonia microphylla* / *Parthenium incanum* Shrubland
43. *Parkinsonia microphylla* / *Tiquilia canescens* (*Zinnia acerosa*) Shrubland
44. *Pinus* (*arizonica* - *ponderosa*) Regenerating Woodland
45. *Pinus arizonica* (*Pinus strobiformis*) / *Muhlenbergia virescens* Forest
46. *Pinus arizonica* / *Pteridium aquilinum* Forest
47. *Pinus arizonica* / *Quercus hypoleucoides* Woodland
48. *Pinus arizonica* Forest
49. *Pinus discolor* (*Quercus arizonica* - *Juniperus deppeana* - *Quercus hypoleucoides*) Woodland
50. *Pinus discolor* / *Arctostaphylos* (*pungens* - *pringlei*) Wooded Shrubland
51. *Pinus discolor* - *Quercus emoryi* / *Muhlenbergia emersleyi* Open Woodland
52. [*Pinus discolor* - *Quercus arizonica* - *Juniperus deppeana*] / *Arctostaphylos pungens* / *Muhlenbergia emersleyi* Wooded Shrubland
53. *Pinus discolor* / *Piptochaetium fimbriatum* Woodland
54. *Pinus discolor* / *Quercus rugosa* Woodland
55. *Pinus discolor* / *Quercus toumeyii* Woodland
56. *Pinus leiophylla* / *Quercus hypoleucoides* Woodland
57. *Pinus ponderosa* - *Pinus strobiformis* Forest
58. *Pinus ponderosa* (*Pinus strobiformis*) / *Muhlenbergia virescens* Woodland
59. *Pinus ponderosa* / *Pteridium aquilinum* Forest
60. *Pinus ponderosa* / *Quercus arizonica* - *Quercus emoryi* Woodland
61. *Pinus ponderosa* / *Quercus hypoleucoides* Woodland
62. *Platanus wrightii* - *Fraxinus velutina* Intermittently Flooded Woodland
63. *Platanus wrightii* / *Quercus oblongifolia* Riparian Woodland
64. *Populus fremontii* / *Muhlenbergia rigens* Riparian Woodland
65. *Populus tremuloides* Forest
66. *Prosopis velutina* - *Chilopsis linearis* / *Ambrosia monogyra* Intermittently Flooded Woodland
67. *Prosopis velutina* - *Senegalia greggii* Intermittently Flooded Shrubland
68. *Prosopis velutina* - *Senegalia greggii* Intermittently Flooded Woodland
69. *Prosopis velutina* / Annual Forb Woodland

70. *Prosopis velutina* / *Opuntia engelmannii* - *Ericameria laricifolia* / *Muhlenbergia porteri* Wooded Shrubland
71. *Prosopis velutina* / *Opuntia engelmannii* (*Senegalia greggii* - *Celtis ehrenbergiana*) Wooded Shrubland
72. *Prosopis velutina* / *Opuntia engelmannii* / *Encelia farinosa* (*Cottisia gracilis*) Wooded Shrubland
73. *Prosopis velutina* / *Ziziphus obtusifolia* - *Condalia warnockii* Woodland
74. *Prosopis velutina* Woodland
75. *Pseudotsuga menziesii* - *Pinus arizonica* / (*Quercus gambelii*) Forest
76. *Pseudotsuga menziesii* - *Pinus arizonica* / *Quercus rugosa* Forest
77. *Pseudotsuga menziesii* - *Pinus ponderosa* / (*Quercus gambelii*) Forest
78. *Pseudotsuga menziesii* - *Pinus ponderosa* / *Quercus rugosa* Forest
79. *Pseudotsuga menziesii* / *Pinus strobiformis* Forest
80. *Pteridium aquilinum* Herbaceous
81. *Quercus arizonica* - *Quercus emoryi* (*Platanus wrightii*) Intermittently Flooded Woodland
82. *Quercus emoryi* / *Arctostaphylos pungens* / *Muhlenbergia emersleyi* Wooded Shrub Savanna
83. *Quercus emoryi* / *Nolina microcarpa* / *Muhlenbergia emersleyi* Wooded Shrub Savanna
84. *Quercus gambelii* / *Robinia neomexicana* / *Symphoricarpos oreophilus* Woodland
85. *Quercus gambelii* / *Symphoricarpos oreophilus* Shrubland
86. *Quercus oblongifolia* / *Bouteloua curtipendula* Scrub
87. *Quercus rugosa* - *Ceanothus integerrimus* Woodland
88. *Quercus turbinella* - *Nolina microcarpa* / *Muhlenbergia emersleyi* - *Agave schottii* Shrub Savanna
89. *Simmondsia chinensis* (Mixed Cacti) Shrubland
90. *Simmondsia chinensis* / *Encelia farinosa* Shrubland
91. *Simmondsia chinensis* / *Hilaria belangeri* Shrub Savanna

3 Mapping of Plant Communities

3.1 Tucson Mountain District

3.1.1 Methods

Unlike previous vegetation maps created by SODN, the map for Saguaro National Park was not created via in-situ mapping. At the start of this project, we intended to fully map the TMD on the ground. However, we subsequently determined the district was too large and complex for this methodology to be viable. Instead, we employed a remote-sensing approach aided by our robust field dataset. The final version of the map was created in summer 2016. This section documents that final version.

The map was created using the image-classification toolbox included in the spatial analyst extension for ArcMap (ESRI 2017). Using these tools, we performed a supervised classification with the maximum-likelihood classifier. This tool uses a set of user-defined training samples (polygons) to classify imagery by placing pixels with the maximum likelihood into each map class. We used a pixel size equivalent to the coarsest raster included in the classification, 30 meters.

The image file used to run this classification was a stack of rasters ranging from Landsat Thematic Mapper (TM) satellite imagery to digital elevation models. A breakdown of all rasters used can be found in Appendix D. A principal component analysis (PCA) was run on the stack prior to running the classification. A PCA is used to “reduce the dimensionality of the data, in this case the number of bands, to maximize the amount of information from the original bands into the least number of principal components” (Estornell et al. 2013). This analysis showed

that over 95% of the variance was captured within the first three principal components. As such, these three components became the file used to run the maximum-likelihood classification.

Using the polygon data collected during the vegetation-classification field effort, we created a set of training polygons. These polygons were altered from their original size and shape to only include consistent habitat in the immediate vicinity of classification plots. These changes were informed by plot data, aerial imagery (PAG 2011), and the rasters included in the classification. Typically, polygons were greatly reduced in size. In total, we used 351 training polygons spread across 14 map classes and covering roughly 15% (1,517 ha/3,748 ac) of the district. The Wash class was not included due to its narrow, linear nature, which classified poorly with 30-meter pixels.

Next, polygons were divided into parcels of 1–5 hectares and randomly assigned to training (80%) and test (20%) datasets. Using the image-classification toolbar in ArcMap (ESRI 2011), we imported our training data into the training sample manager. Using the toolbar, we assessed the distribution of pixel values within each class and checked for areas of notable overlap between classes. For the final step before the maximum-likelihood classifier, we created a signature file from the training dataset and the raster resulting from the PCA.

The maximum-likelihood classifier was run on five different PCA analyses run on groupings of predictor rasters (Table 3-1). These groups each received a PCA, and new signature files were created. Each of these groups

Table 3-1. Groupings of predictor rasters used to run the maximum-likelihood classifier.

Code	Description	Number	Bands
All Raster	Includes all predictor rasters	12	45
NoDEM	Excludes digital elevation models	11	44
NoCatLS	Excludes categorical and Landsat data	6	8
NoLS	Excludes Landsat data	8	10
NoCat	Excludes categorical data	10	43

was run five separate times, with a different test dataset set aside for each run. Using the resulting raster maps and the test datasets, we created contingency tables to assess the accuracy of each map and the consistency within each grouping. We selected the raster map with the highest and most-consistent accuracy as the basis for the final map. This map was created using the grouping that contained all included rasters.

Following the creation of the raster map, we used the majority filter to remove small inclusions of pixels based on the majority value of the surrounding pixels. This helped to eliminate small inclusions well below the minimum mapping size (0.5 ha). Following this step, the raster feature was converted to a polygon feature. To minimize jagged edges, we used smoothing tools and manual boundary edits. Additional polygon features were created to cover developed areas (buildings and paved roads) and account for the wash community excluded from the raster classification. These were digitized based on the PAG (2011) imagery.

3.1.2 Results

The map created during the raster-classification process covered the entirety of the TMD. It included 577 polygons spread

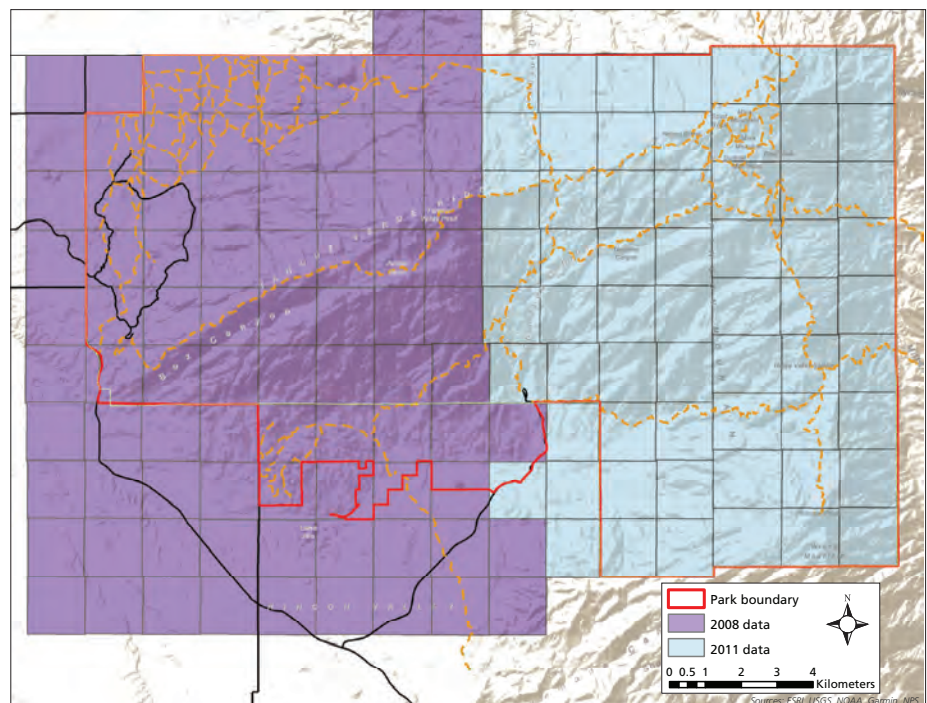
across 16 map classes, including classes for developed lands and roads. These polygons ranged in size from 0.5 hectares (often the result of polygons split by roads) to one at 1,817 hectares covering the alluvial fan along the western boundary.

3.2 Rincon Mountain District

3.2.1 Digital imagery acquisition and processing

At the RMD, multiple remote-sensing mapping efforts were used throughout this project. Not all were fully successful, but the project team learned from each of them. The same PAG imagery that was available for the TMD also covered the RMD, in the form of natural-color, aerial photos of 1-foot resolution from 2011. The RMD had also recently been surveyed using Light Detection and Ranging (LiDAR). These raw data were made available to us and our project partners at no cost. The LiDAR measurements, contracted by the Pima Association of Governments in 2008 and 2011, were collected by Sanborn, Inc. The 2008 measurements encompassed portions of eastern Pima County and the western half of the RMD. The 2011 measurements included the eastern half of the RMD, providing a complete dataset for the study area (Figure 3-1).

Figure 3-1. LiDAR collection over the Rincon Mountain District, Saguaro National Park.



3.2.2 Methods

3.2.2.1 Initial mapping efforts (pre-2014)

In 2012, SODN entered into an agreement with researchers from the U.S. Geological Survey (USGS) to develop a draft polygon map at the formation (aka structural) level for the RMD, showing areas differentiated from one another based on the amount/dominance of different lifeforms. The two primary datasets used were the LiDAR and a 2011 multi-temporal composite of Landsat 5 TM imagery. Through a series of spatial-data manipulations, several surface models were derived from the LiDAR data, including bare-earth and canopy-height models (CHMs), subsequently used to classify the park area into pixels showing the dominant cover type (Figure 3-2). The CHMs proved extremely useful as inputs in the raster classification described below.

Beyond these first models, additional species-presence data were included for a suite of indicator species roughly correlating with major breaks in the biome distribution across the mountain. These included Douglas fir (*Pseudotsuga menziesii*), multiple pine (*Pinus* spp.) and oak (*Quercus* spp.) species combined, juniper (*Juniperus deppeana*), mesquite (*Prosopis velutina*), paloverde (*Parkinsonia microphylla*), whitethorn acacia (*Acacia constricta*), and saguaro (*Carnegiea gigantea*). Using the TM imagery and the species-specific training areas, as well as estimated elevation-range cutoffs, the USGS team tried to further classify the vegetation across the RMD. This map delineated the district into pixels based on a combination of vegetation formation and indicator species. At the end of this process, we assessed how these products could aid and inform the creation of the eventual association-level map. The CHMs and, to a lesser extent, the bare-earth raster proved invaluable for the final classification of the RMD (described below). However, the formation and indicator-species maps were not used to create the final map.

3.2.2.2 Final mapping efforts (2014–2017)

As with the TMD, the RMD was deemed too large and complex to be mapped on the ground. Instead, we employed a remote-sensing approach aided by our robust field

dataset. Concurrent with the classification field effort, we worked with USGS researchers Miguel Villareal and Natalie Wilson to formulate a methodology for mapping the RMD. Multiple map versions were created throughout the project. The earliest was in 2016, between the classification and validation phases of the project. The final version of the map was created in the winter of 2017–2018, upon completion of the validation phase. This section documents that final version.

The map was created using the ModelMap package (Freeman and Frescino 2018) for R (R core team 2017). This package employs Random Forest models to create features based on a raster dataset and training data. Random Forest is a machine-learning algorithm developed by Breiman (2001) and used for numerous vegetation mapping/classification projects in recent years (Cutler et al. 2007; Chapman et al. 2010; Rodriguez-Galiano et al. 2012). Random Forest incorporates a large number of decision trees, of which the most-common prediction is used.

For the current project, we used a pixel-based supervised classification approach. The spatial resolution of our predictor datasets ranged from 1-meter to 30-meter pixel size. Initial attempts with smaller (10 × 10 m) pixels overclassified many of the sparsely vegetated and/or herbaceous communities, and did not include the 30-meter Landsat TM satellite imagery. We decided to convert all rasters used for analysis to a 30-meter pixel size. Continuous variable rasters were resampled using bilinear interpolation, while categorical rasters were resampled using the majority/nearest-neighbor filter. Raster datasets used for this classification were created from Landsat datasets, RMD LiDAR products, and various RMD base layers. A complete list of included rasters can be found in Appendix D.

Polygon data collected during the validation phase (see Section 2.2.5.4) were used to train and test the raster model. The final version of this dataset included 2,217 unique polygons spread across all map classes. In total, these polygons covered around 24% (6,603 ha/16,316 ac) of the RMD, ranging in size from 0.1 hectare (1,000 m²) to 74 hectares

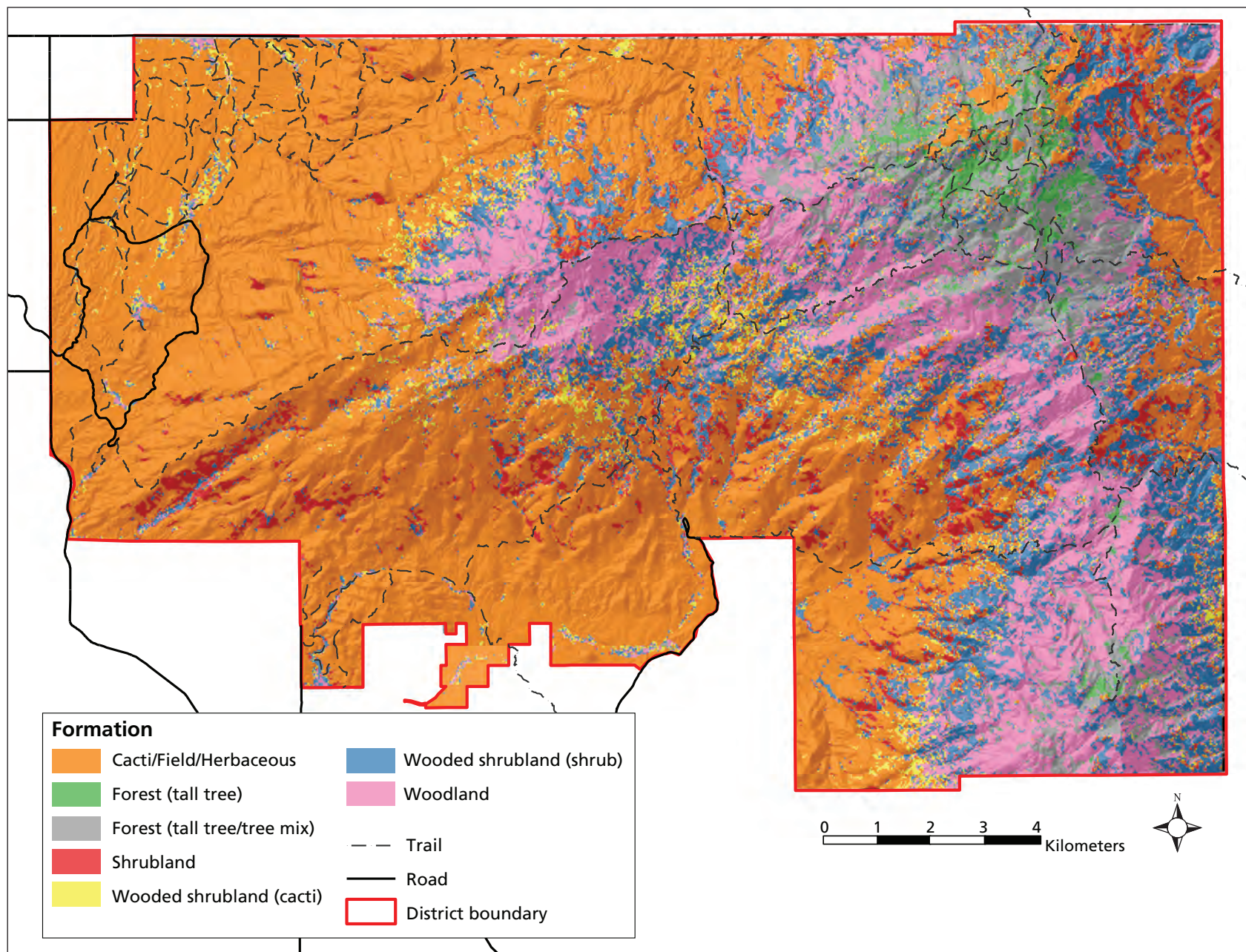


Figure 3-2. Formation map of the Rincon Mountain District created by USGS researchers.

(740,000 m²). Prior to running the model, all polygon training data were converted to the centroid of each overlapping raster pixel ($n = 71,777$). Then, each point was attributed with the values of all included rasters. These points were randomly split into training (80%) and test (20%) points by map class.

After the data were formatted and split properly, we ran a number of models using various groupings of predictor rasters ($n = 7$). Typically, we performed five runs for every model, each time using a different test dataset. Predictor raster groupings ranged from including every raster to excluding all categorical rasters and Landsat data (Table 3-2). The package ModelMap includes a diagnostics command that outputs a number of useful tables and figures. These include a contingency table (see Section 4.3) based on the test dataset and the resulting raster map and “relative influence” graphs that depict the importance of each predictor raster to the overall classification and each individual class. These were consulted after running each model to compare how well each model had determined accuracy by class and across the raster map.

Upon reviewing all models, we determined that two (“All Raster” and “NoCat”) achieved the highest accuracy. The categorical predictors worked well when classifying communities clearly tied to a specific soil/geology type or defined by a fire event. For example, communities associated with the limestone geology of the Loma Alta expansions area achieved a higher accuracy when including the categorical geology raster. However, the categorical fire raster caused

accuracy to decrease when fire severity was highly variable and/or patchy. Some map classes worked better with specific categorical rasters; others improved in their absence. Based on this determination, we decided to synthesize the two maps, incorporating the best elements of each. For that final synthesis, both the “All Raster” and “NoCat” stacks were run with the entire dataset used for training the models, with no data set aside for testing the model.

The process of combining the two raster maps was completed using heads-up digitizing to create a polygon map over the rasters. The numerous photopoints, plots, and training polygons were referenced throughout this process to further improve the accuracy of the map. This process served a secondary purpose of removing the jagged polygon boundaries typical of raster maps.

3.2.3 Results

The map created during the raster-classification process covered the entirety of the RMD. It included 2,385 polygons spread across 86 map classes, including a class each for sparsely vegetated bedrock and developed lands (e.g., roads, visitor center). These polygons ranged in size from 0.1 hectare (often a result of polygons split by roads), to a 952-hectare example that spanned the south-facing slopes of Tanque Verde Ridge. At this point, certain associations were already grouped into map classes ($n = 5$). This typically occurred for similar associations when the training data were not sufficient to consistently classify each association.

Table 3-2. Groupings of predictor rasters used as inputs for Random Forest classification.

Code	Description	Number	Bands
All Raster	Includes all predictor rasters	24	58
NoDEM	Excludes digital elevation models	23	57
NoCatLS	Excludes categorical and Landsat data	17	19
NoLS	Excludes Landsat data	20	22
NoCat	Excludes categorical data	21	55
NoDEMHD	Excludes digital elevation models and hydro distance	22	56
NoLidar	Excludes LiDAR products	16	50

4 Accuracy Assessment

4.1 Methods

The protocol used for the accuracy assessment (AA) phase of this project was based on the thematic accuracy-assessment procedures outlined in Lea and Curtis (2010). We followed these procedures to the greatest extent possible. However, some changes were made to accommodate the small and often linear nature of some map classes, as well as crew size and availability. While the AA methodology for the TMD and RMD were very similar, the districts were assessed during different time periods and with slight variations to the plot distribution and associated survey data.

Using ArcMap (ESRI 2017), we created the AA inference/project area by buffering and removing a number of features throughout the park. All roads (dirt and paved) and facilities were buffered by 10 meters and eliminated from the assessment area. This was done to remove the edge effect that areas close to these features may have. In addition, all private inholdings within the two districts were removed.

Prior to point distribution, we assessed the accessibility of each district. No further buffering was required at the TMD, due to its smaller size and the ample network of roads and trails that crisscross the district. In total, the AA project area at the TMD covered 98% (9,852 ha/24,344 ac) of the district (Figure 4-1, next page).

The RMD proved to be more complex. Due to the RMD's larger size, the inaccessibility of certain areas, and limited resources,

we quickly realized it would be necessary to exclude portions of this district from the project area. To simplify analysis, we used a simple buffering design, in which areas contained within the accessibility buffer have an equal chance of inclusion. We created a number of buffering schemes based on distances from trails, roads, backcountry campgrounds, and various known access points around the park. In the end, we decided to use a 750-meter inclusion buffer around trails and a 1,500-meter buffer around the remaining features. The area within these buffers was deemed accessible and was therefore included in the project area. Trails received a shorter distance buffer to account for the potential distance crews might need to hike to reach certain stretches of trail. We also manually removed a few sections of the inclusion buffer due to safety concerns. This buffering scheme resulted in the inclusion of ~63% (16,937 ha) of the RMD in the access buffer, excluding inholdings (Figure 4-2).

After defining the project areas, we completed an iterative process of determining an appropriate plot size for each vegetation class. Ideally, plot size matched the minimum mapping unit (0.5 ha). However, this was not feasible in a number of classes due to the linear nature of their associated polygons. To prevent plots from overlapping with adjacent classes, we applied a negative buffer to remove a certain amount of the exterior of each polygon. To do this, the interior boundary of each polygon was buffered with the plot radius plus two extra meters for GPS accuracy (Table 4-1). Depending on the size

Table 4-1. Overview of plot sizes, their associated negative buffers, and the number of map classes for each size.

Area (ha)	Plot radius (ha)	GPS accuracy (ha)	Negative buffer (ha)	TMD map classes*	RMD map classes*
0.5	40	2	42	13	24
0.25	28	2	30	1	28
0.1	18	2	20	0	24
0.03	10	2	12	0	4
N/A	0	N/A	0	1	4

*Only vegetated map classes are included in the accuracy assessment. For RMD $n = 84$, for TMD $n = 15$.

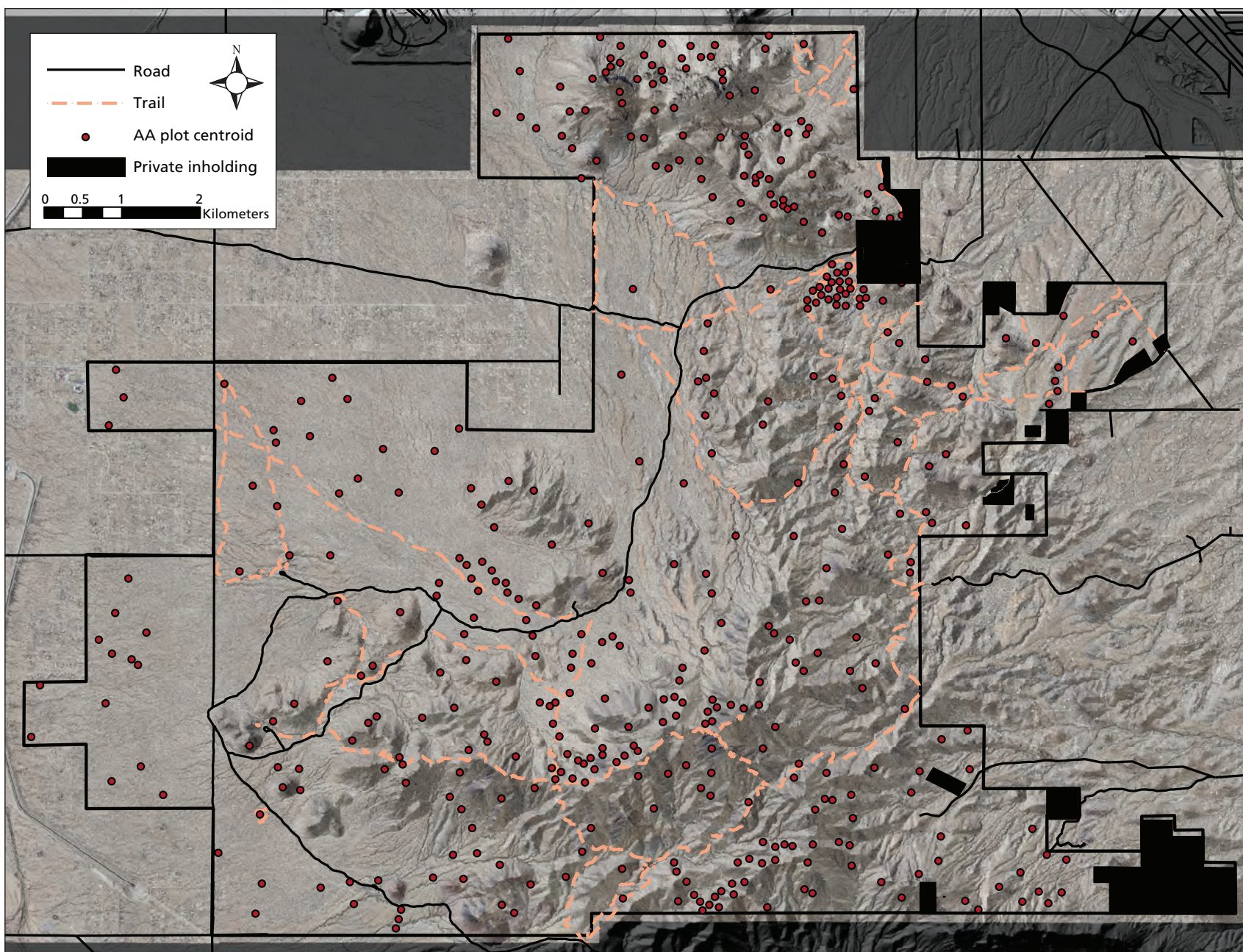


Figure 4-1. Distribution of accuracy-assessment plots within the Tucson Mountain District.

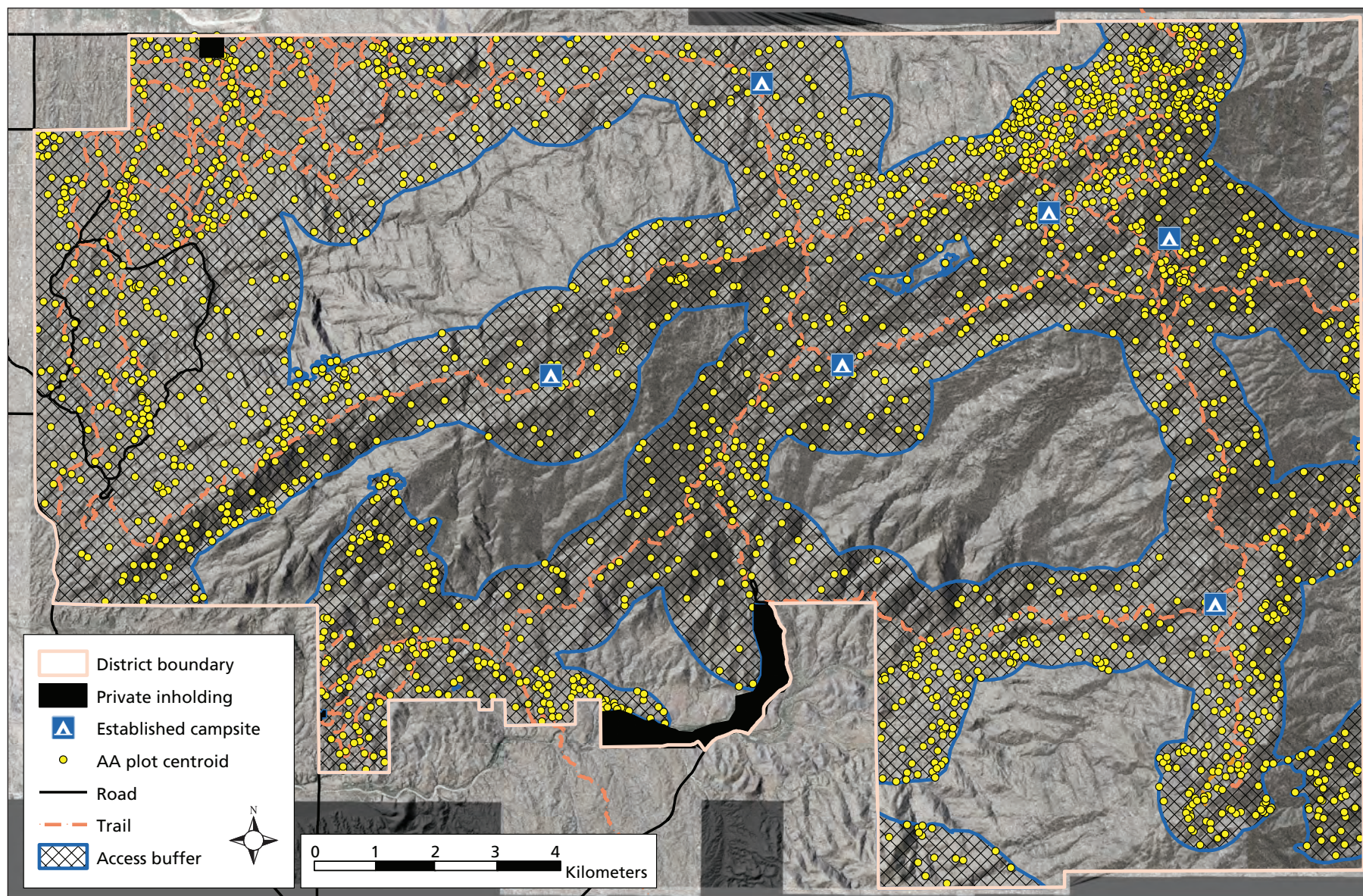


Figure 4-2. Distribution of accuracy-assessment plots within the accessibility buffer at the Rincon Mountain District.

and shape of each polygon, this buffering process may cause large portions of polygons—or entire polygons—to be removed from the area used for centroid distribution. For classes with linear polygons, we decreased the plot radius to maximize the area and number of polygons available for point distribution.

Using the smallest negative buffer (12 m) removed the majority of five linear drainage classes (5 at the RMD and 1 at the TMD) from the project area. As an alternative, we distributed points throughout the full polygons for those five classes without any negative buffering. We created 50-meter buffers around these points and clipped the underlying polygons to the buffer, creating roughly 100-meter stretches of drainage (Figure 4-3). When points landed less than 50 meters from the end of a polygon, minor

shifts were made to avoid overlap with other classes. Finally, we calculated the number of polygons and area lost for each class resulting from the total negative buffer associated with each potential plot size (see Table 4-1). We selected the largest plot size that allowed each map class to maintain 60% of its polygons and total area for point distribution.

We used the pre-buffered polygon areas (plot buffer and accessibility buffer) of each class to determine the appropriate sample size, following the recommended sizes outlined in Lea and Curtis (2010). This required distributing 30 plots within all classes covering more than 50 hectares, 0.6 plots/hectare for classes covering between 8.33 and 50 hectares, and 5 plots for classes covering less than 8.33 hectares. We used the *spsurvey* package (Kincaid et al. 2019) of R (R core team 2017) to create a general-

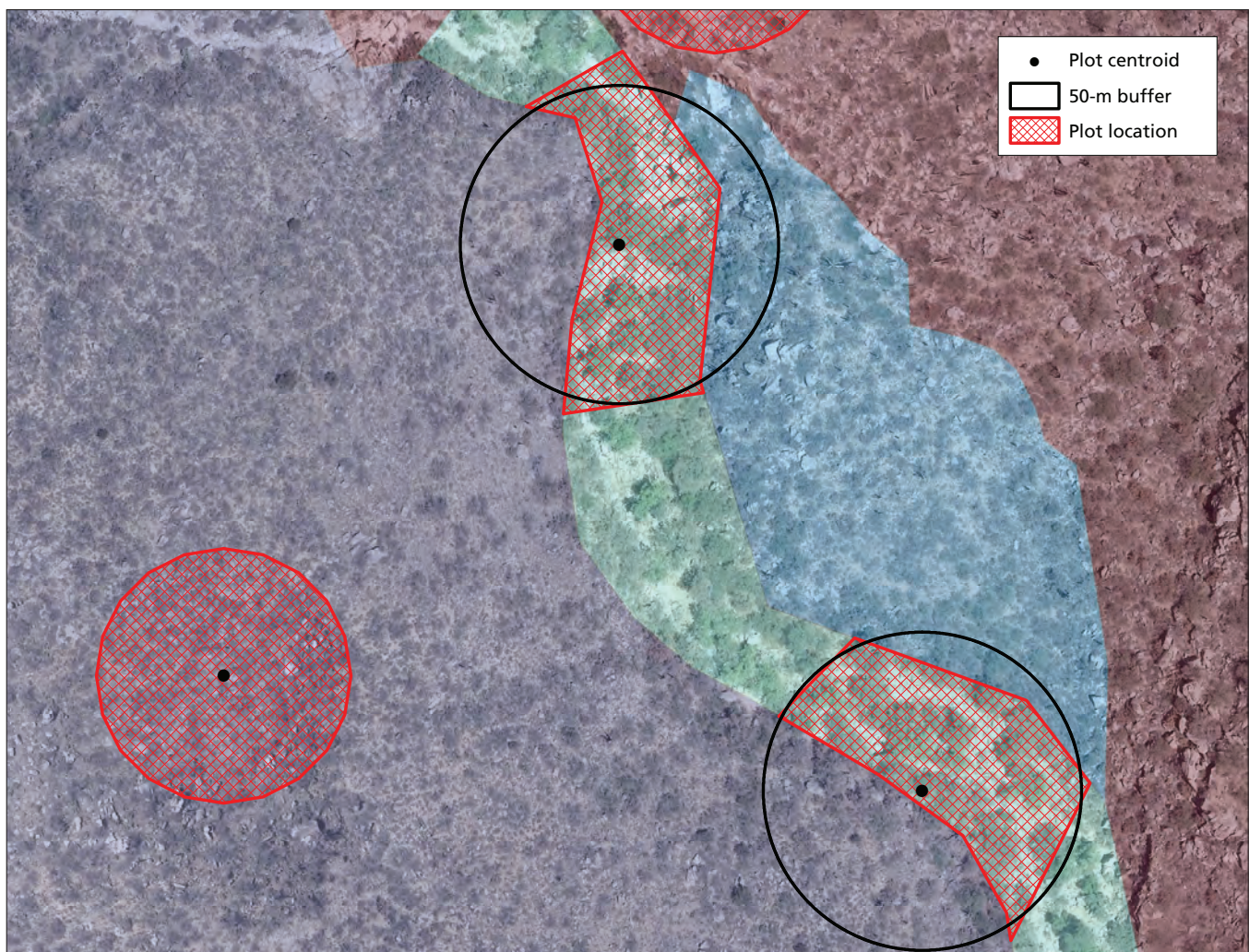


Figure 4-3. Example of accuracy-assessment plot distribution and delineation for linear polygon features.

ized random tessellation stratified (GRTS) sampling design to distribute points. At the TMD, we included a 25% oversample and distributed a total of 546 plots. Of those, 435 were priority plots (intended for sampling) and 111 were oversample plots (that could be sampled if priority plots could not be) (Table 4-2, see Figure 4-1). Each of these points served as the centroid of a circular as-

essment plot, except for the linear drainage classes previously discussed. At the RMD, we included a 100% oversample to be available in the event of an inaccessible plot or to increase sample size in a particular class. In total, we distributed 3,918 plots, 1,936 priority plots, and 1,982 oversample plots at this district (Table 4-3, see Figure 4-2).

Table 4-2. Accuracy-assessment plot distribution within each association at the Tucson Mountain District.

Association name	AA area (ha)	% of TMD	Plots	Plot radius (m)
(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Vachellia constricta</i> - <i>Larrea tridentata</i> / <i>Krameria bicolor</i> Wooded Shrubland	55.15	0.6%	30	40
(<i>Parkinsonia microphylla</i> - <i>Fouquieria splendens</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland	833.81	8.3%	30	40
(<i>Parkinsonia microphylla</i>) / <i>Larrea tridentata</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland	1,222.78	12.2%	30	40
(<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland	263.80	2.6%	30	N/A
<i>Carnegiea gigantea</i> / <i>Parkinsonia microphylla</i> (<i>Olneya tesota</i>) / <i>Ambrosia deltoidea</i> Shrubland	2,739.77	27.4%	30	40
<i>Cylindropuntia acanthocarpa</i> - <i>Vachellia constricta</i> / <i>Calliandra eriophylla</i> - <i>Cottisia gracilis</i> Shrubland	769.08	7.7%	30	40
<i>Larrea tridentata</i> [<i>Ephedra aspera</i> - <i>Parthenium incanum</i>] Shrubland	24.25	1.5%	15	28
<i>Opuntia engelmannii</i> (<i>Calliandra eriophylla</i> - <i>Agave schottii</i>) / <i>Selaginella arizonica</i> Shrubland	147.47	0.2%	30	40
<i>Parkinsonia microphylla</i> / <i>Ambrosia deltoidea</i> Shrubland	492.64	4.9%	30	40
<i>Parkinsonia microphylla</i> / <i>Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland	270.64	2.7%	30	40
<i>Parkinsonia microphylla</i> / <i>Opuntia</i> spp. - <i>Ambrosia salsola</i> / <i>Muhlenbergia porteri</i> Shrubland	327.87	3.3%	30	40
<i>Simmondsia chinensis</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland	936.30	9.4%	30	40
<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland	117.65	1.2%	30	40
<i>Simmondsia chinensis</i> / <i>Encelia farinosa</i> Shrubland	826.43	8.3%	30	40
<i>Yucca baccata</i> - <i>Dasyllirion wheeleri</i> / <i>Muhlenbergia porteri</i> Shrubland	972.70	9.7%	30	40

Table 4-3. Accuracy-assessment plot distribution within each map class at the Rincon Mountain District ($n = 84$).

Map class	Association	AA area (ha)	% of RMD	Plots	Plot radius (m)
(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) / <i>Ambrosia deltoidea</i> Wooded Shrubland, (<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland	957.58	3.56%	30	40
(<i>Fouquieria splendens</i>) / <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> / <i>Cottisia gracilis</i> Shrubland	(same as map class)	1,100.36	4.09%	30	40
(<i>Parkinsonia microphylla</i> - <i>Fouquieria splendens</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland	(same as map class)	2,076.71	7.71%	30	40
(<i>Parkinsonia microphylla</i>) / <i>Cylindropuntia bigelovii</i> / <i>Encelia farinosa</i> Shrubland	(same as map class)	240.73	0.89%	30	40
(<i>Parkinsonia microphylla</i>) / <i>Larrea tridentata</i> Shrubland	(same as map class)	29.98	0.11%	18	18
(<i>Prosopis velutina</i>) / <i>Aloysia wrightii</i> Shrubland	(same as map class)	175.08	0.65%	30	28
(<i>Prosopis velutina</i>) / <i>Larrea tridentata</i> Shrubland	(same as map class)	262.41	0.97%	30	40
(<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> - <i>Opuntia engelmannii</i> Shrubland	(same as map class)	270.61	1.00%	30	40
(<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland	(same as map class)	152.20	0.57%	30	18
(<i>Quercus emoryi</i> - <i>Quercus oblongifolia</i>) / <i>Eragrostis lehmanniana</i> Herbaceous	(same as map class)	30.16	0.11%	15	28
(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Ceanothus fendleri</i> Wooded Shrubland	(same as map class)	10.32	0.04%	7	18
(<i>Symphoricarpos oreophilus</i>) / <i>Ageratina herbacea</i> Shrubland	(same as map class)	24.11	0.09%	14	28
[<i>Pinus discolor</i> - <i>Quercus arizonica</i> - <i>Juniperus deppeana</i>] / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrubland	(same as map class)	2,378.01	8.83%	30	40
[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Shrubland	(same as map class)	36.88	0.14%	23	18
[<i>Quercus arizonica</i> - <i>Quercus hypoleucoides</i>] Intermittently Flooded Woodland	(same as map class)	92.45	0.34%	30	18
[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland	(same as map class)	317.89	1.18%	30	28

Table 4-3 (continued). Accuracy-assessment plot distribution within each map class at the Rincon Mountain District (n = 84).

Map class	Association	AA area (ha)	% of RMD	Plots	Plot radius (m)
[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i>] Shrubland	[<i>Quercus chrysolepis</i> - <i>Quercus rugosa</i> - <i>Holodiscus dumosa</i>] Shrubland, [<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Shrubland	322.07	1.20%	30	28
[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland and Intermittently Flooded Woodland	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Intermittently Flooded Woodland, [<i>Quercus rugosa</i> - <i>Quercus hypoleucoides</i>] Woodland	179.10	0.66%	30	28
<i>Alnus oblongifolia</i> / <i>Acer negundo</i> / <i>Rosa woodsii</i> Intermittently Flooded Woodland	(same as map class)	2.38	0.01%	5	N/A
<i>Cupressus arizonica</i> / <i>Quercus hypoleucoides</i> Forest	(same as map class)	114.57	0.43%	30	18
<i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna	(same as map class)	653.88	2.43%	30	40
<i>Fouquieria splendens</i> - <i>Prosopis velutina</i> / <i>Dodonaea viscosa</i> Shrubland	(same as map class)	147.23	0.55%	30	28
<i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna	(same as map class)	946.37	3.51%	30	40
<i>Fouquieria splendens</i> / (<i>Opuntia engelmannii</i>) / <i>Selaginella rupicola</i> Sparse Rock Outcrop	(same as map class)	132.98	0.49%	30	18
<i>Mimosa aculeaticarpa</i> Shrubland	(same as map class)	14.21	0.05%	9	18
<i>Muhlenbergia virescens</i> - <i>Pteridium aquilinum</i> - <i>Ceanothus fendleri</i> Herbaceous	(same as map class)	55.64	0.21%	30	18
<i>Nolina microcarpa</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna	(same as map class)	168.26	0.62%	29	40
<i>Parkinsonia microphylla</i> / <i>Ambrosia deltoidea</i> Shrubland	(same as map class)	3.49	0.01%	5	18
<i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> (<i>Hibiscus denudatus</i> - <i>Zinnia acerosa</i>) Shrubland	<i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> - <i>Hibiscus denudatus</i> Shrubland, <i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> - <i>Zinnia acerosa</i> Shrubland	269.94	1.00%	30	40
<i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland	(same as map class)	484.91	1.80%	30	40
(<i>Parkinsonia microphylla</i>) / <i>Aloysia wrightii</i> Shrubland	(same as map class)	7.22	0.03%	5	10
<i>Parkinsonia microphylla</i> / <i>Parthenium incanum</i> Shrubland	(same as map class)	105.37	0.39%	30	18
<i>Parkinsonia microphylla</i> / <i>Tiquilia canescens</i> (<i>Zinnia acerosa</i>) Shrubland	(same as map class)	109.49	0.41%	30	40

Table 4-3 (continued). Accuracy-assessment plot distribution within each map class at the Rincon Mountain District (n = 84).

Map class	Association	AA area (ha)	% of RMD	Plots	Plot radius (m)
<i>Pinus (arizonica - ponderosa)</i> Regenerating Woodland	(same as map class)	7.12	0.03%	5	18
<i>Pinus arizonica (Pinus strobiformis)</i> / <i>Muhlenbergia virescens</i> Forest	(same as map class)	48.91	0.18%	30	28
<i>Pinus arizonica</i> / <i>Quercus hypoleucoides</i> Woodland	(same as map class)	706.42	2.62%	30	18
<i>Pinus arizonica</i> / <i>Pteridium aquilinum</i> Forest	(same as map class)	9.11	0.03%	6	28
<i>Pinus arizonica</i> Forest	(same as map class)	115.81	0.43%	30	28
<i>Pinus discolor - Quercus emoryi</i> / <i>Muhlenbergia emersleyi</i> Open Woodland	(same as map class)	1,094.25	4.06%	30	40
<i>Pinus discolor</i> / <i>Arctostaphylos (pungens - pringlei)</i> Wooded Shrubland	(same as map class)	69.00	0.26%	25	28
<i>Pinus discolor</i> / <i>Quercus rugosa</i> Woodland	(same as map class)	482.66	1.79%	30	40
<i>Pinus discolor</i> / <i>Quercus toumeyii</i> Woodland	(same as map class)	499.25	1.85%	30	40
<i>Pinus discolor (Quercus arizonica - Juniperus deppeana - Quercus hypoleucoides)</i> Woodland	(same as map class)	1,530.53	5.68%	30	28
<i>Pinus discolor</i> / <i>Piptochaetium fimbriatum</i> Woodland	(same as map class)	13.75	0.05%	9	28
<i>Pinus leiophylla</i> / <i>Quercus hypoleucoides</i> Woodland	(same as map class)	35.12	0.13%	21	18
<i>Pinus ponderosa (Pinus strobiformis)</i> / <i>Muhlenbergia virescens</i> Woodland	(same as map class)	145.43	0.54%	30	40
<i>Pinus ponderosa</i> / <i>Quercus arizonica - Quercus emoryi</i> Woodland	(same as map class)	1.92	0.01%	5	18
<i>Pinus ponderosa</i> / <i>Quercus hypoleucoides</i> Woodland	(same as map class)	204.04	0.76%	30	28
<i>Pinus ponderosa - Pinus strobiformis</i> Forest	(same as map class)	188.07	0.70%	30	40
<i>Pinus ponderosa</i> / <i>Pteridium aquilinum</i> Forest	(same as map class)	4.34	0.02%	5	18
<i>Platanus wrightii - Fraxinus velutina</i> Intermittently Flooded Woodland	(same as map class)	22.60	0.08%	14	N/A
<i>Platanus wrightii</i> / <i>Quercus oblongifolia</i> Riparian Woodland	(same as map class)	20.94	0.08%	13	N/A
<i>Populus fremontii</i> / <i>Muhlenbergia rigens</i> Riparian Woodland	(same as map class)	3.29	0.01%	5	N/A
<i>Populus tremuloides</i> Forest	(same as map class)	9.60	0.04%	7	18
<i>Prosopis velutina - Senegalia greggii</i> Intermittently Flooded Shrubland	(same as map class)	34.08	0.13%	21	N/A
<i>Prosopis velutina - Senegalia greggii</i> Intermittently Flooded Woodland	(same as map class)	218.71	0.81%	30	18
<i>Prosopis velutina</i> / <i>Opuntia engelmannii (Senegalia greggii - Celtis ehrenbergiana)</i> Wooded Shrubland	(same as map class)	235.94	0.88%	30	28

Table 4-3 (continued). Accuracy-assessment plot distribution within each map class at the Rincon Mountain District (n = 84).

