Interagency Ecological Site

Handbook for Rangelands

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"Helping People Help the Land"

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SECTION 1.0 Introduction

A. Purpose of Handbook

The Interagency Ecological Site Handbook for Rangelands was developed to implement the policy outlined in the Rangeland Interagency Ecological Site Manual. This policy provides direction to Bureau of Land Management (BLM), Forest Service (FS), and Natural Resources Conservation Service (NRCS) to cooperatively identify and describe rangeland ecological sites for use in inventory, monitoring, evaluation, and management of the Nation's rangelands. This is a response, in part, to direction from Congress in the Department of the Interior and Related Agencies Appropriations Act of 2002. In that Appropriations Act, Congress expected the Secretary of Agriculture and the Secretary of the Interior to prepare a coordinated plan and budget that would identify the cost of completing standardized soil surveys and ecological classification on all rangeland for use at local management levels. This interagency handbook promulgates ecological sites as the component of ecological classification at local management levels (USDI and USDA 2003).

This handbook provides a standardized method to be utilized by the BLM, FS, and NRCS to define, delineate, and describe terrestrial ecological sites on rangelands. Rangeland is defined as land on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs, or shrubs, and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangelands include natural grasslands, shrublands, savannas, many deserts, tundra, alpine communities, marshes, and meadows (Society for Range Management 1998).

The BLM, FS, and NRCS have a common objective of utilizing science-based technical processes to sustain and enhance natural resources and the environment. They have used different methods to stratify landscapes into units for planning, analysis, and decision making. Their jurisdictions are intermingled throughout much of the United States, including both private and public lands; therefore, a standardized method to define, delineate, and describe terrestrial ecological sites is more efficient than each agency having their own method.

It is anticipated that future versions of this handbook will incorporate other ecosystems including forest, riparian, and culturally managed lands, such as cropland and pastureland.

B. Legal Authorities, Agency Policy, and Technical Guidance

Executive Order 13352—Facilitation of Cooperative Conservation (69 FR 167, 52989, August 30, 2004). The purpose of this order is to ensure that the Departments of the Interior, Agriculture, Commerce, and Defense, and the Environmental Protection Agency implement laws relating to the environment and natural resources in a way that promotes cooperative conservation, with an emphasis on appropriate inclusion of local participation in Federal decision making, in accordance with their respective agency missions, policies, and regulations.

1. Bureau of Land Management (BLM)

a. Legal Authorities

- The Taylor Grazing Act (TGA) of 1934 as amended (43 U.S.C. 315, 315a through 315r)

- The Federal Land Policy and Management Act (FLPMA) of 1976 (43 U.S.C. 1701 et seq.), as amended by the Public Rangelands Improvement Act of 1978 (43 U.S.C. 1901 et seq.).
- Executive Orders that transfer land acquired under the Bankhead-Jones Farm Tenant Act of July 22, 1937, as amended (7 U.S.C. 1012), to the Secretary and authorize administration under the Taylor Grazing Act.
- Section 4 of the Oregon and California Railroad Land Act of August 28, 1937 (43 U.S.C. 1181d).
- The Public Rangelands Improvement Act of 1978 (43 U.S.C. 1901 et seq.).

b. Agency Policy

- Manual Handbook H-4410-1, National Range Handbook (USDI-Bureau of Land Management 1984, amended 1990).
- Manual 4400, Rangeland Inventory, Monitoring, and Evaluation (USDI-Bureau of Land Management 1989).
- Handbook H-4400-1, Rangeland Monitoring and Evaluation (USDI-Bureau of Land Management 1989, amended 1990).

c. Technical Guidance

- Technical Reference 4400-7, Rangeland Monitoring: Analysis, Interpretation, and Evaluation (USDI-Bureau of Land Management 1985).
- Technical Reference 1737-7, Procedures For Ecological Site Inventory—With Special Reference to Riparian-Wetland Sites (USDI-Bureau of Land Management 1992).
- Interagency Technical Reference 1734-6, Interpreting Indicators of Rangeland Health, version 4 (Pellant et al. 2005).
- Technical Reference 1734-7, Ecological Site Inventory (Habich 2001).

2. Forest Service (FS)

a. Legal Authorities

- The Forest and Rangeland Renewable Resources Planning Act of 1974 (Public Law 93-378, 88 Stat. 476, as amended; 16 U.S.C. 1601 (Note), 1600-1614 and the National Forest Management Act of 1976 (Public Law 94-588, 90 Stat. 2949, as amended; 16 U.S.C. 472a, 476, 500, 513-516, 518, 521b, 528 (Note), 576b, 594-2 (Note), 1600 (Note), 1601 (Note), 1600-1602, 1604, 1606, 1608-1614)
- Public Rangelands Improvement Act of 1978 (Public Law 95-514, 92 Stat. 1806; 43 U.S.C. 1752-1753, 1901-1908; 16 U.S.C. 1333(b)).

b. Agency Policy

- Forest Service Manual 2060 Ecosystem Classification, Interpretation, and Application (USDA-Forest Service 2010)
- Ecological Classification and Inventory Handbook, Forest Service Handbook (FSH) 2090.11 (USDA-Forest Service 1991a)

c. Technical Guidance

- Terrestrial Ecological Unit Inventory (TEUI) Technical Guide: Landscape and Land Unit Scales (Winthers et al. 2005)
- Existing Vegetation Classification and Mapping Technical Guide Version 1.0. (Brohman and Bryant 2005)

3. Natural Resources Conservation Service (NRCS)

a. Legal Authorities

- Soil Conservation and Domestic Allotment Act (Public Law 74-46) April 27, 1935
- Secretary of Agriculture Memorandum 1396, April 10, 1956
- Rural Development Act of 1972 (Public Law 92-419, Section 302)
- Soil and Water Resources Act of 1977 (Public Law 95-192 Sections 2.3 and 5)

b. Agency Policy and Technical Guidance

- Title 450, General Manual, Technology, Part 401 (USDA-Natural Resources Conservation Service 2010)
- Title 190, National Range and Pasture Handbook, Chapters 3 and 4 (USDA-Natural Resources Conservation Service 1997, amended 2003 and 2006 respectively)
- Title 430, National Soil Survey Handbook, Part 622, Section 622.07, and Part 627, Section 627.09 (USDA-Natural Resources Conservation Service 2008 and 2012 respectively)
- Title 190, National Biology Manual, Part 512, Sections 512.30 through 512.32 (USDA-Natural Resources Conservation Service 2003)
- National Forestry Handbook Part 637.3 (USDA-Natural Resources Conservation Service 2004)
- Title 190, National Forestry Manual, Part 537, Section 537.3 (USDA-Natural Resources Conservation Service 2010)

C. Interagency Uses of Ecological Sites

Ecological site classifications and descriptions provide a consistent framework for stratifying and describing rangelands and their soil, vegetation, and abiotic features; thereby delineating units that share similar capabilities to respond to management activities or disturbance processes. Ecological site descriptions provide land managers the information needed for evaluating suitability of the land for various land-use activities, the capability to respond to various management activities or disturbance processes, and the ability to sustain productivity over the long term. The BLM, FS, and NRCS each have business needs that are achieved with use of ecological sites. Below are a few examples of how ecological sites can facilitate common business needs across the agencies:

- Ecological site descriptions provide information to support land and resource assessments, planning, and monitoring including:
    - descriptions of reference plant/soil relationships,

    - disturbance processes,
    - associated ecosystem dynamics, that are critical to assessing and monitoring ecosystem and watershed function, conditions, and trend at the local, landscape, or watershed level.