Map class	Association	AA area (ha)	% of RMD	Plots	Plot radius (m)
<i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> (Cottsie <i>gracilis</i>) Wooded Shrubland	(same as map class)	1,151.92	4.28%	30	40
<i>Prosopis velutina</i> Woodland	(same as map class)	122.18	0.45%	30	28
<i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> - <i>Ericameria laricifolia</i> / <i>Muhlenbergia porteri</i> Wooded Shrubland	(same as map class)	152.50	0.57%	29	40
<i>Prosopis velutina</i> / <i>Ziziphus obtusifolia</i> - <i>Condalia warnockii</i> Woodland	(same as map class)	13.11	0.05%	8	18
<i>Prosopis velutina</i> - <i>Chilopsis linearis</i> / <i>Ambrosia monogyra</i> Intermittently Flooded Woodland	(same as map class)	24.76	0.09%	15	28
<i>Prosopis velutina</i> / Annual Forb Woodland	(same as map class)	62.68	0.23%	25	28
<i>Pseudotsuga menziesii</i> - <i>Pinus arizonica</i> / (<i>Quercus gambelii</i>) Forest	(same as map class)	94.95	0.35%	30	28
<i>Pseudotsuga menziesii</i> - <i>Pinus arizonica</i> / <i>Quercus rugosa</i> Forest	(same as map class)	22.46	0.08%	14	18
<i>Pseudotsuga menziesii</i> - <i>Pinus ponderosa</i> / (<i>Quercus gambelii</i>) Forest	(same as map class)	30.93	0.11%	19	28
<i>Pseudotsuga menziesii</i> - <i>Pinus ponderosa</i> / <i>Quercus rugosa</i> Forest	(same as map class)	36.00	0.13%	22	18
<i>Pseudotsuga menziesii</i> / <i>Pinus strobiformis</i> Forest	(same as map class)	124.03	0.46%	30	28
<i>Pteridium aquilinum</i> Herbaceous	(same as map class)	50.58	0.19%	30	18
<i>Quercus arizonica</i> - <i>Quercus emoryi</i> (<i>Platanus wrightii</i>) Intermittently Flooded Woodland	(same as map class)	1.57	0.01%	5	8
<i>Quercus arizonica</i> - <i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> Woodland and Shrubland	(<i>Quercus arizonica</i> - <i>Quercus emoryi</i>) / <i>Arctostaphylos pungens</i> Shrubland, [<i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Woodland	361.88	1.34%	30	28
<i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna	(same as map class)	1,802.97	6.69%	30	28
<i>Quercus emoryi</i> / <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna	(same as map class)	1159.13	4.30%	30	40
<i>Quercus gambelii</i> / <i>Robinia neomexicana</i> / <i>Symphoricarpos oreophilus</i> Woodland	(same as map class)	21.98	0.08%	14	18
<i>Quercus gambelii</i> / <i>Symphoricarpos oreophilus</i> Shrubland	(same as map class)	37.27	0.14%	22	28
<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos</i> (<i>pungens</i> - <i>pringlei</i>) Shrubland	(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Arctostaphylos</i> (<i>pringlei</i> - <i>pungens</i>) Shrubland, (<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>) / <i>Arctostaphylos pringlei</i> Shrubland	1,229.34	4.56%	30	28

Table 4-3 (continued). Accuracy-assessment plot distribution within each map class at the Rincon Mountain District (n = 84).

Map class	Association	AA area (ha)	% of RMD	Plots	Plot radius (m)
<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos</i> (<i>pungens</i> - <i>pringlei</i>) Wooded Shrubland	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] / <i>Arctostaphylos</i> (<i>pringlei</i> - <i>pungens</i>) Woodland, [<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] / <i>Arctostaphylos pringlei</i> Woodland	245.52	0.91%	30	28
[<i>Quercus oblongifolia</i> - <i>Prosopis velutina</i> - <i>Vauquelinia californica</i>] / Mixed Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna	(same as map class)	842.48	3.13%	30	40
<i>Quercus oblongifolia</i> / <i>Bouteloua curtipendula</i> Scrub	(same as map class)	1,518.27	5.64%	30	40
<i>Quercus rugosa</i> - <i>Ceanothus integerrimus</i> Woodland	(same as map class)	3.35	0.01%	5	10
<i>Quercus turbinella</i> - <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> - <i>Agave schottii</i> Shrub Savanna	(same as map class)	33.38	0.12%	17	28
<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland	(same as map class)	71.37	0.26%	30	28
<i>Simmondsia chinensis</i> / <i>Encelia farinosa</i> Shrubland	(same as map class)	145.53	0.54%	30	40
<i>Simmondsia chinensis</i> / <i>Hilaria belangeri</i> Shrub Savanna	(same as map class)	1.31	0.00%	5	10

4.2 Tucson Mountain District

4.2.1 Field effort

The AA field component at the TMD was completed over the course of 50 field days in late summer and fall 2016. One crew of two assessors sampled all priority plots ($n = 435$) and an additional 11 from the oversample, for a total of 446 plots. As the oversample was an opportunistic and unbalanced distribution across the park and vegetation classes, these plots were not included in the AA analysis. Prior to data collection, assessors were thoroughly briefed on the assessment protocol and the vegetation associations assigned to each map class. The crew members had recently finished the field component of AA at Coronado National Memorial, so they were familiar with the methods and knowledgeable about Saguaro NP's diverse vegetation. The assessors were provided with keys to the vegetation associations (Appendix E), a detailed description of each association, and a field guide to aid in plant identification. Using a GPS unit, the assessors walked throughout each plot until they determined the dominant and/or diagnostic species present and estimated their canopy cover. A detailed protocol and example data sheet are shown in Appendix F.

Using the association key and description, the assessors determined which type provided the best match to the community present within the plot. If no association was applicable, then they labeled it "unplaced" and assigned it a new association name. All plots were assigned a level of fit for their assigned association: excellent, good, fair, or poor, designated as follows:

- **Excellent:** The composition of dominant species (taking into account listed variations within the type) and cover values within the plot match the type description.
- **Good:** The composition of dominant species (taking into account listed variations within the type) within the plot matches the type description, but cover values are outside the values or ranges listed in the type description.
- **Fair:** The composition of the minority of

dominant species (taking into account listed variations within the type) does not match the type description (e.g., a dominant species is not listed in the description or a listed dominant is not in the plot), but the plot is clearly best suited for the type.

- **Poor:** The composition of the majority of dominant species (taking into account listed variations within the type) does not match the type description (e.g., a dominant species is not listed in the description or a listed dominant is not in the plot). This indicates that the plot is similar enough to a description to assign a type, but there are major discrepancies between the two.

For plots with a fair or poor fit, assessors described the discrepancies between the plot and its assigned association and acquired four pictures of the plot (one in each cardinal direction) from a representative location. Within each plot, assessors collected a GPS point attributed with the plot ID, then assigned an association and level of fit. This served as a check on plot ID transcription errors and allowed for quicker analysis.

4.2.2 Results

Accuracy assessment compares field observations with the map-class assignments of a sampled area. Errors occur when the two don't agree. The results are meant to inform the end user of the map's accuracy. We assessed every discrepancy ($n = 97$) between assessors (field-based map checkers) and producers (mapmakers) to determine their validity. Based on AA datasheets, plot photos, and imagery, we determined that 16 plots were incorrectly assessed and instead agreed with the producers' designation. A number of these discrepancies appeared to be a result of the assessors' inadvertently recording the wrong type. Most determinations were based on the dominant species recorded within each plot. A breakdown of these decisions is provided in Appendix H.

In all, there were 81 discrepancies or mismatches between map classes and AA field classes spread across 14 map classes (Table 4-4). The one class without any discrepan-

cies was also the one associated with drainage/wash systems: (*Prosopis velutina*) / *Vachellia constricta* (*Larrea tridentata* - *Senegalia greggii*) Intermittently Flooded Shrubland. Values marked with (A) indicate agreement between the assessor and the map producer. Values not marked with (A) indicate disagreement. Column totals equal the total number of plots placed within that class by the assessors. Row totals are the number of plots assigned to that class by the producers. Overall accuracy calculated at this point was 77.4% (90% CI: 0.73, 0.82).

Based on review of the mismatches, we identified two pairs of associations consistently misidentified as one another (see Table 4-4):

- *Parkinsonia microphylla* / *Lycium berlandieri* (Mixed Shrub) Rocky Shrubland and *Larrea tridentata* [*Ephedra aspera* - *Parthenium incanum*] Shrubland; and
- *Opuntia engelmannii* (*Calliandra eriophylla* - *Agave schottii*) / *Selaginella arizonica* Shrubland and *Simmondsia chinensis* (Mixed Cacti) Shrubland.

The overlap within these pairs of associations was the result of two different issues, and was dealt with in two different ways (Table 4-5). The first pair had numerous mismatches because the restricted *Ephedra* association appeared as conspicuous inclusions within the widely distributed *Parkinsonia* / *Lycium* association. These were floristically distinct associations, but the *Ephedra* association was not mapped to a scale where it was consistently, spatially distinct from the *Lycium* association, so we merged them into a hybrid map class. In the second pair, the associations were not floristically distinct enough to be differentiated in the field. As a result, we merged them into one association, *Simmondsia chinensis* (Mixed Cacti) Shrubland. This resulted in 13 vegetated map classes for the TMD (Table 4-6), 12 of which had a one-to-one relationship of association to map class.

The AA samples were stratified by draft map classes. When two or more classes are merged, the class-specific accuracy for

that merged class cannot be estimated by the overall number correct divided by the total number. Because areas were sampled at different intensities, values must be weighted based on the original map-class areas. Therefore, simply plugging summed numbers into the AA spreadsheet would give invalid estimates for these pooled classes. Instead, the accuracies shown in Table 4-6 were computed in R, taking into account the stratification and weights, and bootstrapping to estimate confidence intervals (R code is available from tom_philippi@nps.gov).

Two of the 13 map classes failed to achieve accuracy at or above 60%, the minimum overall accuracy outlined in the NPS vegetation classification guidelines (Lea 2011):

- *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland
- *Simmondsia chinensis* / *Encelia farinosa* Shrubland

A low accuracy indicates that areas mapped as a particular association contain large areas that belong in a different association. The low accuracy for these associations is predominately the result of the indistinct boundaries typically associated with desert communities. The *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland Association sits on the toeslope and low backslopes in the transition zone between alluvial fan and hill/mountain slopes. Of the 13 mismatches, 5 were with an adjacent, alluvial-fan association and another 5 were with an adjacent backslope community. The *Simmondsia chinensis* / *Encelia farinosa* Shrubland Association was mismatched with the (*Parkinsonia microphylla* - *Fouquieria splendens*) / *Encelia farinosa* (*Cottisia gracilis*) Shrubland in 10 AA plots. These types are primarily differentiated by the dominance of *Simmondsia chinensis*. Across the southern slopes of Wasson Peak, there is a broad gradient between these associations, in which *S. chinensis* becomes less and less abundant from east to west. The majority of the mismatches occurred within this gradient.

Overall “lumped” accuracy was recalculated on the 13 classes at 78.4% (90% CI: 0.74, 0.83).

Table 4-4. Accuracy-assessment contingency table (error matrix) showing the number of plots placed within each map class by the producers (rows) and assessors (columns) at the Tucson Mountain District, Saguaro National Park.^A

#	Association/Map class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Producers' total
1	<i>(Parkinsonia microphylla) / Larrea tridentata</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland	27 (A)	2	–	–	–	–	–	1	–	–	–	–	–	–	–	30
2	<i>Carnegiea gigantea / Parkinsonia microphylla (Olneya tesota) / Ambrosia deltoidea</i> Shrubland	5	25 (A)	–	–	–	–	–	–	–	–	–	–	–	–	–	30
3	<i>(Prosopis velutina) / Vachellia constricta (Larrea tridentata - Senegalia greggii)</i> Intermittently Flooded Shrubland	–	–	30 (A)	–	–	–	–	–	–	–	–	–	–	–	–	30
4	<i>Parkinsonia microphylla / Opuntia spp.- Ambrosia salsola / Muhlenbergia porteri</i> Shrubland	7	–	–	23 (A)	–	–	–	–	–	–	–	–	–	–	–	30
5	<i>Simmondsia chinensis</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland	1	–	–	–	26 (A)	1	1	–	–	–	–	–	1	–	–	30
6	<i>Parkinsonia microphylla / Ambrosia deltoidea</i> Shrubland	1	5	–	–	1	17 (A)	5	–	–	–	–	–	–	–	–	30
7	<i>(Parkinsonia microphylla - Fouquieria splendens) / Encelia farinosa (Cottisia gracilis)</i> Shrubland	–	–	–	–	–	3	27 (A)	–	–	–	–	–	–	–	–	30
8	<i>(Carnegiea gigantea) / Parkinsonia microphylla / Vachellia constricta - Larrea tridentata / Krameria bicolor</i> Wooded Shrubland	–	–	–	–	3	1	–	26 (A)	–	–	–	–	–	–	–	30
9	<i>Cylindropuntia acanthocarpa - Vachellia constricta / Calliandra eriophylla - Cottisia gracilis</i> Shrubland	–	–	–	–	–	–	3	2	22 (A)	2	–	–	–	1	–	30
10	<i>Parkinsonia microphylla / Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland ^B	–	–	–	–	–	2	–	–	1	26 (A)	–	–	–	1	–	30
11	<i>Larrea tridentata [Ephedra aspera - Parthenium incanum]</i> Shrubland ^B	–	–	–	–	–	–	–	–	3	9	2 (A)	–	1	–	–	15
12	<i>Opuntia engelmannii (Calliandra eriophylla - Agave schottii) / Selaginella arizonica</i> Shrubland ^C	–	–	–	–	–	–	2	–	2	–	–	10 (A)	15	–	1	30
13	<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland ^C	–	–	–	–	3	–	–	–	–	–	–	–	26 (A)	1	–	30
14	<i>Simmondsia chinensis / Encelia farinosa</i> Shrubland	–	–	–	–	3	–	10	–	1	–	–	–	1	15 (A)	–	30
15	<i>Yucca baccata - Dasylirion wheeleri / Muhlenbergia porteri</i> Shrubland	–	–	–	–	–	–	–	–	6	–	–	–	5	–	19 (A)	30
Assessors' total		41	32	30	23	36	24	48	29	35	38	2	10	49	18	20	435

^AIn table, (A) = agreement. Cells containing numbers without (A) indicate disagreement.

^B, ^CPair of associations subsequently merged into a map class.

Table 4-5. Map classes created from merged associations post-accuracy assessment, Tucson Mountain District.

Map class	Associations
<i>Parkinsonia microphylla</i> / <i>Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland	<i>Larrea tridentata</i> [<i>Ephedra aspera</i> - <i>Parthenium incanum</i>] Shrubland <i>Parkinsonia microphylla</i> / <i>Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland
<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland	<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland <i>Opuntia engelmannii</i> - (<i>Calliandra eriophylla</i> - <i>Agave schottii</i>) / <i>Selaginella arizonica</i> Shrubland

Table 4-6. Calculated per-class accuracies and confidence intervals for the 13 final map classes of the Tucson Mountain District.

#	Map class	# of sites		Estimated accuracy	90% CI		Area (ha)
		Correct	Total		Lower	Upper	
1	(<i>Parkinsonia microphylla</i>) / <i>Larrea tridentata</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland	27	30	90.0%	77.4%	95.9%	1,222.77
2	<i>Carnegiea gigantea</i> / <i>Parkinsonia microphylla</i> (<i>Olneya tesota</i>) / <i>Ambrosia deltoidea</i> Shrubland	25	30	83.3%	69.5%	91.6%	2,739.76
3	(<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland	30	30	100.0%	91.7%	100.0%	263.79
4	<i>Parkinsonia microphylla</i> / <i>Opuntia</i> spp. - <i>Ambrosia salsola</i> / <i>Muhlenbergia porteri</i> Shrubland	23	30	76.7%	62.1%	86.8%	327.87
5	<i>Simmondsia chinensis</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland	26	30	86.7%	73.4%	93.9%	936.23
6	<i>Parkinsonia microphylla</i> / <i>Ambrosia deltoidea</i> Shrubland	17	30	56.7%	41.9%	70.4%	492.64
7	(<i>Parkinsonia microphylla</i> - <i>Prosopis velutina</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland	27	30	90.0%	77.4%	95.9%	833.80
8	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Larrea tridentata</i> - <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i>) / <i>Krameria bicolor</i> Wooded Shrubland	26	30	86.7%	73.4%	93.9%	55.15
9	<i>Cylindropuntia acanthocarpa</i> - <i>Vachellia constricta</i> / <i>Calliandra eriophylla</i> - <i>Cottisia gracilis</i> Shrubland	22	30	73.3%	58.5%	84.3%	769.08
10	<i>Parkinsonia microphylla</i> / <i>Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland	37	45	82.0%	72.8%	91.0%	418.10
11	<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland Association	51	60	86.1%	76.8%	94.4%	141.90
12	<i>Simmondsia chinensis</i> / <i>Encelia farinosa</i> Shrubland	15	30	50.0%	35.6%	64.4%	826.42
13	<i>Yucca baccata</i> - <i>Dasyllirion wheeleri</i> (<i>Quercus turbinella</i>) / <i>Muhlenbergia porteri</i> Shrubland	19	30	63.3%	48.3%	76.1%	972.70

4.3 Rincon Mountain District

4.3.1 Field effort

The AA field component at the RMD was completed over the course of 86 field days spanning summer and fall 2018. Two-to-three crews of two assessors sampled all but three priority plots ($n = 1,933$). Assessors skipped those three plots due to safety concerns. We did not draw from the oversample to replace these plots due to the time required to reach three scattered plots across the range. Prior to data collection, assessors were thoroughly briefed on the assessment protocol and the vegetation associations assigned to each map class. The lead crew members had recently finished the field component of AA at the TMD, and were knowledgeable of the park's diverse vegetation. Assessors followed a nearly identical protocol to the TMD AA and were provided with similar resources, including a key to vegetation associations (Appendix E) and full descriptions for each association. For this district, all AA plot data were digitally recorded using custom Survey123 (ESRI 2019) forms running on ruggedized smartphones (Cedar CT5s). A detailed field protocol and example digital field form can be found in Appendix G.

In addition to the standard AA protocol used at both districts, the field crew recorded data for a list of 11 exotic species known or likely to occur in the RMD (see Section 4.3.2.2 for list). These species were identified as high-priority species by the park's exotic-plant program manager. Species observations were documented as presence/absence within each AA plot. No estimates of cover or abundance were recorded.

4.3.2 Results

4.3.2.1 Vegetation map accuracy

At the RMD, we assessed every discrepancy ($n = 598$) between assessors (field-based map checkers) and producers (mapmakers) to determine their validity. Based on AA datasheets, plot photos, and imagery, we determined that 165 plots were incorrectly assessed and instead agreed with the producers' designation. A number of these discrepancies appeared to be a result of the

assessors' inadvertently recording the wrong type. Most determinations were based on the dominant species recorded within each plot, photos, and imagery (PAG 2011). A breakdown of these decisions is found in Appendix H.

In all, there were 433 discrepancies or mismatches between map classes and AA field classes spread across 75 of the 84 map classes evaluated (Table 4-7). A total of nine classes contained only matches. Most of these classes are rather restricted, typically covering less than 10 hectares (25 ac). Values marked with (A) indicate agreement between the assessor and the map producer. Values not marked with (A) indicate disagreement. Column totals equal the total number of plots placed within that class by the assessors. Row totals are the number of plots assigned to that class by the producers. Overall accuracy calculated at this point was 66.8% (90% CI: 0.64, 0.70).

Based on a review of the mismatches, we identified 17 groups of associations ($n = 37$) consistently misidentified as one another. Prior to the AA, we had identified many of these as potentially problematic map classes, because they occurred adjacent to one another and had similar species composition. We chose not to merge them at that time, and instead see if the AA results confirmed their high similarity. We dealt with these groups in two ways, depending on the cause of the mismatches. In most cases (15 groups), associations were floristically distinct from one another but distributed within and adjacent to another class to a degree that our map was unable to capture (Table 4-8). In these cases, we merged these associations into a hybrid map class in which each association is described separately but represented in the map as a single class. In two cases, we determined that mismatching associations were too floristically similar for crews to consistently differentiate in the field (Table 4-8). We decided to describe these as a single association, represented in the map by a single class.

In the final map, we converted 37 associations into 15 hybrid map classes and 2 merged map classes, resulting in a final total of 68 vegetated map classes (Table 4-9).

Table 4-7. Accuracy-assessment contingency table (error matrix) showing the number of plots placed within each map class by the producers (rows) and assessors (columns) at the Rincon Mountain District, Saguaro National Park.^a

[illegible]

Table 4-8. Map classes created from merged associations post-accuracy assessment, Rincon Mountain District.

Hybrid / Merged class	Associations
(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland, (<i>Parkinsonia microphylla</i>) / <i>Larrea tridentata</i> Shrubland
<i>Parkinsonia microphylla</i> / <i>Parthenium incanum</i> (<i>Aloysia wrightii</i>) Shrubland	<i>Parkinsonia microphylla</i> / <i>Parthenium incanum</i> Shrubland, (<i>Parkinsonia microphylla</i>) / <i>Aloysia wrightii</i> Shrubland
(<i>Parkinsonia microphylla</i> - <i>Prosopis velutina</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland	(<i>Parkinsonia microphylla</i> - <i>Fouquieria splendens</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland, <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Wooded Shrubland
<i>Prosopis velutina</i> / Mixed Shrub Wooded Shrubland	<i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> (<i>Senegalia greggii</i> - <i>Celtis ehrenbergiana</i>) Wooded Shrubland, <i>Prosopis velutina</i> Woodland
<i>Prosopis velutina</i> (<i>Senegalia greggii</i>) Intermittently Flooded Shrubland and Woodland	<i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Shrubland, <i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Woodland
<i>Prosopis velutina</i> (<i>Chilopsis linearis</i>) / Annual Forb Floodplain	<i>Prosopis velutina</i> - <i>Chilopsis linearis</i> / <i>Ambrosia monogyra</i> Intermittently Flooded Woodland, <i>Prosopis velutina</i> / Annual Forb Woodland
<i>Quercus oblongifolia</i> / Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna	[<i>Quercus oblongifolia</i> - <i>Prosopis velutina</i> - <i>Vauquelinia californica</i>] / Mixed Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna, <i>Quercus oblongifolia</i> / <i>Bouteloua curtipendula</i> Scrub
<i>Quercus emoryi</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna	<i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna, <i>Quercus emoryi</i> / <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna
<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos (pungens - pringlei)</i> Shrubland and Wooded Shrubland	(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Arctostaphylos (pringlei - pungens)</i> Shrubland, [<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] / <i>Arctostaphylos (pringlei - pungens)</i> Woodland
<i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Open Woodland	<i>Pinus discolor</i> - <i>Quercus emoryi</i> / <i>Muhlenbergia emersleyi</i> Open Woodland, [<i>Pinus discolor</i> - <i>Quercus arizonica</i> - <i>Juniperus deppeana</i>] / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrubland
<i>Pinus discolor</i> Woodland	<i>Pinus discolor</i> (<i>Quercus arizonica</i> - <i>Juniperus deppeana</i> - <i>Quercus hypoleucoides</i>) Woodland, [<i>Pinus discolor</i> - <i>Juniperus deppeana</i> - <i>Quercus</i> sp.] / <i>Piptochaetium fimbriatum</i> Woodland
[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i>] Shrubland	[<i>Quercus chrysolepis</i> - <i>Quercus rugosa</i> - <i>Holodiscus dumosa</i>] Shrubland, [<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Shrubland
[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland and Intermittently Flooded Woodland	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland, <i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> / <i>Garrya wrightii</i> Intermittently Flooded Woodland

Table 4-8 (continued). Map classes created from merged associations post-accuracy assessment, Rincon Mountain District.

Hybrid / Merged class	Associations
[<i>Quercus rugosa</i> - <i>Quercus hypoleuroides</i>] Woodland and Intermittently Flooded Woodland	[<i>Quercus rugosa</i> - <i>Quercus hypoleuroides</i>] Woodland, [<i>Quercus hypoleuroides</i> - <i>Quercus rugosa</i>] Intermittently Flooded Woodland
<i>Pinus ponderosa</i> Forest	<i>Pinus ponderosa</i> - <i>Pinus strobiformis</i> Forest, <i>Pinus ponderosa</i> / <i>Pteridium aquilinum</i> Forest
<i>Pinus arizonica</i> Forest	<i>Pinus arizonica</i> / <i>Pteridium aquilinum</i> Forest, <i>Pinus arizonica</i> Forest
<i>Pseudotsuga menziesii</i> - <i>Pinus</i> (<i>arizonica</i> - <i>ponderosa</i>) / (<i>Quercus gambelii</i>) Forest	<i>Pseudotsuga menziesii</i> - <i>Pinus arizonica</i> / <i>Quercus hypoleuroides</i> - <i>Quercus rugosa</i> Forest, <i>Pseudotsuga menziesii</i> - <i>Pinus ponderosa</i> / <i>Quercus hypoleuroides</i> - <i>Quercus rugosa</i> Forest

Table 4-9. Calculated per-class accuracies and confidence intervals for the 68 final map classes of the Rincon Mountain District.

#	Map class	# of sites		Estimated accuracy	90% CI		Area (ha)
		Correct	Total		Lower	Upper	
1	<i>(Carnegiea gigantea) / Parkinsonia microphylla / Opuntia engelmannii (Vachellia constricta - Larrea tridentata)</i> Wooded Shrubland	38	48	86.1%	0.76	0.96	987.56
2	<i>(Prosopis velutina) / Larrea tridentata</i> Shrubland	22	30	73.3%	0.59	0.84	262.41
3	<i>(Prosopis velutina) / Vachellia constricta (Larrea tridentata - Senegalia greggii)</i> Intermittently Flooded Shrubland	27	31	87.1%	0.74	0.94	152.20
4	<i>Parkinsonia microphylla / Opuntia engelmannii / Encelia farinosa</i> Shrubland	25	30	83.3%	0.70	0.92	484.91
5	<i>Parkinsonia microphylla / Encelia farinosa - Hibiscus denudatus</i> Shrubland	21	30	70.0%	0.55	0.82	269.94
6	<i>Parkinsonia microphylla / Parthenium incanum (Aloysia wrightii)</i> Shrubland	32	35	90.6%	0.81	0.97	112.60
7	<i>Parkinsonia microphylla / Tiqulia canescens (Zinnia acerosa)</i> Shrubland	22	30	73.3%	0.59	0.84	109.49
8	<i>(Prosopis velutina) / Vachellia constricta - Opuntia engelmannii</i> Shrubland	30	30	100.0%	0.92	1.00	270.61
9	<i>Parkinsonia microphylla / Ambrosia deltoidea</i> Shrubland	5	5	100.0%	0.65	1.00	3.49
10	<i>(Parkinsonia microphylla) / Cylindropuntia bigelovii / Encelia farinosa</i> Shrubland	24	29	82.8%	0.69	0.91	240.73
11	<i>(Parkinsonia microphylla - Prosopis velutina) / Encelia farinosa (Cottisia gracilis)</i> Shrubland	40	61	65.3%	0.55	0.76	3,228.63
12	<i>Simmondsia chinensis / Hilaria belangeri</i> Shrub	5	5	100.0%	0.65	1.00	1.31
13	<i>Simmondsia chinensis / Encelia farinosa</i> Shrubland	27	30	90.0%	0.77	0.96	145.53
14	<i>(Fouquieria splendens) / Prosopis velutina / Opuntia engelmannii / Cottisia gracilis</i> Shrubland	18	30	60.0%	0.45	0.73	1,100.36
15	<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland	21	30	70.0%	0.55	0.82	71.37
16	<i>Prosopis velutina / Mixed Shrub</i> Wooded Shrubland	53	62	87.0%	0.80	0.93	358.12
17	<i>Prosopis velutina / Opuntia engelmannii - Ericameria laricifolia / Muhlenbergia porteri</i> Wooded Shrubland	26	29	89.7%	0.77	0.96	152.50
18	<i>(Prosopis velutina) / Aloysia wrightii</i> Shrubland	15	30	50.0%	0.36	0.64	175.08
19	<i>Fouquieria splendens - Prosopis velutina / Dodonaea viscosa</i> Shrubland	26	30	86.7%	0.73	0.94	147.23
20	<i>Prosopis velutina (Senegalia greggii)</i> Intermittently Flooded Shrubland and Woodland	41	51	75.6%	0.64	0.87	252.79
21	<i>Prosopis velutina (Chilopsis linearis) / Annual</i> Forb Floodplain	35	40	85.7%	0.77	0.94	87.44
22	<i>Prosopis velutina / Ziziphus obtusifolia - Condalia warnockii</i> Woodland	7	8	87.5%	0.59	0.97	13.11
23	<i>Platanus wrightii - Fraxinus velutina</i> Intermittently Flooded Woodland	11	14	78.6%	0.57	0.91	22.60

Table 4-9 (continued). Calculated per-class accuracies and confidence intervals for the 68 final map classes of the Rincon Mountain District.

#	Map class	# of sites		Estimated accuracy	90% CI		Area (ha)
		Correct	Total		Lower	Upper	
24	<i>Platanus wrightii</i> / <i>Quercus oblongifolia</i> Riparian Woodland	9	12	75.0%	0.51	0.90	20.94
25	<i>Populus fremontii</i> / <i>Muhlenbergia rigens</i> Riparian Woodland	4	4	100.0%	0.60	1.00	3.29
26	<i>Alnus oblongifolia</i> / <i>Acer negundo</i> / <i>Rosa woodsii</i> Intermittently Flooded Woodland	3	4	75.0%	0.36	0.94	2.38
27	<i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna	23	30	76.7%	0.62	0.87	946.37
28	<i>Fouquieria splendens</i> / (<i>Opuntia engelmannii</i>) / <i>Selaginella rupincola</i> Sparse Rock Outcrop	28	29	96.6%	0.86	0.99	132.98
29	<i>Nolina microcarpa</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna	12	29	41.4%	0.28	0.57	168.26
30	<i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna	25	30	83.3%	0.70	0.92	653.88
31	(<i>Quercus emoryi</i> - <i>Quercus oblongifolia</i>) / <i>Eragrostis lehmanniana</i> Herbaceous	12	15	80.0%	0.59	0.92	30.16
32	<i>Quercus oblongifolia</i> / Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna	43	62	71.6%	0.62	0.81	2,360.75
33	<i>Quercus emoryi</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna	51	61	83.0%	0.75	0.91	2,962.10
34	<i>Quercus turbinella</i> - <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> - <i>Agave schottii</i> Shrub Savanna	17	17	100.0%	0.86	1.00	33.38
35	<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos (pungens - pringlei)</i> Shrubland and Wooded Shrubland	45	58	85.6%	0.77	0.93	1,474.86
36	(<i>Quercus arizonica</i> - <i>Quercus emoryi</i>) / <i>Arctostaphylos pungens</i> Shrubland	24	30	80.0%	0.66	0.89	361.88
37	(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Ceanothus fendleri</i> Wooded Shrubland	7	7	100.0%	0.72	1.00	10.32
38	<i>Quercus rugosa</i> - <i>Ceanothus integerrimus</i> Woodland	5	5	100.0%	0.65	1.00	3.35
39	<i>Mimosa aculeaticarpa</i> Shrubland	8	9	88.9%	0.62	0.97	14.21
40	<i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland	54	61	89.9%	0.80	0.97	2,447.01
41	<i>Pinus discolor</i> Woodland	29	39	67.0%	0.54	0.80	1,544.28
42	<i>Pinus discolor</i> / <i>Quercus rugosa</i> Woodland	26	30	86.7%	0.73	0.94	482.66
43	<i>Pinus discolor</i> / <i>Quercus toumeyii</i> Woodland	23	30	76.7%	0.62	0.87	499.25
44	<i>Cupressus arizonica</i> / <i>Quercus hypoleucoides</i> Forest	25	30	83.3%	0.70	0.92	114.57
45	<i>Pinus discolor</i> / <i>Arctostaphylos (pungens - pringlei)</i> Wooded Shrubland	12	25	48.0%	0.33	0.64	1,094.25
46	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Shrubland	20	29	69.0%	0.54	0.81	322.07

Table 4-9 (continued). Calculated per-class accuracies and confidence intervals for the 68 final map classes of the Rincon Mountain District.

#	Map class	# of sites		Estimated accuracy	90% CI		Area (ha)
		Correct	Total		Lower	Upper	
47	[<i>Quercus rugosa</i> - <i>Quercus hypoleucoides</i>] Woodland and Intermittently Flooded Woodland	26	30	86.7%	0.73	0.94	179.10
48	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Shrubland	21	23	91.3%	0.77	0.97	36.88
49	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland and Intermittently Flooded Woodland	41	61	76.2%	0.67	0.85	410.34
50	<i>Quercus arizonica</i> - <i>Quercus emoryi</i> (<i>Platanus wrightii</i>) Intermittently Flooded Woodland	3	5	60.0%	0.27	0.86	1.57
51	<i>Pinus arizonica</i> / <i>Quercus hypoleucoides</i> Woodland	24	30	80.0%	0.66	0.89	706.42
52	<i>Pinus (arizonica - ponderosa)</i> Regenerating Woodland	6	6	100.0%	0.69	1.00	7.12
53	<i>Pinus ponderosa</i> / <i>Quercus hypoleucoides</i> Woodland	25	30	83.3%	0.70	0.92	204.04
54	<i>Pinus leiophylla</i> / <i>Quercus hypoleucoides</i> Woodland	14	20	70.0%	0.52	0.84	35.12
55	<i>Pinus ponderosa</i> / <i>Quercus arizonica</i> - <i>Quercus emoryi</i> Woodland	5	5	100.0%	0.65	1.00	1.92
56	<i>Pseudotsuga menziesii</i> / <i>Quercus rugosa</i> Forest	26	35	74.5%	0.63	0.86	58.47
57	(<i>Symphoricarpos oreophilus</i>) / <i>Ageratina herbacea</i> Shrubland	13	15	86.7%	0.67	0.95	24.11
58	<i>Pteridium aquilinum</i> Herbaceous	20	30	66.7%	0.52	0.79	50.58
59	<i>Muhlenbergia virescens</i> - <i>Pteridium aquilinum</i> - <i>Ceanothus fendleri</i> Herbaceous	24	30	80.0%	0.66	0.89	55.64
60	<i>Quercus gambelii</i> / <i>Symphoricarpos oreophilus</i> Shrubland	19	22	86.4%	0.70	0.94	37.27
61	<i>Quercus gambelii</i> / <i>Robinia neomexicana</i> / <i>Symphoricarpos oreophilus</i> Woodland	12	14	85.7%	0.65	0.95	21.98
62	<i>Populus tremuloides</i> Forest	4	5	80.0%	0.44	0.95	9.60
63	<i>Pseudotsuga menziesii</i> / <i>Pinus strobiformis</i> Forest	23	30	76.7%	0.62	0.87	124.03
64	<i>Pseudotsuga menziesii</i> - <i>Pinus (arizonica - ponderosa)</i> / (<i>Quercus gambelii</i>) Forest	34	49	67.2%	0.56	0.79	125.87
65	<i>Pinus ponderosa</i> (<i>Pinus strobiformis</i>) / <i>Muhlenbergia virescens</i> Woodland	25	30	83.3%	0.70	0.92	145.43
66	<i>Pinus ponderosa</i> Forest	31	35	87.0%	0.77	0.97	192.41
67	<i>Pinus arizonica</i> (<i>Pinus strobiformis</i>) / <i>Muhlenbergia virescens</i> Forest	19	30	63.3%	0.48	0.76	48.91
68	<i>Pinus arizonica</i> Forest	30	40	72.7%	0.62	0.84	124.92

Fifty-one map classes contained one association, and 17 contained a minimum of two associations. The remaining three classes were assigned to roads, developed areas, and sparsely vegetated bedrock.

The AA samples were stratified by draft map classes. When two or more classes are merged, the class-specific accuracy for that merged class cannot be estimated by dividing the total number of plots in agreement by the total number of plots sampled in each merged class. Because areas were sampled at different intensities, values must be weighted based on the original map-class areas. Therefore, simply plugging summed numbers into the AA spreadsheet would give invalid estimates for these pooled classes. Instead, the accuracies shown in Table 4-9 were computed in R, taking into account the stratification and weights, and bootstrapping to estimate confidence intervals (R code is available from tom_philippi@nps.gov).

Three of the 68 map classes failed to achieve accuracy at or above 60%:

- *Pinus discolor* / *Arctostaphylos* (*pungens* - *pringlei*) Wooded Shrubland
- *Prosopis velutina* / *Aloysia wrightii* Shrubland
- *Nolina microcarpa* / Perennial Grass - *Agave schottii* Shrub Savanna

The *Pinus discolor* / *Arctostaphylos* (*pungens* - *pringlei*) Wooded Shrubland spans the Madrean Pinyon - Juniper Woodland Group and the Western Madrean Chaparral Group. Of the 13 mismatches, 6 were with the similar *Pinus discolor* Woodland and 3 were with *Pinus discolor* / *Muhlenbergia emersleyi* Woodland. The *Prosopis velutina* / *Aloysia wrightii* Shrubland was consistently

mixed with two similar, sheltered *P. velutina* communities: (*Fouquieria splendens*) / *Prosopis velutina* / *Opuntia engelmannii* / *Cottisia gracilis* Shrubland and *Fouquieria splendens* - *Prosopis velutina* / *Dodonaea viscosa* Shrubland. The *Nolina microcarpa* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna was consistently mixed with other grass-dominated shrub and tree savannas. Overall “lumped” accuracy, recalculated on the 68 classes, was 76.3% (90% CI: 0.74, 0.79).

4.3.2.2 Exotic species

Field crews observed targeted exotic plants in 156 (8.0%) of the 1,933 total plots, including seven of the eleven targeted species (Table 4-10, Figure 4-4). Buffelgrass (*Cenchrus ciliaris*) was the most commonly observed exotic, occurring in 85 (54%) of the 156 plots with documented exotics. It was also noted as a dominant field species in 14 plots. Rose natal grass (*Melinis repens*) was the second most-common exotic, found in 64 (41%) of the 156 plots with documented exotics. The untargeted but invasive exotic Lehmann lovegrass (*Eragrostis lehmanniana*) was found to be a field-dominant in 43 plots; its range has little restriction across the park.

Buffelgrass (*C. ciliaris*) observations were concentrated on the slopes below and south of Tanque Verde Ridge, and near the Douglas Springs Trail, up to the Bridal Wreath Falls area. Rose natal grass (*M. repens*) was similarly dispersed but also frequently observed on the lower backslopes near the Rincon Creek Trail and in the eastern portion of the park, near Turkey Creek trailhead. Graminoid exotics were typically found within semi-desert grassland, thorn-scrub, or desert-scrub formations.

Table 4-10. Number of plots where exotic species targeted during accuracy assessment were documented at the Rincon Mountain District.

Family	Scientific name	Common name	Growth habit	Duration	Plots	Elevation (m)
Asteraceae	<i>Oncosiphon piluliferum</i>	stinknet	Forb/Herb	Annual	0	–
Brassicaceae	<i>Brassica tournefortii</i>	Asian mustard	Forb/Herb	Annual	1	1,048
Brassicaceae	<i>Matthiola parviflora</i>	smallflower stock	Forb/Herb	Annual	1	959
Poaceae	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	0	–
Poaceae	<i>Cenchrus ciliaris</i>	buffelgrass	Graminoid	Perennial	85	838–1,697
Poaceae	<i>Centaurea melitensis</i>	Maltese star thistle	Forb/Herb	Annual	1	965
Poaceae	<i>Enneapogon cenchroides</i>	soft feather pappusgrass	Graminoid	Perennial	23	827–1,780
Poaceae	<i>Eragrostis echinochloidea</i>	tick grass	Graminoid	Perennial	11	869–1,571
Poaceae	<i>Melinis repens</i>	rose natal grass	Graminoid	Annual	64	847–1,861
Poaceae	<i>Setaria adhaerens</i>	bur bristlegrass	Graminoid	Annual	0	–
Ulmaceae	<i>Ulmus pumila</i>	Siberian elm	Tree	Perennial	0	–

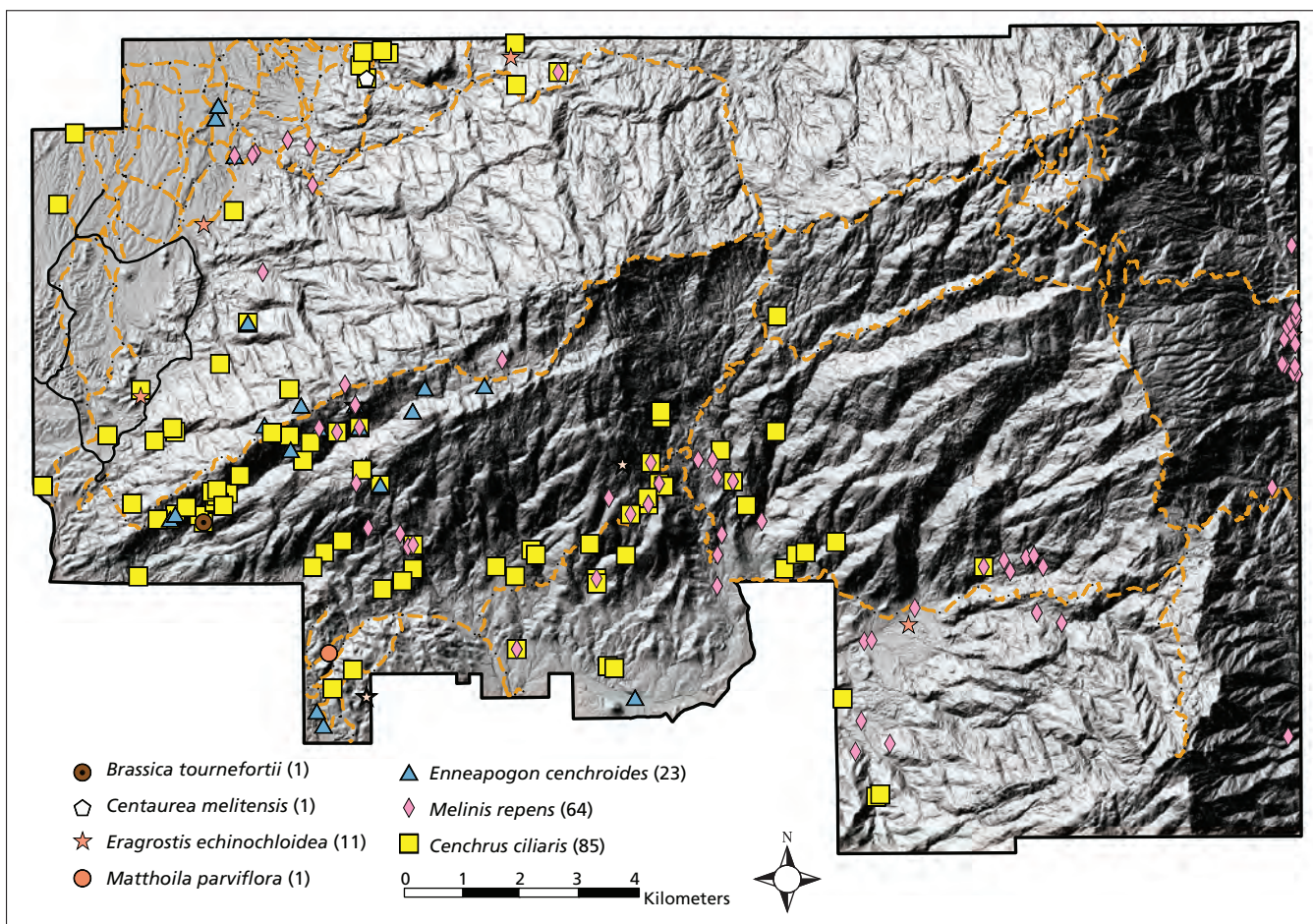


Figure 4-4. Exotic species documented during accuracy-assessment surveys at the Rincon Mountain District of Saguaro National Park, 2018.

5 Final Map Products

5.1 Final classification

In the final map, there are 97 associations placed in 79 map classes across both districts of the park. There are 14 associations found at the TMD and 88 at the RMD, with 5 occurring in both districts. Three map classes represent non-classified land types, including developed (housing, visitor center, facilities), roads (only paved roads), and sparsely vegetated expanses of exposed bedrock. Of the 76 vegetated map classes, 58 contain only one association, while 18 contain 2–4 associations each (Table 5-1). Associations are ordered by elevation, from lowest to highest.

Fifteen of the 97 final associations had accepted corollaries within the NVC at the time of report preparation. This number is expected to increase in future years as the NVC is refined and the inclusion of more data leads to new type descriptions. There were many similar associations documented within the NVC, but they were either not great fits for our associations or lacked detailed descriptions, making comparison impossible. The NVC “Elcodes” or SODN placeholder codes (for currently un-accepted types) are shown in Table 5-1 and includ-

ed in the full community descriptions found in Volume III of the [Saguaro National Park Vegetation Mapping Inventory](#). Associations followed by a (P) indicate they are not in the NVC but will be “Proposed” for inclusion.

5.2 Map graphics

The full TMD map graphic is shown in Figure 5-1. Due to its intense level of detail, the full RMD map cannot be adequately displayed within this report format. Instead, we have provided several close-up map details of well-known areas across the park (Figures 5-2 to 5-5). The full map and full geospatial dataset can be downloaded from the park’s vegetation inventory [website](#).

5.3 Association summaries and type descriptions

Due to space restrictions, two-page summaries of the 97 associations identified and mapped at Saguaro National Park during this project can be found in [Volume II](#) of this report. These summaries are abridged versions of the full association descriptions, found in [Volume III](#).

Table 5-1. Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
1	<i>Parkinsonia microphylla</i> / <i>Opuntia</i> spp. - <i>Ambrosia salsola</i> / <i>Muhlenbergia porteri</i> Shrubland (P)	(same as association)	–	NPSSODN111	TMD	3	–	1	–	327.9	–
2	(<i>Quercus emoryi</i> - <i>Quercus oblongifolia</i>) / <i>Eragrostis lehmanniana</i> Herbaceous (P)	(same as association)	–	NPSSODN177	RMD	–	1	–	12	–	30.2
3	<i>Prosopis velutina</i> Woodland (P)	<i>Prosopis velutina</i> / Mixed Shrub Wooded Shrubland	–	NPSSODN136	RMD	–	11	–	37	–	357.9
4	<i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> - <i>Ericameria laricifolia</i> / <i>Muhlenbergia porteri</i> Wooded Shrubland (P)	(same as association)	–	NPSSODN137	RMD	–	8	–	1	–	152.5
5	<i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> (<i>Senegalia greggii</i> - <i>Celtis ehrenbergiana</i>) Wooded Shrubland (P)	<i>Prosopis velutina</i> / Mixed Shrub Wooded Shrubland	–	NPSSODN135	RMD	–	13	–	37	–	357.9
6	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Larrea tridentata</i> - <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i>) / <i>Krameria bicolor</i> Wooded Shrubland (P)	(same as association)	–	NPSSODN115	TMD	3	–	6	–	55.1	–
7	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) / <i>Ambrosia deltoidea</i> Wooded Shrubland (P)	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland	–	NPSSODN099	RMD	–	3	–	42	–	983.3
8	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland (P)	(<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland	–	NPSSODN095	RMD	–	12	–	42	–	983.3

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
9	<i>(Fouquieria splendens) / Prosopis velutina / Opuntia engelmannii / Cottsia gracilis</i> Shrubland (P)	(same as association)	–	NPSSODN133	RMD	–	24	–	95	–	1,100.4
10	<i>(Parkinsonia microphylla - Fouquieria splendens) / Encelia farinosa (Cottsia gracilis)</i> Shrubland (P)	<i>(Parkinsonia microphylla - Prosopis velutina) / Encelia farinosa (Cottsia gracilis)</i> Shrubland	–	NPSSODN129	Both	23	8	83	91	833.1	3,224.8
11	<i>(Parkinsonia microphylla) / Aloysia wrightii</i> Shrubland (P)	<i>Parkinsonia microphylla / Parthenium incanum (Aloysia wrightii)</i> Shrubland	–	NPSSODN092	RMD	–	5	–	19	–	112.6
12	<i>(Parkinsonia microphylla) / Cyllindropuntia bigelovii / Encelia farinosa</i> Shrubland (P)	(same as association)	–	NPSSODN128	RMD	–	7	–	16	–	240.7
13	<i>(Parkinsonia microphylla) / Larrea tridentata - Mixed Cacti / Ambrosia deltoidea</i> Shrubland (P)	(same as association)	–	NPSSODN093	TMD	30	–	32	–	1,221.7	–
14	<i>(Parkinsonia microphylla) / Larrea tridentata</i> Shrubland (P)	<i>(Carnegiea gigantea) / Parkinsonia microphylla / Opuntia engelmannii (Vachellia constricta - Larrea tridentata)</i> Wooded Shrubland	–	NPSSODN101	RMD	–	3	–	42	–	983.3
15	<i>(Prosopis velutina) / Aloysia wrightii</i> Shrubland (P)	(same as association)	–	NPSSODN138	RMD	–	7	–	29	–	175.1
16	<i>(Prosopis velutina) / Larrea tridentata</i> Shrubland (P)	(same as association)	–	NPSSODN088	RMD	–	6	–	24	–	261.9
17	<i>(Prosopis velutina) / Vachellia constricta - Opuntia engelmannii</i> Shrubland (P)	(same as association)	–	NPSSODN098	RMD	–	7	–	11	–	270.6
18	<i>[Ephedra sp. - Parthenium incanum - Larrea tridentata]</i> Shrubland (P)	<i>Parkinsonia microphylla / Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland	–	NPSSODN175	TMD	2	–	16	–	295.1	–

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
19	<i>Carnegiea gigantea</i> / <i>Parkinsonia microphylla</i> (<i>Olnya tesota</i>) / <i>Ambrosia deltoidea</i> Shrubland (P)	(same as association)	–	NPSSODN094	TMD	40	–	82	–	2,728.1	–
20	<i>Cylindropuntia acanthocarpa</i> - <i>Vachellia constricta</i> / <i>Calliandra eriophylla</i> - <i>Cottisia gracilis</i> Shrubland (P)	(same as association)	–	NPSSODN116	TMD	17	–	62	–	762.5	–
21	<i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna (P)	(same as association)	–	NPSSODN127	RMD	–	14	–	8	–	653.9
22	<i>Fouquieria splendens</i> - <i>Prosopis velutina</i> / <i>Dodonaea viscosa</i> Shrubland (P)	(same as association)	–	NPSSODN139	RMD	–	4	–	9	–	147.2
23	<i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna (P)	(same as association)	–	NPSSODN124	RMD	–	19	–	24	–	946.4
24	<i>Fouquieria splendens</i> / (<i>Opuntia engelmannii</i>) / <i>Selaginella rupincola</i> Sparse Rock Outcrop (P)	(same as association)	–	NPSSODN125	RMD	–	4	–	56	–	133.0
25	<i>Nolina microcarpa</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna (P)	(same as association)	–	NPSSODN126	RMD	–	3	–	9	–	168.3
26	<i>Parkinsonia microphylla</i> / <i>Ambrosia deltoidea</i> Shrubland (P)	(same as association)	–	NPSSODN100	Both	13	1	36	1	493.1	3.5
27	<i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> - <i>Hibiscus denudatus</i> Shrubland (P)	<i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> (<i>Hibiscus denudatus</i> - <i>Zinnia acerosa</i>) Shrubland	–	NPSSODN090	RMD	–	8	–	8	–	269.9
28	<i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> - <i>Zinnia acerosa</i> Shrubland (P)	<i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> (<i>Hibiscus denudatus</i> - <i>Zinnia acerosa</i>) Shrubland	–	NPSSODN102	RMD	–	–	–	8	–	269.9

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
29	<i>Parkinsonia microphylla</i> / <i>Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland (P)	(same as association)	–	NPSSODN117	TMD	6	–	16	–	295.1	–
30	<i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland (P)	(same as association)	–	NPSSODN096	RMD	–	10	–	10	–	478.3
31	<i>Parkinsonia microphylla</i> / <i>Parthenium incanum</i> Shrubland (P)	<i>Parkinsonia microphylla</i> / <i>Parthenium incanum</i> (<i>Aloysia wrightii</i>) Shrubland	–	NPSSODN091	RMD	–	9	–	19	–	112.6
32	<i>Parkinsonia microphylla</i> / <i>Tiquilia canescens</i> (<i>Zinnia acerosa</i>) Shrubland (P)	(same as association)	–	NPSSODN097	RMD	–	12	–	13	–	109.1
33	<i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Wooded Shrubland (P)	(<i>Parkinsonia microphylla</i> - <i>Prosopis velutina</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland	–	NPSSODN130	RMD	–	11	–	166	–	4,057.8
34	<i>Simmondsia chinensis</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland (P)	(same as association)	–	NPSSODN112	TMD	10	–	34	–	939.8	–
35	<i>Simmondsia chinensis</i> (Mixed Cacti) Shrubland (P)	(same as association)	–	NPSSODN134	Both	15	5	87	13	946.9	71.4
36	<i>Simmondsia chinensis</i> / <i>Encelia farinosa</i> Shrubland (P)	(same as association)	–	NPSSODN132	Both	24	10	56	13	971.9	144.2
37	<i>Simmondsia chinensis</i> / <i>Hilaria belangeri</i> Shrub Savanna (P)	(same as association)	–	NPSSODN131	RMD	–	1	–	2	–	1.3
38	<i>Yucca baccata</i> - <i>Dasyllirion wheeleri</i> (<i>Quercus turbinella</i>) / <i>Muhlenbergia porteri</i> Shrubland (P)	(same as association)	–	NPSSODN120	TMD	4	–	3	–	148.1	–
39	(<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland (P)	(same as association)	–	NPSSODN089	Both	4	9	48	29	264.7	151.8

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
40	<i>Prosopis velutina</i> - <i>Chilopsis linearis</i> / <i>Ambrosia monogyra</i> Intermittently Flooded Woodland (P)	<i>Prosopis velutina</i> (<i>Chilopsis linearis</i>) / Annual Forb Floodplain	–	NPSSODN172	RMD	–	3	–	16	–	87.5
41	<i>Alnus oblongifolia</i> / <i>Acer negundo</i> / <i>Rosa woodsii</i> Intermittently Flooded Woodland (P)	(same as association)	–	NPSSODN122	RMD	–	3	–	5	–	2.4
42	<i>Platanus wrightii</i> - <i>Fraxinus velutina</i> Intermittently Flooded Woodland (P)	(same as association)	–	NPSSODN120	RMD	–	5	–	10	–	22.6
43	<i>Platanus wrightii</i> / <i>Quercus oblongifolia</i> Riparian Woodland	(same as association)	CEGL005338	–	RMD	–	7	–	7	–	20.9
44	<i>Populus fremontii</i> / <i>Muhlenbergia rigens</i> Riparian Woodland	(same as association)	CEGL001455	–	RMD	–	5	–	6	–	3.3
45	<i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Shrubland (P)	<i>Prosopis velutina</i> (<i>Senegalia greggii</i>) Intermittently Flooded Shrubland and Woodland	–	NPSSODN178	RMD	–	12	–	61	–	252.6
46	<i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Woodland (P)	<i>Prosopis velutina</i> (<i>Senegalia greggii</i>) Intermittently Flooded Shrubland and Woodland	–	NPSSODN179	RMD	–	11	–	61	–	252.6
47	<i>Prosopis velutina</i> / Annual Forb Woodland (P)	<i>Prosopis velutina</i> (<i>Chilopsis linearis</i>) / Annual Forb Floodplain	–	NPSSODN173	RMD	–	4	–	16	–	87.5
48	<i>Prosopis velutina</i> / <i>Ziziphus obtusifolia</i> - <i>Condalia warnockii</i> Woodland (P)	(same as association)	–	NPSSODN174	RMD	–	4	–	6	–	13.2
49	<i>Quercus rugosa</i> - <i>Ceanothus integrerrimus</i> Woodland (P)	(same as association)	–	NPSSODN153	RMD	–	2	–	7	–	3.3
50	(<i>Quercus arizonica</i> - <i>Quercus emoryi</i>) / <i>Arctostaphylos pungens</i> Shrubland (P)	<i>Quercus arizonica</i> - <i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> Woodland and Shrubland	–	NPSSODN150	RMD	–	8	–	83	–	361.9

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
51	(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Arctostaphylos (pringlei - pungens)</i> Shrubland (P)	<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos (pungens - pringlei)</i> Shrubland and Wooded Shrubland	–	NPSSODN148	RMD	–	9	–	80	–	1,474.9
52	(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Ceanothus fendleri</i> Wooded Shrubland (P)	(same as association)	–	NPSSODN152	RMD	–	5	–	8	–	10.3
53	(<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>) / <i>Arctostaphylos pringlei</i> Shrubland (P)	<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos (pungens - pringlei)</i> Shrubland and Wooded Shrubland	–	NPSSODN155	RMD	–	3	–	80	–	1,474.9
54	[<i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Woodland (P)	<i>Quercus arizonica</i> - <i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> Woodland and Shrubland	–	NPSSODN151	RMD	–	1	–	83	–	361.9
55	[<i>Quercus chrysolepis</i> - <i>Quercus rugosa</i> - <i>Holodiscus dumosa</i>] Shrubland (P)	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i>] Shrubland	–	NPSSODN168	RMD	–	1	–	62	–	322.1
56	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] / <i>Arctostaphylos (pringlei - pungens)</i> Woodland (P)	<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos (pungens - pringlei)</i> Shrubland and Wooded Shrubland	–	NPSSODN149	RMD	–	12	–	80	–	1,474.9
57	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Shrubland (P)	(same as association)	–	NPSSODN163	RMD	–	4	–	22	–	36.9

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
58	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] / <i>Arctostaphylos pringlei</i> Woodland (P)	<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i> - <i>Quercus rugosa</i> / <i>Arctostaphylos pungens</i> - <i>pringlei</i> Shrubland and Wooded Shrubland	–	NPSSODN156	RMD	–	1	–	80	–	1,474.9
59	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Shrubland (P)	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i>] Shrubland	–	NPSSODN161	RMD	–	6	–	62	–	322.1
60	<i>Mimosa aculeaticarpa</i> Shrubland (P)	(same as association)	–	NPSSODN154	RMD	–	3	–	9	–	14.2
61	[<i>Quercus oblongifolia</i> - <i>Prosopis velutina</i> - <i>Vauquelinia californica</i>] / Mixed Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna (P)	<i>Quercus oblongifolia</i> / Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna	–	NPSSODN123	RMD	–	6	–	19	–	2,360.8
62	<i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna (P)	<i>Quercus emoryi</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna	–	NPSSODN157	RMD	–	31	–	98	–	2,962.1
63	<i>Quercus emoryi</i> / <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna (P)	<i>Quercus emoryi</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna	–	NPSSODN158	RMD	–	18	–	98	–	2,962.1
64	<i>Quercus oblongifolia</i> / <i>Bouteloua curtipendula</i> Scrub	<i>Quercus oblongifolia</i> / Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna	CEGL000973	–	RMD	–	14	–	19	–	2,360.8
65	<i>Quercus turbinella</i> - <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> - <i>Agave schottii</i> Shrub Savanna (P)	(same as association)	–	NPSSODN159	RMD	–	5	–	5	–	33.4
66	<i>Pinus discolor</i> (<i>Quercus arizonica</i> - <i>Juniperus deppeana</i> - <i>Quercus hypoleucoides</i>) Woodland (P)	<i>Pinus discolor</i> Woodland	–	NPSSODN169	RMD	–	13	–	141	–	1,544.3
67	<i>Pinus discolor</i> / <i>Arctostaphylos pungens</i> - <i>pringlei</i>) Wooded Shrubland (P)	(same as association)	–	NPSSODN171	RMD	–	9	–	13	–	69.0

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
68	<i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland	(same as association)	CEGL000767	–	RMD	–	29	–	80	–	3,472.4
69	<i>Pinus discolor</i> / <i>Piptochaetium fimbriatum</i> Woodland	<i>Pinus discolor</i> Woodland	CEGL000768	–	RMD	–	2	–	141	–	1,544.3
70	<i>Pinus discolor</i> / <i>Quercus rugosa</i> Woodland	(same as association)	CEGL000772	–	RMD	–	9	–	41	–	482.7
71	<i>Pinus discolor</i> / <i>Quercus toumeyii</i> Woodland	(same as association)	CEGL000773	–	RMD	–	9	–	6	–	499.3
72	<i>Quercus arizonica</i> - <i>Quercus emoryi</i> (<i>Platanus wrightii</i>) Intermittently Flooded Woodland (P)	(same as association)	–	NPSSODN167	RMD	–	–	–	3	–	1.6
73	<i>Cupressus arizonica</i> / <i>Quercus hypoleucoides</i> Forest	(same as association)	CEGL000352	–	RMD	–	4	–	33	–	114.6
74	<i>Pinus (arizonica - ponderosa)</i> Regenerating Woodland (P)	(same as association)	–	NPSSODN146	RMD	–	–	–	7	–	7.1
75	<i>Pinus arizonica</i> / <i>Quercus hypoleucoides</i> Woodland (P)	(same as association)	–	NPSSODN145	RMD	–	15	–	71	–	706.4
76	<i>Pinus leiophylla</i> / <i>Quercus hypoleucoides</i> Woodland	(same as association)	CEGL000824	–	RMD	–	15	–	37	–	35.1
77	<i>Pinus ponderosa</i> / <i>Quercus arizonica</i> - <i>Quercus emoryi</i> Woodland	(same as association)	CEGL000869	–	RMD	–	1	–	1	–	1.9
78	<i>Pinus ponderosa</i> / <i>Quercus hypoleucoides</i> Woodland	(same as association)	CEGL000872	–	RMD	–	7	–	23	–	204.0
79	<i>Pseudotsuga menziesii</i> / <i>Quercus rugosa</i> Forest	(same as association)	CEGL000454	–	RMD	–	7	–	16	–	58.5
80	[<i>Quercus arizonica</i> - <i>Quercus hypoleucoides</i>] Intermittently Flooded Woodland (P)	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland and Intermittently Flooded Woodland	–	NPSSODN165	RMD	–	11	–	102	–	410.3

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
81	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland (P)	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland and Intermittently Flooded Woodland	–	NPSSODN164	RMD	–	17	–	102	–	410.3
82	[<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Intermittently Flooded Woodland (P)	[<i>Quercus rugosa</i> - <i>Quercus hypoleucoides</i>] Woodland and Intermittently Flooded Woodland	–	NPSSODN166	RMD	–	2	–	57	–	179.1
83	[<i>Quercus rugosa</i> - <i>Quercus hypoleucoides</i>] Woodland (P)	[<i>Quercus rugosa</i> - <i>Quercus hypoleucoides</i>] Woodland and Intermittently Flooded Woodland	–	NPSSODN162	RMD	–	11	–	57	–	179.1
84	<i>Quercus gambelii</i> / <i>Symphoricarpos oreophilus</i> Shrubland	(same as association)	CEGL001117	–	RMD	–	3	–	6	–	37.3
85	(<i>Symphoricarpos oreophilus</i>) / <i>Ageratina herbacea</i> Shrubland (P)	(same as association)	–	NPSSODN103	RMD	–	4	–	2	–	24.1
86	<i>Muhlenbergia virescens</i> - <i>Pteridium aquilinum</i> - <i>Ceanothus fendleri</i> Herbaceous (P)	(same as association)	–	NPSSODN093	RMD	–	7	–	16	–	55.6
87	<i>Pteridium aquilinum</i> Herbaceous (P)	(same as association)	–	NPSSODN104	RMD	–	8	–	11	–	50.6
88	<i>Populus tremuloides</i> Forest (P)	(same as association)	–	NPSSODN107	RMD	–	4	–	8	–	9.6
89	<i>Pinus arizonica</i> (<i>Pinus strobiformis</i>) / <i>Muhlenbergia virescens</i> Forest (P)	(same as association)	–	NPSSODN142	RMD	–	4	–	6	–	48.9
90	<i>Pinus arizonica</i> / <i>Pteridium aquilinum</i> Forest (P)	<i>Pinus arizonica</i> Forest	–	NPSSODN144	RMD	–	4	–	25	–	124.9
91	<i>Pinus arizonica</i> Forest (P)	<i>Pinus arizonica</i> Forest	–	NPSSODN143	RMD	–	8	–	25	–	124.9
92	<i>Pinus ponderosa</i> - <i>Pinus strobiformis</i> Forest	<i>Pinus ponderosa</i> Forest	CEGL007091	–	RMD	–	9	–	13	–	192.4
93	<i>Pinus ponderosa</i> (<i>Pinus strobiformis</i>) / <i>Muhlenbergia virescens</i> Woodland (P)	(same as association)	–	NPSSODN140	RMD	–	9	–	7	–	145.4
94	<i>Pinus ponderosa</i> / <i>Pteridium aquilinum</i> Forest	<i>Pinus ponderosa</i> Forest	CEGL002944	–	RMD	–	1	–	13	–	192.4

Table 5-1 (continued). Final vegetation community types, listed with their accepted NVC association codes or SODN placeholder codes, the number of polygons of each type mapped at each unit, and the number of hectares covered.

#	Association	Map class	NVC code	SODN code	District	Number of plots		Number of polygons		Hectares covered	
						TMD	RMD	TMD	RMD	TMD	RMD
95	<i>Pseudotsuga menziesii</i> - <i>Pinus</i> (<i>arizonica</i> - <i>ponderosa</i>) / (<i>Quercus gambelii</i>) Forest (P)	(same as association)	–	NPSSODN108	RMD	–	6	–	18	–	125.9
96	<i>Pseudotsuga menziesii</i> / <i>Pinus strobiformis</i> Forest (P)	(same as association)	–	NPSSODN176	RMD	–	12	–	19	–	124.0
97	<i>Quercus gambelii</i> / <i>Robinia neomexicana</i> / <i>Symphoricarpos oreophilus</i> Woodland (P)	(same as association)	–	NPSSODN106	RMD	–	8	–	13	–	22.0



Vegetation Map, Tucson Mountain District

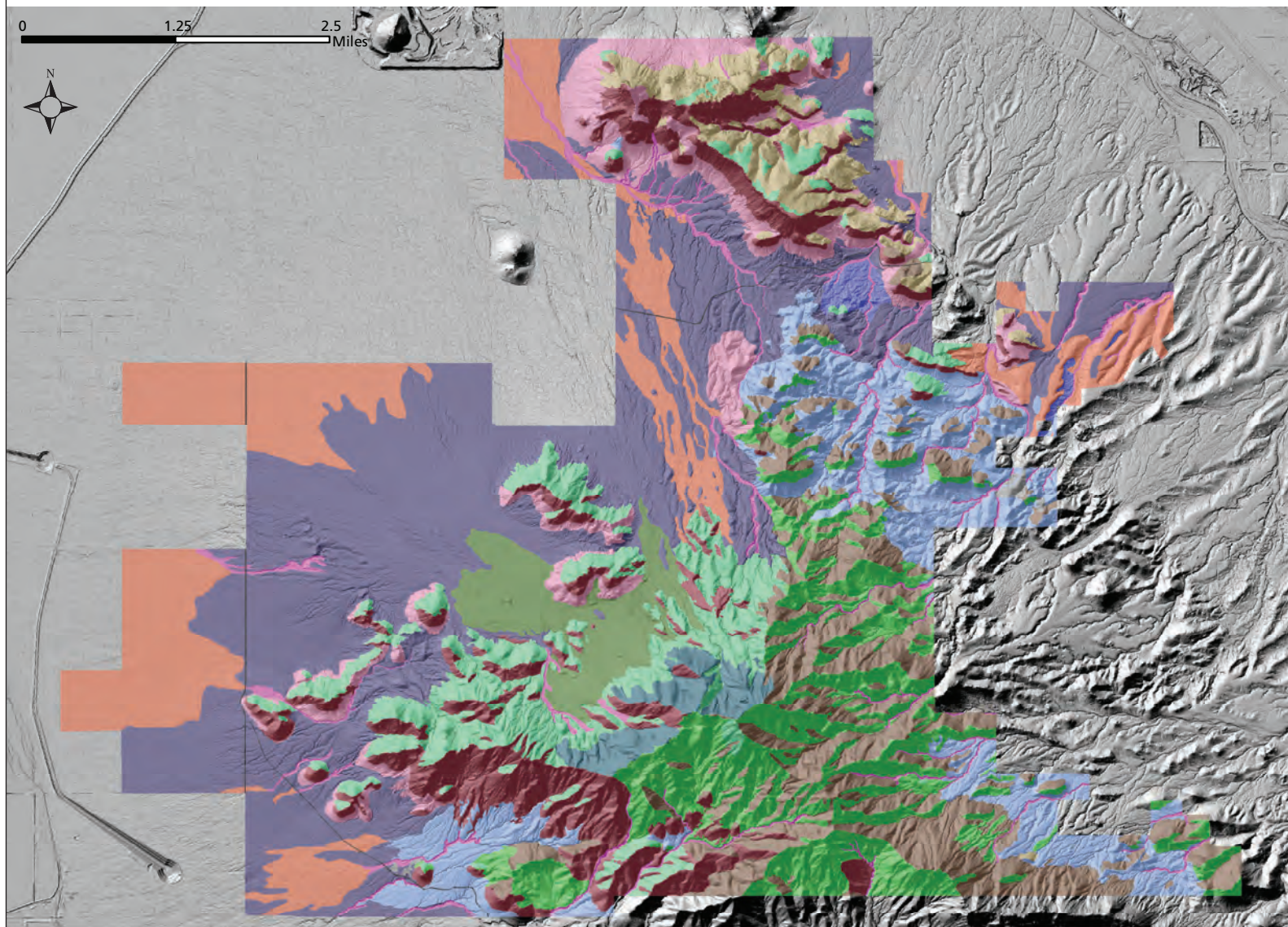


Figure 5-1a. Vegetation map, Tucson Mountain District.

Legend, Tucson Mountain District Vegetation Map

Map Class

-  1. *Parkinsonia microphylla* / *Opuntia* spp. - *Ambrosia salsola* / *Muhlenbergia porteri* Shrubland
-  6. (*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Larrea tridentata* - *Opuntia engelmannii* (*Vachellia constricta*) / *Krameria bicolor* Wooded Shrubland
-  10. (*Parkinsonia microphylla* - *Prosopis velutina*) / *Encelia farinosa* (*Cottisia gracilis*) Shrubland
-  13. (*Parkinsonia microphylla*) / *Larrea tridentata* - Mixed Cacti / *Ambrosia deltoidea* Shrubland
-  18/29. *Parkinsonia microphylla* / *Lycium berlandieri* (Mixed Shrub) Rocky Shrubland
-  19. *Carnegiea gigantea* / *Parkinsonia microphylla* (*Olneya tesota*) / *Ambrosia deltoidea* Shrubland
-  20. *Cylindropuntia acanthocarpa* - *Vachellia constricta* / *Calliandra eriophylla* - *Cottisia gracilis* Shrubland
-  26. *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland
-  34. *Simmondsia chinensis* - Mixed Cacti / *Ambrosia deltoidea* Shrubland
-  35. *Simmondsia chinensis* (Mixed Cacti) Shrubland
-  36. *Simmondsia chinensis* / *Encelia farinosa* Shrubland
-  38. *Yucca baccata* - *Dasyllirion wheeleri* (*Quercus turbinella*) / *Muhlenbergia porteri* Shrubland
-  39. (*Prosopis velutina*) / *Vachellia constricta* (*Larrea tridentata* - *Senegalia greggii*) Intermittently Flooded Shrubland
-  Developed
-  Road
-  Trail
-  Road
-  TMD boundary

Figure 5-1b. Map legend, Tucson Mountain District.



Vegetation Map, Cactus Forest Loop Road

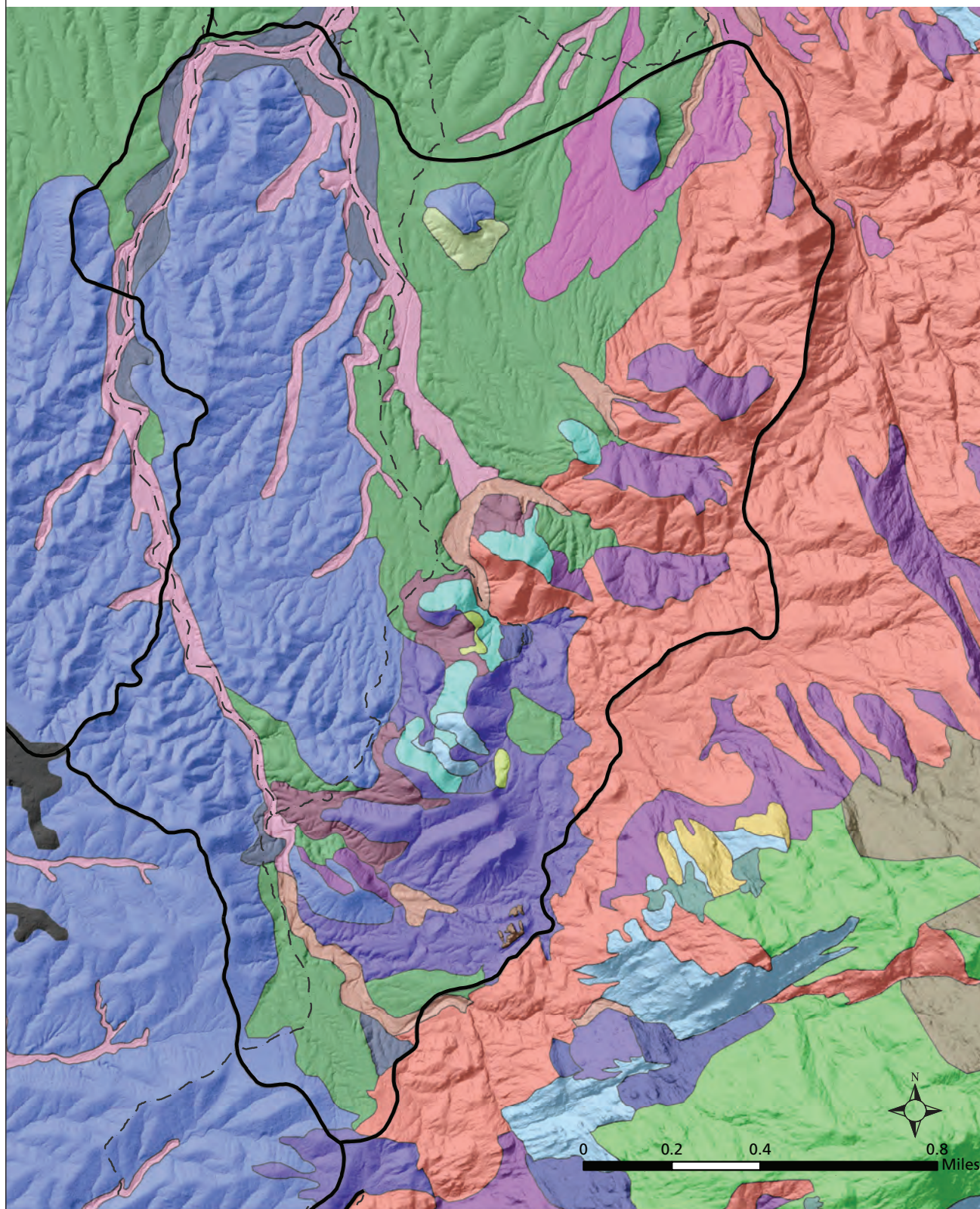


Figure 5-2a. Vegetation map, Cactus Forest Loop Road, Rincon Mountain District.

Legend, Cactus Forest Loop Road Vegetation Map

Map Class

-  3. *Prosopis velutina* / Mixed Shrub Wooded Shrubland
 -  7. (*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Opuntia engelmannii* (*Vachellia constricta* - *Larrea tridentata*) Wooded Shrubland
 -  9. (*Fouquieria splendens*) / *Prosopis velutina* / *Opuntia engelmannii* / *Cottisia gracilis* Shrubland
 -  12. (*Parkinsonia microphylla*) / *Cylindropuntia bigelovii* / *Encelia farinosa* Shrubland
 -  15. (*Prosopis velutina*) / *Aloysia wrightii* Shrubland
 -  16. (*Prosopis velutina*) / *Larrea tridentata* Shrubland
 -  21. *Dalea pulchra* / Mixed Perennial Grass Shrub Savanna
 -  23. *Fouquieria splendens* (*Prosopis velutina*) / *Opuntia engelmannii* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna
 -  24. *Fouquieria splendens* / (*Opuntia engelmannii*) / *Selaginella rupicola* Sparse Rock Outcrop
 -  26. *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland
 -  30. *Parkinsonia microphylla* / *Opuntia engelmannii* / *Encelia farinosa* Shrubland
 -  31. *Parkinsonia microphylla* / *Parthenium incanum* (*Aloysia wrightii*) Shrubland
 -  32. *Parkinsonia microphylla* / *Tiquilia canescens* (*Zinnia acerosa*) Shrubland
 -  33. (*Parkinsonia microphylla* - *Prosopis velutina*) / *Encelia farinosa* (*Cottisia gracilis*) Shrubland
 -  35. *Simmondsia chinensis* (Mixed Cacti) Shrubland
 -  36. *Simmondsia chinensis* / *Encelia farinosa* Shrubland
 -  37. *Simmondsia chinensis* / *Hilaria belangeri* Shrub Savanna
 -  39. (*Prosopis velutina*) / *Vachellia constricta* (*Larrea tridentata* - *Senegalia greggii*) Intermittently Flooded Shrubland
 -  45. *Prosopis velutina* (*Senegalia greggii*) Intermittently Flooded Shrubland and Woodland
 -  Developed
 -  Sparsely Vegetated Bedrock Outcrops
-  Trail
 Road

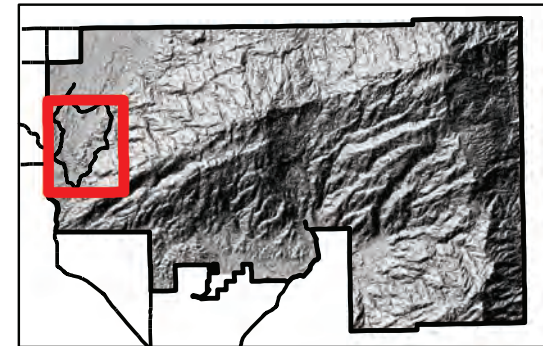


Figure 5-2b. Map legend, Cactus Forest Loop Road, Rincon Mountain District.



Vegetation Map, Tanque Verde Peak

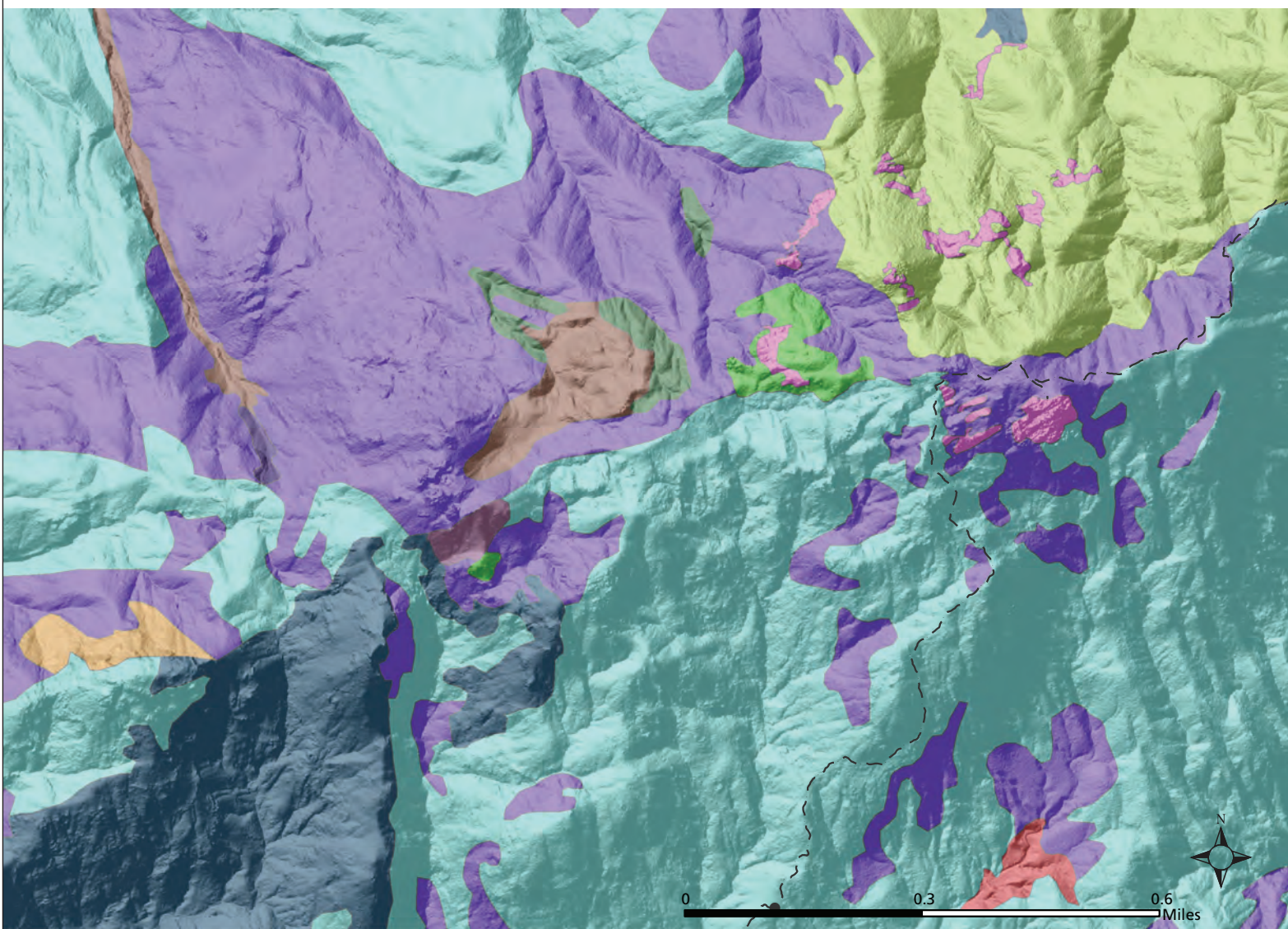


Figure 5-3a. Vegetation map, Tanque Verde Peak, Rincon Mountain District.

Legend, Tanque Verde Peak Vegetation Map

Map Class

-  51. *Quercus hypoleucoides* - *Quercus arizonica* - *Quercus rugosa* / *Arctostaphylos (pungens - pringlei)* Shrubland and Wooded Shrubland
 -  52. (*Quercus hypoleucoides* - *Quercus arizonica*) / *Ceanothus fendleri* Wooded Shrubland
 -  62. *Quercus emoryi* / *Muhlenbergia emersleyi* Wooded Shrub Savanna
 -  66. *Pinus discolor* Woodland
 -  67. *Pinus discolor* / *Arctostaphylos (pungens - pringlei)* Wooded Shrubland
 -  68. *Pinus discolor* / *Muhlenbergia emersleyi* Woodland
 -  70. *Pinus discolor* / *Quercus rugosa* Woodland
 -  77. *Pinus ponderosa* / *Quercus arizonica* - *Quercus emoryi* Woodland
 -  78. *Pinus ponderosa* / *Quercus hypoleucoides* Woodland
 -  80. [*Quercus hypoleucoides* - *Quercus arizonica*] Woodland and Intermittently Flooded Woodland
 -  82. [*Quercus rugosa* - *Quercus hypoleucoides*] Woodland and Intermittently Flooded Woodland
 -  Sparsely Vegetated Bedrock Outcrops
-
-  Trail
 -  Road

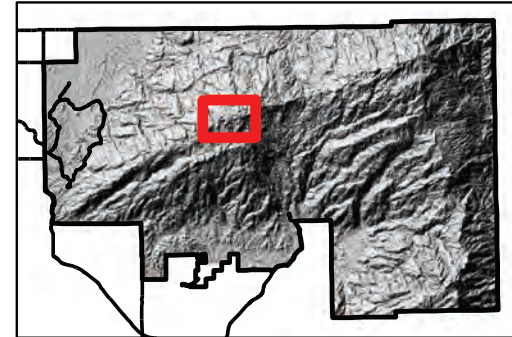


Figure 5-3b. Map legend, Tanque Verde Peak, Rincon Mountain District.

**Saguaro National Park
Rincon Mountain District**

National Park Service
U.S. Department of the Interior



Vegetation Map, Mica Mountain

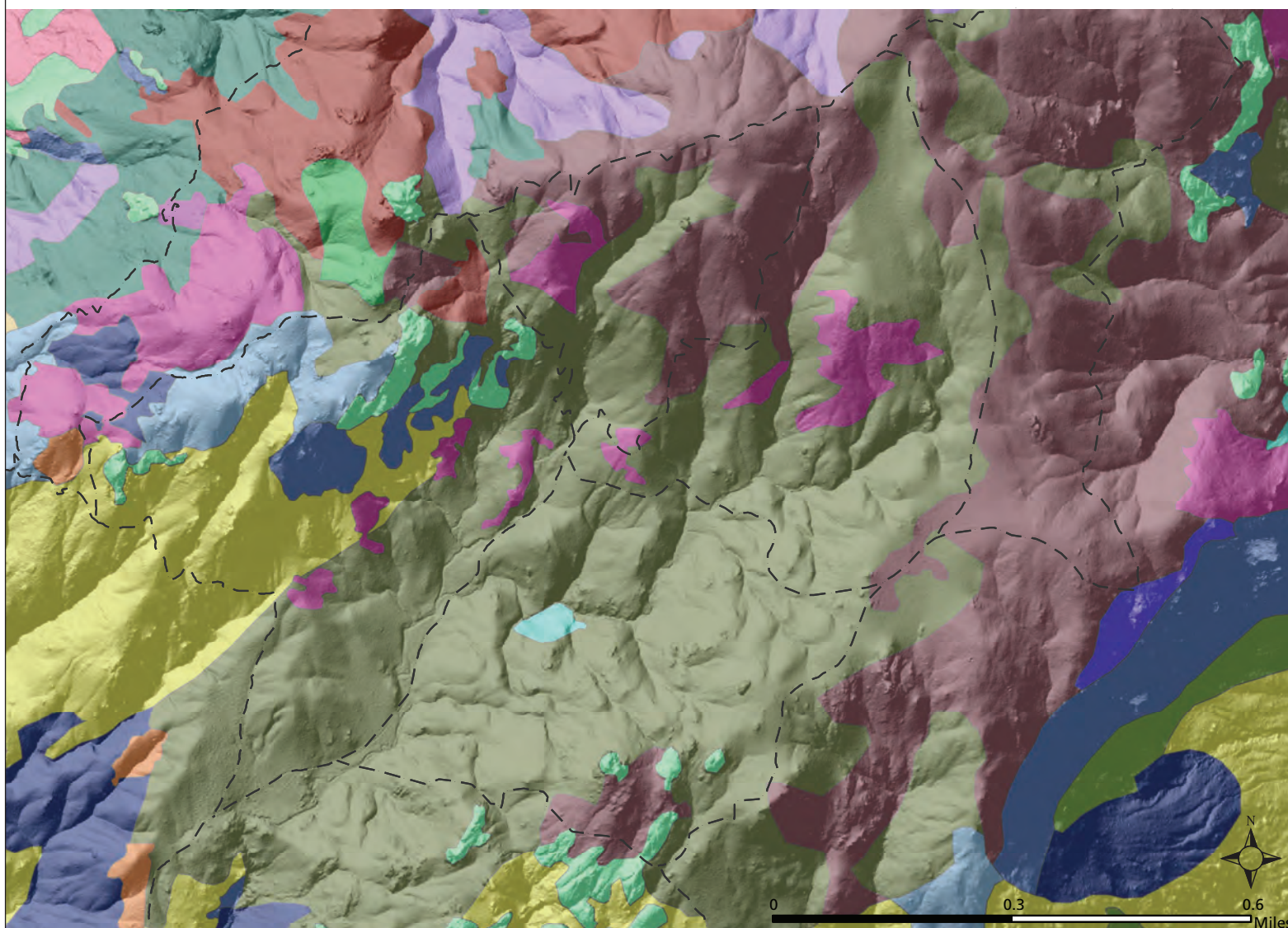
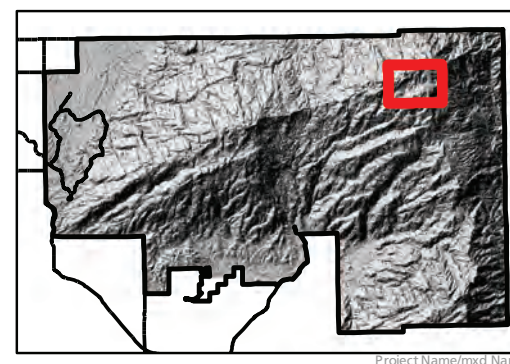


Figure 5-4a. Vegetation map, Mica Mountain, Rincon Mountain District.

Legend, Mica Mountain Vegetation Map

Map Class

-  55. [*Quercus hypoleucoides* - *Quercus rugosa* - *Quercus chrysolepis*] Shrubland
 -  70. *Pinus discolor* / *Quercus rugosa* Woodland
 -  74. *Pinus (arizonica - ponderosa)* Regenerating Woodland
 -  75. *Pinus arizonica* / *Quercus hypoleucoides* Woodland
 -  79. *Pseudotsuga menziesii* / *Quercus rugosa* Forest
 -  82. [*Quercus rugosa* - *Quercus hypoleucoides*] Woodland and Intermittently Flooded Woodland
 -  84. *Quercus gambelii* / *Symphoricarpos oreophilus* Shrubland
 -  85. (*Symphoricarpos oreophilus*) / *Ageratina herbacea* Shrubland
 -  86. *Muhlenbergia virescens* - *Pteridium aquilinum* - *Ceanothus fendleri* Herbaceous
 -  87. *Pteridium aquilinum* Herbaceous
 -  88. *Populus tremuloides* Forest
 -  89. *Pinus arizonica (Pinus strobiformis)* / *Muhlenbergia virescens* Forest
 -  90. *Pinus arizonica* Forest
 -  92. *Pinus ponderosa* Forest
 -  93. *Pinus ponderosa (Pinus strobiformis)* / *Muhlenbergia virescens* Woodland
 -  95. *Pseudotsuga menziesii* - *Pinus (arizonica - ponderosa)* / (*Quercus gambelii*) Forest
 -  96. *Pseudotsuga menziesii* / *Pinus strobiformis* Forest
 -  97. *Quercus gambelii* / *Robinia neomexicana* / *Symphoricarpos oreophilus* Woodland
 -  Sparsely Vegetated Bedrock Outcrops
-  Trail
 Road



Project Name/mxd Name

Figure 5-4b. Map legend, Mica Mountain, Rincon Mountain District.



Vegetation Map, Rincon Peak

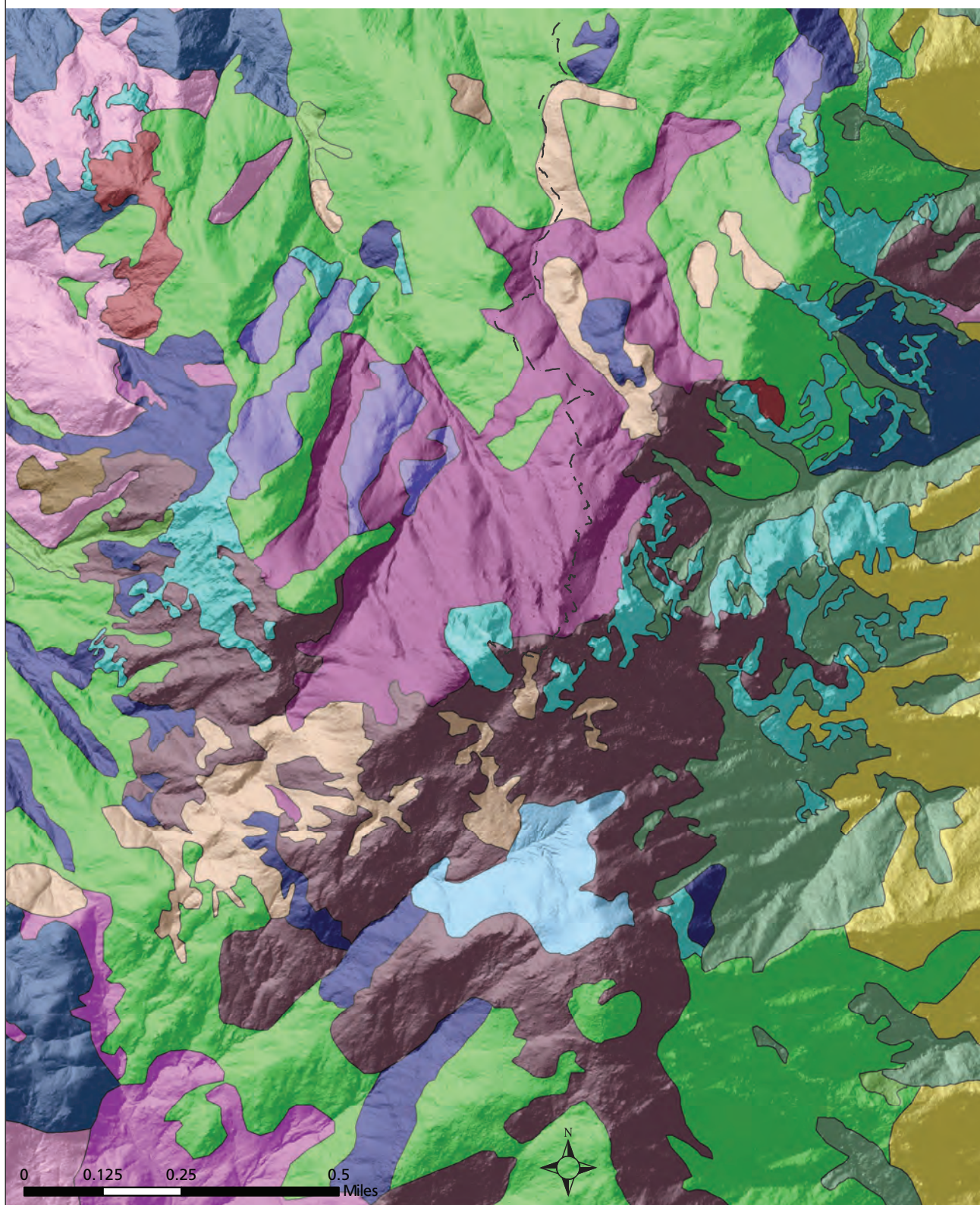


Figure 5-5a. Vegetation map, Rincon Peak, Rincon Mountain District.

Legend, Rincon Peak Vegetation Map

Map Class

-  55. [*Quercus hypoleucoides* - *Quercus rugosa* - *Quercus chrysolepis*] Shrubland
-  66. *Pinus discolor* Woodland
-  67. *Pinus discolor* / *Arctostaphylos (pungens - pringlei)* Wooded Shrubland
-  68. *Pinus discolor* / *Muhlenbergia emersleyi* Woodland
-  70. *Pinus discolor* / *Quercus rugosa* Woodland
-  71. *Pinus discolor* / *Quercus toumeyi* Woodland
-  73. *Cupressus arizonica* / *Quercus hypoleucoides* Forest
-  75. *Pinus arizonica* / *Quercus hypoleucoides* Woodland
-  76. *Pinus leiophylla* / *Quercus hypoleucoides* Woodland
-  79. *Pseudotsuga menziesii* / *Quercus rugosa* Forest
-  80. [*Quercus hypoleucoides* - *Quercus arizonica*] Woodland and Intermittently Flooded Woodland
-  82. [*Quercus rugosa* - *Quercus hypoleucoides*] Woodland and Intermittently Flooded Woodland
-  92. *Pinus ponderosa* Forest
-  95. *Pseudotsuga menziesii* - *Pinus (arizonica - ponderosa)* / (*Quercus gambelii*) Forest
-  96. *Pseudotsuga menziesii* / *Pinus strobiformis* Forest
-  Sparsely Vegetated Bedrock Outcrops

-  Trail
-  Road

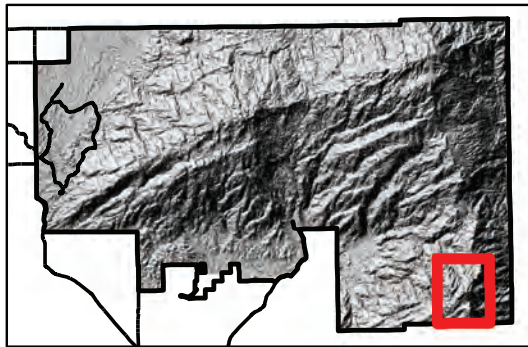


Figure 5-5b. Map legend, Rincon Peak, Rincon Mountain District.

6 Discussion

6.1 Methodology

6.1.1 Vegetation classification

The sampling of classification plots at the TMD and the initial round of classification sampling at the RMD closely followed the methodology used for previous SODN vegetation mapping projects (e.g., Studd et al. 2018, 2019a, 2019b). Typically, plot distribution was done prior to the start of fieldwork using the RRQRR algorithm, often stratified by upland and hydrologic habitats. Plot sampling involved an exhaustive survey of all plant species within a precisely delineated plot. Due to the RMD's large area, and the difficulty of accessing significant portions of the district, we reassessed the sampling protocol after the initial round of sampling (2013–2014).

After analyzing the initial dataset, we determined a substantial increase in sample size was needed to fully capture the diverse array of communities within the district. At this point, the analysis had identified around 34 communities. The majority (75%) were described using less than five plots, while certain widespread communities referenced up to 20. According to NPS guidance, each association should ideally have a membership of at least 10 plots.

The next phase of sampling focused on adding plots to undersampled communities and visiting areas not covered during the initial round of sampling. With a baseline of communities already identified and the need for a considerable increase in sample size, we decided to focus our efforts on subjectively placed plots. Field crews were instructed to visit specific areas of the district that were not sampled during the initial round and/or contained potential examples of under-sampled communities. Provided with a target list of communities requiring additional plots, these crews opportunistically sampled subjectively placed plots.

In an effort to decrease the time requirement per classification plot, we made a number of tweaks to the field methodology. During the initial round of sampling, we delineated

rectangular plots using two 100-meter tapes. In open, herbaceous communities, this was a relatively quick process. In dense, brushy areas, 10–20 minutes might be needed to complete this task. In the second round of sampling, we switched to circular plots with a radius of 18 meters (1,000 m²). This allowed field crews to delineate the plots using rangefinders, negating the need to run tapes. In addition, crews were instructed to spend at most 10 minutes characterizing the plot. This reduced the overall time commitment per sampling unit from 40–120 minutes to 10–20 minutes.

This focus on rapidly assessed, subjectively placed plots allowed for a 200% ($n = 480$) increase in sample size, mainly focused on undersampled and newly identified communities. Following this round of sampling, we identified an additional 57 associations throughout the district. Plots belonging to some of these associations were sampled during the initial round of sampling. However, the small sample size (often just a single plot) and similarities to other associations led these plots to classify as variations of other, more widely distributed communities. With the increased dataset, the differences between closely related communities became more evident. But even with the increase in sample size, certain small (<50-ha) and/or locally rare associations did not receive 10 classification plots. Many of these were from single occurrences, such as the remnant ponderosa pine (*Pinus ponderosa*) woodland near Juniper Basin and the jojoba (*Simmondsia chinensis*) / curly mesquite (*Hilaria belangeri*) shrub savanna near Javelina Rocks.

For future, large-scale classification projects, placing a greater emphasis on the subjective placement of classification plots during initial stages of the project would allow for the documentation of smaller, more restricted communities earlier in the project. SODN's two-phase classification (an initial round of surveys followed by a formal vegetation classification and then a second round of surveys) allowed the second phase to target specific communities and serve as a valida-

tion on communities identified during the initial surveys. This proved effective, allowing us to validate widespread communities as we documented new, more-restricted ones.

6.1.2 Raster classification

The approach used for the RMD vegetation-mapping phase differed greatly from that used at NPS units previously mapped by SODN. As previously mentioned, the size and complexity of the district required us to rely less on intensive field mapping and more on leveraging remote-sensing techniques. While collecting the dataset necessary to classify vegetation communities and train the raster model required a substantial field effort, it was still far lower than that required for in-situ mapping.

As this was SODN's first major mapping project that relied so heavily on remote sensing, outside expertise was required to formulate a strategy and develop the necessary tools for completing the project's mapping phase. As discussed in Section 3.2.2.2, we worked under an interagency agreement with two USGS researchers who aided in the completion of these tasks and provided invaluable expertise on mapping techniques. These researchers developed most of the R code and created many of the rasters used to generate the final map.

As previously mentioned, we employed the R package ModelMap to create the final RMD map. This proved to be an inexpensive (i.e., free) and versatile tool. Considerable knowledge is required to write the code, but once written, it is quickly and easily modified to suit additional variations of the classification. Using this tool, we created and ran a series of models that included differing sets of rasters, clusters of associations, and training/test datasets. In addition, this package provided us with various outputs used to assess the models, including contingency tables, relative-influence plots, and correlation plots.

The contingency tables are the same format as those used for the accuracy-assessment phase of the project (see Chapter 4). For each model, we set aside 20% of the training

data as test data. These test data were used to quantify the overall and within-class accuracy of the map. While this form of accuracy assessment is useful to assess the raster models, it in no way negates the need for a formal, in-situ accuracy assessment. These tables helped inform the iterative process of identifying useful predictor rasters and problematic, low-accuracy classes.

The relative-influence plots depict the usefulness of each predictor raster on the model—for individual classes (Figure 6-1) or the entire map. As the name implies, these plots show the relative importance of each raster and are not comparable across classes. However, they did prove useful for assessing the necessity of including certain rasters.