- Ecological site descriptions provide a consistent framework for describing and communicating information about land capability and suitability for various land uses, such as
    - total annual biomass production per year,
    - annual biomass production by species,
    - various cover and structure values that can facilitate the understanding and management of wildlife habitat, soil functions and processes, and grazing management.

- Ecological site descriptions provide baseline resource information and/or benchmark data, plus alternative state resource information that can facilitate the planning process and the development of land management plans for resource use and monitoring condition.

D. Interagency Coordination

The Rangeland Interagency Ecological Site Manual identifies the establishment of an interagency, interdisciplinary workgroup. A national interagency workgroup, comprised of employees from BLM, FS, and NRCS provides leadership in the implementation of the Rangeland Interagency Ecological Site Manual and the Interagency Ecological Site Handbook for Rangelands. This workgroup develops and recommends policy, procedures, and data management for the development and use of ecological site descriptions.

An interdisciplinary working group at the State level will be established under the direction of the NRCS State Conservationist, FS Regional Forester(s), and BLM State Director to discuss ecological site activities, consider the priorities of all agencies, and recommend actions. Their responsibility includes coordination and oversight for the development and maintenance of ecological site descriptions to ensure they meet unique agency business needs. The working group also identifies local resource interpretations specific to agency business needs, cooperatively prioritize ecological site description development needs, and provide guidance and support to the interdisciplinary working group at the local level to incorporate these priorities into interagency local work plans.

An interdisciplinary working group at the local level will be established to consolidate ecological site description needs into interagency local work plans. The interagency local work plan will be developed by Major Land Resource Area (MLRA) and will more specifically define interdisciplinary team membership, methods for the identification, inventory, analysis, documentation, and delineation of ecological sites, and should provide a crosswalk to other classification and mapping system hierarchies used by the agencies. The interagency local work plan will include review of ecological site descriptions to ensure they meet land and resource interpretation needs for each agency.

SECTION 1.1 Ecological Site Relationships With Other Classification and Mapping Hierarchies

Ecological site classification and descriptions are one of many land potential and existing vegetation classification and mapping systems used in the United States (app. A). A number of the classification systems are organized within a nested hierarchy that describes ecosystem relationships at spatial scales ranging from continental to individual sites. Understanding the relationship between the NRCS Soil Geography hierarchy, the National Hierarchical Framework of Ecological Units (NHFEU), the National Vegetation Classification (NVC), and other classification systems will facilitate the comparison and use of existing classification descriptions and datasets for use in development and documentation of new ecological site descriptions.

Table 1.1 arrays spatial hierarchies currently used by the FS, NRCS, and BLM. Future development of a unified spatial hierarchy for interagency application will provide a consistent basis for classifying and mapping ecological sites across all lands. Ecological sites are appropriately used at the land unit level, (see Table 1.2) where fine scale abiotic and biotic factors are used to characterize ecosystems. Ecological sites are roughly equivalent in scale and landscape context to ecological units at the land type phase, and correspond with plant associations, and habitat type phases (Table 1.2), which are commensurate with soil series and soil series phase taxonomic units (Table 1.1). Land types are broader concepts delineated according to the origin and genesis of landforms, and the relationship of soil properties and floristic patterns and processes. An ecological site may be nested within a land type or land type association at the landscape and land unit planning and analysis levels. Appendix A contains a more detailed discussion of these classification systems.

Table 1.1. Relationships of NRCS and Forest Service hierarchical mapping systems.

Ecological Mapping Systems	
National Hierarchical Framework of Ecological Units[1]	**NRCS Soil Geography Hierarchy**[2]
Domain, Division, and Province (1:5,000,000-1:30,000,000)	Land Resource Region (LRR)/Common Ecological Region (1:7,500,000)
Section (1:3,500,000) and Subsection (1:250,000)	Major Land Resource Area (MLRA) (1:3,500,000) Land Resource Unit (LRU)/Common Resource Area (CRA) (1:1,000,000) General Soil Map (1:250,000)
Land type Association (1:60,000)	NA
Land type (1:24,000)	Detailed Soil Map (1:24,000)
Land type Phase[3] (< 1:12,000)	Soil Series or SoilSeries Phase (1:12,000)
Integrated Plot	Soil Pedon

[1] Map scale from: NHFEU (Cleland et al. 1997)
[2] USDA Natural Resources Conservation Service (2006). MLRA definitions 12/15/2005, Soil Geography Hierarchy, http://soils.usda.gov/survey/geography/hierarchy/index.html
[3] Terrestrial ecological unit inventory technical guide (Table 3.1) indicates soil series and phases of series can be incorporated into land type phase (Winthers et al. 2005).

Table 1.2. Relationships of existing ecological classification systems and planning levels.

	Ecological Classification Systems			
Hierarchical Planning and Analysis Levels	**Ecosystem Classification NRCS and BLM**	**Ecosystem Classification FS** [1]	**Potential Natural Vegetation Hierarchy**[4]	**National Vegetation Classification (NVC)**[3]
Landscape	Biophysical Settings (BLM)	Geomorphology Geology, Relief, Biophysical Settings, Potential Natural Community (PNC) Series; Ecological type[1]	Plant Series; Habitat Type Group	Group/Alliance; (Dominance Type[2])
Land Unit		Ecological type[1]	Potential Plant Association; Habitat type	Association/ Alliance
	Ecological Site	Ecological type[1]	Potential Plant Association Phase; Habitat type phase	Association
Individual Sample Sites	Vegetation plot and soil pedon	Sample site (soil pedon/ vegetation plot)[1]	Vegetation plot	Vegetation plot

[1] Terrestrial ecological unit inventory technical guide (Winthers et al. 2005).

[2] Existing vegetation classification and mapping technical guide (Brohman and Bryant 2005)
[3] National Vegetation Classification Standard, version 2 (Federal Geographic Data Committee 2008)
[4] An ecological land classification framework (Driscoll et al. 1984)

SECTION 2.0 Ecological Site Classification Concepts

A. Background

An **Ecological Site (ES)** is a conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances.

Climate, geomorphology, and soils interact to govern how plant species are distributed along environmental gradients and how the resulting associations of plant species (plant communities) respond to disturbances and management. More than a century of observation and experimental research have established the importance of climate, landscape position, soil characteristics, and disturbance regimes in determining how changes in disturbances and management actions can be expected to affect plant community composition and structure. A systematic understanding of how management and disturbance processes interact with abiotic and biotic factors is a critical element to understanding ecological processes and function. This understanding is also necessary to assess degradation risk, implement appropriate management practices, and assess land capability.

An ES incorporates abiotic and biotic environmental factors such as climate, soils/landform, hydrology, vegetation, and natural disturbance regimes that together define the site. Each ecological site is identified, differentiated, and described based on the relationships between these environmental factors and how they influence plant community composition. The characteristics differentiating ecological sites and their abiotic and biotic features are documented in ecological site descriptions (ESD). The ESD documentation includes:

- data used to define the distinctive properties and characteristics of the sites
- biotic and abiotic characteristics that differentiate the site (i.e., climate, physiographic, soil characteristics, plant communities)
- ecological dynamics of the site that describes how changes in climate, disturbance processes and management can affect the site.

An ESD also provides interpretations about the land uses and ecosystem services that a particular ES can support and management alternatives for achieving land management objectives.

B. Defining the Site Concept

The identification and classification of ES's are based on a fundamental premise that the composition, structure, and function of plant communities are governed by energy, moisture, and nutrient gradients, as well as disturbance regimes. In decreasing order of scale, these gradients vary due to differences in macroclimate, geology, geomorphology, topography (elevation, slope, aspect, and landform position), and soil physical and chemical characteristics. Collectively, these factors determine soil temperature, moisture, and nutrient regimes that affect patterns and processes associated with particular ES's.

At the local scale, soil temperature, moisture, and nutrient regimes are characterized based on key soil physical and chemical properties that are used as differentiating criteria in defining an ES. Key soil properties are identified using direct measures of edaphic conditions including soil morphology, depth, texture, water holding capacity, pH, and so forth. Key soil properties are also determined based on our knowledge of plant-soil relationships, and include the use of vegetation as an indirect indicator of environmental gradients.

The floristic criteria used in combination with environmental factors to define an ES are ecologically significant associations of plant species, or indicator plant communities, which serve as indicators of important environmental conditions. Indicator plant communities are composed of species that are strongly associated with narrow ranges of environmental conditions. When used in combination with direct measurements of environment, indicator species provide features that can be readily observed in field applications such as on-site investigations or ecological site mapping. Knowledge of these associations of indicator species and their relationship to environmental conditions may come from expert opinion following field investigations, through the incorporation of existing vegetative classifications, or it may be more objectively developed through analyses of floristic and soils data collected from sites representing the site concept. These relationships define soil moisture and nutrient gradients associated with differences in inherent land capability to support specific kinds of vegetation, and provide detectible environmental thresholds that allow for separation of one ES from another.

The inherent complexities of vegetation dynamics (e.g., how vegetation originated in an area and how it might change in the future) require an understanding of historical vegetation, disturbance regimes, climatic variability, and existing (current) vegetation. Long-term trends in historic vegetation can be examined over long time periods using pollen analysis and other dendroecological techniques. The relevance of such data diminishes the further back in time one goes due to increasing differences in climate, disturbance regimes, and species distributions. A 500-year or shorter period immediately preceding European settlement is a reasonable time period for establishing reference conditions within the United States (Winthers et al. 2005).

The ES concept is defined based on reference conditions representing natural states. The state changes and transitions are subsequently estimated based on our understanding of succession and ecological thresholds. Reference states and their component community phases represent the historical range of variability due to successional dynamics following disturbances. Within this natural, historical, or reference state, the community phase used to define an ecological site is termed the reference community phase.

The reference community phase is identified as that community phase which exhibits the characteristics of the reference state, and contains the full complement of plant species that historically occupied the site (Bestelmeyer et al. 2010, Briske et al. 2008). The reference community phase formed as a result of interacting environmental gradients, natural disturbance regimes, and physiological characteristics of species comprising the community. Within landscapes that historically experienced relatively infrequent disturbances, late successional communities that required long-time periods to develop are typically selected as the reference community phase. However, in landscapes where frequent natural disturbances occurred, the geographically dominant community in the reference state may be more relevant and therefore selected as the reference community phase, since the latter stages of succession seldom occurred. For example, the former tall grass prairie occurs within a relatively moist macroclimatic zone that would have succeeded to woodlands or forests in the absence of disturbance, but frequent fires maintained the prairie over the majority of its natural geographic extent for thousands of years.

C. Interpreting Ecological Dynamics of the Site

Ecological dynamics describe the changes to vegetation and soils, and the causes of those changes that can occur on an ecological site. Details on the alternative states, ranges of variability within states, and the processes that cause plant community shifts within states as well as transitions among states are described in the text and diagram of a state-and-transition model (STM).

STMs can include single or multiple states, depending upon the nature of the system, and incorporates the concepts of ecological resilience and resistance. Ecological resilience is a measure of the amount of change or disruption that is required to transform a system from being maintained by one set of mutually reinforcing processes and structures to a different set of processes and structures (Peterson et al. 1998). This definition is distinct from that of engineering resilience, which describes the rate at which ecosystems return to their original stable state following disturbance (Holling 1996). The conditions sufficient to modify the structure and function of a state beyond the limits of ecological resilience result in the formation of an alternative state.

STMs are organized as a collection of community phases and states that communicate information about the ecological dynamics of an ES and can provide management alternatives and information about restoration (Fig. 2.1). Alternative states are separated by thresholds that can be induced by natural or human-caused events. Crossing a threshold from one state to another (the transition) indicates persistent changes in vegetation and, often, dynamic soil properties. The persistence or resilience (Peterson et al. 1998) of alternative states is caused by feedbacks between environmental conditions and vegetation or long-time lags in vegetation responses to natural or management drivers(e.g. grazing pressure). In such cases, even if the management or environmental drivers (such as grazing pressure or high rainfall) returns to earlier values, the vegetation may not return to its earlier state, or does so only slowly or in response to unusual events. When transitions are undesirable, costly restoration approaches are typically required to return to the earlier state within management timeframes, or restoration may not be possible given current technology.

Each state may contain one or more community phases representing system dynamics within the limits of the state. The dynamics among community phases may be driven independently or in combination by natural events (e.g., succession or disturbances) or human activities (e.g., land management (Walker et al. 2004)).

STMs are a means of communicating about plant succession, ecological thresholds, non-equilibrium dynamics, and functional and structural change in response to disturbances and management actions. STMs describe relationships between vegetation, soil, animals, hydrology, disturbance (e.g., fire, lack of fire, grazing and browsing, drought, unusually wet periods, insects and disease), and management actions. This information is used to describe existing soil-vegetation relationships, document historical vegetation and dynamics as well as restoration outcomes, and measurements of ecosystem properties and processes occurring within states (e.g., cover, soil aggregate stability, erosion rates, net primary production).

STMs are developed using published literature, expert knowledge, existing agency datasets (e.g., National Resources Inventory, Forest Inventory and Analysis data, agency legacy datasets), newly collected inventory data, and research data. STMs begin as a working hypothesis based largely on expert knowledge and available inventory data. STMs should be refined with empirical information obtained through research, monitoring, and data collection. STMs are ideally developed using four kinds of information: 1) inventory data of soil properties and vegetation, 2) historical reconstructions using long-term monitoring data, historical records, or photography, 3) recent monitoring data, including responses to climate variability and management interventions, and 4) process-based research and studies that test for the mechanisms causing or constraining ecosystem responses. The goal in producing STMs is to provide a conceptual understanding of:

- the ecological dynamics that can occur on an ES,
- the drivers and mechanisms of ecosystem change, and
- the management actions that can be used to influence change.