Appearing toward the top of every relative-influence plot, often in first or second place, the digital elevation model was the most influential raster. Elevation is closely tied to the distribution of plant communities across the mountains of the desert southwest. While many associations occupy similar elevation ranges, these plots depict the influence of each raster on differentiating one association from all others. The roughness of the canopy-height model (standard deviation of pixel values) proved important as well, whether for mixed-level canopies of large conifers and understory oaks with a high roughness value or dense, uniform stands of manzanita chaparral with a low roughness value. Many of the categorical rasters (YSLF, Geo, and Soil) proved influential as well, whether for differentiating the limestone-restricted communities near Hope Camp or the post-fire communities along the north slopes of Mica Mountain. Finally, hydrologic distance proved important for helping to differentiate the smaller drainages from the adjacent upland habitat. Additional detail on each raster used in the classification is provided in Appendix D.

6.2 Disturbance and fire history

6.2.1 Impacts of fire on vegetation

At the RMD, recent and historical fire has shaped the composition of vegetation communities across the mountain. Most fires within the RMD have been a result of

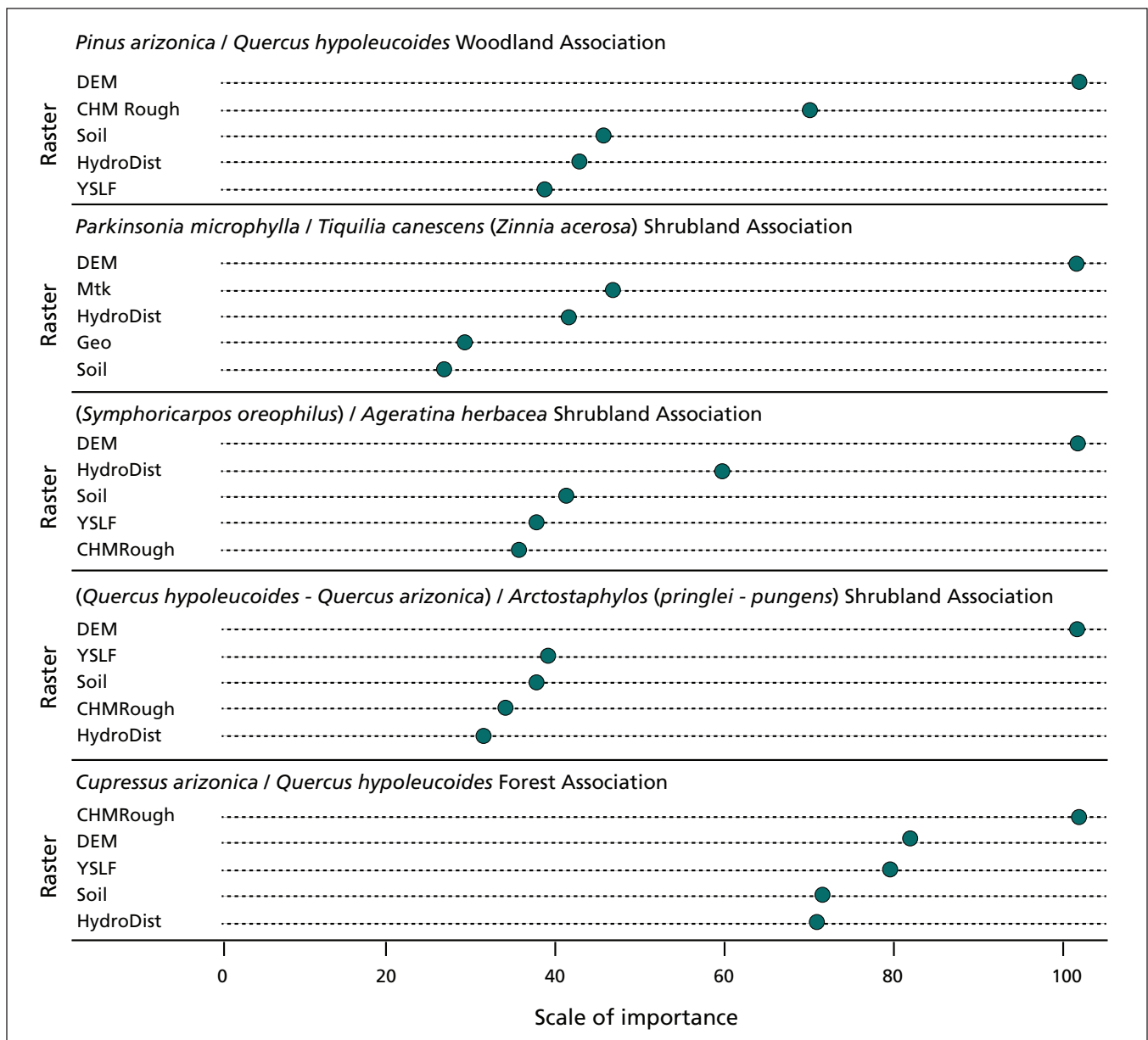


Figure 6-1. Relative-influence plots depicting the top five rasters from a selection of associations. DEM: digital elevation model; CHM Rough: canopy-height model roughness; YSLF: years since last fire; HydroDist: distance from hydrologic feature; Geo: geology; Mtk: multitemporal Kauth-Thomas transformation. Plots are taken from model that used all rasters, including categorical data. See Appendix D for further details.

natural lightning ignitions, typically occurring just before (June) and during (July and August) the summer monsoon. However, human-caused fires, such as the Mother's Day Fire (1994), have also occurred (Baisan and Swetnam 1989). Historically, most fire activity has been focused on the slopes of Mica Mountain and Tanque Verde Ridge. Despite occupying the same elevational range and containing similar vegetation communities, the area surrounding Rincon Peak has remained largely untouched by major fire events in the last 100 years. The conspicuous lack of fire in this area is often attributed to the large, rocky summit of Rincon Peak rising sharply above the adjacent forests and attracting the majority of lightning strikes in the area (Roseberry and Dole 1939a; Baisan 1989). In contrast, the summit of Mica Mountain sits within a low-angle pine forest with ample fuel for fires to spread throughout the area. Historically, intervals between major fires ranged from three to more than 10 years (Baisan 1992).

The most-prominent fire scars across the Rincon Mountains are the result of four major fires that burned across that range from the late 1980s to the early 2000s. All four fires caused major alterations to the formation and species composition of vegetation communities. The ability of these communities to return to their pre-fire state depends on a complex mix of variables that include, but are not limited to, fire severity, the fire resistance of dominant species, and the dominant species' post-fire response. The increased warming and drying of the climate in the 21st century is leading to a decrease in post-fire tree regeneration compared to the end of the 20th century (Stevens-Rumann et al. 2018). This is especially true where dominant species are at the lower elevational end of their typical range.

6.2.1.1 Helen's 2 Fire

In 2003, the Helen's 2 Fire burned the northern slopes of Mica Mountain, mainly in ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) forests. Owing to their thick bark, deep roots, and high crowns, mature individuals of these species are highly resistant to fire events of low and moderate severity (Table 6-1).

Despite this resistance, vast areas covered by this fire exhibited near-complete tree mortality. Areas of living trees did remain, typically when in proximity to more mesic sites, such as drainages and high, sheltered slopes. These species, as with all conifers, are unable to sprout from their root crown following a major fire event and rely on seed germination to re-establish burned areas. Successful seed germination depends on ample seed production, followed by a season of favorable growing conditions (Oliver and Ryker 1990). In the year before and for two years after the fire, most of Arizona experienced a severe-to-exceptional drought (Figure 6-2). Under these conditions, ample cone production prior to the fire was unlikely, as were favorable germination conditions in its aftermath. In addition, the establishment of vast, dense areas of western brackenfern (*Pteridium aquilinum*) may have led to decreased germination in subsequent years. Successful germination has been shown to decrease in areas of high herbaceous cover (Bonnet et al. 2005).

In addition, one of the most important metrics for successful post-fire seed germination is proximity to living, cone-producing individuals (Rodman et al. 2020). As mentioned in Section 1.8.5, the Saguaro NP fire module has established and sampled monitoring plots throughout the RMD's upper-elevation reaches. Prior to the Helen's 2 Fire, a total of 12 plots were established within what would become the fire's boundaries; complete tree mortality was documented in four of these plots. During resampling 10 years later (2012–2013), there was no recruitment of ponderosa pine (*Pinus ponderosa*) or Douglas fir (*Pseudotsuga menziesii*) within these plots.

The mandate of the vegetation mapping inventory is to map vegetation communities as they currently exist—not what they were in the past, or what they might become in the future. As such, we classified and mapped communities severely affected by the Helen's 2 Fire in their post-fire state. In total, we classified and mapped four associations whose presence was a direct result of fire disturbance. These associations ranged from mesic, herbaceous communities of western

Table 6-1. Definitions of burn severity for forested communities (NPS 2003).

Severity	Substrate	Vegetation
Unburned	Not burned.	Not burned.
Scorched	Litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged.	Foliage scorched and attached to supporting twigs.
Lightly Burned	Litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned; logs are scorched or blackened but not charred; rotten wood is scorched to partially burned.	Foliage and smaller twigs partially to completely consumed; branches mostly intact.
Moderately Burned	Litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common.	Foliage, twigs, and small stems consumed; some branches still present.
Heavily Burned	Litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred, and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas.	Foliage, twigs, and small stems consumed; some branches still present.

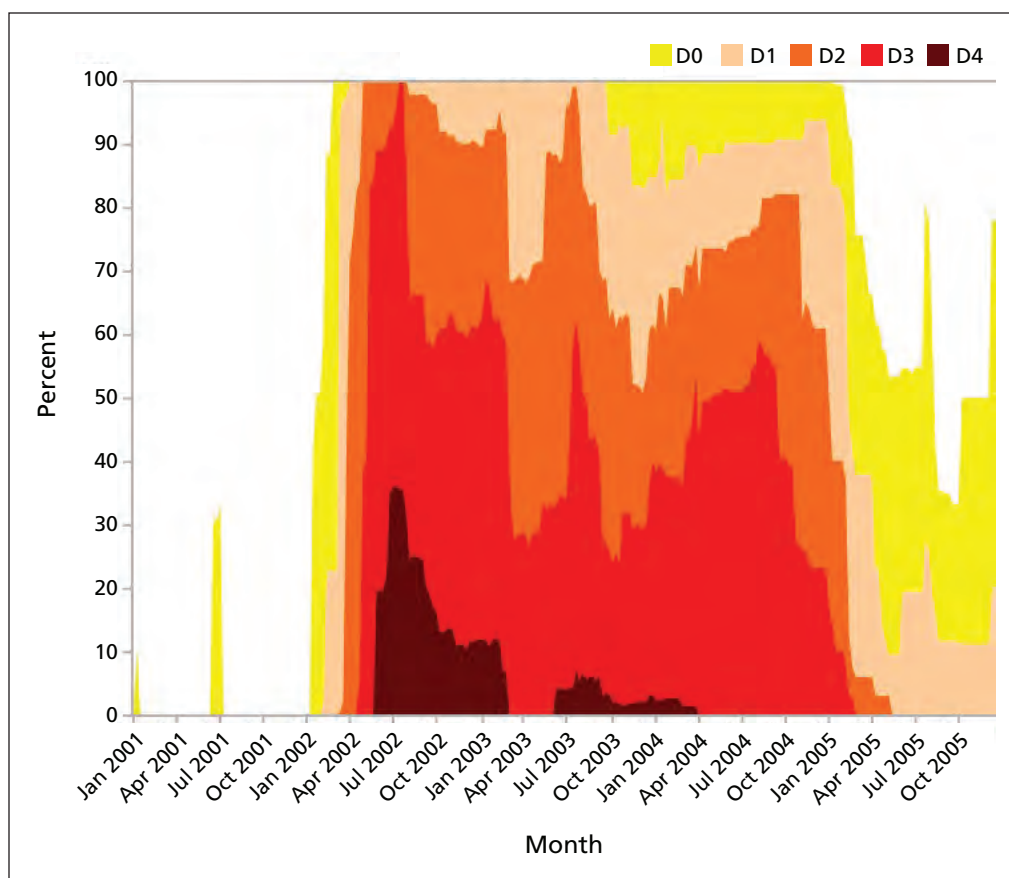


Figure 6-2. Drought conditions throughout Arizona from June 2001 to October 2005. D0—abnormally dry, D1—moderate drought, D2—severe drought, D3—extreme drought, D4—exceptional drought. Graph courtesy of National Drought Mitigation Center (NDMC). The U.S. Drought Monitor is jointly produced by the NDMC at the University of Nebraska-Lincoln, the U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration.

brackenfern (*Pteridium aquilinum*) to more xeric sub-shrublands of fragrant snakeroot (*Ageratina herbacea*):

- (*Symphoricarpos oreophilus*) / *Ageratina herbacea* Shrubland Association (P)
- *Pteridium aquilinum* Herbaceous Association (P)
- *Muhlenbergia virescens* - *Pteridium aquilinum* - *Ceanothus fendleri* Herbaceous Association (P)
- *Quercus gambelii* / *Symphoricarpos oreophilus* Shrubland Association

Based on adjacent, unburned communities, the composition of these four associations aligned to the understory components of pre-fire conifer woodlands and forests. The *Pteridium aquilinum* Herbaceous association occupied the higher, more sheltered slopes previously dominated by the *Pseudotsuga menziesii* / *Pinus strobiformis* Forest (Figure 6-3). In contrast, the drier, more exposed (*Symphoricarpos oreophilus*) / *Ageratina herbacea* Shrubland association was in areas previously dominated by the *Pseudotsuga menziesii* - *Pinus (arizonica - ponderosa)* / (*Quercus gambelii*) Forest association. This association typically spans lower and drier sites. The *Muhlenbergia virescens* - *Pteridium aquilinum* - *Ceanothus fendleri* Herbaceous association occupied area previously dominated by *Pinus ponderosa* (*Pinus strobiformis*) / *Muhlenbergia virescens* Woodland.

6.2.1.2 Chiva and Box Canyon fires

The Chiva (1989) and Box Canyon (1999) fires burned through similar vegetation communities that have largely exhibited the same post-fire impacts. As discussed in Section 1.8.5, these fires burned through semi-desert grasslands, oak savannas, and mixed pine-juniper-oak woodlands. Due to the resilience of grassland communities and the robust post-fire response of oaks (*Quercus* spp.), the semi-desert grasslands and oak savannas showed minimal long-term alteration from these fires, based on our observations. The primary disturbance that has led to long-term changes in vegetation composition occurred within the pine-juniper-oak woodlands. Unlike conifer species, border pinyon (*Pinus discolor*) and alligator juniper

(*Juniperus deppeana*) have a low resistance to fire disturbance, partially due to their relatively thin bark (Zouhar 2015; Brown and Smith 2000). While oaks (*Quercus* spp.) sprout from the root crown, border pinyon (*Pinus discolor*) are unable to regenerate vegetatively following a fire event. Instead, they rely on animals (often scrub jays) to distribute seeds from surviving plants into burned areas to promote post-fire re-establishment. This can be a lengthy process, taking 60–100 years to return to the pre-fire community.

Within the bounds of these fires, areas previously defined by the presence of conifers are currently mapped as oak- (*Quercus* spp.) and/or manzanita- (*Arctostaphylos* spp.) dominated communities. In contrast to conifers, all oaks within the RMD can re-sprout from the root crown following a fire event. This often leads to a rapid flush of shrubby oak throughout the burned area. Depending upon the severity of the burn and the post-fire conditions for seed germination, manzanita can also quickly re-establish in burned areas, often causing a type conversion from pinyon-juniper woodland to manzanita shrublands.

Based on the 1939 map by Roseberry and Dole (see Section 6.3), the area covered by the Chiva Fire was previously dominated by pine and pinyon-juniper communities. While these communities still persist within the burn area, they have largely been replaced by types devoid of conifers (Table 6-2). On the lower-elevation, more-exposed slopes, oak-dominated tree savannas are prevalent, while manzanita-dominated chaparral communities tend to occupy the upper, more-sheltered slopes. During field surveys, snags of both border pinyon (*Pinus discolor*) and alligator juniper (*Juniperus deppeana*) were documented throughout this area.

The Box Canyon Fire, which extended down into the desert-scrub communities, included a broader sample of communities across the Tanque Verde Ridge than the Chiva Fire. Much like the Chiva Fire, communities previously dominated by pinyon-juniper have largely converted to oak-dominated woodlands and tree savannas. Expanses of manzanita (*Arctostaphylos* spp.) chaparral are largely absent from this area.

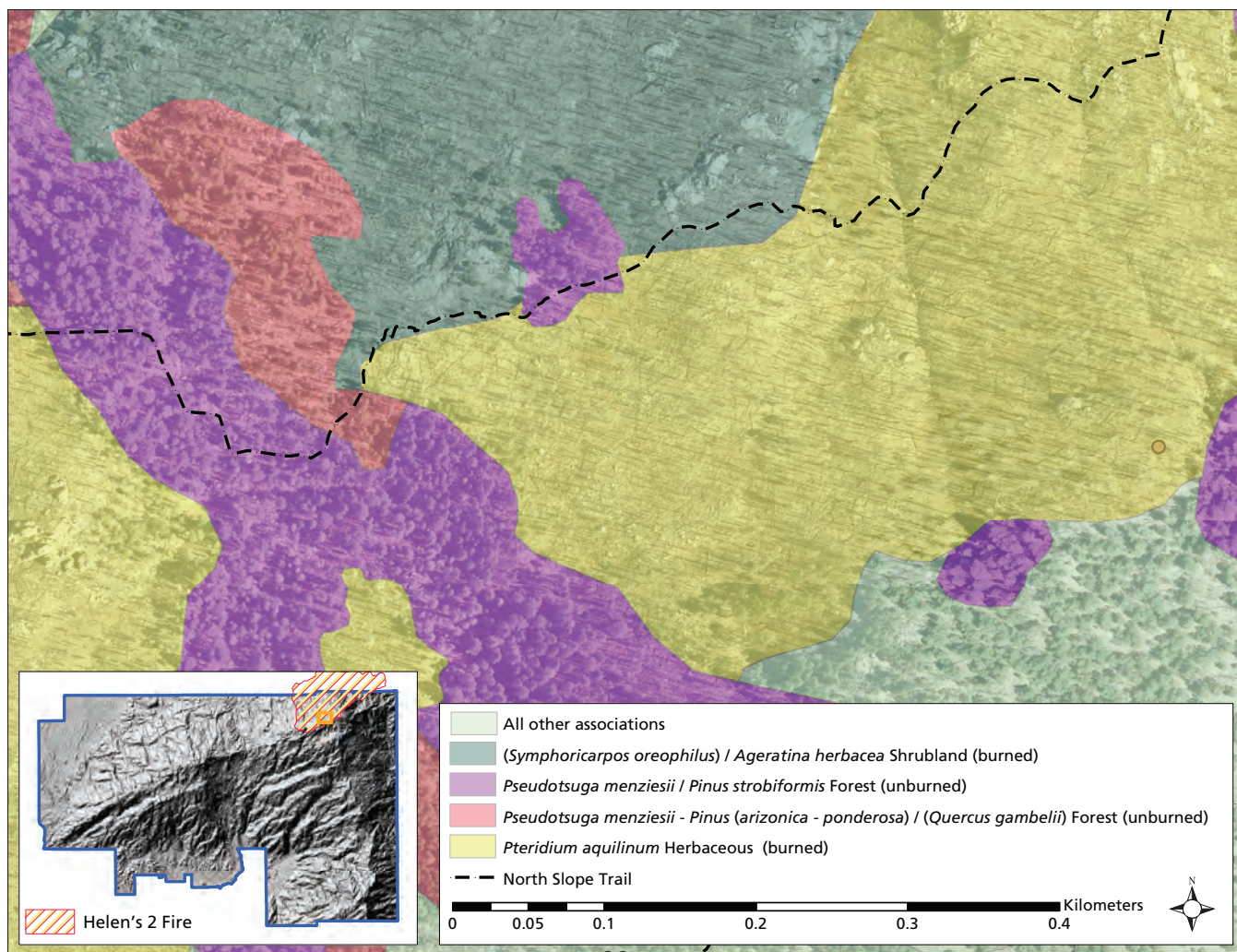


Figure 6-3. Distribution of burned and unburned map classes within the boundaries of the Helen's 2 Fire.

Table 6-2. Communities burned during Chiva and Box Canyon fires.

Community	Presumed pre-fire	Post-fire
<i>Pinus ponderosa</i> / <i>Quercus hypoleucoides</i> Woodland Association	Yes	No
<i>Pinus discolor</i> (<i>Quercus arizonica</i> - <i>Juniperus deppeana</i> - <i>Quercus hypoleucoides</i>) Woodland Association (P)	Yes	No
<i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland Association	Yes	No
<i>Pinus discolor</i> / <i>Arctostaphylos</i> (<i>pungens</i> - <i>pringlei</i>) Wooded Shrubland Association (P)	Yes	No
<i>Pinus discolor</i> / <i>Piptochaetium fimbriatum</i> Woodland Association	Yes	No
<i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna Association (P)	No	Yes
(<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>) / <i>Arctostaphylos</i> (<i>pringlei</i> - <i>pungens</i>) Shrubland Association (P)	No	Yes
[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] / <i>Arctostaphylos</i> (<i>pringlei</i> - <i>pungens</i>) Woodland Association (P)	No	Yes
(<i>Quercus arizonica</i> - <i>Quercus emoryi</i>) / <i>Arctostaphylos pungens</i> Shrubland Association (P)	No	Yes
[<i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Woodland Association (P)	No	Yes

6.2.1.3 Rincon Fire

Of the four fires, the Rincon Fire (1994) burned through the broadest range of vegetation communities, from Douglas fir (*Pseudotsuga menziesii*) to yellow paloverde (*Parkinsonia microphylla*). This fire encompassed all the major shifts in vegetation formation and composition resulting from the Helen's 2, Chiva, and Box Canyon fires. The widespread conversion of pine and pinyon-juniper woodlands to dense manzanita chaparral was the most-prominent shift, with examples occurring along Heartbreak Ridge and in the district's northeast corner.

6.2.2 Invasive plants

The most-prominent and actively managed natural-resource issue at Saguaro NP is the establishment and spread of invasive plant species. Across both districts of the park, buffelgrass (*Cenchrus ciliaris*) is the species of greatest concern, and receiving the most attention from park staff and volunteers. Originating in the semi-arid regions of Africa, the Middle East, and Asia, this species was introduced to the U.S. Southwest in the 1930s as a means to control erosion and support cattle grazing (Olssen et al. 2012; Marshall et al. 2012). As mentioned in Section 1.7.3, management of this species has been ongoing since the early 1990s.

A number of strategies were considered to account for this species within the vegetation classification and mapping. Initially, we planned to classify and map communities dominated by buffelgrass (*C. ciliaris*) as separate associations and polygons. However, this approach was abandoned due to the amount of active management occurring within the park. The majority of plots and training polygons containing dominant buffelgrass (*C. ciliaris*) still contained components of the pre-invasion community. With active management likely reducing the dominance of buffelgrass, we decided to lump invaded and natural versions of associations. Narratives describing both versions are included in local association descriptions.

As this species is typically restricted to communities below 5,000 feet (NPS 2014), often on steep and exposed, south-trending

slopes, only a small number of communities are largely impacted:

- (*Parkinsonia microphylla* - *Fouquieria splendens*) / *Encelia farinosa* (*Cottisia gracilis*) Shrubland Association (P) (both districts)
- (*Parkinsonia microphylla*) / *Cylindropuntia bigelovii* / *Encelia farinosa* Shrubland Association (P) (RMD only)
- *Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland Association (P) (TMD only)
- *Fouquieria splendens* (*Prosopis velutina*) / *Opuntia engelmannii* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna Association (P) (RMD only)

At the RMD, the primary areas of invasion within these communities are on the south-facing slopes of Tanque Verde Ridge, above the Hope Camp area, and in Box Canyon. These areas can include vast (>50-ha) mountain slopes and small (<<1-ha), isolated patches. At the TMD, areas of invasion are spread across south-trending slopes and tend to be smaller than those at the RMD, with the largest mapped invasion around four hectares. Depending on the long-term success of buffelgrass (*C. ciliaris*) management at the park, future updates to the vegetation map may require additional associations describing areas of dominant invasion.

6.3 Legacy map product discussion

In the spring of 1937, two junior foresters, R. D. Roseberry and N. E. Dole, completed fieldwork to create a vegetation type map of Saguaro National Monument (Figure 6-4). At the time, the monument consisted solely of 25,000 hectares within the Rincon Mountains. Fieldwork was completed by scoping vegetation for vantage points throughout the range, accessed with the aid of horses. As these researchers were unable to identify understory components from that vantage point, map classes were solely defined by overstory components.

The resulting map (Roseberry and Dole 1939b) contained 16 classes, of which 14 were vegetated (a class marked "semi-

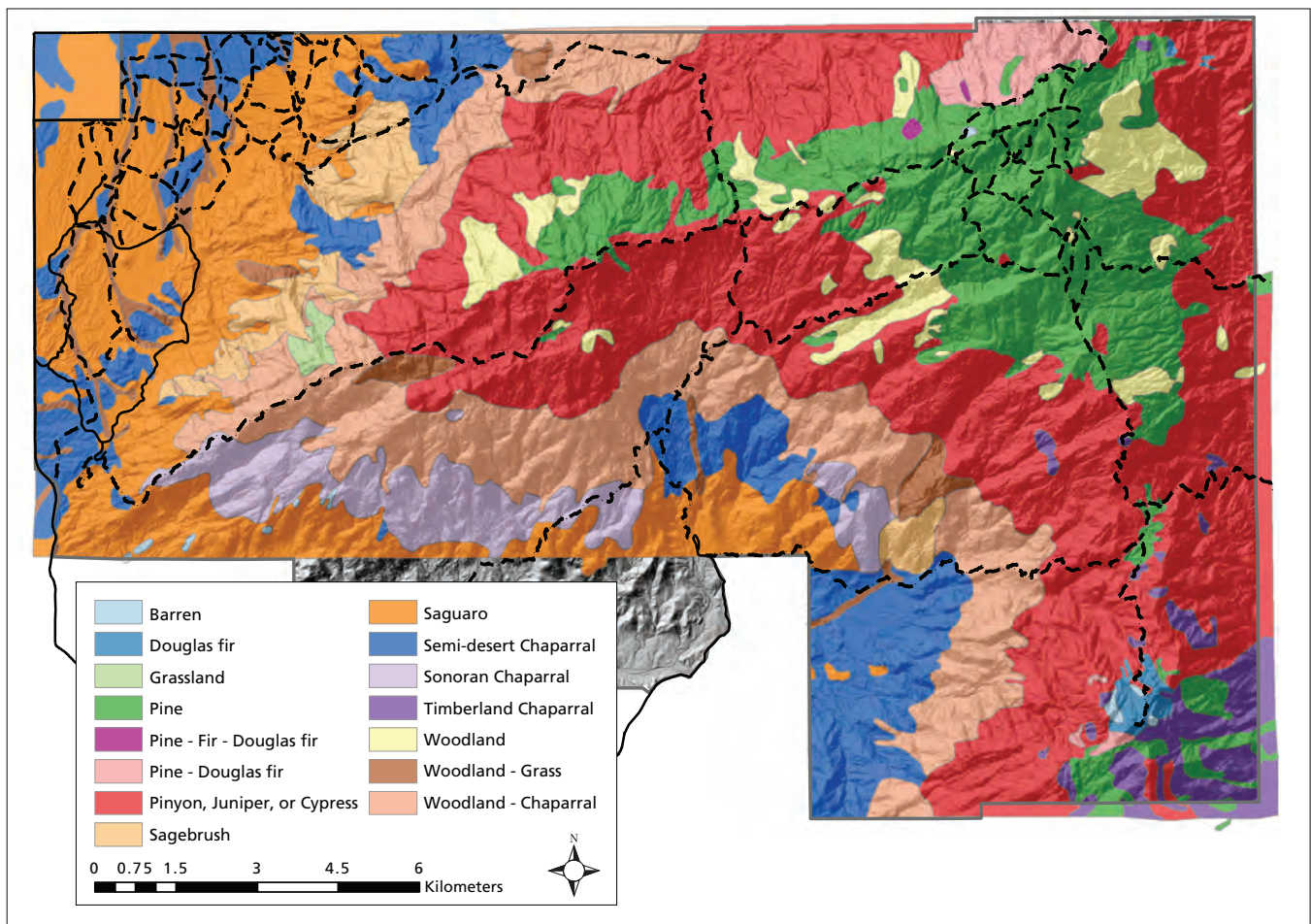


Figure 6-4. Roseberry and Dole's 1937 vegetation map of Saguaro National Monument.

barren” is not shown in Figure 6-4). The classes ranged from the formation level (e.g., Woodland) to those including broad species or genus designations (e.g., pine-fir-Douglas fir). More detailed species locations were notated using species symbols (e.g., Nm = *Nolina microcarpa*) within the delineated polygons. The map is surprisingly detailed given its time period and methodology. However, its overall accuracy and class descriptions are problematic. We attempted to compare our map to the 1939 map, but encountered numerous difficulties. The primary issue was that classes identified by Roseberry and Dole were not well-defined, making it difficult to crosswalk the two maps. In addition, certain classes spanned a broad elevational range and included areas with strikingly different vegetation communities. The Sonoran chaparral class encompassed both creosote (*Larrea tridentata*) shrublands and semi-desert grasslands. Other classes, namely sagebrush, were not

appropriate for the communities included in the monument’s area. The Roseberry and Dole map is an interesting historical document, and useful for broad comparisons to current conditions, but does not contain enough detail to allow any quantitative comparisons with the current map.

6.4 Distribution and importance of vegetation communities

6.4.1 National Vegetation Classification System placement

Placing the documented vegetation communities at Saguaro National Park into accepted NVC associations proved difficult, mostly due to the limited vegetation-mapping work previously done in the borderlands of southeast Arizona—or at least the limited number of relevant types added to the NVC database (usnvc.org). In some cases, an NVC association name matched a park

association, but lacked a narrative detailing that association. In these cases, we did not consider the NVC association to be a match. Of the 97 associations we identified, only 15 had accepted corollaries within the NVC at the time of report preparation. The majority (10) of these accepted associations fell under the Madrean-Balconian Forest and Woodland Division [1.B.1.Nd]. In future years, the number of accepted associations at Saguaro NP is expected to increase as the NVC is refined and more data lead to new and expanded descriptions. In the absence of a complete hierarchy, we attempted to fit the park's associations into the existing framework (Table 6-3). All associations were placed in a division, with around 95% in Macrogroups, 78% in Groups, and 66% in Alliances. At this time, placements without an accepted Association are considered provisional and are subject to change as the NVC is further expanded and refined.

6.4.2 Overview of communities

6.4.2.1 Tucson Mountain District (14)
Sonoran Paloverde - Mixed Cacti Desert Scrub Group— (13 associations) While Saguaro NP is situated within the Sonoran

Desert, its vegetation communities span several other biomes due to the RMD's wide range in elevation and topographic landscapes (see Section 1.7.1). By contrast, 98.5% of the TMD (9,901 ha/24,466 ac) is occupied by vegetation associations with true desert affinities. These associations are contained within the Arizona upland subdivision of the Sonoran Desert (Brown 1994). This project classified a total of 13 associations within the Sonoran Paloverde - Mixed Cacti Desert Scrub Group (G293). This covers associations containing columnar cacti, typically saguaro (*Carnegiea gigantea*); shrubby, leguminous trees, typically yellow paloverde (*Parkinsonia microphylla*), interspersed with a mix of cacti and armed, microphyllus shrubs; and a low ground cover of subshrubs and occasional grasses (Figure 6-5). Across the bajada and low mountain slopes, triangle bur ragweed (*Ambrosia deltoidea*) is the dominant low shrub, while brittlebush (*Encelia farinosa*) takes over on the exposed mountain slopes. These Sonoran Desert associations are bisected by a braided network of washes that create dense green bands amid the open, adjacent shrublands.

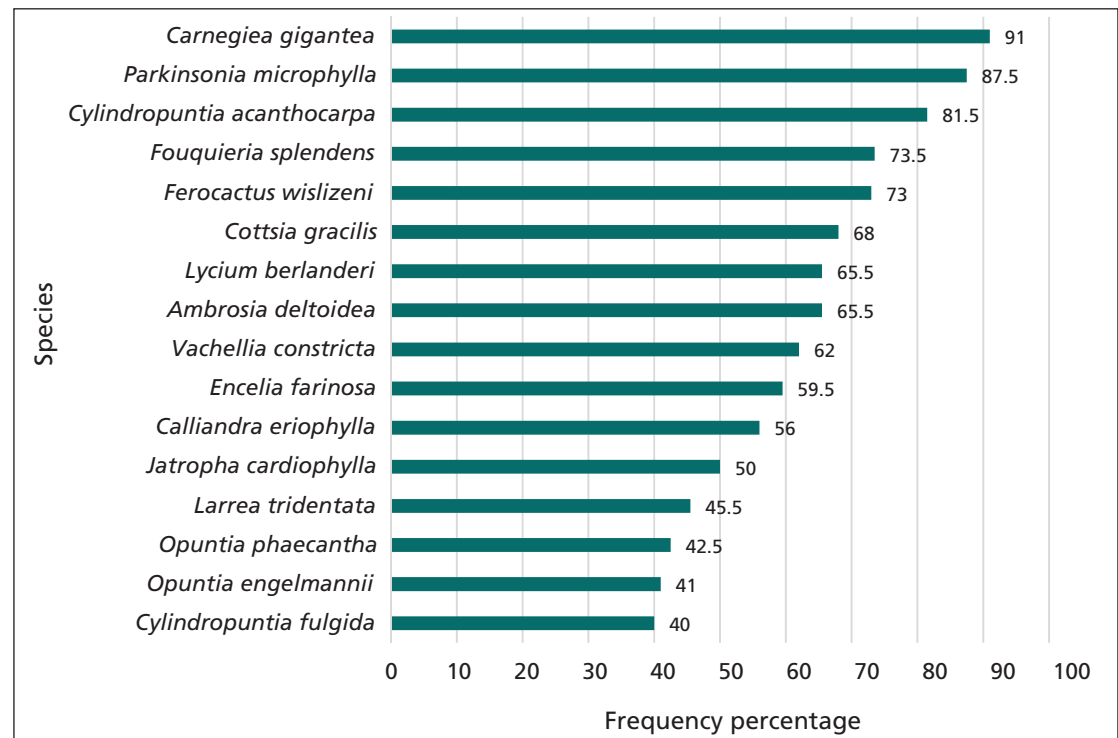


Figure 6-5. Bar plot of species constancy within classification plots ($n = 195$) used to describe Arizona upland communities at the Tucson Mountain District.

Table 6-3. Placement of Saguaro National Park vegetation-community associations within the NVC hierarchy.^A

NVC Division	NVC Macrogroup	NVC Group	NVC Alliance	NVC-accepted associations/ Total associations	
				RMD	TMD
Madrean-Balconian Forest & Woodland [1.B.1.Nd]	Madrean Lowland Evergreen Woodland [M010]	Madrean Encinal [G201]	Mexican Blue Oak Scrub Woodland [A0791]	1/1	–
			Unplaced	0/1	–
			Madrean Oak Scrub Woodland [A3101]	0/2	–
		Madrean Pinyon-Juniper Woodland [G200]	Madrean Pinyon - Juniper / Grass Woodland [A3132]	2/3	–
			Madrean Pinyon - Juniper / Shrub Woodland [A3131]	2/3	–
		Unplaced	Unplaced	0/1	–
	Madrean Montane Forest & Woodland [M011]	Madrean Lower Montane Pine - Oak Forest & Woodland [G203]	Arizona Cypress Forest & Woodland [A0163]	1/1	–
			Arizona Pine - Apache Pine - Chihuahuan Pine Woodland [A3112]	3/5	–
		Madrean Upper Montane Conifer - Oak Forest & Woodland [G202]	Madrean Douglas-fir / Oak Forest & Woodland [A3108]	1/1	–
		Unplaced	Unplaced	0/4	–
North American Warm Desert Scrub and Grassland [3.A.2.Na]	Mojave-Sonoran Semi-Desert Scrub [M088]	Mojave-Sonoran Bajada & Valley Desert Scrub [G295]	Unplaced	–	1
		Unplaced	Unplaced	0/3	1
		Sonoran Paloverde - Mixed Cacti Desert Scrub [G293]	Saguaro - Yellow Paloverde - Velvet Mesquite Desert Scrub [A3282]	0/16	7
			Jojoba - Crucifixion-thorn - Eastern Mojave Buckwheat Desert Scrub [A3283]	0/3	3
	North American Warm Desert Ruderal Scrub & Grassland [M512]	North American Warm Desert Ruderal Grassland [G677]	Ruderal Lovegrass Desert Grassland [A2687]	0/1	–
		North American Warm Desert Ruderal Scrub [G819]	Ruderal Velvet Mesquite Desert Scrub [A3163]	0/3	–
	North American Warm-Desert Xeric-Riparian Scrub [M092]	Warm Semi-Desert Shrub & Herb Dry Wash & Colluvial Slope [G541]	Desert-willow - Smoketree Desert Wash Scrub [A1044]	0/1	–
			Unplaced	0/5	1
	Chihuahuan Semi-Desert Grassland [M087]	Chihuahuan Desert Foothill - Piedmont & Lower Montane Grassland [G490]	Unplaced	0/4	1
Rocky Mountain Forest & Woodland [1.B.2.Nb]	Rocky Mountain Subalpine-High Montane Conifer Forest [M020]	Rocky Mountain Subalpine - Montane Aspen Forest & Woodland [G222]	Rocky Mountain Aspen Forest & Woodland [A2036]	0/1	–
	Southern Rocky Mountain Lower Montane Forest [M022]	Unplaced	Unplaced	0/4	–
		Southern Rocky Mountain Ponderosa Pine Open Woodland [G229]	Southern Rocky Mountain Ponderosa Pine / Grass Open Woodland [A3419]	2/3	–
		Southern Rocky Mountain White Fir - Douglas-fir Dry Forest [G226]	Southern Rocky Mountain Douglas-fir Forest & Woodland [A3454]	0/2	–
Western North American Grassland & Shrubland [2.B.2.Nf]	Southern Rocky Mountain Montane Shrubland [M049]	Unplaced	Unplaced	0/3	–
		Southern Rocky Mountain Gambel Oak - Mixed Montane Shrubland [G277]	Gambel Oak - Mountain Snowberry Shrubland [A3735]	1/1	–
Western North American Interior Chaparral [2.B.2.Ng]	Cool Interior Chaparral [M094]	Western North American Montane Sclerophyll Scrub [G282]	Unplaced	0/1	–
	Warm Interior Chaparral [M091]	Unplaced	Unplaced	0/1	–
		Western Madrean Chaparral [G281]	Manzanita - Ceanothus Chaparral [A3790]	0/7	–
			Unplaced	0/3	–
Western North American Interior Flooded Forest [1.B.3.Nd]	Interior Warm & Cool Desert Riparian Forest [M036]	Western Interior Riparian Forest & Woodland [G797]	Arizona Alder Riparian Forest [A0953]	0/1	–
			Arizona Sycamore Riparian Forest [A3801]	1/2	–
			Fremont Cottonwood - Velvet Ash - Goodding's Willow Riparian Forest & Woodland [A3803]	1/1	–
			Fremont Cottonwood - Velvet Ash - Goodding's Willow Riparian Forest & Woodland [A3803]	15/88	0/14

^AColor is used in this table to help the reader detect groupings of community types across headings.



Figure 6-6. *Parkinsonia microphylla* / *Tiquilia canescens* (*Zinnia acerosa*) Shrubland Association near the Camino Loma Alta trailhead.

Chihuahuan Desert Foothill - Piedmont & Lower Montane Grassland Group—. (1 association) The remaining 1.5% of the TMD (148 ha/366 ac) encompasses the transition to semi-desert grassland associations, which includes one association belonging to the Chihuahuan Desert Foothill - Piedmont & Lower Montane Grassland Group [G490]. This association is exclusively found on the mountain slopes in the vicinity of Wasson and Amole peaks. At the TMD, the shift to this community is marked by an increase in the consistency and diversity of perennial grasses, often sideoats grama (*Bouteloua curtipendula*), and the appearance of numerous succulents, including sotol (*Dasylirion wheeleri*), banana yucca (*Yucca baccata*), and Schott's century plant (*Agave schottii*).

6.4.2.2 Rincon Mountain District (84) Sonoran Paloverde - Mixed Cacti Desert Scrub Group—. (22 associations) Only 28% (7,727 ha/19,094 ac) of the RMD is occupied by associations with a strong Sonoran Desert affinity. Similar to the TMD, these associations are encompassed by the Arizona upland subdivision of the Sonoran Desert (Brown 1994). Desert associations in this district are more diverse than those at the TMD, with a total of 22 documented desert associations at the RMD, compared to only 13 at the TMD. This is in part due to the more diverse geology present throughout the lower reaches of the RMD, especially within the expansion lands around Hope Camp. These 22 associations fall within the Sonoran Paloverde - Mixed Cacti

Desert Scrub Group (G293). While these associations fit well within this group, none is currently accepted in the NVC. They include associations containing columnar cacti, typically saguaro (*Carnegiea gigantea*); shrubby, leguminous trees, typically yellow paloverde (*Parkinsonia microphylla*) and/or velvet mesquite (*Prosopis velutina*), interspersed with a mix of cacti and armed, microphyllus shrubs; and a low ground cover of subshrubs and occasional grasses. Unlike at the TMD, triangle bur ragweed (*Ambrosia deltoidea*) is uncommon throughout the RMD, with only one prominent area of dominance centered on a small hill toward the northern end of the Cactus Forest Loop Road. Instead, a variable mix of low shrubs occurs throughout, most prominently desert zinnia (*Zinnia acerosa*). A few of the additional associations only found at the RMD are defined by the dominance of low subshrubs that typically occupy low hills of limestone and sandstone (Figure 6-6). These include mariola (*Parthenium incanum*), woody crinklemat (*Tiquilia canescens*), and paleface (*Hibiscus denudatus*).

Warm Semi-Desert Shrub & Herb Dry Wash & Colluvial Slope Group—. (6 associations) Numerous desert wash communities occur throughout the North American Warm Desert Scrub and Grassland Division (3.A.2.Na). At the RMD, these include six associations in the Warm Semi-Desert Shrub & Herb Dry Wash & Colluvial Slope Group [G541], covering around 2% (505 ha/1,248 ac) of the district. Ranging from intermittently flooded shrubland to dense, canopied woodlands, these communities typically contain a canopy of velvet mesquite (*Prosopis velutina*) with a mixed, shrubby understory of catclaw acacia (*Senegalia greggii*), whitethorn acacia (*Vachellia constricta*), lotebush (*Ziziphus obtusifolia*), Warnock's snakewood (*Condalia warnockii*), and, occasionally, desert willow (*Chilopsis linearis*).

Western Interior Riparian Forest & Woodland Group—. (4 associations) Bisecting the Arizona upland communities and reaching higher into the range, drainage communities belonging to the Western Interior Riparian Forest & Woodland Group [G797] are present. At the RMD, this group encom-

passes four associations. Two are accepted by the NVC, covering 0.2% (50 ha/122 ac) of the district. These communities are characterized by a canopy of Arizona sycamore (*Platanus wrightii*), Mexican blue oak (*Quercus oblongifolia*), Fremont cottonwood (*Populus fremontii*), velvet ash (*Fraxinus velutina*), and/or Arizona alder (*Alnus oblongifolia*). Especially in proximity to spring-fed tinajas, the understory can include a diverse suite of obligate wetland plants, such as southern cattail (*Typha domingensis*), common buttonbush (*Cephalanthus occidentalis*), and Baltic rush (*Juncus balticus*). The primary examples of these communities occur near Rincon Creek and its tributaries, Chiminea and Madrona creeks.

North American Warm Desert Ruderal Scrub and North American Warm Desert Ruderal Grassland groups—. (4 associations) The remaining low-elevation desert communities are a mix of velvet mesquite (*Prosopis velutina*)-dominated ruderal scrub. Three associations fall within the North American Warm Desert Ruderal Scrub Group [G819], and one association falls within the North American Warm Desert Ruderal Grassland Group [G677]. Combined, these associations cover around 2% (540 ha/1,335 ac) of the district.

Chihuahuan Desert Foothill - Piedmont & Lower Montane Grassland Group—. (4 associations) Beginning at the upper elevational range of the Arizona upland communities, semi-desert grasslands belonging to the Chihuahuan Desert Foothill - Piedmont & Lower Montane Grassland Group [G490] appear and cover around 10% (2,768 ha/6,840 ac) of the district. This area of the park includes four associations, none of which is accepted in the NVC. These communities typically present as tree savannas, with an open canopy of velvet mesquite (*Prosopis velutina*), Arizona rosewood (*Vauquelinia californica*), ocotillo (*Fouquieria splendens*), and/or Mexican blue oak (*Quercus oblongifolia*) overlying a dense layer of perennial grasses. Grass composition varies with elevation (Appendix I) and exposure, with sideoats grama (*Bouteloua curtipendula*), Lehmann lovegrass (*Eragrostis lehmanniana*), tanglehead (*Heteropogon contortus*), and cane bluestem (*Bothriochloa barbinodis*)

providing the most consistent cover. As at the TMD, these communities mark the appearance of various succulents, including sotol (*Dasylirion wheeleri*), yucca (*Yucca madrensis*), beargrass (*Nolina microcarpa*), and Schott's century plant (*Agave schottii*).

Madrean Encinal Group—. (4 associations) As elevation increases, oaks (*Quercus* spp.) become the sole canopy dominant, marking the transition to the Madrean Encinal Group (G201). Covering around 16% (4,356 ha/10,763 ac) of the RMD, this group includes four associations, one of which is accepted in the NVC. It is characterized by an open canopy of oaks (*Quercus* spp.), with a mixed understory of shrubs and perennial grasses. Moving up the mountain through this group, Mexican blue oak (*Quercus oblongifolia*) is first to appear, with occasional patches of Sonoran scrub oak (*Quercus turbinella*), followed by Emory oak (*Quercus emoryi*) and Arizona white oak (*Quercus arizonica*) at the upper elevational limit (Figure 6-7). Perennial grasses, primarily bullgrass (*Muhlenbergia emersleyi*), and shrubs are a mix of pointleaf manzanita (*Arctostaphylos pungens*) and beargrass (*Nolina microcarpa*). Many areas of the park placed in this group have been subjected to historical fire disturbance, mainly from the Chiva (1989) and Box Canyon (1999) fires. Evidence of these

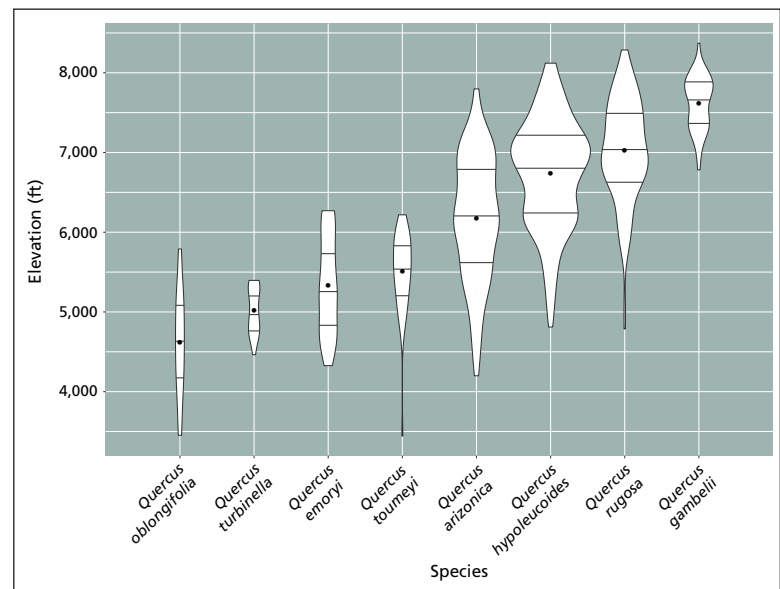


Figure 6-7. Violin plots depicting the elevational range of oak species at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot. The width of each "violin" is proportional to the number of observations.

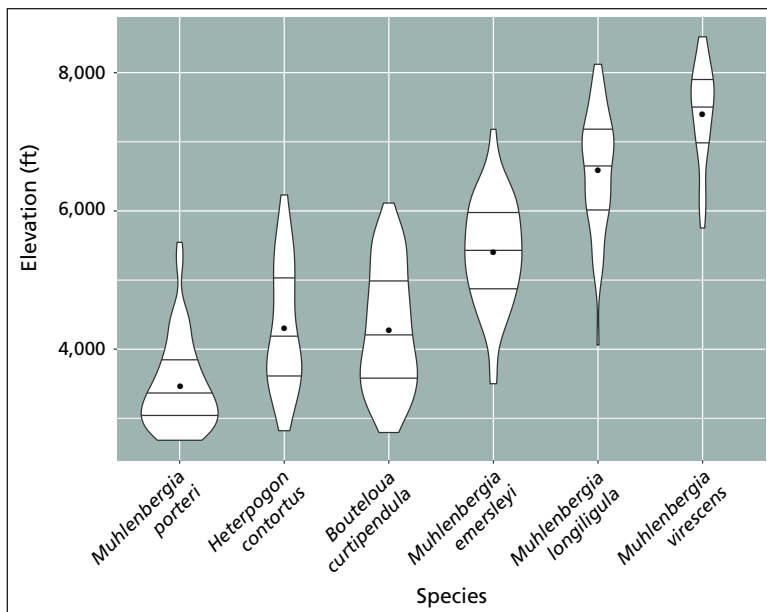


Figure 6-8. Violin plots depicting the elevational range of common perennial grass species at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot. The width of each “violin” is proportional to the number of observations.