1. Components of a State-and-Transition Model

An STM for an ecological site has five fundamental components (fig. 2.1). Characteristics of the components follow Stringham et al. (2003), Briske et al. (2008), and Bestelmeyer et al. (2010).

a. The *state* (large boxes in fig. 2.1) is a suite of community phases that interact with the environment to produce a characteristic composition of plant species, functional and structural groups, soil functions, and a characteristic range of variability. The state is defined with reference to community phases, dynamic soil properties, and animal populations that are linked to one another via feedback mechanisms. Inherent natural ranges of variability of plant species composition (production, canopy or foliar cover), soil properties (inherent and dynamic), ground cover, and disturbance processes should be described. Alternative states differ in the operation of one or more *primary ecological processes* including the hydrologic (water) cycle, nutrient cycle, the process of energy capture and transformation (energy flow).

Because the designation of alternative states in STMs denotes changes in ecosystem properties that require intensive efforts—or are practically impossible—to reverse within management timeframes, the presence of alternative states can be used to support changes in management approaches. Given such a potentially important role, evidence for the existence of alternative states should be carefully identified (Bestelmeyer 2006). The assumptions, methods, and supporting data or literature used for the definition of alternative states and thresholds in STMs should be documented, peer reviewed, and further developed if needed. These include:

- careful description of the properties of reference and alternative states,

- description of the ecological mechanisms causing transitions and precluding recovery of reference or other states,
- identification of evidence sources and assumptions, and
- level of confidence in portions of the STM given the evidence.

Care should be taken not to confuse dynamics between community phases, with transitions between states.

Persistent changes in vegetation and related processes recognized via states and transitions can involve several interacting causes (Allen 2007). The causes of state changes can be associated with processes at different spatial scales (e.g., land use changing at site scales that is interacting with directional changes in climate occurring at broader scales.), involve episodic events (e.g., extreme rainfall events), and time lags (e.g., gradual plant recruitment following episodic events). Consequently, the assertion of an alternative state is often inherently uncertain and should be treated as an hypothesis that can be tested via long-term observations of ecosystem behavior (e.g., evidence of slow or episodic recovery of formerly dominant species) and repeated application of conservation and restoration practices (e.g., the successful recovery of ecosystem structure with a change in fire management). The designation of alternative states should be subjected to constant reevaluation and refinement. Evidence for existence of alternative states, and the varying constraints to recovery of desired conditions, should be pursued and evaluated over long time periods.

A r*eference state* (fig. 2.1) is recognized in each STM that describes the ecological potential and natural or historical range of variability of the ecological site. The reference state should also incorporate information on dynamic soil properties as well as native plant and animal populations.

Due to natural disturbance and climatic processes, reference conditions can be represented by more than one community phase depending on the time period in which an ecological site is observed. In some ecological sites (e.g., some grass-dominated sites) only one community phase may be recognized in the reference state. Ecological sites featuring natural fire regimes will most likely have more than one community phase in the reference state. In such cases, a cessation of natural disturbance may lead to transitions.

b. *Transitions* (arrows starting with T) describe the biotic or abiotic variables or events, acting independently or in combination, that contribute directly to loss of state resilience and result in shifts between states. A transition can be triggered by natural events (e.g., climatic events or fire), management actions (e.g., grazing, burning, fire suppression, recreational use) or both. Whereas transitions describe the drivers and mechanisms of shifts between states, the term “threshold” indicates set of conditions separating two states where conditions sufficient to modify ecosystem structure and function beyond the limits of ecological resistance or resilience results in the formation of alternative states (Briske et al. 2008). Because alternative states are persistent and exhibit characteristic differences in feedbacks and primary ecological processes, transitions may be irreversible, or at least do not reverse themselves within management timeframes (e.g., several decades). Transitions can occur quickly as in the case of catastrophic events like fire, flood, or a hurricane event whereas others may unfold over a long period of time in response to long-term management conditions and gradual changes in the environment. In practical terms, changes that warrant the use of intensive management practices and restoration technologies to return to the previous state are considered to be transitions.

Changes in dynamic soil properties (e.g., soil organic carbon, bulk density, pH, salinity, and aggregate stability) can parallel changes in community phases or transitions between states. These coupled changes may be due to feedbacks between plant cover and composition and dynamic soil properties. Thus, dynamic soil properties can be used to help understand the risk of transition, especially when it is not easily understood via observations of vegetation.

Description of transitions should emphasize soil and vegetation indicators that are related to feedbacks and the processes that reduce the resilience of states. The approximate time period required for triggers and feedbacks to reduce resilience and for alternative states to develop should be estimated.

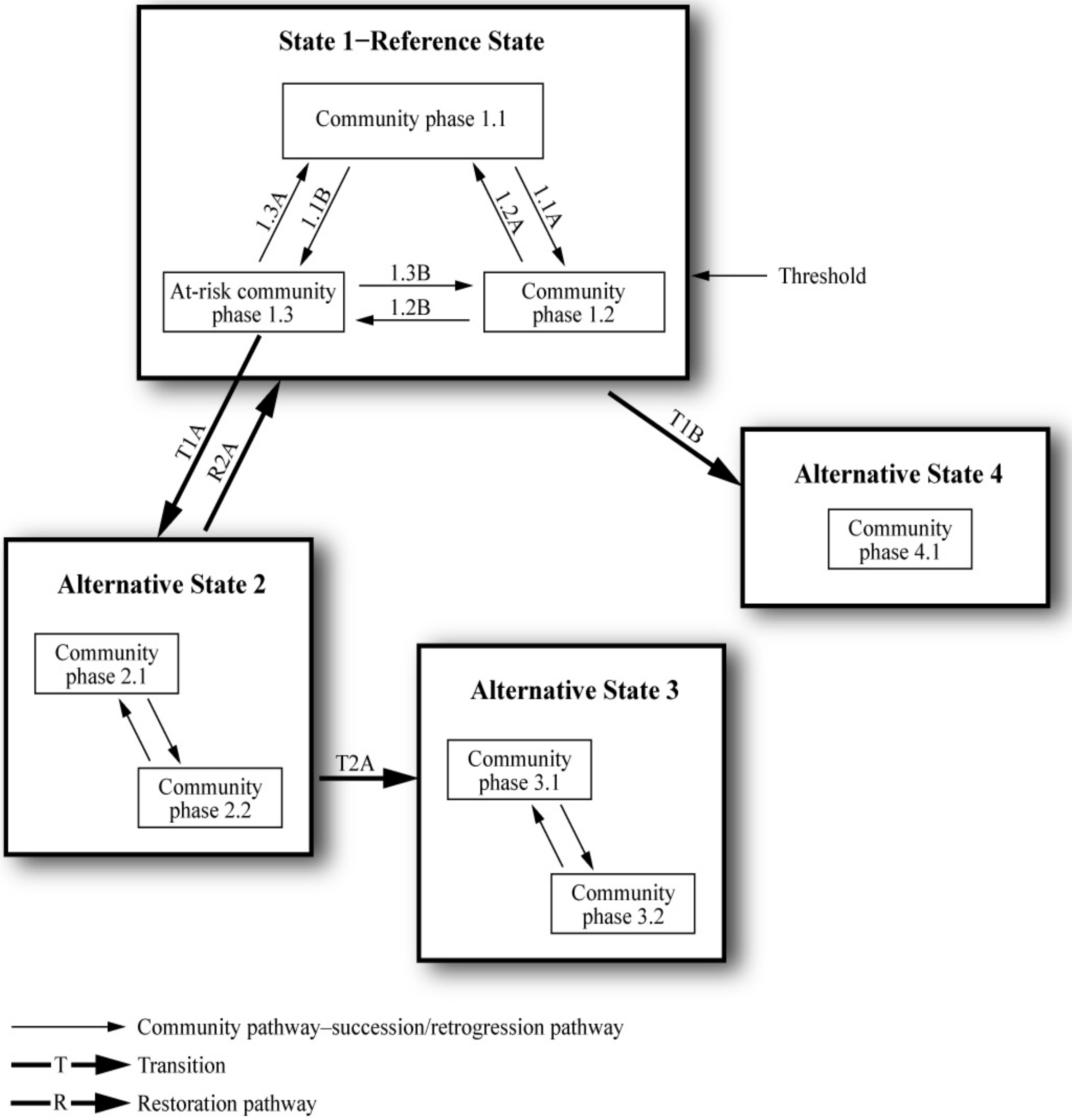
c. *Restoration pathways* (arrows starting with R) describe the environmental conditions and practices that are required to recover a state that has undergone a transition. Ecosystem properties that promote restoration should be identified. Such ecosystem properties (e.g., seed sources, species composition, nutrient distribution, and hydrologic function) greatly influence the rate, probability of success, and prescriptions required for restoration, including remediation. Environmental conditions, for example, may include relatively high rainfall years. Practices include significant management inputs (e.g., chemical/mechanical treatments or planting) coupled to facilitating and management practices (e.g., prescribed fire, wildland fire managed for resource benefit, fencing and grazing management prescriptions).

d. *Community phases* (small boxes within states) are unique assemblages of plants and associated dynamic soil property levels that can occur over time within a state. In states that attain equilibrium, community phases are equivalent to seral or successional stages that may undergo orderly changes in response to natural disturbance, management, and succession. In states that do not attain equilibrium, community phases may shift from one to the other in complex ways depending on the interactions of climate, natural disturbance, and management. Community phases included in a single state may have similar floristic or functional groups, but may differ in dominant or subordinate species. However, the community phases may be quite different in floristic or functional groups when disturbance drivers cause changes in plant composition and structure (e.g., fire). Collectively, the community phases represent the range of variation within a state, including conditions that place the state at risk of a transition.

An *at-risk community phase* is a community phase that can be designated within the reference state and also in alternative states. This community phase is the most vulnerable to transition to an alternative state. The at-risk community phase can be considered as part of a transition process that is reversible with changes in management. Indicators should be identified and described for this phase in order to help managers recognize increasing likelihood of a transition. For example, the presence of large bare gaps or small shrubs may be used to indicate that a grassland state is at risk of transition to a shrub-dominated state in semi-arid and arid ecosystems. It is also important to identify management changes that can cause or are needed to avert a transition. Management changes prior to a transition may be more effective and more economical than implementing restoration practices after a transition has taken place. In some states, designation of an at-risk community phase is not needed when transitions are equally likely in multiple community phases or when a state has only one community phase or state. Indicators of imminent transition and management needs to avert a transition should be explicitly described for the state.

e. *Community pathways* (arrows between community phases within a state) describe the causes of shifts between community phases. Community pathways can include the concepts of episodic plant community changes as well as succession and seral stages. Community pathways in state-and-transition models can be used to represent both linear and non-linear plant community changes. In contrast to transitions between alternative states, shifts in community phases are easily reversed due to succession, natural disturbances, short-term climatic variation, and facilitating practices such as grazing management.

Figure 2.1 Example of a state-and-transition diagram for an ecological site.



2. General Considerations in Producing State-and-Transition Models

The following issues, as applicable, should be considered when developing STMs.

- All states and community phases that are known to occur on an ecological site should be described in STMs. In cases where empirical data are lacking, states and community phases can be described based on expert knowledge and should be identified as provisional. The long term goal is to support each state and community phase description with empirical data.

- Abandoned cropland that has been allowed to naturally revegetate, and seeded rangeland can be considered as alternative states when important native species or soil functions do not recover to the former state without restoration actions. Such intensively modified systems may change to another state.

- Naturalized communities, plant communities that have become established naturally and dominated by non-native or exotic species, will always be considered as belonging to an alternative state, except when used to define a site (see Section 2.0 D). Examples include timothy, smooth brome, or annual bromes.

- Describe "at-risk community" phases where possible and useful.

- STMs should make explicit reference to dynamic soil properties and rangeland health indicators in narratives for states and transitions.

- In cases where the time scales of community pathways or transitions are known, they should be described in the narratives.

- Consider all relevant drivers and disturbance agents in models, including the impacts of native and domesticated animals, wildland fire and lack of fire, recreation activities, and other management actions.

D. State Change versus Change in Ecological Site

Alternative states often persist for many decades without evidence of recovery to the reference state. This persistence certainly extends beyond practical timeframes for land use and management planning. As long as the soil and physiographic characteristics that defined the ecological site remain unchanged, a change to another ecological site need not be considered. The ecological potential for the site is not considered to have been altered permanently merely because the alternative state is persistent. The inability of current knowledge and technology or economics to restore alternative states does not warrant a new ecological site designation or description. Alternative states are recognized and described that deal with severely altered locations within ecological sites.

Some ecological sites have been invaded or planted with non-native species. These non-native species may become well-established, or naturalized, on the site. They may dominate the site, or may persist within community phases in states that have recovered much of its historic structure and composition. In these cases of invasion or introduction of non-native species, a change in ecological site is not recognized.

In some parts of the United States naturalized plant communities have become established on some ecological sites and it is impossible to reconstruct the reference state with any degree of reliability. A naturalized plant community is a plant community that is dominated by naturalized exotic plant species and is a relatively stable community resulting from secondary succession after disturbance. In these regions, ecological site descriptions will be developed using the naturalized plant communities for the site. Examples of areas in the United States where this may be used are the State of Hawaii, the Caribbean Area, and the annual grasslands of California.

Approval to utilize naturalized plant communities to define the site concept must be obtained jointly by the Chief, Forest, Rangeland, Riparian, and Plant Conservation Division, BLM; Director of Rangelands Management, FS; and Director, Ecological Sciences Division, and Director, Soil Survey Division, NRCS; or their official designee(s).

SECTION 3.0 Classification, Differentiation, And Description of Ecological Sites

A. Purpose

Ecological sites are classified and their concepts are assembled into a written document called an ecological site description (ESD) (see app. E). ESD development includes two complementary efforts or processes. The first process is to identify the abiotic and biotic relationships that help define the unique soil, geomorphic, vegetation, and climate characteristics of the ecological site. The classification and differentiation of the ecological site centers on the identification of the abiotic and biotic factors associated with the reference community phase within the reference state. The second part of ESD development is the process of classifying or describing other community phases and states of the ecological site. After the site has been classified, community phase and state information is incorporated into the ecological site descriptions. The natural disturbances and management actions that cause shifts between community phases and/or states are described using the STM diagram and the associated narratives of transitions and community pathways.

B. Classification and Differentiation of an Ecological Site

Ecological sites integrate a variety of information sources, including expert knowledge, historical reconstructions, and inventory and monitoring data to help establish or understand soil/plant/landform relationships and management considerations for different ecological sites. A well-organized plan is essential to characterizing the ecological site concept and in developing an ESD.