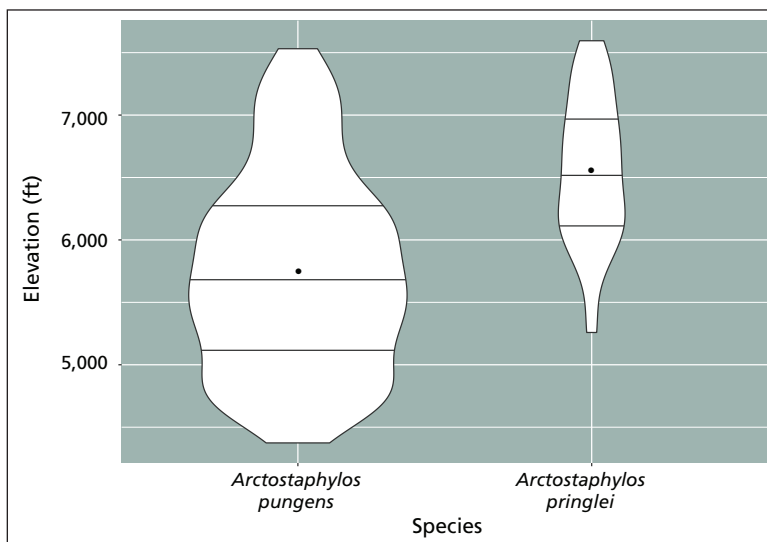


Figure 6-9. Violin plots depicting the elevational range of manzanita (*Arctostaphylos* spp.) at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot. The width of each “violin” is proportional to the number of observations.

fires is still present throughout these communities, with charred snags of both border pinyon (*Pinus discolor*) and alligator juniper (*Juniperus deppeana*) dotting the landscape. In the absence of these fires, some areas currently classified in the encinal group would be included in the Madrean Pinyon - Juniper Woodland Group (G200).

Madrean Pinyon-Juniper Woodland Group—. (6 associations) Above the encinal group, border pinyon (*Pinus discolor*) appears and marks the transition to the Madrean Pinyon-Juniper Woodland Group (G200). This group covers 22% (6,068 ha/14,993 ac) of the district and includes six associations, four of which are accepted in the NVC. At the RMD, this group is characterized by a canopy of border pinyon (*Pinus discolor*), alligator juniper (*Juniperus deppeana*), and a mix of oaks (*Quercus* spp.), with a variable understory of shrubs and perennial grasses. These associations range from open tree savannas at low elevations to dense woodlands at higher elevations. The oaks (*Quercus* spp.) include the elevational band dominated by Emory oak (*Quercus emoryi*), reaching to netleaf oak (*Quercus rugosa*) at the elevational limit (see Figure 6-7). As with the encinal group, bullgrass (*Muhlenbergia emersleyi*) is the primary perennial grass, but can be replaced by long-tongue muhly (*Muhlenbergia longiligula*) at higher elevations (Figure 6-8).

Western Madrean Chaparral Group—. (10 associations) Interspersed with the Madrean Woodland, a number of Western Madrean Chaparral (G281) communities appear and cover around 8% (2,220 ha/5,485 ac) of the district. A total of 10 classified associations at the RMD belong to this group, of which none is accepted by the NVC. These communities are defined by a dense shrub layer of manzanita (*Arctostaphylos* spp.) and/or oaks (*Quercus* spp.). The dominance of *Arctostaphylos* follows an elevational gradient with pointleaf manzanita (*Arctostaphylos pungens*) at the lower end and Pringle’s manzanita (*Arctostaphylos pringlei*) at the upper. Oak (*Quercus* spp.) follows the same distribution outlined in Figure 6-9.

Madrean Lower Montane Pine - Oak Forest & Woodland Group—. (6 associations) The appearance of emergent pines (*Pinus* spp.) above the oak (*Quercus* spp.) canopy marks the transition to the Madrean Lower Montane Pine - Oak Forest & Woodland Group [G203], which covers roughly 4% (1,069 ha/2,643 ac) of the district. At the RMD, this group contains six classified associations, of which four are accepted in the NVC. In order of appearance along the elevational gradient (low to high), dominant pines include Chihuahuan pine (*Pinus leiophylla*), Arizona pine (*Pinus arizonica*), southwestern white pine (*Pinus strobiformis*), and ponderosa pine (*Pinus ponderosa*) (Figure 6-10). Outlying occurrences of ponderosa pine (*Pinus ponderosa*) are associated with disjunct woodlands/forests that occur in Happy Valley Saddle, east of Juniper Basin campground, and south of Rincon Peak. Border pinyon (*Pinus discolor*) is typically absent from these communities, while alligator juniper (*Juniperus deppeana*) is an occasional associate. Silverleaf oak (*Quercus hypoleucoides*) is the primary dominant oak, with Arizona white oak (*Quercus arizonica*) appearing in lower-elevation examples and netleaf oak (*Quercus rugosa*) in the upper (see Figure 6-7).

Madrean Upper Montane Conifer - Oak Forest & Woodland Group—. (1 association) The appearance of emergent Douglas fir (*Pseudotsuga menziesii*) above the oak (*Quercus* spp.) canopy marks the transition to the Madrean Upper Montane Conifer - Oak Forest & Woodland Group [G202], which covers roughly 0.2% (58 ha/144 ac) of the district. At the RMD, this group contains one classified association that is accepted in the NVC. Netleaf oak (*Quercus rugosa*) is the primary dominant oak in this association (see Figure 6-7).

Madrean Montane Pine - Oak Forests & Woodlands (Unplaced)—. (4 associations) Interspersed with upper and lower Madrean Montane Pine - Oak Forests & Woodlands [G203, G202], four dense oak woodland and forest associations appear that do not contain pine (*Pinus* spp.). These associations cover around 2% (589 ha/1,466 ac) of the RMD. Based on species composition and distribution, these associations belong in the

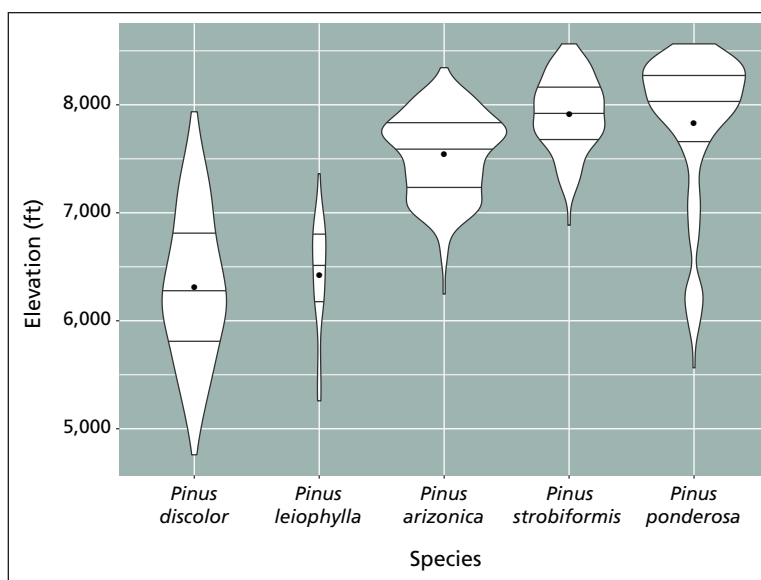


Figure 6-10. Violin plots depicting the elevational range of pine (*Pinus* spp.) at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot. The width of each "violin" is proportional to the number of observations.

Madrean - Balconian Forest & Woodland Division [1.B.1.Nd]. However, no accepted group or alliance exists that matches these communities. These associations represent mature (≥ 5 -m), dense oak woodlands that encompass the oak elevational gradient from Arizona white oak (*Quercus arizonica*) to netleaf oak (*Quercus rugosa*) (see Figure 6-7). Understories are sparse to absent.

Southern Rocky Mountain Ponderosa Pine Open Woodland Group—. (6 associations) Above these communities, the understory oaks, except Gambel oak (*Quercus gambelii*), begin to decrease in cover and consistency, marking the transition to the Southern Rocky Mountain Ponderosa Pine Open Woodland Group [G229]. These communities span the highest reaches of the Rincon Mountains, covering around 2% (535 ha/1,322 ac) of the district. Of the six documented associations, four are accepted in the NVC. While not specifically mentioned in the group description, we included communities dominated by Arizona pine (*Pinus arizonica*), previously classified as both a subspecies and variety of ponderosa pine (*Pinus ponderosa*). These communities are defined by an open-to-closed canopy of ponderosa pine (*Pinus ponderosa*) or Arizona pine (*Pinus arizonica*), with a vari-

able understory of graminoids and ferns. The most-common understory species are western brackenfern (*Pteridium aquilinum*), screwleaf muhly (*Muhlenbergia virescens*), and pine dropseed (*Muhlenbergia tricholepis*).

Southern Rocky Mountain White Fir - Douglas-Fir Dry Forest Group— (2 associations) Occupying a similar elevation range as the Southern Rocky Mountain Ponderosa Pine Open Woodland Group [G229], the Southern Rocky Mountain White Fir - Douglas-Fir Dry Forest Group [G226] spans the sheltered, north-facing slopes of Mica Mountain and Rincon Peak. This change is marked by the consistent presence and typical dominance of Douglas fir (*Pseudotsuga menziesii*), with or without associate pines (*Pinus* spp.). We classified two associations within this group, which covers around 1% (250 ha/618 ac) of the RMD. Neither is accepted in the NVC.

Upper-elevation Post-fire Communities (unplaced) and Rocky Mountain Subal-

pine - Montane Aspen Forest & Woodland Groups— (5 associations) The remaining 4% of the district is spread across a suite of unique and/or restricted communities. In areas of fire disturbance around Mica Mountain, mainly from the Helen's 2 Fire, we described four associations. Also in the higher reaches of the range, we described one association within the Rocky Mountain Subalpine - Montane Aspen Forest & Woodland Group [G222]. This association is defined by the overwhelming dominance of quaking aspen (*Populus tremuloides*), and is found in scattered groves around Mica Mountain and Rincon Peak. The largest and most prominent of these groves occurs on the eastern flank of the range, near the Spud Rock campground (Figure 6-11).

6.5 The flora

Over the course of this project, a total of 538 species were observed on plots: 506 at the RMD and 154 at the TMD, with 122 species recorded at both districts. During field-data collection, three new species were identified

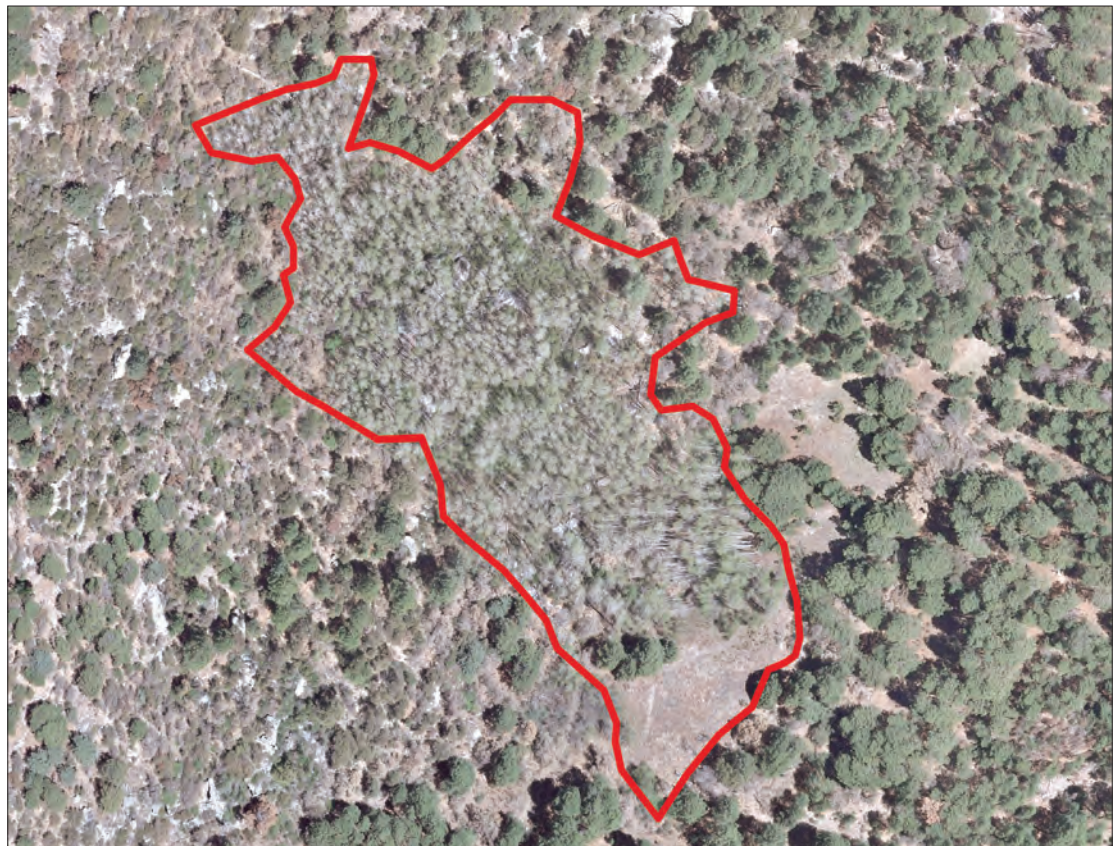


Figure 6-11. Quaking aspen (*Populus tremuloides*) grove near Spud Rock campground, Rincon Mountain District.

and added to the park plant checklist (Table 6-4). In addition, one species believed to be extirpated from the park, smooth sumac (*Rhus glabra*), was documented. A full list of species recorded during this project can be found in Appendix J.

Based on the rarity ranking system originally developed by The Nature Conservancy (now managed by NatureServe), we evaluated all plants observed during this effort to determine if any were considered rare or imperiled. “Global rank” describes each species’s status globally and indicates the risk of extinction, with rank G1 being critically imperiled and G5 being secure. State ranks are also on a scale of 1–5, relative to distributions and abundances within state boundaries.

Twelve species had a rank of S3 (Table 6-5), defined as “Vulnerable–At moderate risk of extinction due to a restricted range, relatively few populations, recent or widespread declines, or other factors” (natureserve.org), or lower. Of these, two species also had a comparable global ranking of G3 or lower. Two other species had a state ranking of S3 but a global ranking of G4 (defined as “Apparently secure”). More details on these ranking systems are available from NatureServe.

6.6 Final products and geodatabase delivery

Both spatial and tabular data collected during this project were input into a geodatabase designed to support relationships

Table 6-4. New species records collected during inventory fieldwork at Saguaro National Park.		
Family	Scientific name	Common name
Phrymaceae	<i>Mimulus cardinalis</i>	scarlet monkeyflower
Solanaceae	<i>Solanum americanum</i>	American black nightshade
Cactaceae	<i>Peniocereus greggii</i> var. <i>transmontanus</i>	nightblooming cereus

between the different data sources. This geodatabase contains all final map data, including photographs from plots and polygon locations, and pdf versions of the type descriptions. Each spatial feature in the database (points and polygons) can be selected such that data listing species and their associated cover classes is displayed. Searches can be performed both forward and backward in this format, so the user can browse data by species and see all the locations, or by location and see all the species. Sensitive data, such as locations of threatened and endangered species, will be shown only in internal NPS versions. A description of the geodatabase structure and attachment formats is provided in Appendix K.

All final products, including this report and the geodatabase, are available for download and viewing from the NPS [DataStore](#) and Vegetation Mapping Inventory website. Data can also be requested from the Sonoran Desert Network or accessed via the [SODN website](#).

Table 6-5. Species observed during project fieldwork with either global or Arizona state rarity rankings.

Family	Scientific name	Common name	Global rank ^A	State rank ^B	Nativity	RMD	TMD
Pinaceae	<i>Pinus leiophylla</i> var. <i>chihuahuana</i>	Chihuahuan pine	G5T4	S3	Native	X	–
Cactaceae	<i>Echinocereus rigidissimus</i>	rainbow hedgehog cactus	G5	S3	Native	X	–
Fabaceae	<i>Lysiloma watsonii</i>	littleleaf false tamarind	G4	S1	Native	X	–
Asteraceae	<i>Perityle lemmonii</i>	Lemmon's rockdaisy	G4	S3	Native	X	–
Cactaceae	<i>Cylindropuntia versicolor</i>	staghorn cholla	G4	S2S3	Native	X	X
Orchidaceae	<i>Malaxis porphyrea</i>	Cochise adder's-mouth orchid	G4	S2	Native	X	–
Ranunculaceae	<i>Aquilegia chrysantha</i>	golden columbine	G4	S3	Native	X	–
Fabaceae	<i>Dalea lumholtzii</i>	Lumholtz's prairie clover	G3G4	S2S3	Native	X	–
Solanaceae	<i>Lycium parishii</i>	Parish's desert-thorn	G4	S3	Native	–	X
Crassulaceae	<i>Graptopetalum bartramii</i>	Patagonia Mountain leatherpetal	G3	S3	Native	X	–
Malvaceae	<i>Abutilon parishii</i>	Parish's Indian mallow	G3	S3	Native	–	X
Primulaceae	<i>Samolus vagans</i>	Chiricahua Mountain brookweed	GUQ	S2	Native	X	–

^AG3 = Vulnerable—At moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors. G4 = Apparently Secure—At fairly low risk of extinction or elimination due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors. G5 = Secure—At very low risk of extinction or elimination due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats. GUQ = Unrankable because of daunting taxonomic questions. T# = Rank applies to a subspecies or variety. A numeric range rank (e.g., G2G3) is used to indicate uncertainty about the exact status of a taxon or ecosystem type.

^BS1 = Critically Imperiled—At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors. S2 = Imperiled—At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors. S3 = Vulnerable—At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors. A numeric range rank (e.g., S1S2) is used to indicate uncertainty about the exact status of a taxon or ecosystem type.

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Appendices 115

Screenshot showing a graphic example of the first page of the datasheet used to record information in field plots.

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Appendix B. Polygon Datasheets

 Sonoran Desert Network Inventory and Monitoring Program		National Park Service U.S. Department of the Interior		
		Page ____ of ____		
PARK:	Date (MM/DD/YYYY):	Time (00:00):	Crew:	PolyCode:
Map:		Plot Id(s):		Formation:
Polygon visited?		Orig. PolyID(s):		Submap(s):
PolyCode suffix "D" for visited, "NV" for not visited or no photos		Dominants and common associates: (List strata below each taxon; the taxa will be assigned dominance in the first stratum listed and ranks will be assigned in order from left to right in each stratum)		
Recon/GPS:		Alliance/Association Name:		
Camera:		Veg. Notes:		
Photos:				
N:				
E:				
S:				
W:				
		Difference from surrounding veg:		
Proofread:		Landscape notes:		
Copied:				
GIS Edits:				
Entered:	Bounding features:		Elev (ft):	
QA/QC:			Aspect:	
If datasheet found completed, please call (520) 343-8845				

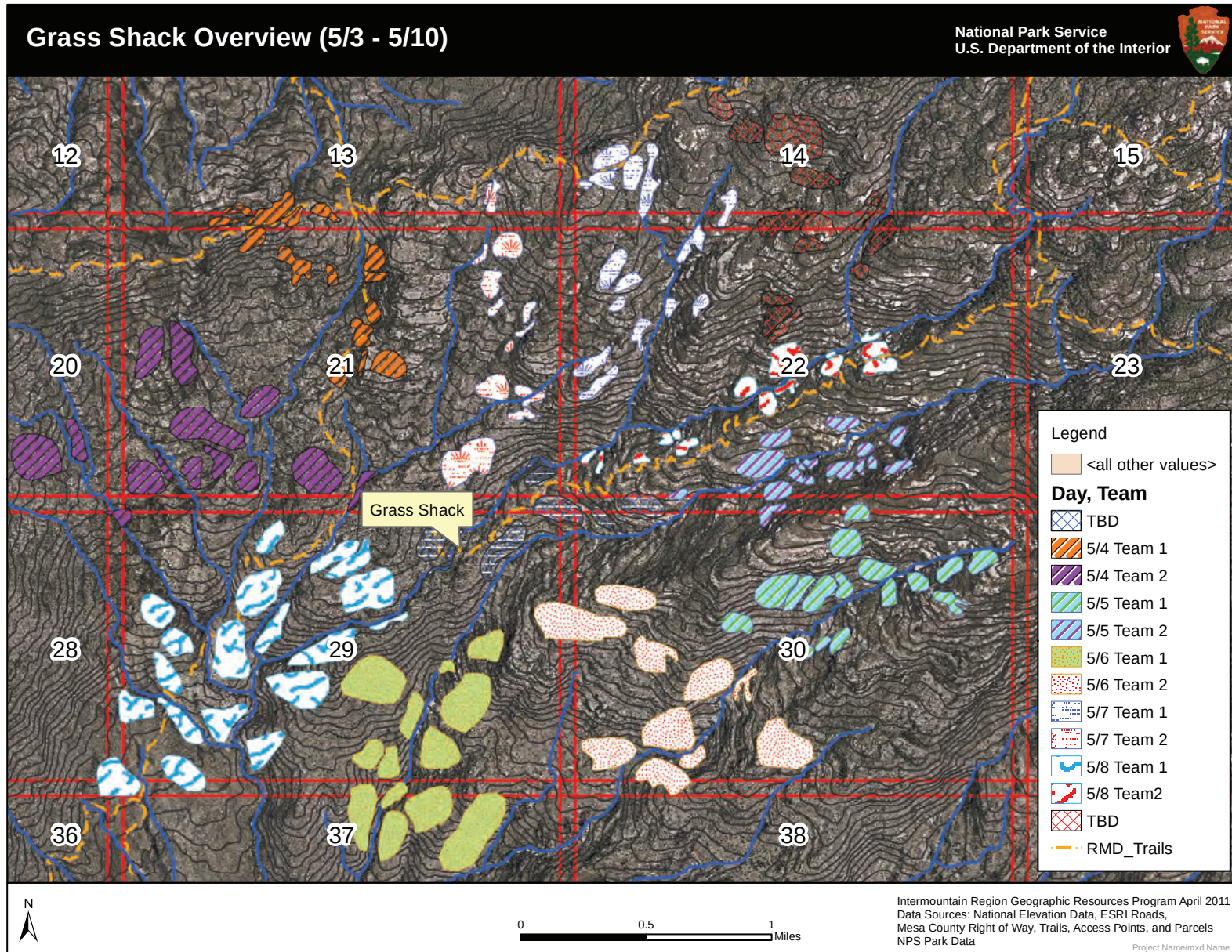
VegMap_ShortForm_Polygon_datasheet_v4_20110301.xlsx

Screenshot showing a graphic example of the first page of the datasheet used to record polygon information.

 Sonoran Desert Network Inventory and Monitoring Program		National Park Service U.S. Department of the Interior
		Page ____ of ____
Continued notes:		
If datasheet found completed, please call (520) 343-8845		
VegMap_ShortForm_Polygon_datasheet_v4_20110301.xlsx		

Screenshot showing a graphic example of the first page of the datasheet used to record polygon information.

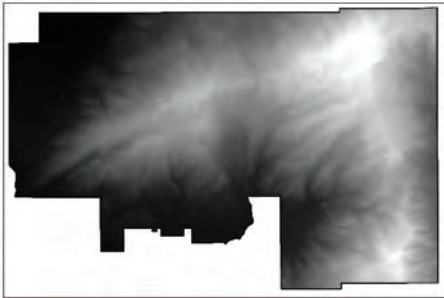
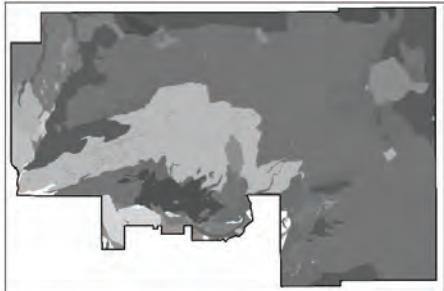
Appendix C. Example of Validation Phase Planning Map



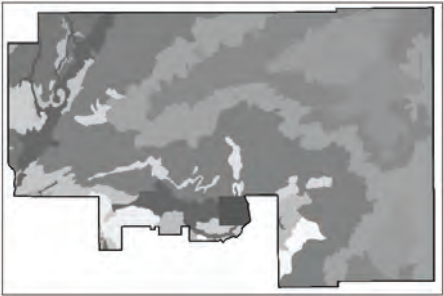
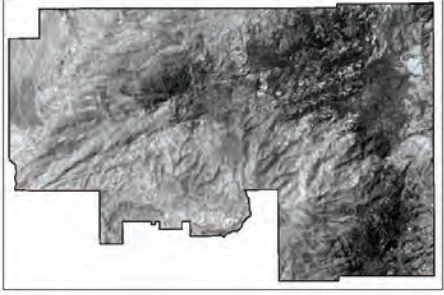
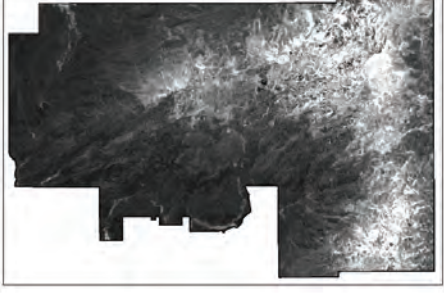
Validation-phase planning map for Grass Shack area.

Appendix D. Raster Files Used in the Supervised Classification of Both Districts of Saguaro National Park

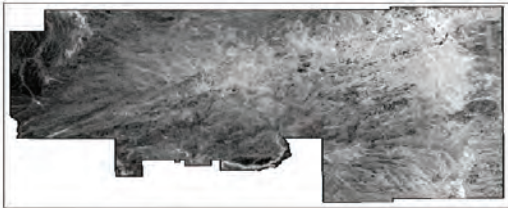
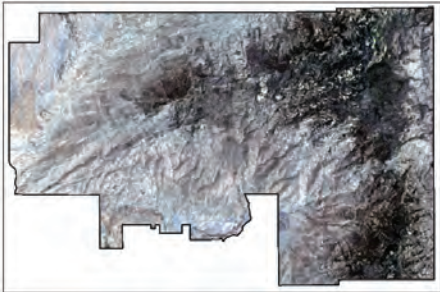
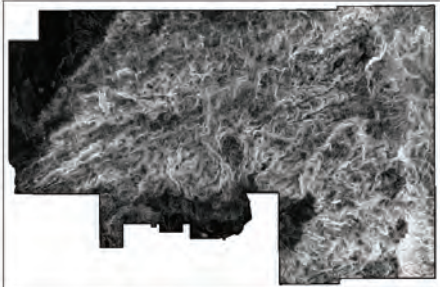
Raster files used in the supervised classification of both districts of Saguaro National Park.

Name	District	Bands	Spatial resolution (m)	Notes	Image
Digital elevation model (DEM)	Both	1	30	This digital elevation model was derived from the 2011 LiDAR dataset captured at Saguaro National Park.	
Geology (Geo)	Both	1	30	This raster was derived from the Saguaro National Park Geologic Inventory Report (Graham 2010).	

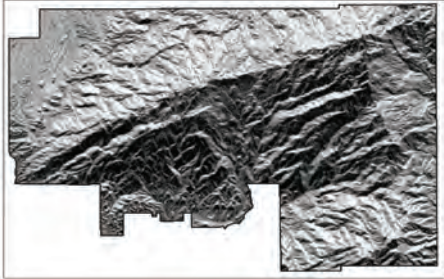
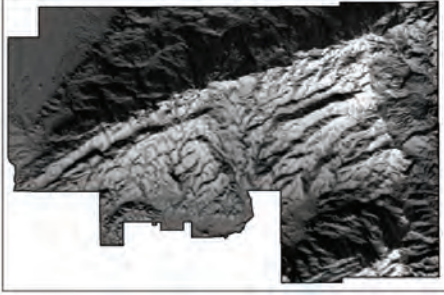
Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Soil	Both	1	30	This raster was derived from the 2006 Soil Survey for Saguaro National Park.	
Multitemporal Kauth Thomas transformation (Mtk)	Both	12	30	These rasters were created by our USGS collaborators from pre and post-monsoon thematic mapper scenes, 6 bands each.	
Normalized Difference Vegetation Index (NDVI)	Both	3	30	These rasters were created from each of the thematic mapper scenes, 1 band for each, by our USGS collaborators. NDVI is calculated as: $NDVI = (NIR - Red) / (NIR + Red)$. NDVI rasters give an estimation of green vegetation.	

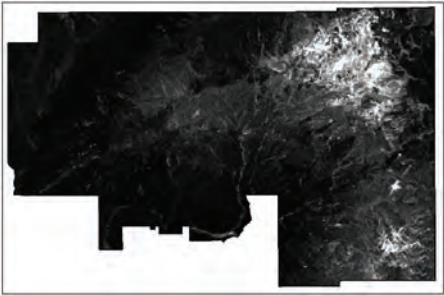
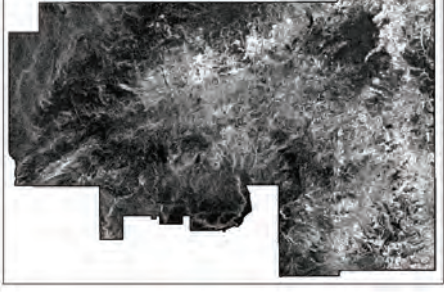
Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Soil Adjusted Vegetation Index (SAVI)	Both	3	30	These rasters were created from each of the thematic mapper scenes, 1 band for each, by our USGS collaborators. SAVI is calculated as: $SAVI = (1 + L) (NIR - Red) / (NIR + Red + L)$. SAVI is a vegetation index adjusted for soil brightness (Huete 1988).	
Thematic Mapper (Pre-Monsoon, Post-Monsoon, Fall)	Both	6	30	This raster was acquired from the USGS national map and was atmospherically corrected using ATCOR2 by our USGS collaborators. This scene was from 06/22/2011.	
Slope (degrees)	Both	1	30	This raster was created using the slope tool in the spatial analyst extension of ArcMap (ESRI, 2011). Slope was calculated in degrees using the planar method.	

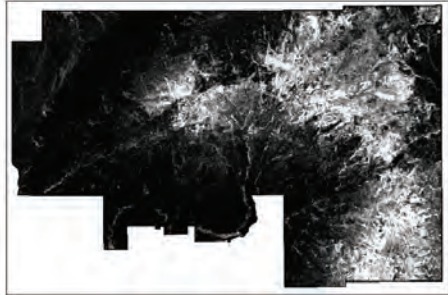
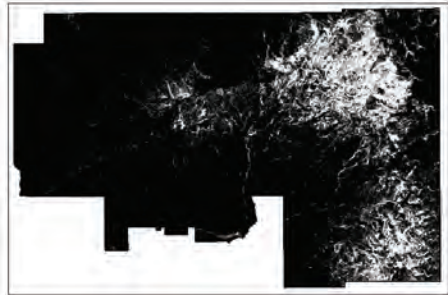
Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Northness	Both	1	30	This raster was created from an aspect raster. The aspect raster's pixel values were converted from degrees to radians ($\pi \times \text{degrees}/180$). Then eastness was calculated as $\cos(\text{radians})$. This converts degrees to values ranging from -1 to 1, with 1 due north and -1 for south.	
Eastness	Both	1	30	This raster was created from an aspect raster. The aspect raster's pixel values were converted from degrees to radians ($\pi \times \text{degrees}/180$). Then eastness was calculated as $\sin(\text{radians})$. This converts degrees to values ranging from -1 to 1, with 1 for due east and -1 for west.	
Solar Radiation	Both	3	30	This 3-band raster was created from a DEM using the area solar radiation tool in the spatial analyst extension of ArcMap (ESRI 2011). We selected the 'special days' time configuration which creates the bands, 1 each that coincides with the summer solstice, equinox, and winter solstice.	

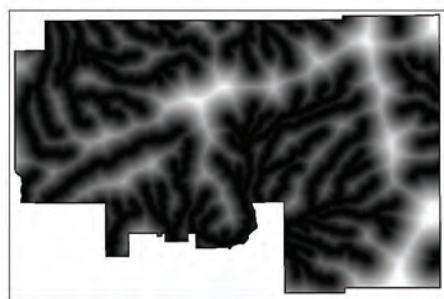
Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Canopy Height Model (CHM) roughness	RMD	1	30	This raster was derived from the CHM and standard deviation of 1-m CHM pixel values across a 30-m pixel.	
Cover 1-5	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation from 1 to 5 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	
Cover 0.5-2	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation from 0.5 to 2 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	

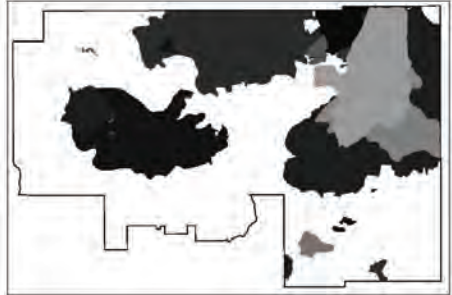
Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Cover 2-10	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation from 2 to 10 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	
Cover >20	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation >20 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	
Cover 5-15	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation from 5 to 15 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	

Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Cover 15–25	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation from 15 to 25 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	
Cover 10–20	RMD	1	30	This raster was derived from a 1-m CHM raster and depicts percent cover of vegetation from 10 to 20 m. Values were calculated by tallying the number of 1-m pixel values within the height range, nested within a 30-m pixel ($n/900$).	
Hydrology Distance	RMD	1	30	This raster was derived from the DEM of Saguaro National Park. A feature of washes, arroyos, and drainages was created using the hydrology toolset in the spatial analyst extension of ArcMap (2011). The final raster was created using the 'euclidian distance' tool to assign pixel values based on their distance from hydrologic features.	

Raster files used in the supervised classification of both districts of Saguaro National Park (continued).

Name	District	Bands	Spatial resolution (m)	Notes	Image
Years since last fire (YSLF)	RMD	1	30	This raster was derived from a polygon feature of all fire boundaries in RMD up until 2011. Pixels were assigned values based on the number of years since the last fire.	

Appendix E. Key to Vegetation Associations of Saguaro National Park

This key is a combination of the two keys developed for the accuracy assessment of the Rincon and Tuscon Mountain districts of Saguaro National Park. Association names have been changed to reflect their final naming convention.

Key to subgroups

- 1' Community is primarily associated with upland habitats 2
- 2' Community is characterized by the noteworthy presence and/or dominance of coniferous species 3
 - 3' The upper-canopy stratum (>5 m) is dominated by large conifers, including ponderosa pine (*Pinus ponderosa*), Arizona pine (*Pinus arizonica*), Douglas fir (*Pseudotsuga menziesii*), southwestern white pine (*Pinus strobiformis*), and Chihuahuan pine (*Pinus leiophylla*), excluding Arizona cyress (*Cupressus arizonica*), with combined cover above 10%. This group includes regenerating conifer forest.....**Group A**
 - 3'' The lower-canopy stratum (2–5 m) contains border pinyon (*Pinus discolor*), ranging from a common associate (~5%) to the sole dominant (40+%) with co-dominant/subdominant alligator juniper (*Juniperus deppeana*) and various oak species, including Emory oak (*Quercus emoryi*), Arizona white oak (*Quercus arizonica*), silverleaf oak (*Quercus hypoleucoides*), netleaf oak (*Quercus rugosa*), and Toumey oak (*Quercus toumeyii*). Scattered, emergent conifers (those listed for Group A) may be present, but should never compete for dominance with the low-canopy trees**Group B**
- 2'' Community not as described above 4
 - 4' Community is characterized by the dominance of oaks (*Quercus* sp.), manzanita (*Arctostaphylos* sp.), cat-claw mimosa (*Mimosa aculeaticarpa*), and/or ceanothus (*Ceanothus* sp.), without a dominant understory of perennial grass or forbs 5
 - 5' Community characterized by the presence and/or dominance of Gambel oak (*Quercus gambelii*)**Group I**
 - 5'' Community has dominant manzanita (*Arctostaphylos* sp.), or ceanothus (*Ceanothus* sp.) or, if the community is defined by oak (*Quercus* sp.) presence/dominance, it is not by Gambel oak (*Quercus gambelii*) 6
 - 6' Oaks (*Quercus* sp.) are the primary dominants, ranging from a shrubland to a woodland formation. Community does not contain dominant manzanita (*Arctostaphylos* sp.), dominant perennial grass, or ceanothus (*Ceanothus* sp.)**Group D**
 - 6'' Community is defined by a dense (20+%) subcanopy or low canopy dominated by manzanita (*Arctostaphylos* sp.), ceanothus (*Ceanothus* sp.), and/or catclaw mimosa (*M. aculeaticarpa*) that is co-dominant with or considerably more dominant than a mix of short-statured oak (*Quercus* sp.)**Group F**
 - 4'' Community not as described above 7
 - 7' Community defined by the prevalence of bedrock slabs, with sparse vegetation often dominated by rock-loving spikemoss (*Selaginella rupicola*).....**Fouquieria splendens** / (**Opuntia engelmannii**) / **Selaginella rupicola** Sparse Rock Outcrop
 - 7'' Community not as above 8
 - 8' Upper-elevation (>2,100 m) communities that often exhibit clear signs of historic fire disturbance. Dominant species include western brackenfern (*Pteridium aquilinum*), fragrant snakeroot (*Ageratina herbacea*), Fendler's ceanothus (*Ceanothus fendleri*), quaking aspen (*Populus tremuloides*), and/or screwleaf muhly (*Muhlenbergia virescens*). Some examples with dominant quaking aspen (*P. tremuloides*) may not have been subject to recent fire activity**Group I**
 - 8'' Community not as above 9

9' Community contains a dominant understory of perennial grasses (excluding *Hilaria belangeri*) and spans mountain slopes of variable type. The community is not present on an alluvial fan or pediment 10

10' Community is a tree/shrub savanna with a low canopy dominated by oaks (*Quercus* sp.) and a field by perennial grass, typically bullgrass (*Muhlenbergia emersleyi*). In most cases, these communities exhibit distinct signs of historic fire disturbance. Border pinyon (*Pinus discolor*) is an inconsistent species that is usually absent, but can occasionally provide limited cover (1%), typically in unburned inclusions within areas of historic fire disturbance Group C

10" Community is dominated by shrubs, succulents, perennial forbs, and perennial grasses. If trees are present, they are typically composed of velvet mesquite (*Prosopis velutina*), Arizona rosewood (*Vauquelinia californica*), and/or ocotillo (*Fouquieria splendens*) without noteworthy oaks (*Quercus* sp.). If oaks (*Quercus* sp.) are present they should provide similar cover to one of the previously listed species Group H

9" If community contains dominant grasses, it should span an alluvial fan or pediment. Vegetation is characterized by a low canopy of velvet mesquite (*Prosopis velutina*) and/or yellow paloverde (*Parkinsonia microphylla*), with a variable subcanopy that can include brittlebush (*Encelia farinosa*), creosote (*Larrea tridentata*), whitethorn acacia (*Vachellia constricta*), jojoba (*Simmondsia chinensis*), and/or catclaw acacia (*Senegalia greggii*) Group G

1" Community spans or is directly adjacent to a hydrologic feature which causes a noticeable change in canopy height and density and/or a shift in species composition Group E

Group A: Mid- to upper-elevation (1,500–2,600 m) woodlands and forests dominated by pines (*Pinus* sp.) and Douglas fir (*Pseudotsuga* sp.) with an understory ranging from absent to oak (*Quercus* sp.) or perennial-grass dominated.

1' Community includes an understory of shrubby and/or tree-size oaks, including silverleaf oak (*Quercus hypoleucoides*), netleaf oak (*Quercus rugosa*), Emory oak (*Quercus emoryi*), and/or Arizona white oak (*Quercus arizonica*) (excludes Gambel oak (*Quercus gambelii*)) with cover ranging from subdominant (10%) to co-dominant (40+%) with the overstory of large pines. In post-fire regenerating examples, the conifers and oaks occupy the same stratum 2

2' The upper-canopy stratum contains variable cover of Douglas fir (*Pseudotsuga menziesii*) ranging from a common associate (10%) to the sole dominant (50+%) 3

3' Ponderosa pine (*Pinus ponderosa*) is present as a co/sub dominant with/to Douglas fir (*P. menziesii*)
.....*Pseudotsuga menziesii* / *Quercus rugosa* Forest Association

3" Arizona pine (*Pinus arizonica*) is present as a co/sub dominant with/to Douglas fir (*P. menziesii*)
.....*Pseudotsuga menziesii* - *Pinus arizonica* / *Quercus hypoleucoides* Forest Association

2" Douglas fir (*P. menziesii*) is absent or only represented by uncommon, scattered individuals 4

4' Conifers are primarily composed of Chihuahuan pine (*Pinus leiophylla*)
Pinus leiophylla / *Quercus hypoleucoides* Woodland Association

4" Conifers not as described above 5

5' Conifers are primarily composed of Arizona pine (*P. arizonica*) 6

6' Community is a mature woodland/forest with trees ranging from 5 to 30 m tall
Pinus arizonica / *Quercus hypoleucoides* Woodland Association

6" Community is a post-fire regenerating woodland with most trees ranging from 1 to 4 m
Pseudotsuga menziesii / *Quercus rugosa* Forest Association

5" Conifers are primarily composed of ponderosa pine (*P. ponderosa*) 7

- 7' Understory does not contain noteworthy Emory oak (*Quercus emoryi*)
Pinus ponderosa / *Quercus hypoleucoides* Woodland Association
- 7" Understory does contain noteworthy Emory oak (*Q. emoryi*)
Pinus ponderosa / *Quercus arizonica* - *Quercus emoryi* Woodland Association
- 1" Community does not include a dominant understory of shrubby and/or tree-size oaks (excluding Gambel oak (*Q. gambelii*)). If present, oak species provides sparse cover (<5%) 8
- 8' The upper-canopy stratum contains variable cover of Douglas fir (*P. menziesii*) ranging from a common associate (10%) to the sole dominant (50+%) 9
- 9' Douglas fir (*P. menziesii*) is the sole canopy dominant or is co-dominant with southwestern white pine (*Pinus strobiformis*), typically providing cover above 50%. Total canopy cover ranges from 60% to 90%
Pseudotsuga menziesii / *Pinus strobiformis* Forest Association
- 9" Ponderosa pine (*P. ponderosa*) or Arizona pine (*P. arizonica*) is present as a sub/co-dominant to/with Douglas fir (*P. menziesii*). Total canopy cover ranges from 30% to 60%*Pseudotsuga menziesii* - *Pinus ponderosa* / (*Quercus gambelii*) Forest Association
- 8" If present, Douglas fir (*P. menziesii*) is represented by uncommon, scattered individuals with cover less than 5% 10
- 10' Understory contains a consistent and noteworthy (10–40%) layer of perennial graminoids, most commonly dominated by screwleaf muhly (*Muhlenbergia virescens*), with a relatively open canopy (10–40%) 11
- 11' Dominant conifers are a mix of ponderosa pine (*P. ponderosa*) and southwestern white pine (*P. strobiformis*)*Pinus ponderosa* (*Pinus strobiformis*) / *Muhlenbergia virescens* Woodland Association
- 11" Dominant conifers are a mix of Arizona pine (*P. arizonica*) and southwestern white pine (*P. strobiformis*)*Pinus arizonica* (*Pinus strobiformis*) / *Muhlenbergia virescens* Forest Association
- 10" Understory does not contain a consistent and noteworthy (>10%) layer of perennial grass. When present, grasses range from a consistent, but very low cover (1–2%) distribution, to small and inconsistent patches where cover may reach above 10%. The upper canopy should be denser, with cover ranging from 40% to 80% 12
- 12' The understory is dominated by a consistent and dense layer of western brackenfern (*Pteridium aquilinum*), with cover typically above 20% 13
- 13' Overstory conifers are dominated by ponderosa pine (*P. ponderosa*) and southwestern white pine (*P. strobiformis*)*Pinus ponderosa* / *Pteridium aquilinum* Forest Association
- 13" Overstory conifers are dominated by Arizona pine (*P. arizonica*) and southwestern white pine (*P. strobiformis*)*Pinus arizonica* / *Pteridium aquilinum* Forest Association
- 12" The understory is not dominated by a consistent and dense layer of western brackenfern (*P. aquilinum*). Instead, the understory is a sparse mix of graminoids and perennial forbs with total cover ≤5%. If present, western brackenfern (*P. aquilinum*) provides only patchy cover 14
- 14' Overstory conifers are dominated by ponderosa pine (*P. ponderosa*) and southwestern white pine (*P. strobiformis*)*Pinus ponderosa* - *Pinus strobiformis* Forest Association
- 14" Overstory conifers are dominated by Arizona pine (*P. arizonica*) and southwestern white pine (*P. strobiformis*)*Pinus arizonica* Forest Association

Group B: Mid- to upper-elevation (1,200–2,500 m) woodlands dominated by a mix of border pinyon (*Pinus discolor*), alligator juniper (*Juniperus deppeana*), and oaks (*Quercus* sp.), with a variable understory ranging from absent to shrub and grass-dominated.

- 1' Arizona cypress (*Cupressus arizonica*) is a co-dominant with, or more dominant than, border pinyon (*Pinus discolor*). The understory may contain dominant oak (*Quercus* sp.) and/or manzanita (*Arctostaphylos* sp.) cover
.....***Cupressus arizonica* / *Quercus hypoleucoides* Forest Association**
- 1" Arizona cypress (*C. arizonica*) is absent or provides scant cover (<<5%) 2
- 2' Manzanita (*Arctostaphylos* sp.) is a consistent and dense subcanopy dominant with cover similar to, or greatly surpassing, the low-canopy trees. The field is extremely sparse with cover rarely surpassing 1%
.....**Group F**
- 2" If present, manzanita (*Arctostaphylos* sp.) is a patchy common associate, occasionally with small, dense inclusions of dominance 3
- 3' The community formation ranges from a tree/shrub savanna with a dominant shrub layer (*Arctostaphylos* sp., and/or *Garrya wrightii*), perennial grasses (mostly *Muhlenbergia emersleyi*), and succulents (*Agave schottii*), to an open woodland with a similar but less consistent shrub layer. Low-canopy oak (*Quercus* sp.) and border pinyon (*Pinus discolor*) typically provide cover ranging from 10% to 40% 4
- 4' Community shows obvious signs (snags) of a major fire disturbance and border pinyon (*Pinus discolor*) is absent to extremely patchy with minimal cover (<2%). Community is characterized by an open (5–15%) canopy of oaks (*Quercus* sp.) present as shrubs or small (2–3 m) trees, a variable subcanopy (0.5–2 m), and a dominant field (<0.5 m) of bullgrass (*Muhlenbergia emersleyi*)**Group C**
- 4" Community not as above 5
- 5' The dominant oak species is Toumey oak (*Quercus toumeyii*), typically present in a shrubby growth form with cover ranging from 5% to 15%. Sonoran shrub oak (*Quercus turbinella*) and netleaf oak (*Quercus rugosa*) may also be present and either one can occasionally become a co-dominant with Toumey oak (*Q. toumeyii*). This community is strongly associated with bedrock/boulder dominated slopes
.....***Pinus discolor* / *Quercus toumeyii* Woodland Association**
- 5" The dominant oak species is Emory oak (*Quercus emoryi*) and/or Arizona white oak (*Quercus arizonica*). If present, Toumey oak (*Q. toumeyii*) may provide limited, patchy cover (<1–2%), typically associated with inclusions of bedrock/boulder dominance 6
- 6' The dominant oak species is Emory oak (*Q. emoryi*), which provides cover ranging from [2] 5–15 [20]%. At the upper and lower elevational limits of this community, Arizona white oak (*Q. arizonica*) or Mexican blue oak (*Quercus oblongifolia*) may appear, but should never provide more cover than Emory oak (*Q. emoryi*)***Pinus discolor* / *Muhlenbergia emersleyi* Woodland Association**
- 6" The dominant oak species is Arizona white oak (*Q. arizonica*), which provides cover ranging from 5% to 20[30]%. At the lower elevational limit of this community, Emory oak (*Q. emoryi*) may appear, but should never outcompete Arizona white oak (*Q. arizonica*)***Pinus discolor* / *Muhlenbergia emersleyi* Woodland Association**
- 3" Community is a closed woodland/forest with total tree cover surpassing 40% 7
- 7' Community primarily spans upland habitat that is not influenced by nearby or included drainages 8
- 8' Community contains a tall (7–10 m) and dense (40–60%) canopy of border pinyon (*P. discolor*), alligator juniper (*Juniperus deppeana*), Arizona white oak (*Q. arizonica*), and Emory oak (*Quercus emoryi*) with a consistently dominant field layer (<0.5 m) of pinyon ricegrass (*Piptochaetium fimbriatum*) providing cover that ranges from [5] 10 to 20%***Pinus discolor* / *Piptochaetium fimbriatum* Woodland Association**
- 8" Community not as above 9

9' Canopy is dominated by border pinyon (*P. discolor*) with two subdominant/common associate oaks, Arizona white oak (*Q. arizonica*) and silverleaf oak (*Q. hypoleucoides*). At the upper elevational limit of this community, shrubby netleaf oak (*Quercus rugosa*) may begin to appear, but should never outcompete the other oak species. Longtongue muhly (*Muhlenbergia longiligula*) is typically present in the field stratum (<0.5 m)***Pinus discolor* (*Quercus arizonica* - *Juniperus deppeana* - *Quercus hypoleucoides*) Woodland Association**

9" Canopy is dominated by border pinyon (*P. discolor*) with co-dominant/subdominant netleaf oak (*Q. rugosa*) and silverleaf oak (*Q. hypoleucoides*)***Pinus discolor* / *Quercus rugosa* Woodland Association**

7" Community is primarily associated with a nearby or included drainage, causing a noticeable increase in tree size, canopy density, and/or a composition change from the adjacent upland habitat**Group E**

Group C: Mid-elevation (1,100–2,100 m) tree and shrub savannas dominated by an open canopy of oak (*Quercus* sp.); a patchy subcanopy by shrubs and succulents; and a field by perennial grass, typically bullgrass (*Muhlenbergia emersleyi*), and Schott's century plant (*Agave schottii*). These communities are typically a result of historic fire disturbance.