Site classification and differentiation are based on the reference community phase and associated soil, climate, geologic, topographic, and landform properties. Replicated observation of the reference community phase within the reference state and associated soils are needed to classify an ecological site. Replicated observations should be geographically distributed in order to capture the range of environmental variability associated with the ecological site.

The use of integrated plot data is preferred for classifying and differentiating ecological sites. Integrated plots are plots in which vegetation, soil, and other physical data are collected concurrently. When integrated plot data are not available, initial differentiation may be estimated through use of expert knowledge, analysis of soil survey pedon, transect or traverse data and vegetation data that may have been collected at different times and for different purposes. It is critical that the supporting data be adequately described so that the strength of evidence can be evaluated.

Plots used to characterize the reference community phase should be sampled from multiple locations representing the reference community phase. Plot locations should not have experienced recent disturbance, nor should have been protected from natural disturbance for long periods of time. These data sets are used to identify relationships between vegetation, soils, and other environmental factors. Data on plant species composition, soil properties, and other environmental factors are analyzed to document the distinctive characteristics of, and variability within, each ecological site, and serve as documentation for the site. Data or expert knowledge on disturbance and management responses should also be considered. The initial outcome of data analysis is the identification of attributes that differentiate, classify, and characterize the ecological site concept. Data analysis for ecological site classification is a systematic process to detect patterns of similar vegetation composition and relationships between vegetation, soil properties, and other environmental elements within a dataset.

Where changes in soils, aspect, topography, or climate are abrupt, ecological site boundaries are usually well-defined. Boundaries are broader and more subtle where plant communities and environmental gradients change more gradually. Making distinctions between ecological sites that vary along a gradual continuum is difficult, and site differentiation may not be readily apparent until the cumulative effects of soil, topography, and climate on vegetation are examined over a broad area.

No single factor or criterion is used to differentiate an ecological site. Criteria should be considered in combination rather than individually. The following criteria should be considered in differentiating one ecological site from another when developing an ecological site description:

- Abiotic factors that influence plant production, composition, ecological processes of the water cycle, nutrient cycles, and energy flow,
- Significant differences in the presence of species or ecologically significant species groups,
- Significant differences in the relative proportion of species or species groups,
- Significant differences in the total annual production, and.
- Significant differences in an ecological site's response to management actions or disturbance processes.

Examples of guidelines (adapted from Miles and Leonard 1984, Winthers et al. 2005) that have been used for determining significant differences are:

- Differences in abiotic factors (soil factors and/or climate, geomorphology, surficial geology, and hydrology),
- Differences in biotic factors including indicator plant communities that have been correlated with abiotic factors,
- Presence (or absence) of one or more species that make up 10 percent or more of the reference community phase, by air dry weight,
- A 20-percent change in composition, by air dry weight, between any two species in the reference community phase, and
- A percent difference in average annual herbaceous production potential in the reference community phase of:
  - plus or minus 50 percent, when the potential is 200 to 500 pounds (lbs)/acre (ac),
  - plus or minus 30 percent, when the potential ranges between 500 to 1,000 lbs/ac,
  - plus or minus 20 percent, when the potential is greater than 1,000 lbs/ac, and
  - a difference in average annual production of 100 lbs/ac is of minor importance on ecological sites capable of producing 2,000 lbs/ac. This difference, however, is highly significant on sites capable of producing only 200 to 300 lbs/acre.

Ecological sites may be differentiated using finer or broader differences than those described above. Overall, the attributes used to distinguish ecological sites should indicate significant differences of site capability for management.

SECTION 3.1 Steps For Classification, Differentiation, And Description of Ecological Sites

The process and methods for classification, differentiation, and description of ecological sites involve several steps. The steps are grouped into preliminary stages, iterative stages, and final stages (fig. 3.1). The process is adapted from the Existing Vegetation Classification and Mapping Technical Guide (Brohman and Bryant 2005), Terrestrial Ecological Unit Inventory Technical Guide (Winthers et al. 2005), the National Range and Pasture Handbook, Chapter 3 (USDA Natural Resources Conservation Service 1997, amended 2003).

The preliminary and iterative stages focus on classification and differentiation of ecological sites. Ecological site concepts are formulated and differentiating abiotic and biotic factors are identified and tested. The final stage focuses on completing an ecological site description. It includes the classification and characterization of community phases, description of ecosystem dynamics associated with the site, and documentation of reference and alternative states.

Strong interdisciplinary participation is critical to the ESD development process. This process is best performed concurrently with soil survey projects. In areas where soil survey activities have been completed or where published soil surveys exist, validation of existing ecological site classification will be conducted concurrently by soil scientists and vegetation specialists.

Establish Local Work Groups

To bring expert knowledge together, an interdisciplinary working group should be formed at the local level. Persons who interact with the land on a regular basis may have gained practical knowledge about how ecosystems function by living and managing them and thus can be included in this group. Where ecological sites cover both private and public lands the local work group will include public land agency personnel. Every effort should be made to invite and involve local experts from sources, such as, scientists, academia, agency professionals, conservation partners, land owners, and land managers.

SECTION 3.1.1 Preliminary Stages

A. Define Geographic/Ecological Extent

For immediate development needs, the geographic/ecological extent covered by a single ecological site classification effort will be a Major Land Resource Area (MLRA)/Land Resource Unit (LRU) or ecological sections/subsections. Future development of a unified spatial hierarchy that resolves differences between NRCS's and FS's spatial hierarchies will provide an interagency application for establishing the geographic extent of ESDs. Once developed, the unified spatial hierarchy will enable a one-to-one crosswalk of respective agency systems and will be utilized to describe the appropriate geographic extent for sets of related ecological sites. Needed adjustments to the boundaries and descriptions of MLRAs or FS ecoregions will be coordinated through the interagency teams under the direction of the national interagency workgroup.

B. Gather Background Information

Review ecological literature, data, and local expert knowledge relevant to the area covered by the classification, including information on local climate, geology, soils, and current and historical vegetation. Published literature as well as mapping for the region should be reviewed. Existing ecological and vegetation classifications provide knowledge and information useful for developing site concepts. These classifications, such as potential natural vegetation (PNV) or habitat type classifications, often describe ecologically significant plant species (indicator species) or potential plant communities associated with soil moisture-nutrient-temperature gradients and differences in ecological potential within landscapes.
Types of background information include, but are not limited to:

- current ecological (synecological) information
- past vegetation history
- past vegetation data
- vegetation and ecological classifications and descriptions
- plant species (autecological) information
- natural disturbance regimes
- botanical references
- physical environment
- soil surveys and other land system inventories
- hydrologic information
- zoological information
- farm, ranch and research station data or records
- interviews with long-time residents and land managers

C. Evaluate Existing Data

Existing data sources previously collected from an area can be used for various aspects of the ecological site classification and description. Depending on the source of the data and its quality, some data may be suitable for:

- the classification itself,
- stratifying the landscape for reconnaissance or further sampling, and
- providing interpretations for the descriptions such as wildlife habitat, fuels, etc.

Existing data may include integrated plots (vegetation, soil data, and other physical data collected concurrently), or vegetation data only. Plot data may differ in how plant species attributes were collected (e.g., species production, species canopy cover, species foliar cover, basal cover, vegetation structure). Sources of existing data include maps, remote sensing, ecological classification publications, and inventory and monitoring plots from government agencies and nongovernment organizations within the area.