1' The dominant oak species is Sonoran scrub oak (*Quercus turbinella*)**2**

2' Community contains banana yucca (*Yucca baccata*) and/or bush muhly (*Muhlenbergia porteri*)***Yucca baccata* - *Dasyllirion wheeleri* / *Muhlenbergia porteri* Shrubland Association**

2" Community does not contain banana yucca (*Y. baccata*), dominant grass is bullgrass (*Muhlenbergia emersleyi*)***Quercus turbinella* - *Nolina microcarpa* / *Muhlenbergia emersleyi* - *Agave schottii* Shrub Savanna Association**

1" The dominant oak species is not Sonoran scrub oak (*Q. turbinella*)**3**

3' The dominant oak species is Mexican blue oak (*Quercus oblongifolia*). At the upper elevational limit of these communities, Emory oak (*Quercus emoryi*) may appear, but should never compete for dominance**4**

4' Velvet mesquite (*Prosopis velutina*) and/or Arizona rosewood (*Vauquelinia californica*) are co-dominant with, or subdominant to, Mexican blue oak (*Quercus oblongifolia*)**[*Quercus oblongifolia* - *Prosopis velutina* - *Vauquelinia californica*] / Mixed Perennial Grass - *Agave schottii* Wooded Shrub Savanna Association**

4" If present, velvet mesquite (*P. velutina*) and Arizona rosewood (*V. californica*) are sparse (1%) associates that never compete for dominance with Mexican blue oak (*Q. oblongifolia*). The subcanopy is characterized by the presence of beargrass (*Nolina microcarpa*), and the field by the dominance of bullgrass (*Muhlenbergia emersleyi*)***Quercus oblongifolia* / *Bouteloua curtipendula* Scrub Association**

3" The dominant oak species is Emory oak (*Q. emoryi*) and/or Arizona white oak (*Q. arizonica*) with a variable subcanopy and a field dominated by bullgrass (*M. emersleyi*). Mexican blue oak (*Quercus oblongifolia*) may appear, but should never compete for dominance**5**

5' The subcanopy is primarily dominated by beargrass (*Nolina microcarpa*). If present, pointleaf manzanita (*Arctostaphylos pungens*) only provides sparse (<2%) cover that never competes for dominance***Quercus emoryi* / *Nolina microcarpa* / *Muhlenbergia emersleyi* Wooded Shrub Savanna Association**

5" The subcanopy is primarily dominated by pointleaf manzanita (*A. pungens*). Cover and distribution of this species can be variable, ranging from scattered individuals providing low-cover (<5%) to dense patches approaching 20%***Quercus emoryi* / *Arctostaphylos pungens* / *Muhlenbergia emersleyi* Wooded Shrub Savanna Association**

Group D: Mid- to upper-elevation (1,400–2,600 m) shrublands, woodlands, and intermittently flooded woodlands solely dominated by oaks (*Quercus* sp.)

- 1' The community is characterized as a woodland/forest of single-trunked trees ranging in height from 5 to 10 m ...
.....2
- 2' The community is predominately associated with a drainage or other hydrologic feature which causes increased canopy height and density with inclusions of riparian trees and/or upland species typically found at higher elevations 3
- 3' The community is characterized by a mix of oak species dominated by Emory oak (*Quercus emoryi*) and Arizona white oak (*Quercus arizonica*), with scattered riparian trees, including Arizona sycamore (*Platanus wrightii*) and velvet ash (*Fraxinus velutina*)*Quercus arizonica* - *Quercus emoryi* (*Platanus wrightii*) Intermittently Flooded Woodland Association
- 3" The community is characterized by a dominant mix of oak species which does not include Emory oak (*Quercus emoryi*) 4
- 4' The community is dominated by a mix of Mexican blue oak (*Quercus oblongifolia*) and Arizona sycamore (*P. wrightii*)*Platanus wrightii* / *Quercus oblongifolia* Riparian Woodland Association
- 4" The community is not as above 5
- 5' The community is dominated by a mix of Arizona white oak (*Q. arizonica*) and silverleaf oak (*Quercus hypoleucoides*), often with an understory of Wright's silktassel (*Garrya wrightii*)
..[*Quercus arizonica* - *Quercus hypoleucoides*] Intermittently Flooded Woodland Association
- 5" The community is dominated by a mix of silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Quercus rugosa*), often with an understory of Wright's silktassel (*Garrya wrightii*)
[*Quercus hypoleucoides* - *Quercus rugosa*] Intermittently Flooded Woodland Association
- 2" The community is not as described above 6
- 6' The community is characterized by a canopy dominated by Arizona white oak (*Q. arizonica*) and silverleaf oak (*Quercus hypoleucoides*)[*Quercus hypoleucoides* - *Quercus arizonica*] Woodland Association
- 6" The community is characterized by a canopy dominated by silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Quercus rugosa*)[*Quercus rugosa* - *Quercus hypoleucoides*] Woodland Association
- 1" The community is characterized as a shrubland, wooded shrubland or a regenerating woodland, which presents predominantly as a low (2–3 m), dense layer of multi-stemmed trees 7
- 7' The community is characterized by a subcanopy dominated by shrubby Arizona white oak (*Q. arizonica*) and silverleaf oak (*Quercus hypoleucoides*)[*Quercus hypoleucoides* - *Quercus arizonica*] Shrubland Association
- 7" Community not as described above 8
- 8' The community is characterized by a subcanopy dominated by shrubby silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Quercus rugosa*)[*Quercus hypoleucoides* - *Quercus rugosa*] Shrubland Association
- 8" The community is characterized by a subcanopy dominated by netleaf oak (*Quercus rugosa*) and canyon live oak (*Quercus chrysolepis*), with noteworthy rockspirea (*Holodiscus dumosus*)
[*Quercus chrysolepis* - *Quercus rugosa* - *Holodiscus dumosa*] Shrubland Association

Group E: Communities associated/directly influenced by washes, drainages, and/or floodplains

- 1' The community is characterized by the dominance of whitethorn acacia (*Vachellia constricta*) and/or creosote (*Larrea tridentata*) Group H
- 1" Community not as described above 2
- 2' The community is characterized by the dominance of one or more oak (*Quercus* sp.) species Group D
- 2" The community is not as described above 3
- 3' The community is characterized by the dominance of Arizona cypress (*Cupressus arizonica*)
***Cupressus arizonica* / *Quercus hypoleucoides* Forest Association**
- 3" The community is not as described above 4
- 4' The community is dominated by Arizona sycamore (*Platanus wrightii*) with various co/subdominants 5
- 5' Mexican blue oak (*Quercus oblongifolia*) is co-dominant with, or subdominant to, Arizona sycamore (*P. wrightii*)***Platanus wrightii* / *Quercus oblongifolia* Riparian Woodland Association**
- 5" If present, Mexican blue oak (*Q. oblongifolia*) is only a sparse associate providing trivial cover (<1%)
.....6
- 6' Arizona sycamore (*P. wrightii*) has a number of co/subdominant tree species, including velvet ash (*Fraxinus velutina*), Fremont cottonwood (*Populus fremontii*), and Goodding's willow (*Salix gooddingii*)
.....***Platanus wrightii* - *Fraxinus velutina* Intermittently Flooded Woodland Association**
- 6" The community is characterized by the dominance of Arizona alder (*Alnus oblongifolia*) and/or boxelder (*Acer negundo*), often with an understory of Woods' rose (*Rosa woodsia*)
.....***Alnus oblongifolia* / *Acer negundo* / *Rosa woodsii* Intermittently Flooded Woodland Association**
- 4" If present, Arizona sycamore (*P. wrightii*) provides trivial cover (<1%) 7
- 7' Community is not characterized by the dominance of velvet mesquite (*Prosopis velutina*) or desert willow (*Chilopsis linearis*) 8
- 8' The community is an open (10–20%) woodland dominated by Fremont's cottonwood (*P. fremontii*) with patchy Goodding's willow (*S. gooddingii*) and a noteworthy field layer (<0.5 m) of deergrass (*Muhlenbergia rigens*)***Populus fremontii* / *Muhlenbergia rigens* Riparian Woodland Association**
- 8" The community is characterized by the variable dominance of Arizona alder (*Alnus oblongifolia*) and boxelder (*Acer negundo*), often with an understory of Woods' rose (*Rosa woodsia*)
.....***Alnus oblongifolia* / *Acer negundo* / *Rosa woodsii* Intermittently Flooded Woodland Association**
- 7" Community is characterized by the dominance of velvet mesquite (*Prosopis velutina*) and/or desert willow (*C. linearis*) 9
- 9' The community is characterized by the presence and typical dominance of desert willow (*C. linearis*).***Prosopis velutina* - *Chilopsis linearis* / *Ambrosia monogyra* Intermittently Flooded Woodland Association**
- 9" The community is not as described above 10
- 10' The field layer is characterized by consistent cover of annual forbs and grasses, most commonly dominated by carelessweed (*Amaranthus palmeri*), sixweeks grama (*Bouteloua barbata*), spiderling (*Boerhavia* sp.), and/or morning-glory (*Ipomoea* sp.) 11
- 11' The community is an open (10–40%) woodland of velvet mesquite (*P. velutina*) with a patchy shrub layer***Prosopis velutina* / Annual Forb Woodland Association**
- 11" The community is a tall (>5 m) closed (40+%) woodland of velvet mesquite (*P. velutina*) with a

noteworthy and often dominant shrub layer of lotebush (*Ziziphus obtusifolia*) and Warnock's snake-wood (*Condalia warnockii*)*Prosopis velutina* / *Ziziphus obtusifolia* - *Condalia warnockii* Woodland Association

10" The field layer is not as described above. If annual species are present, they should be patchy and outcompeted by perennial grasses and subshrubs 12

12' The community is a woodland/intermittently flooded woodland of tall (4+ m), single-trunk velvet mesquite (*P. velutina*) 13

13' Community is characterized by a variably dense (15–40%) upper canopy dominated by velvet mesquite (*P. velutina*) with catclaw acacia (*Senegalia greggii*) and netleaf hackberry (*Celtis reticulata*). Velvet mesquite (*P. velutina*) is typically present as a large (4–6 m) single-trunk tree*Prosopis velutina* - *Senegalia greggii* Intermittently Flooded Woodland Association

13" The community is a tall (>5 m) closed (40+%) woodland of velvet mesquite (*P. velutina*) with a noteworthy and often dominant shrub layer of lotebush (*Ziziphus obtusifolia*) and Warnock's snake-wood (*Condalia warnockii*)*Prosopis velutina* / *Ziziphus obtusifolia* - *Condalia warnockii* Woodland Association

12" The community is dominated by velvet mesquite (*P. velutina*) that presents as shrubs or short (<3 m), multi-trunk trees*Prosopis velutina* - *Senegalia greggii* Intermittently Flooded Shrubland Association

Group F: Mid-elevation (1,300–2,500 m) shrubland and wooded shrubland communities with subcanopies dominated by manzanita (*Arctostaphylos* sp.), ceanothus (*Ceanothus* sp.), or catclaw mimosa (*Mimosa aculeaticarpa*). This group does not include shrublands solely dominated by oak (*Quercus* sp.).

1' The community contains dominant ceanothus (*Ceanothus* sp.) or catclaw mimosa (*Mimosa aculeaticarpa*) 2

2' The community is characterized by the sole dominance of catclaw mimosa (*M. aculeaticarpa*) with cover ranging from 30% to 50+%*Mimosa aculeaticarpa* Shrubland Association

2" The community not as described above 3

3' The community is characterized by the dominance of Fendler's ceanothus (*Ceanothus fendleri*) with associate/co-dominant oaks (*Quercus* sp.)(*Quercus hypoleucoides* - *Quercus arizonica*) / *Ceanothus fendleri* Wooded Shrubland Association

3" The community is characterized by the co-dominance of deerbrush (*Ceanothus integerrimus*) and netleaf oak (*Quercus rugosa*)*Quercus rugosa* - *Ceanothus integerrimus* Woodland Association

1" The community does not contain dominant ceanothus (*Ceanothus* sp.) or catclaw mimosa (*Mimosa aculeaticarpa*). If present, these species should be strongly outcompeted by oak (*Quercus* sp.) and/or manzanita (*Arctostaphylos* sp.) 4

4' The ratio of manzanita (*Arctostaphylos* sp.) to oaks (*Quercus* sp.) and/or border pinyon (*P. discolor*) ranges from 2:1 to 4:1 5

5' The low canopy is dominated by border pinyon (*P. discolor*) with associated oaks (*Quercus* sp.) and alligator juniper (*Juniperus deppeana*)*Pinus discolor* / *Arctostaphylos (pungens - pringlei)* Wooded Shrubland Association

5" The low canopy is primarily characterized by oaks (*Quercus* sp.). If present, border pinyon (*P. discolor*) provides trivial (<1%) cover 6

6' The low-canopy oaks (*Quercus* sp.) are primarily composed of Emory oak (*Quercus emoryi*) and Arizona white oak (*Quercus arizonica*) with combined cover ranging from 5% to 15 [20]%. The dominant manzanita (*Arctostaphylos* sp.) is typically pointleaf manzanita (*Arctostaphylos pungens*)
(*Quercus arizonica* - *Quercus emoryi*) / *Arctostaphylos pungens* Shrubland Association

6" The low-canopy oaks are primarily composed of silverleaf oak (*Quercus hypoleucoides*) with Arizona white oak (*Q. arizonica*) and/or netleaf oak (*Q. rugosa*). While pointleaf manzanita (*A. pungens*) can still be present, Pringle's manzanita (*A. pringlei*) tends to be the dominant manzanita (*Arctostaphylos* sp.) 7

7' The low-canopy oaks (*Quercus* sp.) are primarily composed of silverleaf oak (*Q. hypoleucoides*) and Arizona white oak (*Q. arizonica*) with combined cover ranging from 5% to 15 [20]%. The dominant manzanita (*Arctostaphylos* sp.) is typically Pringle's manzanita (*Arctostaphylos pringlei*)(***Quercus hypoleucoides* - *Quercus arizonica***) / ***Arctostaphylos (pringlei - pungens)* Shrubland Association**

7" The low-canopy oaks (*Quercus* sp.) are primarily composed of silverleaf oak (*Q. hypoleucoides*) and netleaf oak (*Q. rugosa*) with combined cover ranging from 5% to 15 [20]%. The dominant manzanita (*Arctostaphylos* sp.) is Pringle's manzanita (*Arctostaphylos pringlei*)(***Quercus hypoleucoides* - *Quercus rugosa***) / ***Arctostaphylos pringlei* Shrubland Association**

4" The ratio of manzanita (*Arctostaphylos* sp.) to oaks (*Quercus* sp.) and/or border pinyon (*P. discolor*) is close to 1:1 8

8' The low canopy is dominated by border pinyon (*P. discolor*) with associated oaks (*Quercus* sp.) and alligator juniper (*Juniperus deppeana*)***Pinus discolor* / *Arctostaphylos (pungens - pringlei)* Wooded Shrubland Association**

8" The low canopy is primarily characterized by oaks (*Quercus* sp.). If present, border pinyon (*P. discolor*) provides trivial (<1%) cover 9

9' The low-canopy oaks (*Quercus* sp.) are primarily composed of Emory oak (*Quercus emoryi*) and Arizona white oak (*Quercus arizonica*) with combined cover ranging from 20% to 40%. The dominant manzanita (*Arctostaphylos* sp.) is typically pointleaf manzanita (*Arctostaphylos pungens*)
[*Quercus arizonica* - *Quercus emoryi*] / *Arctostaphylos pungens* Woodland Association

9" The low-canopy oaks are primarily composed of silverleaf oak (*Quercus hypoleucoides*) with Arizona white oak (*Q. arizonica*) and/or netleaf oak (*Q. rugosa*). While pointleaf manzanita (*A. pungens*) can still be present, Pringle's manzanita (*A. pringlei*) tends to be the dominant manzanita (*Arctostaphylos* sp.)
10

10' The low-canopy oaks (*Quercus* sp.) are primarily composed of silverleaf oak (*Q. hypoleucoides*) and Arizona white oak (*Q. arizonica*) with combined cover ranging from 20% to 40%. The dominant manzanita (*Arctostaphylos* sp.) is typically Pringle's manzanita (*Arctostaphylos pringlei*)[***Quercus hypoleucoides* - *Quercus arizonica***] / ***Arctostaphylos (pringlei - pungens)* Woodland Association**

10" The low-canopy oaks (*Quercus* sp.) are primarily composed of silverleaf oak (*Q. hypoleucoides*) and netleaf oak (*Q. rugosa*) with combined cover ranging from 20% to 40%. The dominant manzanita (*Arctostaphylos* sp.) is Pringle's manzanita (*Arctostaphylos pringlei*)(***Quercus hypoleucoides* - *Quercus rugosa***) / ***Arctostaphylos pringlei* Shrubland Association**

Group G: Low-elevation (800–1,400 m) shrublands and wooded shrublands dominated by drought deciduous and often armed shrubs and low trees, often with the presence of saguaros (*Carnegiea gigantea*).

1' The field stratum (<0.5 m) is characterized by the consistent sub/co/sole dominance of brittlebush (*Encelia farinosa*) with cover ranging from 5% to 30+%. In areas dominated by buffelgrass (*Cenchrus ciliaris*) or with extremely shallow soils, brittlebush (*E. farinosa*) may be noticeably reduced (1–2%), but should still provide consistent cover throughout the community. Tree, shrub, and succulent cover are variable 2

2' The subcanopy stratum (0.5–2 m) is characterized by the variable presence of jojoba (*Simmondsia chinensis*),

- contributing cover that ranges from [2] 5% to 10 [20]%*Simmondsia chinensis* / *Encelia farinosa* Shrubland Association
- 2" The subcanopy stratum (0.5–2 m) is not as above. If present, jojoba (*S. chinensis*) should be extremely sparse (<<1%) 3
- 3" The primary subcanopy succulent is teddybear cholla (*Cylindropuntia bigelovii*). This community is typically present on steep, boulder strewn, and exposed south-facing slopes(*Parkinsonia microphylla*) / *Cylindropuntia bigelovii* / *Encelia farinosa* Shrubland Association
- 3" The primary subcanopy succulent is cactus apple (*Opuntia engelmannii*) or succulents are uncommon. If teddybear cholla (*C. bigelovii*) is present, it should be patchy with minimal cover (<1%) across the broader community 4
- 4' Paleface (*Hibiscus denudatus*) and/or desert zinnia (*Zinnia acerosa*) is co-dominant with, subdominant to, or more dominant than brittlebush (*E. farinosa*) 5
- 5' The field is characterized by the co/subdominance of paleface (*Hibiscus denudatus*)
.....*Parkinsonia microphylla* / *Encelia farinosa* - *Hibiscus denudatus* Shrubland Association
- 5" The field is characterized by the co/subdominance of desert zinnia (*Zinnia acerosa*)
.....*Parkinsonia microphylla* / *Encelia farinosa* - *Zinnia acerosa* Shrubland Association
- 4" Vegetation not as above 6
- 6' The field stratum is solely and strongly dominated (10–30%) by brittlebush (*E. farinosa*) without any consistent and/or noteworthy associates. The surface cover is solely defined by a dominant layer of coarse gravel (4+ cm)*Parkinsonia microphylla* / *Opuntia engelmannii* / *Encelia farinosa* Shrubland Association
- 6" The field stratum contains a diverse mix of co/subdominants and associates in addition to brittlebush (*Encelia farinosa*). These include, but are not limited to, slender janusia (*Cottisia gracilis*), fairyduster (*Caliandra eriophylla*), sangre de cristo (*Jatropha cardiophylla*), and a variable mix of native and non-native perennial grasses. Diversity may be low in areas invaded by buffelgrass (*C. ciliaris*) 7
- 7' This community occupies steep (>20%) and exposed south-facing backslopes. The low canopy is typically dominated by yellow paloverde (*P. microphylla*) and ocotillo (*Fouquieria splendens*)
.....(*Parkinsonia microphylla* - *Fouquieria splendens*) / *Encelia farinosa* (*Cottisia gracilis*) Shrubland Association
- 7" This community occupies low-angle (<20%) pediments of variable exposure and aspect. The low canopy is typically dominated by velvet mesquite (*P. velutina*)*Prosopis velutina* / *Opuntia engelmannii* / *Encelia farinosa* (*Cottisia gracilis*) Wooded Shrubland Association
- 1" Field stratum (<0.5 m) not as above. If present, brittlebush (*Encelia farinosa*) abundance is very patchy, with cover rarely surpassing 1% 8
- 8' The subcanopy stratum (0.5–2 m) is characterized by the variable presence of jojoba (*Simmondsia chinensis*), contributing cover that ranges from [2] 5% to 10 [20]% 9
- 9' Field stratum (<0.5 m) dominated by triangle bur ragweed (*Ambrosia deltoidea*)
Simmondsia chinensis - Mixed Cacti / *Ambrosia deltoidea* Shrubland Association
- 9" If present, triangle bur ragweed (*Ambrosia deltoidea*) provides low (<1%), patchy cover 10
- 10' The field is dominated by a dense layer of curly mesquite (*Hilaria belangeri*)
Simmondsia chinensis / *Hilaria belangeri* Shrub Savanna Association
- 10" The field is not as described above*Simmondsia chinensis* (Mixed Cacti) Shrubland Association
- 8" The subcanopy stratum (0.5–2 m) is not as above. If present, jojoba (*S. chinensis*) should be extremely sparse (<<1%) 11

- 11' The community is dominated by Wright's beebrush (*Aloysia wrightii*), mariola (*Parthenium incanum*), rough jointfir (*Ephedra aspera*), and/or woody crinklemat (*Tiquilia canescens*) 12
- 12' The community is dominated by mariola (*P. incanum*), rough jointfir (*Ephedra aspera*) and/or woody crinklemat (*T. canescens*) 13
- 13' The community is present on low-angle footslopes or low, rolling hills with a field predominantly composed of woody crinklemat (*Tiquilia canescens*), often with dominant desert zinnia (*Zinnia acerosa*) and sparse mariola (*P. incanum*)***Parkinsonia microphylla* / *Tiquilia canescens* (*Zinnia acerosa*) Shrubland Association**
- 13" Community with sparse (<<1%) to absent woody crinklemat (*T. canescens*) 14
- 14' The open shrubland community is present on north-trending, low-angle mountain slopes dominated by a mix of mariola (*P. incanum*), rough jointfir (*Ephedra aspera*), and creosote (*Larrea tridentata*) ..
.....***Larrea tridentata* [*Ephedra aspera* - *Parthenium incanum*] Shrubland Association**
- 14" The community is present on steep, predominately north-facing backslopes containing dominant mariola (*P. incanum*) and/or Wright's beebrush (*A. wrightii*) with sparse (<1%) to absent woody crinklemat (*T. canescens*) 15
- 15' Mariola (*P. incanum*) is the sole dominant shrub, providing 10–20+% cover. If present, Wright's beebrush is a low-cover (<5%) associate that never competes for dominance with mariola (*P. incanum*)***Parkinsonia microphylla* / *Parthenium incanum* Shrubland Association**
- 15" Wright's beebrush (*Aloysia wrightii*) is the primary shrub dominant with mariola (*P. incanum*) present as a sparse to common associate that never competes for dominance
(*Parkinsonia microphylla*) / *Aloysia wrightii* Shrubland Association
- 12" Wright's beebrush (*A. wrightii*) is the primary dominant shrub, providing [5] 10–40% cover. If present, mariola (*P. incanum*) is a low-cover (<5%) associate that never competes for dominance with Wright's beebrush (*A. wrightii*) 15
- 15' Velvet mesquite (*Prosopis velutina*) is the primary low-canopy (2–5 m) tree and whitethorn acacia (*Vachellia constricta*) is absent**(*Prosopis velutina*) / *Aloysia wrightii* Shrubland Association**
- 15" Yellow paloverde (*Parkinsonia microphylla*) is the primary low-canopy (2–5 m) tree and whitethorn acacia (*V. constricta*) is present. Both of these species provide cover ranging from 3% to 10%
.....**(*Parkinsonia microphylla*) / *Aloysia wrightii* Shrubland Association**
- 11" The community is not dominated by any of the above species 16
- 16' The community spans an alluvial fan, floodplain, drainage or wash 17
- 17' The community is characterized by the overwhelming dominance (10–40+%) of creosote (*Larrea tridentata*) with few associate species 18
- 18' The community spans a floodplain of silty soil where velvet mesquite (*P. velutina*) is the primary low-canopy tree**(*Prosopis velutina*) / *Larrea tridentata* Shrubland Association**
- 18" The community spans a floodplain of silty soil where yellow paloverde (*P. microphylla*) is the primary low-canopy tree 19a
- 19a' Field stratum (<0.5 m) contains triangle bur ragweed**(*Parkinsonia microphylla*) / *Larrea tridentata* – Mixed Cacti / *Ambrosia deltoidea* Shrubland Association**
- 19a" Field stratum (<0.5 m) does not contain triangle bur ragweed**(*Parkinsonia microphylla*) / *Larrea tridentata* Shrubland Association**
- 17" If present, creosote (*L. tridentata*) shares dominance with a suite of additional shrub species 19b

- 19b' The community is strongly associated with washes and their adjacent slopes that bisect the alluvial fan. Whitethorn acacia (*V. constricta*) is the primary dominant with noteworthy velvet mesquite (*P. velutina*), creosote (*L. tridentata*), and catclaw acacia (*Senegalia greggii*)(*Prosopis velutina*) / *Vachellia constricta* (*Larrea tridentata* - *Senegalia greggii*) Intermittently Flooded Shrubland Association
- 19b'' The community is not as above 20
- 20' The community spans a wash, drainage, and/or floodplain Group E
- 20'' The community spans the interfluvium of an alluvial fan and is primarily associated with upland vegetation and not influenced by a hydrologic feature 21
- 21' The low-canopy trees are solely dominated by velvet mesquite (*P. velutina*) 22
- 22' The subcanopy stratum is dominated by whitethorn acacia (*V. constricta*) and cactus apple (*O. engelmannii*). The community occurs on alluvial fans dominated by fine gravel(*Prosopis velutina*) / *Vachellia constricta* - *Opuntia engelmannii* Shrubland Association
- 22'' The subcanopy stratum is not as above 23
- 23' The field is dominated by Lehmann lovegrass (*Eragrostis lehmanniana*) and/or annual grasses, such as sixweeks grama (*Bouteloua barbata*)*Prosopis velutina* / *Opuntia engelmannii* (*Senegalia greggii* - *Celtis ehrenbergiana*) Wooded Shrubland Association
- 23'' The field layer is typically composed of patchy bush muhly (*Muhlenbergia porteri*) and/or burroweed (*Isocoma tenuisecta*)*Prosopis velutina* Woodland Association
- 21'' The low-canopy trees are primarily dominated by yellow paloverde (*Parkinsonia microphylla*) with some areas of co-dominance with velvet mesquite (*P. velutina*) 24
- 24' The field stratum is dominated by burrobrush (*Ambrosia salsola*) with bush muhly (*Muhlenbergia porteri*) and pricklypear (*Opuntia* spp.)*Parkinsonia microphylla* / *Opuntia* spp. - *Ambrosia salsola* / *Muhlenbergia porteri* Shrubland Association
- 24'' Community not as above 25
- 25' The field stratum is consistently dominated by triangle bur ragweed (*Ambrosia deltoidea*) 26
- 26' The community is overwhelmingly dominated by triangle bur ragweed (*A. deltoidea*), providing 50–75% of the total vegetation cover*Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland Association
- 26'' Triangle bur ragweed (*A. deltoidea*) is not present as described above. Instead, it provides lower relative cover (<50%) along with a suite of additional species, including desert zinnia (*Zinnia acerosa*, whitethorn acacia (*Vachellia constricta*), and cactus apple (*O. engelmannii*) 27
- 27' Field stratum (<0.5 m) is dominated by white ratany (*Krameria grayi*)(*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Vachellia constricta* - *Larrea tridentata* / *Krameria bicolor* Wooded Shrubland Association
- 27'' Community not as above 28
- 28' Desert ironwood (*Olneya tesota*) is a consistent low-cover canopy tree*Carnegiea gigantea* / *Parkinsonia microphylla* (*Olneya tesota*) / *Ambrosia deltoidea* Shrubland Association

- 28" Desert ironwood (*Olneya tesota*) is not present(*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Opuntia engelmannii* (*Vachellia constricta* - *Larrea tridentata*) / *Ambrosia deltoidea* Wooded Shrubland Association
- 25" If present, triangle bur ragweed (*A. deltoidea*) provides trivial cover (<1%). Instead, the field contains a mix of low-cover associates that include desert zinnia (*Zinnia acerosa*), bush muhly (*M. porteri*), and rough menodora (*Menodora scabra*)(*Carnegiea gigantea*) / *Parkinsonia microphylla* / *Opuntia engelmannii* (*Vachellia constricta* - *Larrea tridentata*) Wooded Shrubland Association
- 16" The community spans a pediment or mountain slope 29
- 29" Canopy with velvet mesquite (*Prosopis velutina*) 30
- 30" The subcanopy is characterized by the consistent dominance of Florida hopbush (*Dodonaea viscosa*)*Fouquieria splendens* - *Prosopis velutina* / *Dodonaea viscosa* Shrubland Association
- 30" The subcanopy is not as described above. If present, Florida hopbush (*D. viscosa*) is very patchy and provides little cover 31
- 31" Community contains a field stratum (<0.5 m) dominated by triangle bur ragweed (*Ambrosia deltoidea*)*Parkinsonia microphylla* / *Ambrosia deltoidea* Shrubland Association
- 31" Triangle bur ragweed (*A. deltoidea*) is absent 32
- 32" The community is characterized by a diverse, but low-cover mix of shrubs and succulents, most commonly dominated by velvet mesquite (*P. velutina*), ocotillo (*Fouquieria splendens*), cactus apple (*Opuntia engelmannii*), catclaw acacia (*Senegalia greggii*), and slender janusia (*Cottisia gracilis*). The community is present on a low-angle pediment or sheltered north-facing backslope(*Fouquieria splendens*) / *Prosopis velutina* / *Opuntia engelmannii* / *Cottisia gracilis* Shrubland Association
- 32" The community is characterized by the consistent dominance of velvet mesquite (*P. velutina*), cactus apple (*O. engelmannii*), bush muhly (*Muhlenbergia porteri*), and turpentine bush (*Ericameria laricifolia*). The community is present on low-angle shelves within the broader mountain backslope*Prosopis velutina* / *Opuntia engelmannii* - *Ericameria laricifolia* / *Muhlenbergia porteri* Wooded Shrubland Association
- 29" Canopy does not contain velvet mesquite (*P. velutina*) 33
- 33" Community is a dense mix of shrubs and succulents dominated by buckhorn cholla (*Cylindropuntia acanthocarpa*) and/or whitethorn acacia (*Vachellia constricta*). Canopy is sparse to absent*Cylindropuntia acanthocarpa* - *Vachellia constricta* / *Calliandra eriophylla* - *Cottisia gracilis* Shrubland Association
- 33" Community spans steep and rocky, north-trending slopes dominated by Berlandier's wolfberry (*Lycium berlandieri*) with a diverse mix of associate shrubs, including spiny hackberry (*Celtis ehrenbergiana*), Schott's yellowhood (*Nissolia schottii*), shrubby thoroughwort (*Koanophyllon solidaginifolium*), and Coulter's brickellbush (*Brickellia coulteri*)*Parkinsonia microphylla* / *Lycium berlandieri* (Mixed Shrub) Rocky Shrubland Association

Group H: Low- to mid-elevation (1,000–1,700 m) shrub and herbaceous-dominated communities

- 1' Community spans a steep backslope that is primarily dominated by buffelgrass (*Cenchrus ciliaris*) with patchy brittlebush (*Encelia farinosa*) Group I
- 1" Community not as described above. If buffelgrass (*C. ciliaris*) is dominant, then brittlebush (*E. farinosa*) is absent 2

- 2' The community is associated with vast expanses of bedrock and adjacent areas of shallow soil, often with a noteworthy layer of rock-loving spikemoss (*Selaginella rupincola*)***Fouquieria splendens* / (*Opuntia engelmannii*) / *Selaginella rupincola* Sparse Rock Outcrop Association**
- 2" Community not as described above. Inclusions of bedrock can exist, but should not define the area 3
- 3' Community is characterized by the dominance of Santa Catalina prairie clover (*Dalea pulchra*) and/or Thurber's cotton (*Gossypium thurberi*), with patchy catclaw mimosa (*Mimosa aculeaticarpa*) and a variable layer of perennial grasses. If present, low-canopy trees, such as velvet mesquite (*Prosopis velutina*), Mexican blue oak (*Quercus oblongifolia*), and Arizona rosewood (*Vauquelinia californica*), are patchy and usually associated with included drainages or bedrock outcrops***Dalea pulchra* / Mixed Perennial Grass Shrub Savanna Association**
- 3" Community not as described above 4
- 4' Community is a tree savanna/grassland with very open (<10%) canopy of Emory oak (*Quercus emoryi*) and Mexican blue oak (*Q. oblongifolia*) overlying a dense (40+%) layer of Lehmann lovegrass (*Eragrostis lehmanniana*)(***Quercus emoryi* - *Quercus oblongifolia* / *Eragrostis lehmanniana* Herbaceous Association**)
- 4" Community not as described above 5
- 5' Community is dominated by a mix of banana yucca (*Yucca baccata*), bush muhly (*Muhlenbergia porteri*), and common sotol (*Dasylirion wheeleri*)***Yucca baccata* - *Dasylirion wheeleri* / *Muhlenbergia porteri* Shrubland Association**
- 5" Community does not contain banana yucca (*Yucca baccata*) 6
- 6' The community is characterized by a subcanopy of beargrass (*Nolina microcarpa*), and a field dominated by perennial grasses (native and non-native) and Schott's century plant (*Agave schottii*). Low-canopy trees and shrubs are sparse (<1%) to non-existent and most commonly consist of Arizona rosewood (*Vauquelinia californica*)***Nolina microcarpa* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna Association**
- 6" The community contains a more consistent and dominant layer of low-canopy trees and tree-like shrubs with cover ranging from 5% to 20+% 7
- 7' The low-canopy trees and tree-like shrubs are characterized by the dominance of ocotillo (*Fouquieria splendens*) and velvet mesquite (*P. velutina*)***Fouquieria splendens* (*Prosopis velutina*) / *Opuntia engelmannii* / Mixed Perennial Grass - *Agave schottii* Shrub Savanna Association**
- 7" The low-canopy trees and tree-like shrubs are characterized by the dominance of Mexican blue oak (*Quercus oblongifolia*), velvet mesquite (*P. velutina*), and/or Arizona rosewood (*Vauquelinia californica*). If present, ocotillo (*F. splendens*) should be very patchy and low-cover (1%) compared to the dominant low-canopy components 8
- 8' Velvet mesquite (*Prosopis velutina*) and/or Arizona rosewood (*Vauquelinia californica*) are co-dominant with, or subdominant to, Mexican blue oak (*Quercus oblongifolia*)**[*Quercus oblongifolia* - *Prosopis velutina* - *Vauquelinia californica*] / Mixed Perennial Grass - *Agave schottii* Wooded Shrub Savanna Association**
- 8" If present, velvet mesquite (*P. velutina*) and Arizona rosewood (*V. californica*) are sparse (1%) associates that never compete for dominance with Mexican blue oak (*Q. oblongifolia*). The subcanopy is characterized by the presence of beargrass (*Nolina microcarpa*), and the field by the dominance of bullgrass (*Muhlenbergia emersleyi*)***Quercus oblongifolia* / *Bouteloua curtipendula* Scrub Association**

Group I: Upper-elevation (>2,100 m) communities not defined by a canopy of large pines (*Pinus* sp.), Douglas fir (*Pseudotsuga* sp.), and/or oaks (excluding Gambel oak [*Quercus gambelii*]). Often, these communities are a result of historic fire disturbance.

1' Community is characterized by the presence and/or dominance of Gambel oak (*Quercus gambelii*) ranging from tall (>5 m), single-trunk trees to short (<3 m) and multi-stemmed, shrub-like trees 2

2' The community is an open (10–20%) and short-statured (<5 m) wooded shrubland/regenerating woodland with clear evidence of historic fire activity. The understory often contains noteworthy mountain snowberry (*Symphoricarpos oreophilus*), New Mexico locust (*Robinia neomexicana*), and western brackenfern (*Pteridium aquilinum*)*Quercus gambelii* / *Symphoricarpos oreophilus* Shrubland Association

2" The community is characterized by a variably dense (20–50+%) upper canopy dominated by large ([6] 8–15 m), single-trunk Gambel oak (*Q. gambelii*), and a variable understory ranging from dense (>25%) mountain snowberry (*Symphoricarpos oreophilus*) and New Mexico locust (*Robinia neomexicana*), to these same species providing sparse (<5%) to non-existent cover*Quercus gambelii* / *Robinia neomexicana* / *Symphoricarpos oreophilus* Woodland Association

1" If present, Gambel oak (*Q. gambelii*) is a sparse associate with cover rarely exceeding 1–2% 3

3' Community is dominated by quaking aspen (*Populus tremuloides*)*Populus tremuloides* Forest Association

3" Community not as described above 4

4' Community is characterized by a consistently dense (25–50+%) layer of western brackenfern (*Pteridium aquilinum*) with patchy New Mexico locust (*Robinia neomexicana*), typically associated with included drainages. This community does not contain a dominant layer of perennial grass or Fendler's ceanothus (*C. fendleri*)*Pteridium aquilinum* Herbaceous Association

4" Community is not as described above. If western brackenfern (*P. aquilinum*) is a dominant, it should be accompanied by dominant perennial grasses and/or Fendler's ceanothus (*C. fendleri*) 5

5' Community is a moderately open (10–30%) and low-statured (<1 m) shrubland characterized by the consistent dominance of fragrant snakeroot (*Ageratina herbacea*) with patchy mountain snowberry (*S. oreophilus*)(*Symphoricarpos oreophilus*) / *Ageratina herbacea* Shrubland Association

5" Community is characterized by a variably dense (30–50%) field layer dominated by a mix of screwleaf muhly (*M. virescens*), western brackenfern (*P. aquilinum*), and Fendler's ceanothus (*Ceanothus fendleri*)*Muhlenbergia virescens* - *Pteridium aquilinum* - *Ceanothus fendleri* Herbaceous Association

Appendix F. Accuracy Assessment Guidelines and Example Data Sheet, Tucson Mountain District, Saguaro National Park, 2016

Saguaro National Park - TMD Accuracy Assessment Guidelines

Prior to this field effort, a spatially balanced series of points ($n = 546$) was distributed throughout the TMD mapping frame. Each point is associated with a circular plot having a radius ranging from a low of 28 m (area = 2,464 m²) to a high of 40 m (area = 5,000 m²). Throughout the course of this project, all efforts should be made to sample every plot. Crew members should only consider the vegetation within the plot when assessing the community and not take the broader landscape into account when assigning a plot to an association. To decrease potential observer bias, crewmembers will not be provided with boundaries for the polygons created during the mapping phase. Plots are meant to be assessed in a rapid manner, with crew members spending less than 10 minutes per plot.

In a systematic manner, crew members will navigate to an AA plot and, using the plot boundaries on the GPS, walk throughout the plot assessing the vegetation (e.g., dominant/associate species, formation type, cover values). Tapes will not be used. Instead, surveyors will use a GPS to delineate plots. Datasheets (Figure F-1) should be completed and spatial data taken according to the following guidelines.

Notes:

- Wash and drainage landform features do not have polygons associated with their points, as their width varies; infrequently, they cannot fit even a small circular plot. Instead, these will be assessed as linear features. Once you arrive at the plot, walk approximately a minimum of 50 m upstream and 50 m downstream of the point to determine the type designation. If one direction is hard to travel along, assess ~100 m in one direction.
- Only washes of a certain size class were digitized on the map. Minor washes will run through *all* of the alluvial slopes, and plots may fall on these. Unless the wash system covers 35% or more of the plot area, you should ignore it and only assess the non-wash influenced vegetation. If the wash covers 35% or more of the plot area, then you can assess it based on the wash vegetation OR, if possible, move the sample point sufficient distance as to miss the large wash feature.
- The TMD has many species that are present throughout the entire park. It is important to understand the vegetation types vary in terms of the relative abundance, constancy and consistent distribution of those species. Presence alone does not warrant much weight.
- The key has been designed to first separate the vegetation types by the landform on which they occur. Every effort was made to include types in multiple sections to cover all instances of the landforms on which they could occur. However, please read all key breaks to ensure the best fit type is chosen EVEN IF the ve type is not listed as occurring on a given landform where you see it.

A) For each plot, fill out the TMD AA Datasheet.

- At the top of the datasheet record the AA ID (plot/point ID = AA###) and Date.
- On the next line, circle 'YES' if the plot was assessed from the distributed location. Circle 'NO' if you had to alter the plot (change size) or move its location. If any alterations are made, describe all changes and the reason(s) for making them in the 1st narrative section. Plots should only be moved or resized if you are unable to safely assess the plot from the distributed location (e.g., located on cliff band), it's predominately characterized by recent human/natural disturbance, and/or the plot is dominated by sparsely vegetated bedrock that doesn't match any of the existing types. In these cases, move the plot the minimum distance possible to avoid the issue, while capturing the type that the original plot covered or the dominant type surrounding the issue.
- On the next line, circle 'Yes' if you took photos ('No' if you didn't). You should only take photos if there are issues assigning a type and/or the fit is 'fair' or 'poor'. If photos are required, take four with one in each of the cardinal directions (north, south, east, and west), from the center of the plot, or, if those photos would be substantially obstructed, from a representative location elsewhere in the plot.
- In the next section, record the three most dominant and/or diagnostic species (using the SODN six letter veg codes), within each of four height classes: top-canopy (>5 m), low canopy (2–5 m), subcanopy (0.5–2 m), and

field (0–0.5 m). This section is very similar to the classification plot datasheet.

- Please also assign cover values for each species listed.
- While there are spaces for three species per class, it is not necessary to fill all of them in. If there are no dominant or diagnostic species within a height class, write ‘none’ across that section.
- In the first narrative section, record any changes to the plot size or location, any other issues, a brief summary of the vegetation captured by the plot, and/or anything else noteworthy. Only record a vegetation summary if there are issues assigning a type to the plot and/or it receives a ‘fair’ or ‘poor’ fit.
- Prior to completing the next section, ‘type fit’, flip over the datasheet and assign one of the listed types.
 - Check the box next to the type that best fits the plot based on the vegetation association key and the type description summaries.
 - Do not rank types or select more than one.
 - If you don’t consider any of the types to be a fit, even a poor one, check the box for the unplaced type and assign an association name. If you encounter numerous unplaced that you consider to be the same, be consistent with the naming convention.
- Once a type is selected, return to the front of the datasheet to select a type fit. Circle the fit category that best captures the relation of the vegetation within the plot to the description of the selected type.

Excellent: Select this option if the composition of dominant species (taking into account listed variations within the type) and cover values within the plot match the type description.

Good: Select this option if the composition of dominant species (taking into account listed variations within the type) within the plot matches the type description, but cover values are outside the values or ranges listed in the type description.

Fair: Select this option if the composition of the minority of dominant species (taking into account listed variations within the type) does not match the type description (e.g., a dominant species is not listed in the description or a listed dominant is not in the plot), but the plot is clearly best suited for the type.

Poor: Select this option if the composition of the majority of dominant species (taking into account listed variations within the type) does not match the type description (e.g., a dominant species is not listed in the description or a listed dominant is not in the plot). This indicates that the plot is similar enough to a description to assign a type, but there are major discrepancies between the two.

If either ‘fair’ or ‘poor’ is selected, use the space below to detail all the reasons the plot is not an ‘excellent’ or ‘good’ fit. This should include listing the dominant species that are either missing from the plot or type description and/or issues with cover values.

- Just below the fit categories, there are two ‘yes or no’ questions that may require a narrative component.
 - **Is the plot representative of the surrounding habitat?** Select ‘yes’ if the vegetation within the plot continues beyond the boundaries of the plot. Select ‘no’ if the plot appears to be in a location that is not representative of the surrounding landscape. If you select ‘no,’ then use the narrative section to describe the surrounding habitat, what associated it fits in, and how it differs from the plot.
 - **Is the plot in an ecotone?** Select ‘no’ if the assigned association is more or less consistent across the plot. Select ‘Yes’ if there is a clear gradient between the assigned association and a different community. If you select ‘yes’, use the narrative section to describe the ecotone and the two communities that are present.

B) For each sampled plot, add a point to the AA feature class from anywhere within the plot boundary.

- Attribute the form with the AA ID (plot/point ID = AA###), check the ‘data’ box, pick the selected association from the dropdown, select the fit category of that association.
- Due to the high volume of plots to be sampled, a tracking sheet has been created to keep track of plots that have/need to be sampled. Upon completion of each plot, a consistent mark should be added to the completed column to notate that sampling is done.

Saguaro National Park – TMD --Vegetation Mapping **Field Data Sheet: Thematic Accuracy Assessment**

Proofread by: _____ Copied by: _____
 Entered by: _____ Verified by: _____

AA ID: AA __ __ __	Date (mm/dd/yyyy):	Observer(s): NRG EMS
Assessed within distributed AA plot? (circle one): YES NO If no, record reason(s) for moving the plot in narrative section.		
Photos taken? YES / NO	Camera Name:	Jpeg Numbers - North: East: South: West:

In table below list the top three dominant species (by cover) for each stratum. Write 'NONE' if none present for a stratum. Use additional spaces and notes section to record other species that are characteristic or diagnostic of a vegetation community, but that may not be dominant in cover.

1 = < 1% 2 = 1-5% 3 = 6-10% 4 = 11-25% 5 = 26-33% 6 = 34-50% 7 = 51-75% 8 = 76-95% 9 = 96-100%

Canopy >5m	R	C	Canopy 2 – 5m	R	C	Sub-canopy 0.5 – 2m	R	C	Field 0 – 0.5m	R	C

Record any notes pertinent to your assessment of this polygon.

Select a type on the backside of this datasheet prior to completing this step. The fit of the vegetation type to this plot is (circle one) :

Excellent

Good

Fair

Poor

Is the plot representative of the surrounding habitat? **Yes** **No** If no, record the name of that type below | Is the plot in an ecotone? **Yes** **No** If yes, elaborate in the space below

Appendix G. Accuracy Assessment Guidelines and Example Data Sheet, Rincon Mountain District, Saguaro National Park, 2018

In preparation for this accuracy assessment (AA) field effort, a spatially balanced series of points ($n = \sim 1,936$) was distributed throughout the RMD mapping frame, across all vegetation map units. Each point is associated with a circular plot having a radius ranging between 10 m (area = 314 m²) up to 40 m (area = 5,000 m²). In a few very rare instances, the point will appear within a polygonal area, not a circle, due to the atypically shaped boundary of the underlying vegetation type.

Throughout the course of this project, all efforts should be made to sample every plot. Crew members should only consider the vegetation within the plot when assessing the community and not take the broader landscape into account when assigning a plot to an association. To decrease potential observer bias, crewmembers will not be provided with boundaries for the polygons created during the mapping phase. Plots are meant to be assessed in a rapid manner, with crew members spending 10–15 minutes per plot.

In a systematic manner, crew members will navigate to an AA plot and, using the circular plot boundaries on the GPS, walk throughout the plot assessing the vegetation (e.g., dominant/associate species, formation type, cover values). Tapes will not be used. Instead, surveyors will use the GPS and/or range finder to delineate/estimate the plot edges. Each team will also have a map with plots labelled with the plot name and the radius in meters (e.g., AA1234_40m). Crews should calibrate their visual distance estimates at the beginning of each day, as good practice. Spatial data will be taken according to the following guidelines:

Crews will use the CEDAR CT5 units for navigation, data collection, and taking photographs. These units have the Android operating system and will be using the Backcountry navigator and Survey 123 apps. The Survey 123 has a custom-built form for all data collected at each site (see Appendix G). Each unit will be pre-loaded for each team, and data syncing at the end of each tour will be discussed below.

A) For each plot sampled, collect a data point and photo in the SAGE_VegMap_AA survey, in Survey 123.

- Open Survey 123 from the home screen and tap on the SAGE_VegMap_AA form. At the bottom of the screen, tap “Collect” to begin data collection.
- Fill out each part of the form in order. Mandatory fields are marked with a red *. If these are not completed, the form will not allow you to close.
- **Observer:** Enter as many observers as are present. Hit the up arrow to close the drop-down.
- **Plot ID:** Populate the plot ID field with a FOUR DIGIT number, after the pre-filled “AA”. If you do not enter a valid number (e.g., AA0009, AA1047), the rest of the form will not appear. NOTE: the unit *will* allow you to enter the ID of a plot that has already been completed, so verify what is done/not done using other methods. **If you enter the wrong, but accepted code it can be changed. However, if other data for the survey have already been collected, they will be deleted. If you realize you entered the wrong Plot ID after you’ve already collected data, just make a note and leave the name as is.**
- **Radius:** The radius will autofill based on the Plot ID you enter. You can change this if needed. If you accidentally change it, tap the green arrow icon at the end of the data field to “undo”.
- **Survey Date and time:** These fields will autofill for you. If you notice the data or time is incorrect, go to the Home Screen - Settings - Date & Time, to fix it.
- **Changes to Survey:** This is asking if you changed anything about the plot such as radius or location. If you say “yes” new fields will appear to be filled out.
 - **Did you change the radius?** Yes/No
 - **Did you move the plot?** Choose a response from the list.
 - Plots should only be moved or resized if you are unable to safely assess the plot from the distributed location (e.g., located on cliff band), it’s predominately characterized by recent human/natural disturbance, and/or the plot is dominated by sparsely vegetated bedrock that doesn’t match any of the existing types. In these cases, move the plot the minimum distance possible to avoid the issue, while capturing the type

that the original plot covered or the dominant type surrounding the issue.