A resulting product of information and literature research should be a rudimentary grouping of climate zones/elevation zones, parent materials, soil properties, and vegetation communities.

Literature-based research should be combined with field reconnaissance and resulting data collection strategies covering the extent over which an ecological site concept applies.

D. Conduct Reconnaissance—Low Intensity Traverses

Reconnaissance is used to develop ecological site concepts. It helps determine the sampling strategy and design for ecological site classification. Reconnaissance is a low intensity inventory (traverse) technique to become familiar with the general features of the landscape, such as landforms, surficial geology, soils, vegetation patterns, and plant species. Reconnaissance employs a rapid characterization of plant communities and associated environmental settings (e.g., slope, aspect, landform, slope shape) to formulate the initial ecological site concepts. Reconnaissance observations should be gathered across the extent of an ecological site development effort.

In reconnaissance, a large number of sampling points are observed. At these points, soil augers or shallow pits are dug to examine the soils and classify them to soil taxonomic family or series. Soil characteristics, landform, slope, aspect, and plant community characteristics are documented. Often these points are selected by driving along roadways that cover the extent of the study area and to traverse major landforms, landform components, and distinct plant assemblages. Review of previous soil surveys, digital elevation models, or coarse-scale vegetation maps provide insight into patterns associated with environmental gradients and disturbance processes; and help identify traverse routes. Several representatives of specific soil map units or ecological map units established in previous soil surveys or ecological unit inventories may be targeted for observation.

It is important to recognize that the primary objective of this phase is to cover the range of environmental gradients within the geographic extent of the project area, to gain understanding about vegetation, soil, and landscape patterns. Notations about possible sample site locations to be visited for medium intensity sampling (see sec. 3.1.2A) should be documented.

E. Develop State-and-Transition Model Concepts

STMs are developed utilizing historical information, local and professional knowledge, and inventory, monitoring, and experimental data (see Bestelmeyer et al. 2010). Background information and existing data previously gathered can be linked with local and professional knowledge from local workgroups to develop initial diagrams and narratives for each component of a STM for an ecological site.

STM development typically begins with the grouping of community phases associated with the ecological site concept that were identified during the review of existing data and field reconnaissance. Community phases are sorted based on structures (e.g., dominant species and functional groups) that control feedback mechanisms and ecological processes to develop the state concepts. Then, narratives describing the states, community phases, community pathways, transitions, and restoration pathways, are developed. (see sec. 3.3).

As the ecological site development process continues and new information or data is collected, STMs should be revised as necessary.

F. Develop Sampling Strategy

Initial ecological site concepts identified during the reconnaissance phase are used to develop the sampling strategy and design the medium intensity (see sec. 3.1.2.A) field inventory to test and refine the site concept. Sample locations across the project area are selected using maps, aerial photography, or applicable Web services, and locations documented during the reconnaissance phase. It is important to determine and document the data collection strategy that will best capture the spatial and temporal variations of ecological sites across the landscape. Sample sites should be relatively uniform in landform, topographic position, and vegetation (Federal Geographic Data Committee 2008, Winthers et al. 2005). The specific protocol or combination of protocols used should be sufficient to characterize the soil diagnostic horizons and their properties (e.g., soil texture, soil texture modifiers, soil depth to a restrictive horizon), landform, topographic features (slope and aspect), complete species lists, variations in plant species cover and structure, and soil surface properties.

The sampling strategy selected depends on whether soil surveys have been completed or not. Where soil surveys have been completed and ESDs are being developed or revised, sampling can be stratified by soil map unit component. On National Forest System lands where terrestrial ecological unit inventories are used in place of soil map units sample sites would be stratified by ecological map unit. Where soil surveys and ESDs have not been completed, samples are stratified by elevation, landform, slope, aspect, geologic parent material, and vegetation patterns via information gathered during reconnaissance and using aerial photography and other spatial data. Aerial photography and remote sensing can be useful tools for stratifying the landscape prior to or during field reconnaissance This approach is applicable for areas without an active soil survey and where soil survey or terrestrial ecological unit inventory is being completed concurrently with ESD development.

G. Select Sampling Methods

Select sampling methods best suited for meeting the classification criteria, descriptive attributes, and interpretations chosen for the ecological site classification and description. Vegetation plots and soil pedon descriptions comprise an integrated plot. Detailed descriptions of appropriate plot size, plot shape, and vegetation sampling methods are found in existing agency and interagency handbooks and technical guides/references, including:

- Sampling Vegetation Attributes (USDI Bureau of Land Management, Cooperative Extension Service, USDA Forest Service, and USDA Natural Resources Conservation Service 1996, revised 1997,1999)
- Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems (Herrick et al. 2009)
- BLM Ecological Site Inventory (Habich 2001)
- National Vegetation Classification Standard (NVCS) Version 2 (Federal Geographic Data Committee 2008)
- Terrestrial Ecological Unit Inventory Technical Guide (Winthers et al. 2005)
- Existing Vegetation Classification and Mapping Technical Guide (Brohman and Bryant 2005)
- National Range and Pasture Handbook, Chapter 4 (USDA Natural Resources Conservation Service 1997, amended 2003)

Methods for soils data collection are found in:

- Field Book for Describing and Sampling Soils Version 2.0 (Schoeneberger et al. 2002)
- Soil Survey Manual (USDA Soil Survey Division Staff 1993)
- National Soil Survey Handbook (USDA Natural Resources Conservation Service 1996)
- Soil Taxonomy, A Basic System of Soil Classification for Making and Interpreting Soil Surveys Second Edition (USDA Soil Survey Staff 1999).

SECTION 3.1.2 Iterative Stages

The iterative stages implement the sampling strategy and methods identified in the preliminary stages. It involves initial field sampling, analysis, defining ecological site characteristics, field testing of the classification, and modification as needed. Classification of ecological sites, as well as associated community phases in reference or alternative states, can be best thought of as testing a working hypothesis. The classification of ecological sites and their associated community phases can be refined or augmented as new information or knowledge becomes available. Medium intensity sampling is required in order to formalize the site concept.

A. Data Collection—Medium Intensity Sampling

Medium intensity sampling is intended to be rapid and focused on sampling the environmental range associated with initial ecological site concepts. Data are collected to test for relationships between climate, vegetation, soil properties, landforms, and relief. Relationships between disturbance processes and vegetation composition, structure, and soil dynamic properties can also be considered.

Collect field data according to the sampling strategy using the appropriate sampling methods identified in section 3.1.1(F) and (G) of this publication. Ideally, soil scientists, range management specialists, vegetation ecologists, biologists, and other specialists (as needed) work together as interdisciplinary teams.