- If a plot lands on a road, scoot the assessment area to whichever side contains the majority of the polygon area, trying to maintain the same radius assigned.
- **Plot location:** Next you will see a small box reading ‘offline map preview not available’, but the coordinates and the estimated GPS accuracy are given in the top black bar.
 - If your accuracy is at or below +/- 5 - 6m, all is well ☺
 - If your accuracy is over +/- 6m you can try to improve the accuracy by initiating the GPS to begin averaging positions - do this by holding down the radial compass button on the right side of the box. Tap this again to end averaging.
- **Photo:** Select ‘yes’ or ‘no’ to indicate if you are taking more than 1 photo. Each survey is required to have a minimum of one.
 - If the plot is a good/excellent fit or could easily be captured by one representative photo, then select ‘no’. Selecting ‘no’ makes one photo field appear. Take one representative picture from anywhere within the plot, in any direction, trying to capture all heights of vegetation and limiting the amount of sky in the frame.
 - If the plot is a poor/fair fit or is unplaced, then select ‘yes’ and take one photo in each of the cardinal directions (N, S, E, W). Selecting ‘yes’ makes 4 photo fields appear, one for each direction. Again, these can be taken anywhere within the plot, but should be in a spot that is representative of the entire plot.
 - To take a photo click on the camera icon to open the camera. Take a picture. **WAIT** for a couple of seconds, and it will automatically return you to the survey. **DO NOT click the back arrow at the upper left of the camera window.** Doing so will exit the survey and lose your work.
 - Once back in the survey form you can review the picture and retake it if necessary, by simply hitting the camera icon and taking another picture which will overwrite the first one.
 - Try to minimize areas without diagnostic vegetation.
 - Take pictures horizontal, not vertically.
- **Primary type Selection:** Type in the code for the vegetation type you have selected from the key. This format must be in capital letters followed by numbers with no spaces (TS03, HEO01). Hit the green check mark ON THE KEYBOARD to ‘enter’ the value. (If you hit the green check mark at the bottom of the survey form it will try to end the survey).
 - If you don’t consider any of the types to be a fit, even a poor one, enter “UP” for unplaced and use the “notes” field to briefly describe it. You will also be filling out the dominant species in the veg summary section. If you encounter numerous unplaced that you consider to be the same, be consistent with your notation.
 - Once you have successfully entered a correct code, the full type name will appear. Double check this is the type you intended, and change the code if necessary.
- **Fit of Primary type:** Choose the fit category that best captures the relation of the vegetation within the plot to the description of the selected type.

Excellent (or Most Triumphant): Select this option if the composition of dominant species (taking into account listed variations within the type) and cover values within the plot match the type description, or match it most triumphantly.

Good: Select this option if the composition of dominant species (taking into account listed variations within the type) within the plot matches the type description, but cover values are outside the values or ranges listed in the type description.

Fair: Select this option if the composition of the minority of dominant species (taking into account listed variations within the type) does not match the type description (e.g., a dominant species is not listed in the description or a listed dominant is not in the plot), but the plot is clearly best suited for the type.

Poor (or Most heinous): Select this option if the composition of the majority of dominant species (taking

into account listed variations within the type) does not match the type description (e.g., a dominant species is not listed in the description or a listed dominant is not in the plot). This indicates that the plot is similar enough to a description to assign a type, but there are major discrepancies between the two, leading you to feeling most heinous about the whole thing.

If either 'fair' or 'poor/most heinous' is selected, use the notes field to detail the reason the plot is not an 'excellent' or 'good' fit. List the dominant species that are either missing from the plot or type description and/or issues with cover values.

- **Secondary type:** If you feel like the area is a *true mix* between two types, list the second best type in this field. It is not a required field and should be used sparingly.
- **In the Veg Summary section:** record the 1–3 most dominant and/or diagnostic species (using the prepopulated drop-down lists), within each of four height classes: top-canopy (>5 m), lower canopy (2–5 m), subcanopy (0.5–2 m), and field (0–0.5 m). This section is very similar to the classification plot datasheet; however, you are not assigning cover values, heights (outside of assigning species to a height class), lifeforms, or total covers by strata. **NOTE**** While there are spaces for three species per class, it is not necessary to fill all of them in. If there are no dominant or diagnostic species within a height class, leave it blank, none are required fields. The dropdowns are based on the most frequently recorded species by stratum from the classification phase. This means that not every species is present in every dropdown list.
- **Notes:** Only record a vegetation summary if there are issues assigning a type to the plot and/or it receives a 'fair' or 'poor' fit. Note other things like: recent fire, very large invasive species patches, seeps or spring locations within or close to the plot, T&E species (?), cultural artifacts, etc.
- **Exotic plants:** Record Yes/No if any non-natives of interest are present within or super-close to the plot. There are 10 high-priority species listed. Check the box next to any that are present. You can click on the thumbnail photo to enlarge it.
- **Has this survey been proofed?** Once all data have been recorded, pass the unit to the other crew member for them to proofread. They should read through the entire form and check for mistakes. Once this is completed, press the button for this field. **Again, if you notice an issue with the plot ID at this point, leave it as is and make a note.**
- Due to the high volume of plots to be sampled, a tracking sheet has been created to keep track of plots that have/need to be sampled. Upon completion of each plot, a consistent mark should be added to the completed column to notate that sampling is done. You should also cross through the completed plot on the paper map.

To end the survey once completed, tap the green arrow at the bottom right. When you are offline, it will notify you that the data has been saved in the outbox. Say OK. The screen will bring you to the outbox, where you'll see a list of the completed plots from that day/tour.

If you need to edit a completed survey, select it from this list, and follow the prompts to edit.

You can show this outbox summary as a list or as a map. Choose from the options at the bottom of the screen.

Hit the back arrow at screen top left to return to the survey home page. From here, collect another point or return to the outbox screen. To exit Survey 123 entirely, use the device back- arrow until at the home screen.

Incidental Data Collection

A second form, SAGE_VegMap_Incidental, was created to record any incidental observations you may have while travelling between plots. The types of incidentals include:

1. Exotics (same list as the AA form)
2. Cultural sites
3. Trash: substantial amounts, not every balloon you see.
4. Other
5. Springs

Very little time should be spent recording incidentals. If the volume of exotics you find is prohibitively time consuming, then don't do it and move on to the next plot. This form is quite simple with fields for:

1. Observer: same as AA survey form
2. Date/time: read only field
3. Plot location: follow same guidance for the AA survey form
4. What type of incidental data are you recording?: List of incidental types that can be selected (select one). If 'Exotic Plants' is selected the same list appears that is used for the AA survey form.
5. Take one photo (no exotics): take one representative photo. For exotics, only take a photo if you are unsure of ID.
6. Notes: required for all incidentals except exotics.

Survey

Observer *
Jeff Galvin, Sarah Studd

Plot ID *
AA1234

Radius
40

Survey Date *
Monday, April 6, 2020 9:06 AM

Changes to Survey

Did you change anything about the survey? *

☐ Yes
☒ No

Plot Location (Average points for 5 Seconds)

No location
Position source closed error

Press to capture location using a map

Do you need to take more than 1 photo? *

☐ Yes
☒ No

Take 1 Representative Photo

Primary Type Selection

Primary Vegetation Type Code (e.g. DS01) *
TS01

Primary Vegetation Type *
(Parkinsonia microphylla) / Cyindropuntia bigelovii / Encelia farinosa Shrubland Association

Fit of Primary Type *
Excellent

Secondary Type Selection

Secondary Vegetation Type Code (e.g. DS01)
TS02

Secondary Vegetation Type
(Parkinsonia microphylla / Fouquieria splendens) / Encelia farinosa (Cottisia gracilis) Shrubland Association

Fit of Secondary Type
Fair

Veg Summary

Upper Canopy (> 5m)

Upper-Can 1st Dominant
Carnegiea gigantea

Upper-Can 2nd Dominant

Lower Canopy (> 2 - 5m)

Lower-Can 1st Dominant
Parkinsonia microphylla

Lower-Can 2nd Dominant

Sub Canopy (0.5 - 2m)

Sub-Can 1st Dominant
Cyindropuntia bigelovii

Sub-Can 2nd Dominant

Field (< 0.5)

Field 1st Dominant
Encelia farinosa

Field 2nd Dominant

Notes

Exotics

Are Exotics Plants Present? *

☐ Yes
☐ No

Has this survey been proofed? *

☐ Yes

Example digital data collection form built in Survey 123 software.

Appendix H. Accuracy Assessment Decision Tables

Accuracy-assessment decision table, Tucson Mountain District.

AA plot(s)	Decision	Reason
765, 865, 809	Plots changed from (<i>Parkinsonia microphylla</i>) / <i>Larrea tridentata</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland to <i>Carnegiea gigantea</i> / <i>Parkinsonia microphylla</i> (<i>Olneya tesota</i>) / <i>Ambrosia deltoidea</i> Shrubland	All plots contain dominant <i>Olneya tesota</i> .
703	Plot changed from <i>Carnegiea gigantea</i> / <i>Parkinsonia microphylla</i> (<i>Olneya tesota</i>) / <i>Ambrosia deltoidea</i> Shrubland to <i>Cylindropuntia acanthocarpa</i> - <i>Vachellia constricta</i> / <i>Calliandra eriophylla</i> - <i>Cottisia gracilis</i> Shrubland	Contains dominant <i>Cylindropuntia acanthocarpa</i> and <i>Vachellia constricta</i> with low <i>Ambrosia deltoidea</i> and no <i>Olneya tesota</i> .
365	Plot changed from <i>Carnegiea gigantea</i> / <i>Parkinsonia microphylla</i> (<i>Olneya tesota</i>) / <i>Ambrosia deltoidea</i> Shrubland to <i>Parkinsonia microphylla</i> / <i>Larrea tridentata</i> / <i>Ambrosia deltoidea</i> Shrubland	Lacks <i>Olneya tesota</i> and associate species are more in line with hill slope types, such as <i>Ambrosia deltoidea</i> Shrubland to <i>Parkinsonia microphylla</i> / <i>Larrea tridentata</i> / <i>Ambrosia deltoidea</i> Shrubland.
197, 783	Plots changed from <i>Simmondsia chinensis</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland to <i>Simmondsia chinensis</i> - <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland	<i>Encelia farinosa</i> is more dominant than <i>Ambrosia deltoidea</i> in both plots.
216, 329	Plots changed from <i>Simmondsia chinensis</i> - Mixed Cacti / <i>Ambrosia deltoidea</i> Shrubland to <i>Simmondsia chinensis</i> (<i>Opuntia engelmannii</i> - <i>Aloysia wrightii</i>) Shrubland	<i>Ambrosia deltoidea</i> is sparse to absent, while <i>Selaginella arizonica</i> is dominant.
267	Plot changed from <i>Parkinsonia microphylla</i> / <i>Larrea tridentata</i> / <i>Ambrosia deltoidea</i> Shrubland to <i>Parkinsonia microphylla</i> / <i>Lycium berlandieri</i> (Mixed Shrub) Rocky Shrubland	<i>Parkinsonia microphylla</i> and <i>Lycium berlandieri</i> are primary dominants while <i>Ambrosia deltoidea</i> is absent.
563, 580, 857	Plots changed from (<i>Parkinsonia microphylla</i> - <i>Fouquieria splendens</i>) / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Shrubland to <i>Simmondsia chinensis</i> - <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland	All plots contain dominant <i>Simmondsia chinensis</i> .
804	Plot changed from (<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Larrea tridentata</i> - <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i>) / <i>Krameria bicolor</i> Wooded Shrubland to <i>Cylindropuntia acanthocarpa</i> - <i>Vachellia constricta</i> / <i>Calliandra eriophylla</i> - <i>Cottisia gracilis</i> Shrubland	Overall species composition is a better fit for <i>Cylindropuntia acanthocarpa</i> - <i>Vachellia constricta</i> / <i>Calliandra eriophylla</i> - <i>Cottisia gracilis</i> Shrubland.
491, 578	Plots changed from <i>Simmondsia chinensis</i> (<i>Opuntia engelmannii</i> - <i>Aloysia wrightii</i>) Shrubland to <i>Simmondsia chinensis</i> - <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland	Both plots contain dominant <i>Encelia farinosa</i> .

Accuracy-assessment decision table, Rincon Mountain District.

AA plots	Decision	Reason
515, 937, 1014, 1711	Changed from <i>Pinus arizonica</i> Forest Association and <i>Alnus oblongifolia</i> / <i>Acer negundo</i> / <i>Rosa woodsii</i> Intermittently Flooded Woodland Association to <i>Pinus arizonica</i> / <i>Quercus hypoleucoides</i> Woodland Association	Contains dominant understory of <i>Quercus hypoleucoides</i> .
244, 1128	Changed from <i>Pinus arizonica</i> / <i>Quercus hypoleucoides</i> Woodland Association and <i>Pinus arizonica</i> / <i>Pteridium aquilinum</i> Forest Association to <i>Pinus (arizonica - ponderosa)</i> Regenerating Woodland Association	Contains dominant layer of regenerating conifers without dominant overstory trees.
657	Changed from [<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland Association to <i>Pinus ponderosa</i> / <i>Quercus hypoleucoides</i> Woodland Association	Dominant layer of emergent <i>Pinus ponderosa</i> .
227, 772, 912, 1237, 1357, 1674, 1922, 1927	Changed from [<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland Association to <i>Pinus leiophylla</i> / <i>Quercus hypoleucoides</i> Woodland Association	Dominant layer of emergent <i>Pinus leiophylla</i> .
55, 111, 327, 1255, 1288, 1601	Changed from [<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Intermittently Flooded Woodland Association, <i>Pinus discolor</i> / <i>Quercus rugosa</i> Woodland Association, and [<i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i>] Shrubland to <i>Pseudotsuga menziesii</i> / <i>Quercus rugosa</i> Forest Association	Dominant layer of emergent <i>Pseudotsuga menziesii</i> .
375	Changed from <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland Association to (<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland Association	<i>Encelia farinosa</i> too low and patchy.
406	Changed from <i>Prosopis velutina</i> / Annual Forb Woodland Association to (<i>Prosopis velutina</i>) / <i>Larrea tridentata</i> Shrubland Association	Contains open canopy with dominant <i>Larrea tridentata</i> .
538	Changed from <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland Association to (<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland Association	Contains dominant <i>Vachellia constricta</i> . Located in a drainage.
1718	Changed from (<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland Association to <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> Shrubland Association	Not located in a wash. Contains dominant <i>Encelia farinosa</i> .
451, 630	Changed from (<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland Association and (<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland Association to (<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> - <i>Opuntia engelmannii</i> Shrubland Association	Not located in a wash. No <i>Parkinsonia microphylla</i> .
33, 714, 1370, 1874	Changed from (<i>Carnegiea gigantea</i>) / <i>Parkinsonia microphylla</i> / <i>Opuntia engelmannii</i> (<i>Vachellia constricta</i> - <i>Larrea tridentata</i>) Wooded Shrubland Association to <i>Parkinsonia microphylla</i> / <i>Encelia farinosa</i> - <i>Hibiscus denudatus</i> Shrubland Association (P)	Contains both <i>Encelia farinosa</i> and <i>Hibiscus denudatus</i> .
355	Changed from <i>Pseudotsuga menziesii</i> - <i>Pinus (arizonica - ponderosa)</i> / (<i>Quercus gambelii</i>) Forest Association to <i>Pteridium aquilinum</i> Herbaceous Association	Canopy too open and patchy for forest community.

Accuracy-assessment decision table, Rincon Mountain District (continued).

AA plots	Decision	Reason
5, 51, 647, 654, 1317, 1400, 1485, 1936	Changed from <i>Quercus gambelii</i> / <i>Robinia neomexicana</i> / <i>Symphoricarpos oreophilus</i> Woodland Association and <i>Muhlenbergia virescens</i> - <i>Pteridium aquilinum</i> - <i>Ceanothus fendleri</i> Herbaceous Association to <i>Quercus gambelii</i> / <i>Symphoricarpos oreophilus</i> Shrubland Association	Dominant <i>Quercus gambelii</i> present as small, shrubby individuals.
1227, 1729	Changed from <i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Woodland Association to <i>Platanus wrightii</i> - <i>Fraxinus velutina</i> Intermittently Flooded Woodland Association	Contains emergent <i>Platanus wrightii</i> .
1052	Changed from <i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Woodland Association to <i>Platanus wrightii</i> / <i>Quercus oblongifolia</i> Riparian Woodland Association	Contains emergent <i>Platanus wrightii</i> and <i>Quercus oblongifolia</i> .
401, 685, 940, 1027	Changed from <i>Pseudotsuga menziesii</i> - <i>Pinus (arizonica - ponderosa)</i> / (<i>Quercus gambelii</i>) Forest Association (P) and <i>Pteridium aquilinum</i> Herbaceous Association to <i>Pseudotsuga menziesii</i> / <i>Pinus strobiformis</i> Forest Association	Contain minimal to absent <i>Pinus ponderosa</i> or <i>Pinus arizonica</i> . Dominant canopy of <i>Pseudotsuga menziesii</i> .
1808	Changed from <i>Quercus gambelii</i> / <i>Symphoricarpos oreophilus</i> Shrubland Association to <i>Pseudotsuga menziesii</i> - <i>Pinus (arizonica - ponderosa)</i> / (<i>Quercus gambelii</i>) Forest Association	Contains dominant canopy of <i>Pseudotsuga menziesii</i> .
309, 1009	Changed from <i>Pinus ponderosa</i> / <i>Quercus hypoleucoides</i> Woodland Association and <i>Pinus ponderosa</i> / <i>Pteridium aquilinum</i> Forest Association to <i>Pinus ponderosa (Pinus strobiformis)</i> / <i>Muhlenbergia virescens</i> Woodland Association	Contains dominant understory of <i>Muhlenbergia virescens</i> .
1076	Changed from <i>Muhlenbergia virescens</i> - <i>Pteridium aquilinum</i> - <i>Ceanothus fendleri</i> Herbaceous Association to <i>Pinus ponderosa</i> - <i>Pinus strobiformis</i> Forest Association	Contains dominant overstory of <i>Pinus ponderosa</i> .
91, 166, 601	Changed from <i>Pinus arizonica</i> / <i>Quercus hypoleucoides</i> Woodland Association and <i>Pinus (arizonica - ponderosa)</i> Regenerating Woodland Association to <i>Pinus arizonica (Pinus strobiformis)</i> / <i>Muhlenbergia virescens</i> Forest Association	Contains dominant understory of <i>Muhlenbergia virescens</i> .
1087	Changed from <i>Pseudotsuga menziesii</i> - <i>Pinus (arizonica - ponderosa)</i> / (<i>Quercus gambelii</i>) Forest Association to <i>Pinus arizonica</i> Forest Association	<i>Pseudotsuga menziesii</i> cover too low.
20, 715	Changed from [<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Shrubland and Woodland Associations to [<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] / <i>Arctostaphylos (pringlei - pungens)</i> Woodland Association	Contains dominant <i>Arctostaphylos</i> spp.
1790	Changed from [<i>Quercus chrysolepis</i> - <i>Quercus rugosa</i> - <i>Holodiscus dumosa</i>] Shrubland Association to <i>Quercus rugosa</i> - <i>Ceanothus integerrimus</i> Woodland Association	Contains dominant <i>Ceanothus integerrimus</i> .
102, 892, 1366, 1646	Changed from <i>Quercus arizonica</i> - <i>Quercus emoryi (Platanus wrightii)</i> Intermittently Flooded Woodland Association to [<i>Quercus arizonica</i> - <i>Quercus hypoleucoides</i>] Intermittently Flooded Woodland Association	No recorded <i>Quercus emoryi</i> . Contains dominant <i>Quercus hypoleucoides</i> .
1279, 1669	Changed from [<i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Woodland Association to <i>Quercus arizonica</i> - <i>Quercus emoryi (Platanus wrightii)</i> Intermittently Flooded Woodland Association	Located in drainage.

Accuracy-assessment decision table, Rincon Mountain District (continued).

AA plots	Decision	Reason
7, 990	Changed from <i>Pinus discolor</i> (<i>Quercus arizonica</i> - <i>Juniperus deppeana</i> - <i>Quercus hypoleuroides</i>) Woodland Association and <i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna Association to <i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland Association	Open Pine/oak woodland with layer of dominant grass.
338, 1473	Changed from <i>Pinus discolor</i> / <i>Arctostaphylos</i> (<i>pungens</i> - <i>pringlei</i>) Wooded Shrubland Association and [<i>Quercus hypoleuroides</i> - <i>Quercus arizonica</i>] Woodland Association to <i>Pinus discolor</i> (<i>Quercus arizonica</i> - <i>Juniperus deppeana</i> - <i>Quercus hypoleuroides</i>) Woodland Association	Contains dominant <i>Pinus discolor</i> . <i>Arctostaphylos</i> spp. cover too low.
370, 1768	Changed from <i>Pinus discolor</i> / <i>Quercus toumeyi</i> Woodland Association and <i>Pinus discolor</i> / <i>Quercus rugosa</i> Woodland Association to <i>Cupressus arizonica</i> / <i>Quercus hypoleuroides</i> Forest Association	Contains <i>Cupressus arizonica</i> .
518, 1218, 1398, 1549, 1635, 1668, 1786	Changed from <i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna Association and <i>Nolina microcarpa</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna Association to [<i>Quercus oblongifolia</i> - <i>Prosopis velutina</i> - <i>Vauquelinia californica</i>] / Mixed Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna Association	Canopy cover too high.
1584	Changed from <i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna Association to <i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna Association	Contains consistent <i>Fouquieria splendens</i> .
949	Changed from <i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna Association to <i>Fouquieria splendens</i> / (<i>Opuntia engelmannii</i>) / <i>Selaginella rupicola</i> Sparse Rock Outcrop Association	Ground cover dominated by bedrock.
1075, 1146, 1436, 1913	Changed from <i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna Association and <i>Quercus oblongifolia</i> / <i>Bouteloua curtipendula</i> Scrub Association to <i>Nolina microcarpa</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna Association	Dominant <i>Nolina microcarpa</i> with minimal canopy cover.
1086	Changed from <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> - <i>Ericameria laricifolia</i> / <i>Muhlenbergia porteri</i> Wooded Shrubland Association to <i>Dalea pulchra</i> / Mixed Perennial Grass Shrub Savanna Association	Contains dominant layer of <i>Dalea pulchra</i> .
168, 268, 1035, 1058, 1092, 1301, 1744	Changed from <i>Quercus oblongifolia</i> / <i>Bouteloua curtipendula</i> Scrub Association to (<i>Quercus emoryi</i> - <i>Quercus oblongifolia</i>) / <i>Eragrostis lehmanniana</i> Herbaceous Association	Contain dominant layer of <i>Eragrostis lehmanniana</i> .
18, 169, 896, 998, 1877	Changed from (<i>Quercus arizonica</i> - <i>Quercus emoryi</i>) / <i>Arctostaphylos pungens</i> Shrubland Association and <i>Pinus discolor</i> (<i>Quercus arizonica</i> - <i>Juniperus deppeana</i> - <i>Quercus hypoleuroides</i>) Woodland Association to <i>Quercus emoryi</i> / <i>Arctostaphylos pungens</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna Association	<i>Pinus discolor</i> cover too low. Dominant layer of perennial grasses.

Accuracy-assessment decision table, Rincon Mountain District (continued).

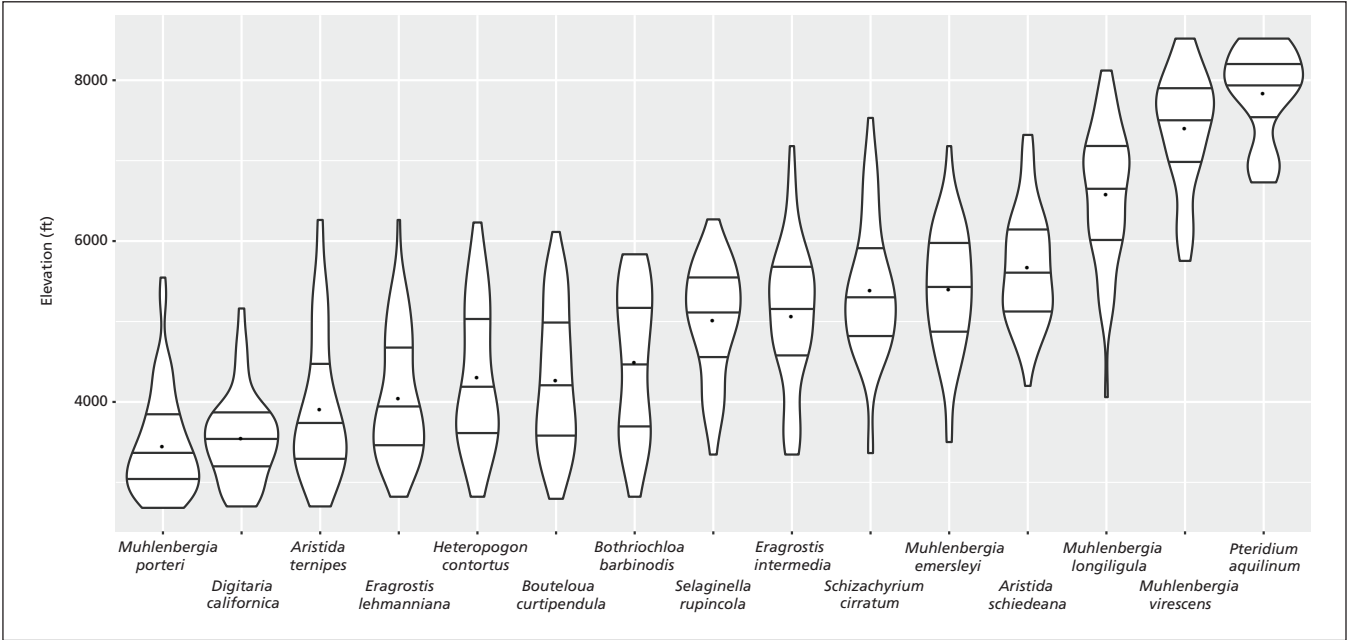
AA plots	Decision	Reason
428	Changed from [<i>Quercus oblongifolia</i> - <i>Prosopis velutina</i> - <i>Vauquelinia californica</i>] / Mixed Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna Association to <i>Quercus emoryi</i> / <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Wooded Shrub Savanna Association	Contains dominant canopy of <i>Quercus emoryi</i> .
1063, 1211, 1351, 1356, 1499, 1628	Changed from [<i>Quercus oblongifolia</i> - <i>Prosopis velutina</i> - <i>Vauquelinia californica</i>] / Mixed Perennial Grass - <i>Agave schottii</i> Wooded Shrub Savanna Association and <i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland Association to <i>Quercus oblongifolia</i> / <i>Bouteloua curtipendula</i> Scrub Association	Contains consistent canopy of <i>Quercus oblongifolia</i> .
352, 576, 1042, 1725	Changed from 4 different desert scrub communities to <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> / <i>Encelia farinosa</i> (<i>Cottisia gracilis</i>) Wooded Shrubland Association	Contains canopy of <i>Prosopis velutina</i> and understory of <i>Encelia farinosa</i> .
21, 155, 592, 1667, 1779	Changed from 4 different desert scrub communities to <i>Simmondsia chinensis</i> / <i>Encelia farinosa</i> Shrubland Association	Contains <i>Simmondsia chinensis</i> .
372	Changed from <i>Prosopis velutina</i> / Annual Forb Woodland Association to <i>Prosopis velutina</i> Woodland Association	Wrong habitat for community.
1111	Changed <i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna Association to <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> - <i>Ericameria laricifolia</i> / <i>Muhlenbergia porteri</i> Wooded Shrubland Association	Contains dominant layer of <i>Muhlenbergia porteri</i> .
235, 266, 600	Changed from <i>Fouquieria splendens</i> - <i>Prosopis velutina</i> / <i>Dodonaea viscosa</i> Shrubland Association and <i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Shrubland Association to (<i>Prosopis velutina</i>) / <i>Aloysia wrightii</i> Shrubland Association	Contains dominant layer of <i>Aloysia wrightii</i> .
438, 1525, 1569	Changed from <i>Fouquieria splendens</i> (<i>Prosopis velutina</i>) / <i>Opuntia engelmannii</i> / Mixed Perennial Grass - <i>Agave schottii</i> Shrub Savanna Association, (<i>Prosopis velutina</i>) / <i>Aloysia wrightii</i> Shrubland Association, and <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> (<i>Senegalia greggii</i> - <i>Celtis ehrenbergiana</i>) Wooded Shrubland Association to <i>Fouquieria splendens</i> - <i>Prosopis velutina</i> / <i>Dodonaea viscosa</i> Shrubland Association	Contain a dominant layer of <i>Dodonaea viscosa</i> .
1097, 1202, 1240, 1750, 1814	Changed from <i>Prosopis velutina</i> / Annual Forb Woodland Association, (<i>Prosopis velutina</i>) / <i>Vachellia constricta</i> (<i>Larrea tridentata</i> - <i>Senegalia greggii</i>) Intermittently Flooded Shrubland Association, and (<i>Fouquieria splendens</i>) / <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> / <i>Cottisia gracilis</i> Shrubland Association to <i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Woodland Association	Present in and along washes. Contains dominant canopy of <i>Prosopis velutina</i> .
241, 1023, 1031, 1776	Changed from <i>Platanus wrightii</i> - <i>Fraxinus velutina</i> Intermittently Flooded Woodland Association and <i>Prosopis velutina</i> / <i>Opuntia engelmannii</i> (<i>Senegalia greggii</i> - <i>Celtis ehrenbergiana</i>) Wooded Shrubland Association to <i>Prosopis velutina</i> - <i>Senegalia greggii</i> Intermittently Flooded Shrubland Association	No dominant riparian trees. Located in and along washes.

Accuracy-assessment decision table, Rincon Mountain District (continued).

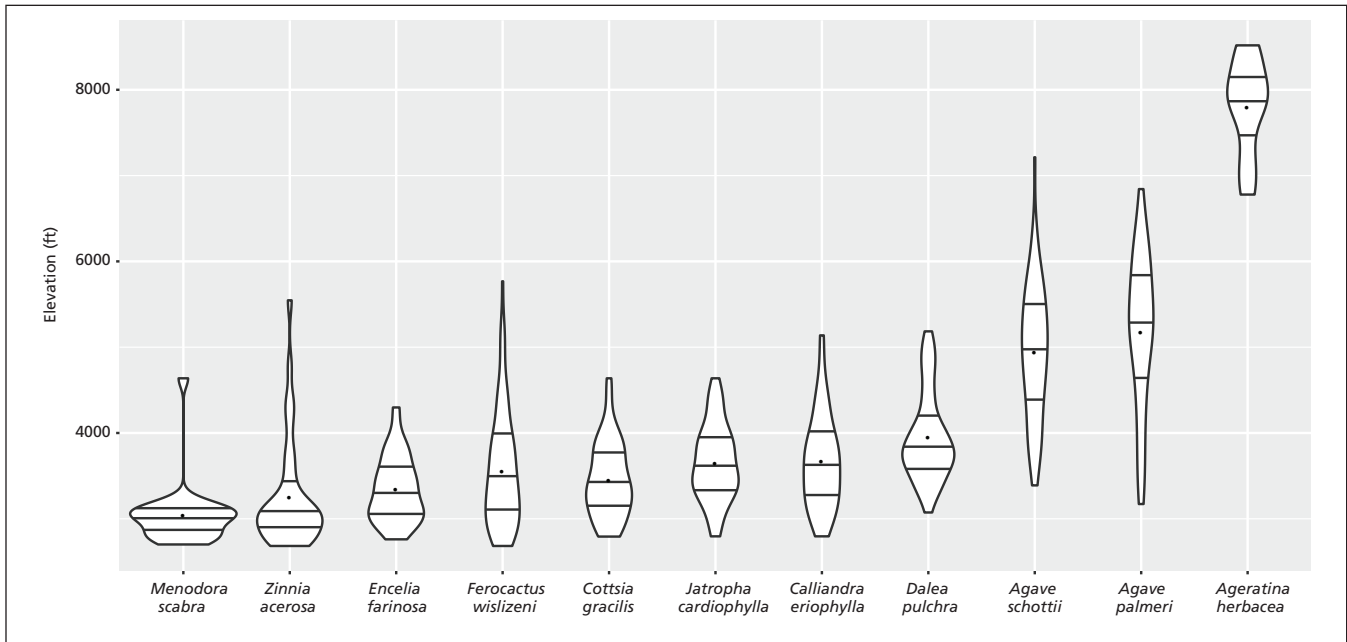
AA plots	Decision	Reason
1326	Changed from (<i>Prosopis velutina</i>) / <i>Larrea tridentata</i> Shrubland Association to <i>Prosopis velutina</i> / Annual Forb Woodland Association	Minimal <i>Larrea tridentata</i> with dominant annual forbs.
1568	Changed from <i>Prosopis velutina</i> - <i>Chilopsis linearis</i> / <i>Ambrosia monogyra</i> Intermittently Flooded Woodland Association to <i>Prosopis velutina</i> / <i>Ziziphus obtusifolia</i> - <i>Condalia warnockii</i> Woodland Association	Contains dominant understory of <i>Ziziphus obtusifolia</i> and <i>Condalia warnockii</i> .

Appendix I. Additional Box Plots Depicting Elevational Range of Species at the Rincon Mountain District

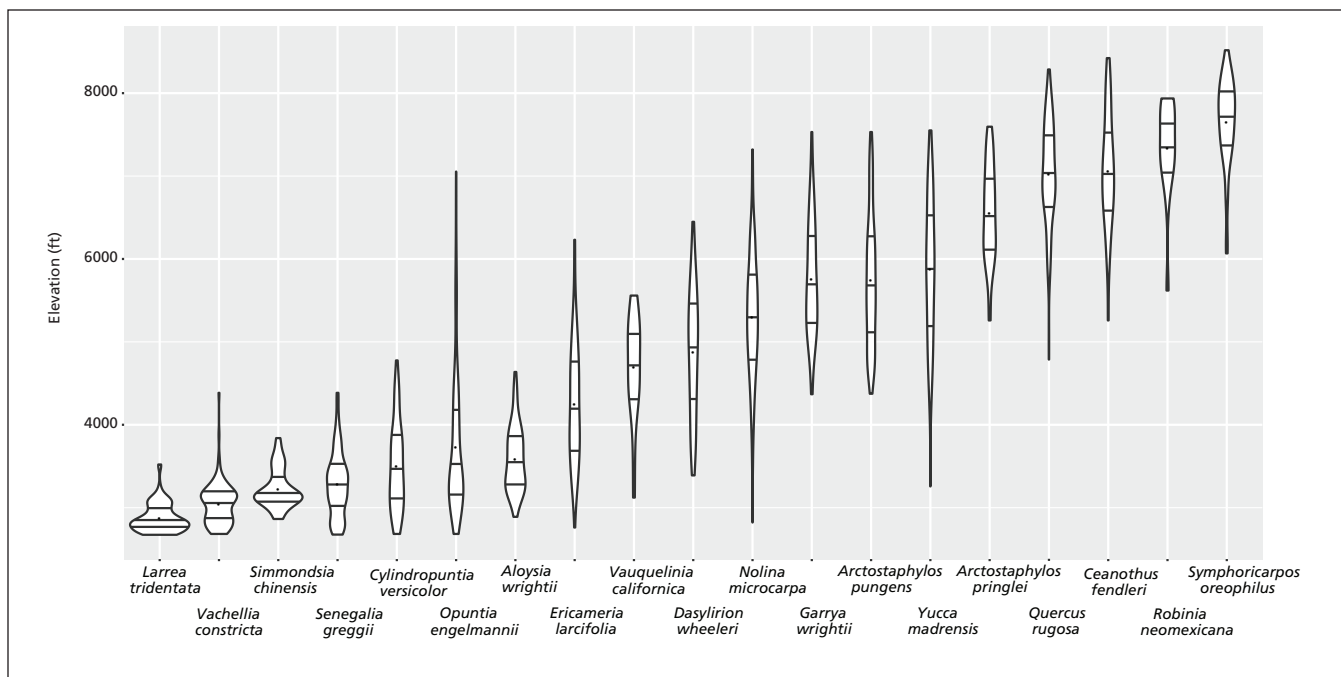
Species are split by height strata (field, subcanopy, and canopy), with the field strata split by shrub/succulent and grass/herbaceous



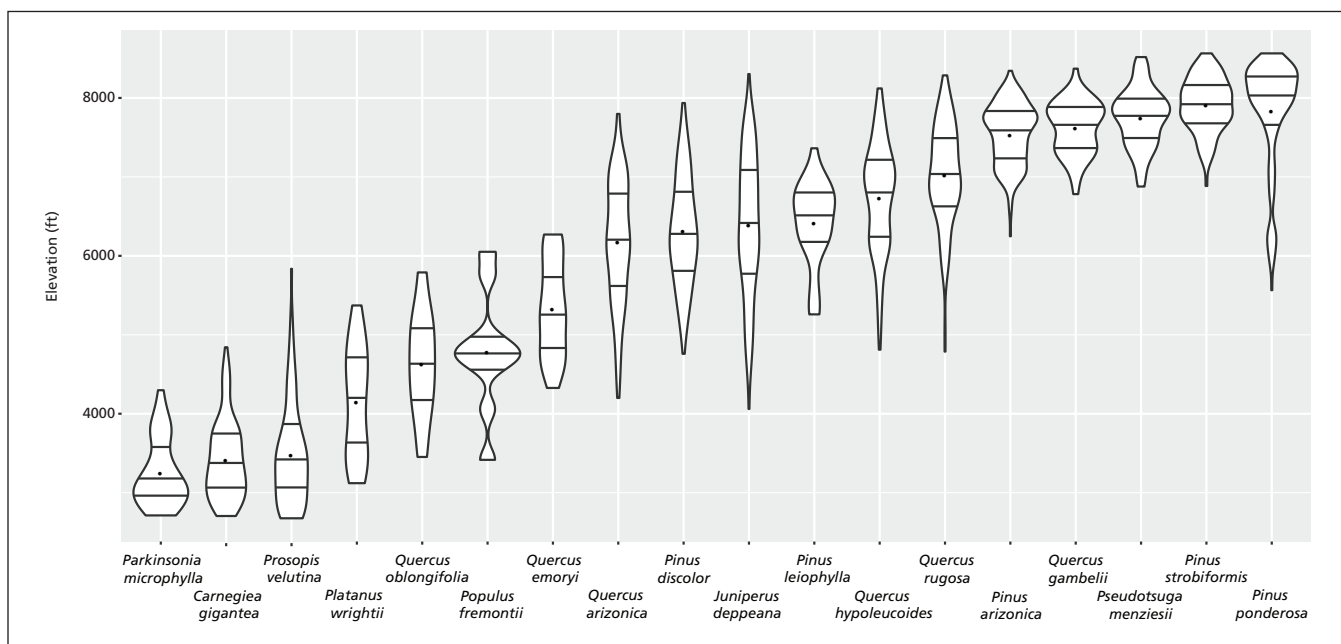
Violin plots depicting the elevational range of field-stratum (<0.5 m) perennial grass and other common herbaceous species at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot.



Violin plots depicting the elevational range of field-stratum (<0.5 m) subshrubs and succulents at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot.



Violin plots depicting the elevational range of subcanopy-stratum (0.5–2 m) shrubs and succulents at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot.



Violin plots depicting the elevational range of canopy-stratum (>2 m) trees and succulents at the Rincon Mountain District. The three horizontal lines depict the median (center), upper quartile (upper), and lower quartile (lower). The mean value is represented by the black dot.

Appendix J. Species Lists by Unit

List of all plant species observed during intermediate plot data collection and accuracy assessment data collection at Saguaro NP from 2013 to 2018. The columns indicate which district (TMD or RMD), is associated with a species observation.

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013-2018.					
Family	Scientific name	Common name	Nativity	RMD	TMD
Acanthaceae	<i>Anisacanthus thurberi</i>	Thurber's desert honeysuckle	Native	Yes	Yes
Acanthaceae	<i>Carlowrightia arizonica</i>	Arizona wrightwort	Native	Yes	Yes
Acanthaceae	<i>Justicia longii</i>	longflower tube tongue	Native	Yes	Yes
Acanthaceae	<i>Ruellia nudiflora</i>	violet wild petunia	Native	Yes	No
Acanthaceae	<i>Tetramerium nervosum</i>	hairy fourwort	Native	Yes	No
Adoxaceae	<i>Sambucus nigra</i>	black elderberry	Non-native	Yes	No
Amaranthaceae	<i>Amaranthus palmeri</i>	carelessweed	Native	Yes	No
Amaranthaceae	<i>Atriplex canescens</i>	fourwing saltbush	Native	Yes	Yes
Amaranthaceae	<i>Atriplex linearis</i>	thinleaf fourwing saltbush	Native	Yes	No
Amaranthaceae	<i>Dysphania graveolens</i>	fetid goosefoot	Native	Yes	No
Amaranthaceae	<i>Gomphrena sonora</i>	Sonoran globe amaranth	Native	Yes	No
Amaranthaceae	<i>Salsola tragus</i>	prickly Russian thistle	Non-native	Yes	No
Amaryllidaceae	<i>Allium geyeri</i>	Geyer's onion	Native	Yes	No
Amaryllidaceae	<i>Allium macropetalum</i>	largeflower onion	Native	No	Yes
Anacardiaceae	<i>Rhus aromatica</i>	fragrant sumac	Native	Yes	No
Anacardiaceae	<i>Rhus glabra</i>	smooth sumac	Native	Yes	No
Anacardiaceae	<i>Toxicodendron radicans</i>	eastern poison ivy	Native	Yes	No
Apiaceae	<i>Lomatium nevadense</i> var. <i>nevadense</i>	Nevada biscuitroot	Native	Yes	No
Apiaceae	<i>Pseudocymopterus montanus</i>	alpine false springparsley	Native	Yes	No
Apocynaceae	<i>Apocynum cannabinum</i>	Indianhemp	Native	Yes	No
Apocynaceae	<i>Asclepias angustifolia</i>	Arizona milkweed	Native	Yes	No
Apocynaceae	<i>Asclepias linaria</i>	pineneedle milkweed	Native	Yes	No
Apocynaceae	<i>Asclepias nyctaginifolia</i>	Mojave milkweed	Native	No	Yes
Apocynaceae	<i>Funastrum crispum</i>	wavyleaf twinevine	Native	Yes	No
Apocynaceae	<i>Haplophyton crooksii</i>	cockroachplant	Native	Yes	No
Apocynaceae	<i>Matelea parvifolia</i>	spearleaf	Native	Yes	Yes
Apocynaceae	<i>Metastelma arizonicum</i>	Arizona swallow-wort	Native	No	Yes
Apocynaceae	<i>Sarcostemma cynanchoides</i>	fringed twinevine	Native	Yes	No
Araliaceae	<i>Aralia humilis</i>	Arizona spikenard	Native	Yes	No
Aristolochiaceae	<i>Aristolochia watsonii</i>	Watson's dutchman's pipe	Native	Yes	No
Asparagaceae	<i>Agave palmeri</i>	Palmer's century plant	Native	Yes	No
Asparagaceae	<i>Agave schottii</i>	Schott's century plant	Native	Yes	Yes
Asparagaceae	<i>Dasyllirion wheeleri</i>	common sotol	Native	Yes	Yes
Asparagaceae	<i>Dichelostemma capitatum</i>	bluedicks	Native	Yes	Yes
Asparagaceae	<i>Maianthemum stellatum</i>	starry false lily of the valley	Native	Yes	No
Asparagaceae	<i>Nolina microcarpa</i>	sacahuista	Native	Yes	No
Asparagaceae	<i>Sarcocolla schottii</i>	Schott's yucca	Native	Yes	No
Asparagaceae	<i>Yucca baccata</i>	banana yucca	Native	Yes	Yes
Asparagaceae	<i>Yucca madrensis</i>	yucca	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Asteraceae	<i>Achillea millefolium</i>	common yarrow	Native	Yes	No
Asteraceae	<i>Acourtia nana</i>	dwarf desertpeony	Native	Yes	Yes
Asteraceae	<i>Acourtia wrightii</i>	brownfoot	Native	Yes	Yes
Asteraceae	<i>Adenophyllum porophylloides</i>	San Felipe dogweed	Native	Yes	Yes
Asteraceae	<i>Ageratina herbacea</i>	fragrant snakeroot	Native	Yes	No
Asteraceae	<i>Ageratina paupercula</i>	Santa Rita snakeroot	Native	Yes	No
Asteraceae	<i>Amauriopsis dissecta</i>	ragleaf bahia	Native	Yes	No
Asteraceae	<i>Ambrosia ambrosioides</i>	ambrosia leaf bur ragweed	Native	Yes	Yes
Asteraceae	<i>Ambrosia confertiflora</i>	weakleaf bur ragweed	Native	Yes	No
Asteraceae	<i>Ambrosia cordifolia</i>	Tucson bur ragweed	Native	No	Yes
Asteraceae	<i>Ambrosia deltoidea</i>	triangle bur ragweed	Native	Yes	Yes
Asteraceae	<i>Ambrosia dumosa</i>	burrobush	Native	No	Yes
Asteraceae	<i>Ambrosia monogyra</i>	singlewhorl burrobush	Native	Yes	Yes
Asteraceae	<i>Ambrosia salsola</i>	burrobrush	Native	Yes	No
Asteraceae	<i>Antennaria marginata</i>	whitemargin pussytoes	Native	Yes	No
Asteraceae	<i>Artemisia dracunculus</i>	tarragon	Native	Yes	No
Asteraceae	<i>Artemisia ludoviciana</i>	white sagebrush	Native	Yes	Yes
Asteraceae	<i>Baccharis brachyphylla</i>	shortleaf baccharis	Native	Yes	Yes
Asteraceae	<i>Baccharis pteronioides</i>	yerba de pismo	Native	Yes	No
Asteraceae	<i>Baccharis salicifolia</i>	mule-fat	Native	Yes	No
Asteraceae	<i>Baccharis sarothroides</i>	desertbroom	Native	Yes	No
Asteraceae	<i>Baccharis thesioides</i>	Arizona baccharis	Native	Yes	No
Asteraceae	<i>Bahia absinthifolia</i>	hairyseed bahia	Native	Yes	Yes
Asteraceae	<i>Bebbia juncea</i>	sweetbush	Native	Yes	Yes
Asteraceae	<i>Bidens heterosperma</i>	Rocky Mountain beggarticks	Native	Yes	No
Asteraceae	<i>Brickellia betonicifolia</i>	betonyleaf brickellbush	Native	Yes	No
Asteraceae	<i>Brickellia californica</i>	California brickellbush	Native	Yes	No
Asteraceae	<i>Brickellia coulteri</i>	Coulter's brickellbush	Native	Yes	Yes
Asteraceae	<i>Brickellia eupatorioides</i>	false boneset	Native	Yes	No
Asteraceae	<i>Brickellia floribunda</i>	Chihuahuan brickellbush	Native	Yes	No
Asteraceae	<i>Brickellia grandiflora</i>	tasselflower brickellbush	Native	Yes	No
Asteraceae	<i>Brickellia rusbyi</i>	stinking brickellbush	Native	Yes	No
Asteraceae	<i>Brickellia venosa</i>	veiny brickellbush	Native	Yes	No
Asteraceae	<i>Carphochaete bigelovii</i>	Bigelow's bristlehead	Native	Yes	No
Asteraceae	<i>Centaurea melitensis</i>	Maltese star-thistle	Non-native	Yes	No
Asteraceae	<i>Cirsium neomexicanum</i>	New Mexico thistle	Native	Yes	No
Asteraceae	<i>Cirsium wheeleri</i>	Wheeler's thistle	Native	Yes	No
Asteraceae	<i>Coreocarpus arizonicus</i>	little lemonhead	Native	Yes	No
Asteraceae	<i>Encelia farinosa</i>	brittlebush	Native	Yes	Yes
Asteraceae	<i>Ericameria cuneata</i>	cliff goldenbush	Native	Yes	No
Asteraceae	<i>Ericameria laricifolia</i>	turpentine bush	Native	Yes	Yes
Asteraceae	<i>Erigeron divergens</i>	spreading fleabane	Native	Yes	No
Asteraceae	<i>Erigeron flagellaris</i>	trailing fleabane	Native	Yes	No
Asteraceae	<i>Erigeron neomexicanus</i>	New Mexico fleabane	Native	Yes	No
Asteraceae	<i>Erigeron oreophilus</i>	chaparral fleabane	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Asteraceae	<i>Erigeron speciosus</i>	aspen fleabane	Native	Yes	No
Asteraceae	<i>Galinsoga parviflora</i>	gallant soldier	Non-native	Yes	No
Asteraceae	<i>Guardiola platyphylla</i>	Apache plant	Native	Yes	No
Asteraceae	<i>Gutierrezia microcephala</i>	threadleaf snakeweed	Native	Yes	Yes
Asteraceae	<i>Gutierrezia sarothrae</i>	broom snakeweed	Native	Yes	No
Asteraceae	<i>Gutierrezia serotina</i>	late snakeweed	Native	Yes	No
Asteraceae	<i>Gymnosperma glutinosum</i>	gumhead	Native	Yes	Yes
Asteraceae	<i>Helenium thurberi</i>	Thurber's sneezeweed	Native	Yes	No
Asteraceae	<i>Helianthella quinquenervis</i>	fivenerve helianthella	Native	Yes	No
Asteraceae	<i>Heliomeris multiflora</i>	showy goldeneye	Native	Yes	No
Asteraceae	<i>Heterotheca fulcrata</i>	rockyscree false goldenaster	Native	Yes	No
Asteraceae	<i>Heterotheca subaxillaris</i>	camphorweed	Native	Yes	No
Asteraceae	<i>Hieracium crepidispermum</i>	Lemmon's hawkweed	Native	Yes	No
Asteraceae	<i>Hieracium fendleri</i>	yellow hawkweed	Native	Yes	No
Asteraceae	<i>Hymenothrix wislizeni</i>	Trans-Pecos thimblehead	Native	Yes	No
Asteraceae	<i>Hymenothrix wrightii</i>	Wright's thimblehead	Native	Yes	No
Asteraceae	<i>Hymenoxys hoopesii</i>	owl's-claws	Native	Yes	No
Asteraceae	<i>Isocoma tenuisecta</i>	burroweed	Native	Yes	No
Asteraceae	<i>Koanophyllon solidaginifolium</i>	shrubby thoroughwort	Native	Yes	Yes
Asteraceae	<i>Lactuca serriola</i>	prickly lettuce	Non-native	Yes	No
Asteraceae	<i>Laennecia schiedeana</i>	pineland horseweed	Native	Yes	No
Asteraceae	<i>Laennecia sophiifolia</i>	leafy horseweed	Native	Yes	No
Asteraceae	<i>Melampodium leucanthum</i>	plains blackfoot	Native	Yes	No
Asteraceae	<i>Packera neomexicana</i>	New Mexico groundsel	Native	Yes	No
Asteraceae	<i>Parthenium incanum</i>	mariola	Native	Yes	Yes
Asteraceae	<i>Perityle coronopifolia</i>	crowfoot rockdaisy	Native	Yes	No
Asteraceae	<i>Perityle lemmonii</i>	Lemmon's rockdaisy	Native	Yes	No
Asteraceae	<i>Porophyllum gracile</i>	slender poreleaf	Native	Yes	Yes
Asteraceae	<i>Pseudognaphalium canescens</i>	Wright's cudweed	Native	Yes	No
Asteraceae	<i>Pseudognaphalium macounii</i>	Macoun's cudweed	Native	Yes	No
Asteraceae	<i>Psilostrophe cooperi</i>	whitestem paperflower	Native	Yes	Yes
Asteraceae	<i>Rudbeckia laciniata</i>	cutleaf coneflower	Native	Yes	No
Asteraceae	<i>Senecio bigelovii</i>	nodding ragwort	Native	Yes	No
Asteraceae	<i>Senecio lemmonii</i>	Lemmon's ragwort	Native	Yes	Yes
Asteraceae	<i>Senecio wootonii</i>	Wooton's ragwort	Native	Yes	No
Asteraceae	<i>Solidago canadensis</i>	Canada goldenrod	Native	Yes	No
Asteraceae	<i>Solidago velutina</i>	threenerve goldenrod	Native	Yes	No
Asteraceae	<i>Solidago wrightii</i>	Wright's goldenrod	Native	Yes	No
Asteraceae	<i>Sonchus asper</i>	spiny sowthistle	Non-native	Yes	No
Asteraceae	<i>Sonchus oleraceus</i>	common sowthistle	Non-native	Yes	No
Asteraceae	<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Native	Yes	Yes
Asteraceae	<i>Stevia serrata</i>	sawtooth candyleaf	Native	Yes	No
Asteraceae	<i>Tagetes lemmonii</i>	Lemmon's marigold	Native	Yes	Yes
Asteraceae	<i>Tagetes micrantha</i>	licorice marigold	Native	Yes	No
Asteraceae	<i>Thymophylla pentachaeta</i>	fiveneedle pricklyleaf	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Asteraceae	<i>Trixis californica</i>	American threefold	Native	Yes	Yes
Asteraceae	<i>Viguiera cordifolia</i>	heartleaf goldeneye	Native	Yes	No
Asteraceae	<i>Viguiera dentata</i>	toothleaf goldeneye	Native	Yes	No
Asteraceae	<i>Xanthisma gracile</i>	slender goldenweed	Native	No	Yes
Asteraceae	<i>Xanthisma spinulosum</i>	spiny haplopappus	Native	Yes	Yes
Asteraceae	<i>Xanthium spinosum</i>	spiny cocklebur	Non-native	Yes	No
Asteraceae	<i>Xanthium strumarium</i>	rough cocklebur	Native	Yes	No
Asteraceae	<i>Zinnia acerosa</i>	desert zinnia	Native	Yes	Yes
Berberidaceae	<i>Berberis fremontii</i>	Fremont's mahonia	Native	Yes	No
Berberidaceae	<i>Berberis wilcoxii</i>	Wilcox's barberry	Native	Yes	No
Betulaceae	<i>Alnus oblongifolia</i>	Arizona alder	Native	Yes	No
Bignoniaceae	<i>Chilopsis linearis</i>	desert willow	Native	Yes	Yes
Bignoniaceae	<i>Tecoma stans</i>	yellow trumpetbush	Native	Yes	Yes
Boraginaceae	<i>Eriodictyon angustifolium</i>	narrowleaf yerba santa	Native	Yes	No
Boraginaceae	<i>Phacelia heterophylla</i>	varileaf phacelia	Native	Yes	No
Boraginaceae	<i>Tiquilia canescens</i>	woody crinklemat	Native	Yes	Yes
Brassicaceae	<i>Boechera perennans</i>	perennial rockcress	Native	Yes	No
Brassicaceae	<i>Brassica tournefortii</i>	Asian mustard	Non-native	Yes	No
Brassicaceae	<i>Draba petrophila</i>	Santa Rita Mountain draba	Native	Yes	No
Brassicaceae	<i>Dryopetalon runcinatum</i>	rockmustard	Native	Yes	No
Brassicaceae	<i>Hesperidanthus linearifolius</i>	slimleaf plainsmustard	Native	Yes	No
Brassicaceae	<i>Physaria gordonii</i>	Gordon's bladderpod	Native	Yes	No
Brassicaceae	<i>Physaria purpurea</i>	rose bladderpod	Native	No	Yes
Brassicaceae	<i>Sisymbrium irio</i>	London rocket	Non-native	Yes	No
Cactaceae	<i>Carnegiea gigantea</i>	saguaro	Native	Yes	Yes
Cactaceae	<i>Coryphantha vivipara</i>	spiny star	Native	Yes	No
Cactaceae	<i>Cylindropuntia acanthocarpa</i> subsp. <i>major</i>	Benson buckhorn cholla	Native	No	Yes
Cactaceae	<i>Cylindropuntia arbuscula</i>	Arizona pencil cholla	Native	Yes	Yes
Cactaceae	<i>Cylindropuntia bigelovii</i>	teddybear cholla	Native	Yes	Yes
Cactaceae	<i>Cylindropuntia fulgida</i>	jumping cholla	Native	Yes	Yes
Cactaceae	<i>Cylindropuntia spinosior</i>	walkingstick cactus	Native	Yes	Yes
Cactaceae	<i>Cylindropuntia versicolor</i>	staghorn cholla	Native	Yes	Yes
Cactaceae	<i>Echinocereus engelmannii</i>	Engelmann's hedgehog cactus	Native	No	Yes
Cactaceae	<i>Echinocereus fasciculatus</i>	pinkflower hedgehog cactus	Native	Yes	Yes
Cactaceae	<i>Echinocereus fendleri</i>	pinkflower hedgehog cactus	Native	Yes	Yes
Cactaceae	<i>Echinocereus rigidissimus</i>	rainbow hedgehog cactus	Native	Yes	No
Cactaceae	<i>Echinocereus triglochidiatus</i>	kingcup cactus	Native	Yes	No
Cactaceae	<i>Ferocactus cylindraceus</i>	California barrel cactus	Native	No	Yes
Cactaceae	<i>Ferocactus wislizeni</i>	candy barrelcactus	Native	Yes	Yes
Cactaceae	<i>Mammillaria grahamii</i>	Graham's nipple cactus	Native	Yes	Yes
Cactaceae	<i>Mammillaria heyderi</i> subsp. <i>macdougalii</i>	Macdougal's nipple cactus	Native	Yes	No
Cactaceae	<i>Opuntia chlorotica</i>	dollarjoint pricklypear	Native	Yes	Yes
Cactaceae	<i>Opuntia engelmannii</i>	cactus apple	Native	Yes	Yes

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Cactaceae	<i>Opuntia phaeacantha</i>	tulip pricklypear	Native	Yes	Yes
Campanulaceae	<i>Lobelia anatina</i>	Apache lobelia	Native	Yes	No
Cannabaceae	<i>Celtis ehrenbergiana</i>	spiny hackberry	Native	Yes	Yes
Cannabaceae	<i>Celtis laevigata</i>	sugarberry	Native	Yes	No
Cannabaceae	<i>Celtis reticulata</i>	netleaf hackberry	Native	Yes	No
Cannabaceae	<i>Humulus lupulus</i>	common hop	Native	Yes	No
Caprifoliaceae	<i>Symphoricarpos oreophilus</i>	mountain snowberry	Native	Yes	No
Caryophyllaceae	<i>Arenaria lanuginosa</i>	spreading sandwort	Native	Yes	No
Caryophyllaceae	<i>Cerastium nutans</i>	nodding chickweed	Native	Yes	No
Commelinaceae	<i>Commelina erecta</i>	whitemouth dayflower	Native	Yes	No
Commelinaceae	<i>Commelina tuberosa</i>	birdbill dayflower	Native	Yes	No
Convolvulaceae	<i>Evolvulus arizonicus</i>	wild dwarf morning-glory	Native	Yes	No
Convolvulaceae	<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Native	Yes	Yes
Convolvulaceae	<i>Ipomoea longifolia</i>	pinkthroat morning-glory	Native	Yes	No
Convolvulaceae	<i>Jacquemontia pringlei</i>	Pringle's clustervine	Native	Yes	No
Crassulaceae	<i>Graptopetalum bartramii</i>	Patagonia Mountain leatherpetal	Native	Yes	No
Crassulaceae	<i>Sedum cockerellii</i>	Cockerell's stonecrop	Native	Yes	No
Crossosomataceae	<i>Crossosoma bigelovii</i>	ragged rockflower	Native	Yes	Yes
Cucurbitaceae	<i>Marah gilensis</i>	Gila manroot	Native	Yes	No
Cupressaceae	<i>Hesperocyparis arizonica</i>	Arizona cypress	Native	Yes	No
Cupressaceae	<i>Juniperus arizonica</i>	redberry juniper	Native	Yes	No
Cupressaceae	<i>Juniperus deppeana</i>	alligator juniper	Native	Yes	No
Cyperaceae	<i>Carex geophila</i>	White Mountain sedge	Native	Yes	No
Cyperaceae	<i>Carex meadii</i>	Mead's sedge	Native	Yes	No
Cyperaceae	<i>Carex occidentalis</i>	western sedge	Native	Yes	No
Cyperaceae	<i>Carex praegracilis</i>	clustered field sedge	Native	Yes	No
Cyperaceae	<i>Carex senta</i>	swamp carex	Native	Yes	No
Cyperaceae	<i>Carex subfusca</i>	brown sedge	Native	Yes	No
Cyperaceae	<i>Carex thurberi</i>	Thurber's sedge	Native	Yes	No
Cyperaceae	<i>Eleocharis montevidensis</i>	sand spikerush	Native	Yes	No
Dennstaedtiaceae	<i>Pteridium aquilinum</i>	western brackenfern	Native	Yes	No
Ephedraceae	<i>Ephedra trifurca</i>	longleaf jointfir	Native	Yes	Yes
Ericaceae	<i>Arbutus arizonica</i>	Arizona madrone	Native	Yes	No
Ericaceae	<i>Arctostaphylos pringlei</i>	Pringle manzanita	Native	Yes	No
Ericaceae	<i>Arctostaphylos pungens</i>	pointleaf manzanita	Native	Yes	No
Euphorbiaceae	<i>Ditaxis lanceolata</i>	narrowleaf silverbush	Native	Yes	Yes
Euphorbiaceae	<i>Ditaxis neomexicana</i>	New Mexico silverbush	Native	Yes	No
Euphorbiaceae	<i>Ditaxis serrata</i>	Yuma silverbush	Native	No	Yes
Euphorbiaceae	<i>Euphorbia melanadenia</i>	red-gland spurge	Native	Yes	No
Euphorbiaceae	<i>Euphorbia polycarpa</i>	smallseed sandmat	Native	Yes	No
Euphorbiaceae	<i>Jatropha cardiophylla</i>	sangre de cristo	Native	Yes	Yes
Euphorbiaceae	<i>Tragia nepetifolia</i>	catnip noseburn	Native	Yes	Yes
Fabaceae	<i>Acaciella angustissima</i>	prairie acacia	Native	Yes	No
Fabaceae	<i>Amorpha californica</i>	California false indigo	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Fabaceae	<i>Amorpha fruticosa</i>	false indigo bush	Native	Yes	No
Fabaceae	<i>Astragalus nothoxys</i>	sheep milkvetch	Native	Yes	No
Fabaceae	<i>Calliandra eriophylla</i>	fairyduster	Native	Yes	Yes
Fabaceae	<i>Calliandra humilis</i>	dwarf stickpea	Native	Yes	No
Fabaceae	<i>Cologania angustifolia</i>	longleaf cologania	Native	Yes	No
Fabaceae	<i>Coursetia glandulosa</i>	rosary babybonnets	Native	Yes	Yes
Fabaceae	<i>Dalea albiflora</i>	whiteflower prairie clover	Native	Yes	No
Fabaceae	<i>Dalea formosa</i>	featherplume	Native	Yes	No
Fabaceae	<i>Dalea lumholtzii</i>	Lumholtz's prairie clover	Native	Yes	No
Fabaceae	<i>Dalea mollis</i>	hairy prairie clover	Native	No	Yes
Fabaceae	<i>Dalea polygonoides</i>	sixweeks prairie clover	Native	Yes	No
Fabaceae	<i>Dalea pringlei</i>	Pringle's prairie clover	Native	Yes	No
Fabaceae	<i>Dalea pulchra</i>	Santa Catalina prairie clover	Native	Yes	No
Fabaceae	<i>Dalea versicolor</i>	oakwoods prairie clover	Native	Yes	No
Fabaceae	<i>Desmodium batocaulon</i>	San Pedro ticktrefoil	Native	Yes	No
Fabaceae	<i>Desmodium grahamii</i>	Graham's ticktrefoil	Native	Yes	No
Fabaceae	<i>Erythrina flabelliformis</i>	coralbean	Native	Yes	No
Fabaceae	<i>Eysenhardtia orthocarpa</i>	Tahitian kidneywood	Native	Yes	No
Fabaceae	<i>Galactia wrightii</i>	Wright's milkpea	Native	Yes	No
Fabaceae	<i>Lathyrus graminifolius</i>	grassleaf pea	Native	Yes	No
Fabaceae	<i>Lotus greenei</i>	Greene's bird's-foot trefoil	Native	Yes	No
Fabaceae	<i>Lotus rigidus</i>	shrubby deervetch	Native	Yes	Yes
Fabaceae	<i>Lotus wrightii</i>	Wright's deervetch	Native	Yes	No
Fabaceae	<i>Lysiloma watsonii</i>	littleleaf false tamarind	Native	Yes	No
Fabaceae	<i>Marina parryi</i>	Parry's false prairie-clover	Native	Yes	Yes
Fabaceae	<i>Mariosousa millefolia</i>	milfoil wattle	Native	Yes	No
Fabaceae	<i>Melilotus officinalis</i>	sweetclover	Non-native	Yes	No
Fabaceae	<i>Mimosa aculeaticarpa</i>	catclaw mimosa	Native	Yes	No
Fabaceae	<i>Nissolia schottii</i>	Schott's yellowhood	Native	No	Yes
Fabaceae	<i>Olneya tesota</i>	desert ironwood	Native	No	Yes
Fabaceae	<i>Parkinsonia florida</i>	blue paloverde	Native	Yes	No
Fabaceae	<i>Parkinsonia microphylla</i>	yellow paloverde	Native	Yes	Yes
Fabaceae	<i>Phaseolus parvulus</i>	Pinos Altos Mountain bean	Native	Yes	No
Fabaceae	<i>Prosopis glandulosa</i>	honey mesquite	Native	Yes	No
Fabaceae	<i>Prosopis velutina</i>	velvet mesquite	Native	Yes	Yes
Fabaceae	<i>Rhynchosia senna</i> var. <i>texana</i>	Texas snoutbean	Native	Yes	No
Fabaceae	<i>Robinia neomexicana</i>	New Mexico locust	Native	Yes	No
Fabaceae	<i>Senegalia greggii</i>	catclaw acacia	Native	Yes	Yes
Fabaceae	<i>Senna covesii</i>	Coues' cassia	Native	Yes	Yes
Fabaceae	<i>Tephrosia leiocarpa</i>	smoothpod hoarypea	Native	Yes	No
Fabaceae	<i>Tephrosia vicioides</i>	red hoarypea	Native	Yes	No
Fabaceae	<i>Trifolium variegatum</i>	whitetip clover	Native	Yes	No
Fabaceae	<i>Trifolium wormskioldii</i>	cows clover	Native	Yes	No
Fabaceae	<i>Vachellia constricta</i>	whitethorn acacia	Native	Yes	Yes
Fabaceae	<i>Vicia americana</i>	American vetch	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Fabaceae	<i>Vicia pulchella</i>	sweetclover vetch	Native	Yes	No
Fagaceae	<i>Quercus arizonica</i>	Arizona white oak	Native	Yes	No
Fagaceae	<i>Quercus chrysolepis</i>	canyon live oak	Native	Yes	No
Fagaceae	<i>Quercus emoryi</i>	Emory oak	Native	Yes	No
Fagaceae	<i>Quercus gambelii</i>	Gambel oak	Native	Yes	No
Fagaceae	<i>Quercus hypoleucoides</i>	silverleaf oak	Native	Yes	No
Fagaceae	<i>Quercus oblongifolia</i>	Mexican blue oak	Native	Yes	No
Fagaceae	<i>Quercus palmeri</i>	Palmer oak	Native	Yes	No
Fagaceae	<i>Quercus rugosa</i>	netleaf oak	Native	Yes	No
Fagaceae	<i>Quercus toumeyi</i>	Toumey oak	Native	Yes	No
Fagaceae	<i>Quercus turbinella</i>	Sonoran scrub oak	Native	Yes	Yes
Fouquieriaceae	<i>Fouquieria splendens</i>	ocotillo	Native	Yes	Yes
Garryaceae	<i>Garrya wrightii</i>	Wright's silktassel	Native	Yes	No
Gentianaceae	<i>Gentianella microcalyx</i>	Chiricahua dwarf gentian	Native	Yes	No
Gentianaceae	<i>Swertia radiata</i>	elkweed	Native	Yes	No
Geraniaceae	<i>Erodium cicutarium</i>	redstem stork's bill	Non-native	Yes	Yes
Geraniaceae	<i>Geranium caespitosum</i>	pineywoods geranium	Native	Yes	No
Geraniaceae	<i>Geranium richardsonii</i>	Richardson's geranium	Native	Yes	No
Hydrangeaceae	<i>Fendlera rupicola</i>	cliff fendlerbush	Native	Yes	No
Hydrangeaceae	<i>Philadelphus microphyllus</i>	littleleaf mock orange	Native	Yes	No
Iridaceae	<i>Sisyrinchium cernuum</i>	nodding blue-eyed grass	Native	Yes	No
Iridaceae	<i>Sisyrinchium demissum</i>	stiff blue-eyed grass	Native	Yes	No
Juglandaceae	<i>Juglans major</i>	Arizona walnut	Native	Yes	No
Juncaceae	<i>Juncus acuminatus</i>	tapertip rush	Native	Yes	No
Juncaceae	<i>Juncus effusus</i>	common rush	Native	Yes	No
Juncaceae	<i>Juncus ensifolius</i>	swordleaf rush	Native	Yes	No
Juncaceae	<i>Juncus interior</i>	inland rush	Native	Yes	No
Juncaceae	<i>Juncus marginatus</i>	grassleaf rush	Native	Yes	No
Krameriaceae	<i>Krameria erecta</i>	littleleaf ratany	Native	Yes	Yes
Lamiaceae	<i>Hedeoma dentata</i>	dentate false pennyroyal	Native	Yes	No
Lamiaceae	<i>Hedeoma hyssopifolia</i>	aromatic false pennyroyal	Native	Yes	No
Lamiaceae	<i>Hedeoma nana</i>	dwarf false pennyroyal	Native	Yes	No
Lamiaceae	<i>Hedeoma oblongifolia</i>	oblongleaf false pennyroyal	Native	Yes	No
Lamiaceae	<i>Hyptis albida</i>	desert lavender	Native	No	Yes
Lamiaceae	<i>Hyptis emoryi</i>	desert lavender	Native	Yes	No
Lamiaceae	<i>Monarda citriodora</i> subsp. <i>austromontana</i>	lemon beebalm	Native	Yes	No
Lamiaceae	<i>Monarda fistulosa</i>	wild bergamot	Native	Yes	No
Lamiaceae	<i>Salvia arizonica</i>	desert indigo sage	Native	Yes	No
Lamiaceae	<i>Salvia pinguifolia</i>	rock sage	Native	No	Yes
Lamiaceae	<i>Salvia subincisa</i>	sawtooth sage	Native	Yes	No
Lamiaceae	<i>Stachys coccinea</i>	scarlet hedgenettle	Native	Yes	No
Lamiaceae	<i>Trichostema arizonicum</i>	Arizona bluecurls	Native	Yes	No
Liliaceae	<i>Calochortus ambiguus</i>	doubting mariposa lily	Native	Yes	No
Liliaceae	<i>Calochortus kennedyi</i>	desert mariposa lily	Native	No	Yes

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Linaceae	<i>Linum lewisii</i>	Lewis flax	Native	Yes	No
Linaceae	<i>Linum neomexicanum</i>	New Mexico yellow flax	Native	Yes	No
Malpighiaceae	<i>Cottia gracilis</i>	slender janusia	Native	Yes	Yes
Malvaceae	<i>Abutilon berlandieri</i>	Berlandier's Indian mallow	Native	Yes	No
Malvaceae	<i>Abutilon incanum</i>	pelotazo	Native	Yes	Yes
Malvaceae	<i>Abutilon parishii</i>	Parish's Indian mallow	Native	No	Yes
Malvaceae	<i>Ayenia filiformis</i>	Trans-Pecos ayenia	Native	Yes	Yes
Malvaceae	<i>Ayenia microphylla</i>	dense ayenia	Native	Yes	Yes
Malvaceae	<i>Gossypium thurberi</i>	Thurber's cotton	Native	Yes	No
Malvaceae	<i>Herissantia crispa</i>	bladdermallow	Native	Yes	Yes
Malvaceae	<i>Hibiscus coulteri</i>	desert rosemallow	Native	Yes	Yes
Malvaceae	<i>Hibiscus denudatus</i>	paleface	Native	Yes	Yes
Malvaceae	<i>Sida abutifolia</i>	spreading fanpetals	Non-native	Yes	No
Malvaceae	<i>Sida spinosa</i>	prickly fanpetals	Native	Yes	No
Malvaceae	<i>Sphaeralcea fendleri</i>	Fendler's globemallow	Native	Yes	No
Malvaceae	<i>Sphaeralcea laxa</i>	caliche globemallow	Native	Yes	No
Moraceae	<i>Morus microphylla</i>	Texas mulberry	Native	Yes	No
Nyctaginaceae	<i>Allionia incarnata</i>	trailing windmills	Native	Yes	Yes
Nyctaginaceae	<i>Commicarpus scandens</i>	climbing wartclub	Native	Yes	Yes
Nyctaginaceae	<i>Mirabilis albida</i>	white four o'clock	Native	No	Yes
Nyctaginaceae	<i>Mirabilis coccinea</i>	scarlet four o'clock	Native	No	Yes
Nyctaginaceae	<i>Mirabilis laevis</i>	desert wishbone-bush	Native	Yes	Yes
Nyctaginaceae	<i>Mirabilis multiflora</i>	Colorado four o'clock	Native	No	Yes
Oleaceae	<i>Forestiera shrevei</i>	desert olive	Native	No	Yes
Oleaceae	<i>Fraxinus anomala</i>	singleleaf ash	Native	Yes	No
Oleaceae	<i>Menodora scabra</i>	rough menodora	Native	Yes	Yes
Onagraceae	<i>Epilobium canum</i>	hummingbird trumpet	Native	Yes	Yes
Onagraceae	<i>Oenothera cespitosa</i>	tufted evening primrose	Native	Yes	No
Onagraceae	<i>Oenothera elata</i>	Hooker's evening primrose	Native	Yes	No
Orchidaceae	<i>Malaxis porphyrea</i>	Cochise adder's-mouth orchid	Native	Yes	No
Orchidaceae	<i>Malaxis soulei</i>	Chiricahua adder's-mouth orchid	Native	Yes	No
Orchidaceae	<i>Schiedeella parasitica</i>	parasitic lady's tresses	Native	Yes	No
Orobanchaceae	<i>Castilleja austromontana</i>	Rincon Mountain Indian paintbrush	Native	Yes	No
Orobanchaceae	<i>Castilleja integra</i>	wholeleaf Indian paintbrush	Native	Yes	No
Orobanchaceae	<i>Castilleja minor</i>	lesser Indian paintbrush	Native	Yes	No
Orobanchaceae	<i>Castilleja tenuiflora</i>	Santa Catalina Indian paintbrush	Native	Yes	No
Orobanchaceae	<i>Pedicularis centranthera</i>	dwarf lousewort	Native	Yes	No
Phrymaceae	<i>Erythranthe guttata</i>	seep monkeyflower	Native	Yes	No
Phrymaceae	<i>Mimulus cardinalis</i>	scarlet monkeyflower	Native	Yes	No
Pinaceae	<i>Abies concolor</i>	white fir	Native	Yes	No
Pinaceae	<i>Pinus arizonica</i>	Arizona pine	Native	Yes	No
Pinaceae	<i>Pinus cembroides</i>	border pinyon	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Pinaceae	<i>Pinus leiophylla</i> var. <i>chihuahuana</i>	Chihuahuan pine	Native	Yes	No
Pinaceae	<i>Pinus ponderosa</i>	ponderosa pine	Native	Yes	No
Pinaceae	<i>Pinus strobiformis</i>	southwestern white pine	Native	Yes	No
Pinaceae	<i>Pseudotsuga menziesii</i>	Douglas fir	Native	Yes	No
Plantaginaceae	<i>Maurandya antirrhiniflora</i>	roving sailor	Native	Yes	No
Plantaginaceae	<i>Mecardonia procumbens</i>	baby jump-up	Native	Yes	No
Plantaginaceae	<i>Penstemon barbatus</i>	beardlip penstemon	Native	Yes	No
Plantaginaceae	<i>Penstemon linarioides</i>	toadflax penstemon	Native	Yes	No
Plantaginaceae	<i>Penstemon parryi</i>	Parry's beardtongue	Native	Yes	Yes
Plantaginaceae	<i>Penstemon pseudospectabilis</i>	desert penstemon	Native	Yes	No
Plantaginaceae	<i>Penstemon subulatus</i>	hackberry beardtongue	Native	No	Yes
Plantaginaceae	<i>Plantago virginica</i>	Virginia plantain	Native	Yes	No
Platanaceae	<i>Platanus wrightii</i>	Arizona sycamore	Native	Yes	No
Plumbaginaceae	<i>Plumbago zeylanica</i>	wild leadwort	Native	Yes	No
Poaceae	<i>Agrostis exarata</i>	spike bentgrass	Native	Yes	No
Poaceae	<i>Agrostis scabra</i>	rough bentgrass	Native	Yes	No
Poaceae	<i>Agrostis stolonifera</i>	creeping bentgrass	Non-native	Yes	No
Poaceae	<i>Aristida adscensionis</i>	sixweeks threeawn	Native	Yes	No
Poaceae	<i>Aristida purpurea</i>	purple threeawn	Native	Yes	Yes
Poaceae	<i>Aristida schiedeana</i>	single threeawn	Native	Yes	No
Poaceae	<i>Aristida ternipes</i>	spidergrass	Native	Yes	Yes
Poaceae	<i>Avena fatua</i>	wild oat	Non-native	Yes	No
Poaceae	<i>Bothriochloa barbinodis</i>	cane bluestem	Native	Yes	No
Poaceae	<i>Bothriochloa ischaemum</i>	yellow bluestem	Non-native	Yes	No
Poaceae	<i>Bouteloua aristidoides</i>	needle grama	Native	Yes	No
Poaceae	<i>Bouteloua barbata</i>	sixweeks grama	Native	Yes	No
Poaceae	<i>Bouteloua chondrosioides</i>	sprucetop grama	Native	Yes	Yes
Poaceae	<i>Bouteloua curtipendula</i>	sideoats grama	Native	Yes	Yes
Poaceae	<i>Bouteloua eriopoda</i>	black grama	Native	Yes	Yes
Poaceae	<i>Bouteloua gracilis</i>	blue grama	Native	Yes	No
Poaceae	<i>Bouteloua hirsuta</i>	hairy grama	Native	Yes	No
Poaceae	<i>Bouteloua radicata</i>	purple grama	Native	Yes	No
Poaceae	<i>Bouteloua repens</i>	slender grama	Native	Yes	Yes
Poaceae	<i>Bouteloua trifida</i>	red grama	Native	No	Yes
Poaceae	<i>Bromus anomalus</i>	nodding brome	Native	Yes	No
Poaceae	<i>Bromus carinatus</i>	California brome	Native	Yes	No
Poaceae	<i>Bromus ciliatus</i>	fringed brome	Native	Yes	No
Poaceae	<i>Bromus rubens</i>	red brome	Non-native	Yes	Yes
Poaceae	<i>Bromus tectorum</i>	cheatgrass	Non-native	Yes	No
Poaceae	<i>Cenchrus ciliaris</i>	buffelgrass	Non-native	Yes	Yes
Poaceae	<i>Cenchrus setaceus</i>	crimson fountaingrass	Non-native	Yes	No
Poaceae	<i>Chloris virgata</i>	feather fingergrass	Native	No	Yes
Poaceae	<i>Cynodon dactylon</i>	Bermudagrass	Non-native	Yes	No
Poaceae	<i>Danthonia californica</i>	California oatgrass	Native	Yes	No
Poaceae	<i>Dasyochloa pulchella</i>	low woollygrass	Native	Yes	Yes

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Poaceae	<i>Dichanthelium oligosanthes</i>	Heller's rosette grass	Native	Yes	No
Poaceae	<i>Digitaria californica</i>	Arizona cottontop	Native	Yes	Yes
Poaceae	<i>Disakisperma dubium</i>	green sprangletop	Native	Yes	Yes
Poaceae	<i>Elionurus barbiculmis</i>	woolyspike balsamscale	Native	Yes	No
Poaceae	<i>Elymus arizonicus</i>	Arizona wheatgrass	Native	Yes	No
Poaceae	<i>Elymus elymoides</i>	squirreltail	Native	Yes	No
Poaceae	<i>Enneapogon cenchroides</i>	soft feather pappusgrass	Non-native	Yes	No
Poaceae	<i>Enneapogon desvauxii</i>	nineawn pappusgrass	Native	No	Yes
Poaceae	<i>Eragrostis cilianensis</i>	stinkgrass	Non-native	Yes	No
Poaceae	<i>Eragrostis curvula</i>	weeping lovegrass	Non-native	Yes	No
Poaceae	<i>Eragrostis echinochloidea</i>	African lovegrass	Non-native	Yes	No
Poaceae	<i>Eragrostis intermedia</i>	plains lovegrass	Native	Yes	No
Poaceae	<i>Eragrostis lehmanniana</i>	Lehmann lovegrass	Non-native	Yes	Yes
Poaceae	<i>Glyceria striata</i>	fowl mannagrass	Native	Yes	No
Poaceae	<i>Heteropogon contortus</i>	tanglehead	Native	Yes	Yes
Poaceae	<i>Hilaria belangeri</i>	curly-mesquite	Native	Yes	Yes
Poaceae	<i>Hilaria mutica</i>	tobosagrass	Native	Yes	Yes
Poaceae	<i>Hordeum murinum</i>	mouse barley	Non-native	Yes	No
Poaceae	<i>Koeleria macrantha</i>	prairie Junegrass	Native	Yes	No
Poaceae	<i>Melica porteri</i>	Porter's melicgrass	Native	Yes	No
Poaceae	<i>Melinis repens</i>	rose natal grass	Non-native	Yes	No
Poaceae	<i>Muhlenbergia alopecuroides</i>	bristly wolfstail	Native	Yes	No
Poaceae	<i>Muhlenbergia arizonica</i>	Arizona muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia dumosa</i>	bamboo muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia emersleyi</i>	bullgrass	Native	Yes	No
Poaceae	<i>Muhlenbergia fragilis</i>	delicate muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia longiligula</i>	longtongue muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia montana</i>	mountain muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia polycaulis</i>	cliff muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia porteri</i>	bush muhly	Native	Yes	Yes
Poaceae	<i>Muhlenbergia rigens</i>	deergrass	Native	Yes	No
Poaceae	<i>Muhlenbergia tenuifolia</i>	slender muhly	Native	Yes	No
Poaceae	<i>Muhlenbergia tricholepis</i>	pine dropseed	Native	Yes	No
Poaceae	<i>Muhlenbergia virescens</i>	screwleaf muhly	Native	Yes	No
Poaceae	<i>Pappophorum philippianum</i>	whiplash pappusgrass	Native	Yes	No
Poaceae	<i>Piptochaetium fimbriatum</i>	pinyon ricegrass	Native	Yes	No
Poaceae	<i>Piptochaetium pringlei</i>	Pringle's speargrass	Native	Yes	No
Poaceae	<i>Poa fendleriana</i>	muttongrass	Native	Yes	No
Poaceae	<i>Poa pratensis</i>	Kentucky bluegrass	Non-native	Yes	No
Poaceae	<i>Polypogon monspeliensis</i>	annual rabbitsfoot grass	Non-native	Yes	No
Poaceae	<i>Schismus barbatus</i>	common Mediterranean grass	Non-native	No	Yes
Poaceae	<i>Schizachyrium cirratum</i>	Texas bluestem	Native	Yes	Yes
Poaceae	<i>Setaria leucopila</i>	streambed bristlegrass	Native	Yes	No
Poaceae	<i>Sporobolus airoides</i>	alkali sacaton	Native	Yes	No
Poaceae	<i>Sporobolus cryptandrus</i>	sand dropseed	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Poaceae	<i>Sporobolus wrightii</i>	big sacaton	Native	Yes	No
Poaceae	<i>Trachypogon spicatus</i>	spiked crinkleawn	Native	Yes	No
Poaceae	<i>Tridens muticus</i>	slim tridens	Native	Yes	Yes
Poaceae	<i>Zuloagaea bulbosa</i>	bulb panicgrass	Native	Yes	No
Polemoniaceae	<i>Eriastrum diffusum</i>	miniature woollystar	Native	Yes	No
Polemoniaceae	<i>Ipomopsis multiflora</i>	manyflowered ipomopsis	Native	Yes	No
Polemoniaceae	<i>Linanthus bigelovii</i>	Bigelow's linanthus	Native	No	Yes
Polygalaceae	<i>Polygala alba</i>	white milkwort	Native	Yes	No
Polygalaceae	<i>Polygala macradenia</i>	glandleaf milkwort	Native	Yes	Yes
Polygonaceae	<i>Eriogonum lachnogynum</i>	woollycup buckwheat	Native	Yes	No
Polygonaceae	<i>Eriogonum wrightii</i>	bastardsage	Native	Yes	Yes
Polygonaceae	<i>Persicaria maculosa</i>	spotted ladysthumb	Non-native	Yes	No
Polygonaceae	<i>Rumex acetosella</i>	common sheep sorrel	Non-native	Yes	No
Polygonaceae	<i>Rumex crispus</i>	curly dock	Non-native	Yes	No
Polygonaceae	<i>Rumex hymenosepalus</i>	canaigre dock	Native	Yes	No
Primulaceae	<i>Androsace septentrionalis</i>	pygmyflower rockjasmine	Native	Yes	No
Primulaceae	<i>Samolus vagans</i>	Chiricahua Mountain brookweed	Native	Yes	No
Pteridaceae	<i>Astrolepis cochisensis</i>	Cochise scaly cloakfern	Native	Yes	Yes
Pteridaceae	<i>Astrolepis sinuata</i>	wavy scaly cloakfern	Native	Yes	Yes
Pteridaceae	<i>Bommeria hispida</i>	copper fern	Native	Yes	No
Pteridaceae	<i>Cheilanthes aemula</i>	rival lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes bonariensis</i>	golden lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes covillei</i>	Coville's lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes eatonii</i>	Eaton's lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes feei</i>	slender lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes fendleri</i>	Fendler's lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes lendigera</i>	nitbearing lipfern	Native	Yes	No
Pteridaceae	<i>Cheilanthes lindheimeri</i>	fairyswords	Native	Yes	Yes
Pteridaceae	<i>Cheilanthes wootonii</i>	beaded lipfern	Native	Yes	Yes
Pteridaceae	<i>Cheilanthes wrightii</i>	Wright's lipfern	Native	No	Yes
Pteridaceae	<i>Cheilanthes yavapensis</i>	graceful lipfern	Native	Yes	No
Pteridaceae	<i>Notholaena grayi</i>	Gray's cloak fern	Native	Yes	No
Pteridaceae	<i>Pellaea mucronata</i>	birdfoot cliffbrake	Native	Yes	No
Pteridaceae	<i>Pellaea truncata</i>	spiny cliffbrake	Native	Yes	Yes
Pteridaceae	<i>Pellaea wrightiana</i>	Wright's cliffbrake	Native	Yes	Yes
Pteridaceae	<i>Pentagramma triangularis</i>	goldback fern	Native	Yes	No
Ranunculaceae	<i>Anemone tuberosa</i>	tuber anemone	Native	Yes	No
Ranunculaceae	<i>Aquilegia chrysantha</i>	golden columbine	Native	Yes	No
Ranunculaceae	<i>Clematis drummondii</i>	Drummond's clematis	Native	Yes	No
Ranunculaceae	<i>Clematis ligusticifolia</i>	western white clematis	Native	Yes	No
Ranunculaceae	<i>Delphinium parishii</i>	desert larkspur	Native	Yes	No
Ranunculaceae	<i>Delphinium scaposum</i>	tall mountain larkspur	Native	Yes	Yes
Ranunculaceae	<i>Thalictrum fendleri</i>	Fendler's meadow-rue	Native	Yes	No
Rhamnaceae	<i>Ceanothus fendleri</i>	Fendler's ceanothus	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Rhamnaceae	<i>Ceanothus integerrimus</i>	deerbrush	Native	Yes	No
Rhamnaceae	<i>Condalia warnockii</i>	Warnock's snakewood	Native	Yes	Yes
Rhamnaceae	<i>Frangula californica</i>	California buckthorn	Native	Yes	No
Rhamnaceae	<i>Rhamnus crocea</i>	redberry buckthorn	Native	Yes	No
Rhamnaceae	<i>Ziziphus obtusifolia</i>	lotebush	Native	Yes	Yes
Rosaceae	<i>Holodiscus dumosus</i>	rockspirea	Native	Yes	No
Rosaceae	<i>Potentilla subviscosa</i> var. <i>ramulosa</i>	Navajo cinquefoil	Native	Yes	No
Rosaceae	<i>Prunus serotina</i>	black cherry	Native	Yes	No
Rosaceae	<i>Rosa woodsii</i>	Woods' rose	Native	Yes	No
Rosaceae	<i>Rubus neomexicanus</i>	New Mexico raspberry	Native	Yes	No
Rosaceae	<i>Vauquelinia californica</i>	Arizona rosewood	Native	Yes	Yes
Rubiaceae	<i>Bouvardia ternifolia</i>	firecrackerbush	Native	Yes	No
Rubiaceae	<i>Cephalanthus occidentalis</i>	common buttonbush	Native	Yes	No
Rubiaceae	<i>Diodia teres</i>	poorjoe	Native	Yes	No
Rubiaceae	<i>Galium aparine</i>	stickywilly	Native	Yes	No
Rubiaceae	<i>Galium microphyllum</i>	bracted bedstraw	Native	Yes	No
Rubiaceae	<i>Galium stellatum</i>	starry bedstraw	Native	No	Yes
Rubiaceae	<i>Galium wrightii</i>	Wright's bedstraw	Native	Yes	No
Rubiaceae	<i>Hedyotis wrightii</i>	pygmy bluet	Native	Yes	No
Rutaceae	<i>Choisya dumosa</i> var. <i>arizonica</i>	Arizonia orange	Native	Yes	No
Rutaceae	<i>Ptelea trifoliata</i>	common hoptree	Native	Yes	No
Rutaceae	<i>Thamnosma texana</i>	rue of the mountains	Native	Yes	No
Salicaceae	<i>Populus fremontii</i>	Fremont cottonwood	Native	Yes	No
Salicaceae	<i>Populus tremuloides</i>	quaking aspen	Native	Yes	No
Salicaceae	<i>Salix exigua</i>	narrowleaf willow	Native	Yes	No
Salicaceae	<i>Salix gooddingii</i>	Goodding's willow	Native	Yes	No
Santalaceae	<i>Arceuthobium vaginatum</i>	pineland dwarf mistletoe	Native	Yes	No
Santalaceae	<i>Comandra umbellata</i>	bastard toadflax	Native	Yes	No
Santalaceae	<i>Phoradendron californicum</i>	mesquite mistletoe	Native	Yes	Yes
Santalaceae	<i>Phoradendron coryae</i>	Cory's mistletoe	Native	Yes	No
Sapindaceae	<i>Acer negundo</i>	boxelder	Native	Yes	No
Sapindaceae	<i>Dodonaea viscosa</i>	Florida hopbush	Native	Yes	No
Sapindaceae	<i>Sapindus saponaria</i> var. <i>drummondii</i>	western soapberry	Native	Yes	No
Saxifragaceae	<i>Heuchera rubescens</i>	pink alumroot	Native	Yes	No
Saxifragaceae	<i>Heuchera sanguinea</i>	coralbelles	Native	Yes	No
Saxifragaceae	<i>Micranthes eriophora</i>	redfuzz saxifrage	Native	Yes	No
Scrophulariaceae	<i>Scrophularia parviflora</i>	pineland figwort	Native	Yes	No
Selaginellaceae	<i>Selaginella arizonica</i>	Arizona spikemoss	Native	Yes	Yes
Selaginellaceae	<i>Selaginella rupicola</i>	rockloving spikemoss	Native	Yes	No
Simmondsiaceae	<i>Simmondsia chinensis</i>	jojoba	Native	Yes	Yes
Solanaceae	<i>Lycium andersonii</i>	water jacket	Native	Yes	Yes
Solanaceae	<i>Lycium berlandieri</i>	Berlandier's wolfberry	Native	Yes	Yes
Solanaceae	<i>Lycium exsertum</i>	Arizona desert-thorn	Native	Yes	Yes
Solanaceae	<i>Lycium fremontii</i>	Fremont's desert-thorn	Native	Yes	Yes
Solanaceae	<i>Lycium macrodon</i>	desert wolfberry	Native	Yes	No

All plant species observed during intermediate plot data collection and accuracy assessment data collection, Saguaro National Park, 2013–2018 (continued).

Family	Scientific name	Common name	Nativity	RMD	TMD
Solanaceae	<i>Lycium parishii</i>	Parish's desert-thorn	Native	No	Yes
Solanaceae	<i>Nicotiana glauca</i>	tree tobacco	Non-native	Yes	No
Solanaceae	<i>Nicotiana obtusifolia</i>	desert tobacco	Native	Yes	No
Solanaceae	<i>Physalis hederifolia</i>	ivyleaf groundcherry	Native	Yes	No
Solanaceae	<i>Solanum americanum</i>	American black nightshade	Native	Yes	No
Typhaceae	<i>Typha domingensis</i>	southern cattail	Native	Yes	No
Verbenaceae	<i>Aloysia wrightii</i>	Wright's beebrush	Native	Yes	Yes
Verbenaceae	<i>Glandularia bipinnatifida</i>	Dakota mock vervain	Native	Yes	No
Verbenaceae	<i>Verbena neomexicana</i>	hillside vervain	Native	No	Yes
Violaceae	<i>Viola nephrophylla</i>	northern bog violet	Native	Yes	No
Vitaceae	<i>Vitis arizonica</i>	canyon grape	Native	Yes	No
Zygophyllaceae	<i>Larrea tridentata</i>	creosote bush	Native	Yes	Yes

Appendix K. Geodatabase Specifications, Description, and Schema

A file geodatabase (GDB) was used to house the final map and related data products. It was populated with point and polygon feature classes, relationship classes, and tables as shown in Figure K-1. All data are NAD 83 zone 12N. The GDB also contains multiple look-up tables, including cover classes and plant species names, among others.

Feature-class and related-table descriptions:

Veg_Polys: 79 polygon features, each attributed with a map-class name and code. This feature is related to table **Veg_Poly_Associations**. This table contains 97 entries that include a primary key, **MapClass_Code**, and fields for **MapClass**, **USNVC_Code**, **SODN_Code**, **USNVC_Division**, **USNVC_Macrogroup**, **USNVC_Group**, **USNVC_Alliance**, **USNVC_Association**, and **Common_Name**. Polygons were symbolized and then converted to a representation using the “convert symbology to representation” tool. This embeds the symbology into the GDB such that when loaded into an ArcMap project, it automatically is symbolized using the same color scheme as in the report.

Plot_Locations: 925 point locations. This feature is related to **tPlots**, which contains landscape, landform, and geological attributes for each site. This table is related to **tPlotEvents**, which lists basic information on plot location and shape, date sampled, and soil-cover characteristics and total cover by strata for vegetation. **tPlotEvents** is linked to **tPlotEventSpecies**, which details the stratum, species code and percent cover of each species recorded in that plot. This table is derived from field data and exported out of MS Access.

AA_Plot_Locations: 2,341 polygon locations. This feature is related to **tPlots_AA** Which contains landscape, landform, and geological attributes for each site. This table is related to **tPlotEvents_AA**, which lists basic information on plot location and shape, date sampled, and soil-cover characteristics and total cover by stratum for vegetation. **tPlotEvents_AA** is linked to **tPlotEventSpecies_AA**, which details the stratum, species code and percent cover of each species recorded in that plot. This table is derived from field data and exported out of MS Access.

Photo_Point_Locations: These are locations where photos were taken outside of intermediate plot locations. These were recorded in the field using a mix of handheld Trimble GPS units and Cedar CT5 units. These data were subsequently merged and imported into the GDB.

Feature-class attachments:

File attachments were created for the feature classes described above, **Veg_Polys**, **Plot_Locations**, **Photo_Point_Locations**, and **AA_plot_Locations**. In ArcMap 10, this attachment function allows for photos or other files to be embedded into the GDB so they are always accessible through the ArcMap environment. Photos were attached to each plot point or polygon, as well as to any additional photo points. PDF versions of the one-page vegetation type descriptions are attached to each polygon. All attachments are viewed by using the HTML pop-up tool in the standard toolbar. Once this tool is activated, the user just clicks on any polygon or point feature and a window opens showing a small icon of the attachment and displays the attributes of the feature.

Geodatabase: SAGUGeoData.gdb

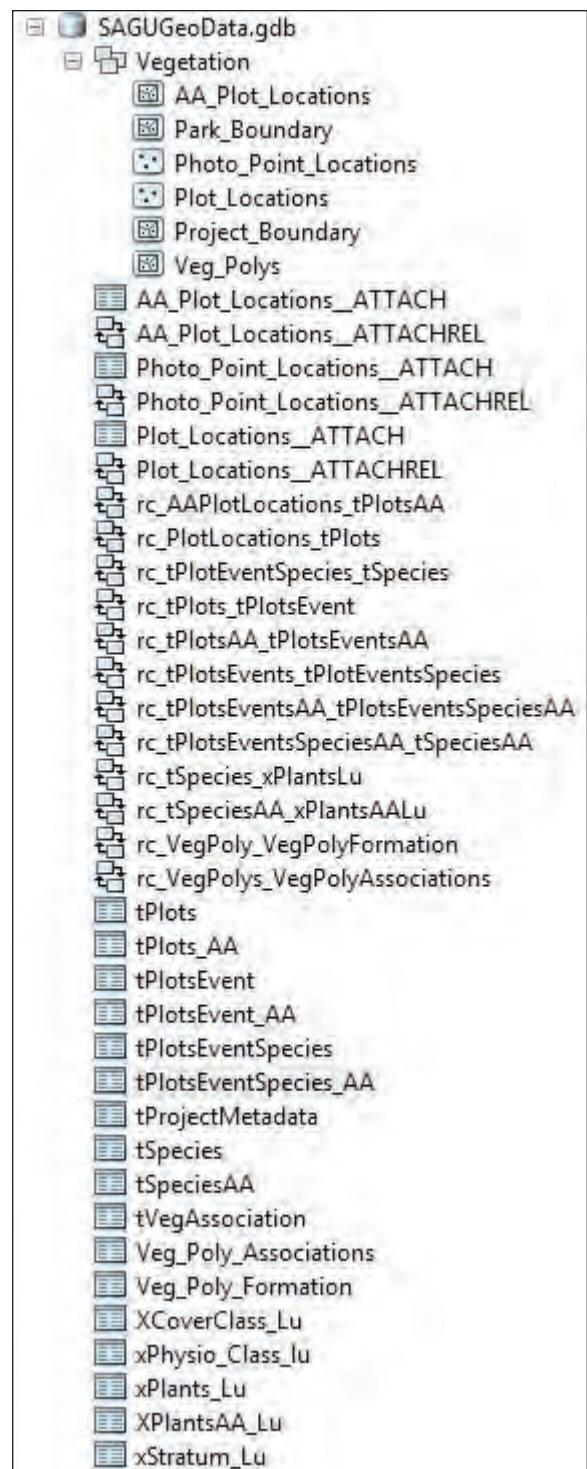
Feature Dataset: Vegetation: UTM Zone 12N. Contains all feature classes.

Feature Classes:

- **AA_Plot_Locations:** Polygon feature representing accuracy assessment plot locations (also used as AA plot photo points for feature attachments).
- **Park_Boundary:** District boundaries
- **Photo_Point_Locations:** Photo points associated with training polygons and validation photo point at both district.
- **Plot_Locations:** Plot corners (also used as plot photo points for feature attachments).
- **Project_Boundary:** Extent of mapped area
- **VegPolys:** Vegetation polygons with a unique identifier (MapClass_Code of MapClass)

Tables:

- **AA_Plot_Locations_ATTACH:** File type and name of all photos (n = 2415) attached to AA plots.
- **Photo_Point_Locations_ATTACH:** File type and name of all photos (n = 7372) attached to photo point locations.
- **Plot_Locations_ATTACH:** File type and name of all photos (n = 2089) attached to Intermediate Plot locations.
- **tPlots:** Landscape attribute data for intermediate plots
- **tPlots_AA:** Landscape attribute data for AA plots
- **tPlotsEvent:** Plot metadata and veg info for intermediate plots.
- **tPlotsEvent_AA:** Plot metadata and veg info for AA plots.
- **tPlotsEventSpecies:** Recorded species within intermediate plots.
- **tPlotsEventSpecies_AA:** Recorded species within AA plots.
- **tProjectMetadata:** Metadata
- **tSpecies:** Species list for intermediate plots.
- **tSpeciesAA:** Species list for AA plots.
- **tVegAssociation:** Western veg associations list
- **Veg_Poly_Associations:** Vegetation associations attached to feature Veg_Polys. Includes placement within USNVC hierarchy.
- **Veg_Poly_Formation:** Vegetation formations attached to feature Veg_Polys.
- **xCoverClass_Lu:** Lookup table for cover classes
- **xPhysioClass_lu:** Lookup table for physio classes
- **xPlants_Lu:** Lookup table for plants with USDA symbol
- **xPlantsAA_Lu:** Lookup table for plants with USDA symbol



Geodatabase schema.

- **xStratum_Lu:** Lookup table for strata

Relationship Classes:

Relates tables to other tables and feature class tables based on a keyed field

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National Park Service
U.S. Department of the Interior



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