The following data are typically utilized to validate the ecological site concept:

- full species list for each described community phase
- canopy cover, by species, growth form (see example definitions, app. B), and vertical strata (see example definitions, app. C)
- production by species (e.g., dry-weight rank/comparative yield)
- vegetation vertical structure (see sec. 5.0 F.10)
- inherent soil properties
- topography (i.e., landform, slope, aspect, elevation, slope shape)
- ground cover (bare ground , basal vegetation cover, litter, gravel, rock, biological soil crust, includes mosses and lichens and cyanobacteria)
- photographs that capture landscape setting as well as dominant vegetation components

Integrated sample plots are located to represent relatively homogenous vegetation, landform, and topographic position that reflect similar environments. Data are collected within fixed area plots (e.g., 20 x 20 meter or 1/10th acre plot) so that soil properties, site factors, and plant species can be related to one another. Partial soil profile descriptions obtained with soil augers or shallow soil pits can be used to identify key soil/site characteristics. Ecologically important soil attributes are observed (e.g., soil horizons, soil structure, rock fragments, soil depth-to-argillic layer, root-restrictive layer) and samples of horizons are gathered for possible laboratory analysis (Bestelmeyer et al. 2009, Moseley et al. 2010). This information is used to test and refine initial ecological site concepts by identifying key soil properties, site factors, and indicator plant species relationships that differentiate sites.

Ocular estimation coupled to quantitative calibration in medium intensity sampling is important to establish consistency and minimize variability between examiners. Variability associated with ocular estimates is often negated with the larger sample size obtained with medium intensity sampling. Calibration of ocular estimation is conducted at the start of an inventory project and periodically throughout the field season and duration of the project. Methods for conducting ocular estimation calibration can be found in Sampling Vegetation Attributes (USDI Bureau of Land Management, Cooperative Extension Service, USDA Forest Service, and USDA Natural Resources Conservation Service 1996, revised 1997, 1999).

B. Data Analysis

There are a variety of analytical methods and tools used for classification and differentiation of sites based on biotic and abiotic factors. Rather than specifying one standard analysis method or tool, it is best to select the method or methods that will best meet the objectives for completing the classification. Procedures used to classify ecological sites may be different than analysis methods used to classify community phases for describing ecological site dynamics. Examples of analysis methods include gradient analysis, ordination programs, cluster analysis, and resulting plant association (e.g., constancy/cover) tables. References for classification analysis include Mueller-Dombois and Ellenberg (1974), Gauch (1982), Ludwig and Reynolds (1988), Kent and Coker (1992), Jongman et al. (1995), McCune and Mefford (1999), Podani (2000), and McCune et al. (2002).

C. Define Differentiating Characteristics of Ecological Sites

Differentiating characteristics of ecological sites are determined using existing information and synthesis, or through more objective analyses of abiotic and biotic data collected in the ecological site development process. The central concepts and the range of variation for the ecological site are described (i.e., the range of soil and plant community properties). Characteristics include a summary of soil properties and/or soil map unit components to which the site is provisionally correlated, site characteristics (i.e., slope, aspect, landform, elevation, and climate), and vegetation composition of associated community phases. This step is based on more than one integrated plot sample.

D. Field Test the Classification

Test the differentiating characteristics in the field to validate the ecological site concepts and differentiating characteristics. The classification process is complete when the differentiating characteristics used to define the ecological site concept work well in the field with a variety of end users. Final soil-site correlation and field review with soil scientists and vegetation specialists (ecologists or range management specialists) can occur during this step.

SECTION 3.1.3 Final Stage

A. Data Collection—High Intensity Sampling

High intensity sampling is used to provide additional, detailed information on a few modal sites once the ecological site concept is established. Modal sites are those that adequately represent the properties of an ecological site. Once a number of site locations have been observed and concepts of states are firmly established, several areas may be chosen as modal types to provide quantitative values used to communicate state concepts.

The sample site should be uniform in vegetation, soils, and landform, and large enough to completely include the vegetation plot and soil pit. Obvious ecotones or sites lacking uniformity are not suitable for sampling. Soil and vegetation specialists should jointly conduct the detailed characterization. Intensive soil characterizations are combined with high-intensity measurements of vegetation. While the number of vegetation and soil characterizations that represent the concept of the reference state may vary, a minimum number of characterizations should be agreed upon in the local work plan. Minimum sampling criteria for alternative states and community phase should also be defined in the work plan. These characterizations should represent the geographic extent, environmental range, disturbance regimes, and temporal variability (e.g., within year, yearly, decadal) of the ecological site.

High-intensity vegetation and soil measurement methods can include line-intercept for canopy cover, and basal and/or canopy gap intercept; line-point intercept of basal and foliar cover; production estimates/species composition utilizing double sampling or total harvest techniques; and surface/subsurface soil stability tests. The following data are required for data supported community phases:

- full species list
- canopy or foliar cover, by species, growth form (see example definitions, app. B), and vertical strata (see example definitions, App. C)
- production by species
- vegetation vertical and horizontal structure (see sec. 5.0 F. 10)
- inherent and dynamic soil properties
- topography (i.e., landform, slope, aspect, elevation, slope shape)
- ground cover (bare ground , basal vegetation cover, litter, gravel, rock, biological soil crust, includes mosses, lichens and cyanobacteria)
- photographs that capture landscape setting as well as dominant vegetation components

The resulting values and associated ranges derived from high intensity sampling data are used to provide quantitative benchmarks to aid in the documentation of states/community phases in ESDs. These quantitative benchmarks can support development of rangeland health reference sheet and other management interpretations.

B. Develop Management Interpretations

Management interpretations are based on the vegetation, soil, and environmental characteristics of the ecological site that are relevant to land use and resource management decisions. Interpretations may be based on vegetation attributes, soil properties, successional relationships between community phases, or expected response to disturbance regimes or management practices. Additional information may be obtained from monitoring or observing vegetation, soil properties, wildlife habitat, and animal's response to management or disturbance processes. This information can be incorporated into the ecological site description to validate and quantify assumptions about ecosystem properties and dynamics associated with STMs.

C. Correlation

Correlation is a process for ensuring consistency in the classification, delineation, description, and interpretation of ecological sites. Correlation needs to be a result of interdisciplinary and interagency input and should include a formal review and quality control process.

D. Quality Control and Assurance

Quality control and quality assurance are important to ensure delivery of a technically sound ESD that meets the defined standards in this handbook. Formal designation of these roles should be identified in documents such as memorandums of understanding, performance work statements, etc.

The interagency workgroup (USDI BLM and USDA FS and NRCS 2010) will develop and recommend policy, procedures, and data management for the development and use of rangeland ESDs. In addition, this workgroup will provide support and quality control/assurance to appropriate state and regional agency leadership coordinating the development and use of rangeland ESDs.

1. Quality Control

Quality control is primarily the responsibility of the first-line supervisor in the field. This is expected to vary between agencies, but will typically be a project leader, party leader, or some similar work position. As much as possible, this individual will have daily contact with the field specialists who are conducting the varied activities associated with the development of an ecological site and its accompanying description. All work is inspected to meet technical standards, although the degree of inspection will vary depending upon the experience and demonstrated skills of the field specialists. Typically, quality control will be the responsibility of the agency(ies) performing or controlling the actual tasks being completed.

2. Quality Assurance

Quality assurance is primarily the responsibility of a technical specialist with oversight duties for the disciplines involved in the development of ESDs. Typically, this individual will be employed at the State or regional levels, providing possible interaction among multiple work parties. Frequency of contact is dictated by the level of work party experience, time management associated with project deadlines, project complexity, etc. Work should be inspected or spot-checked, but certain circumstances could require a full work inspection. The task of quality assurance is shared among all agencies with a vested interest in the ecological site. An agency should perform quality assurance tasks before signing or approving the ESD.

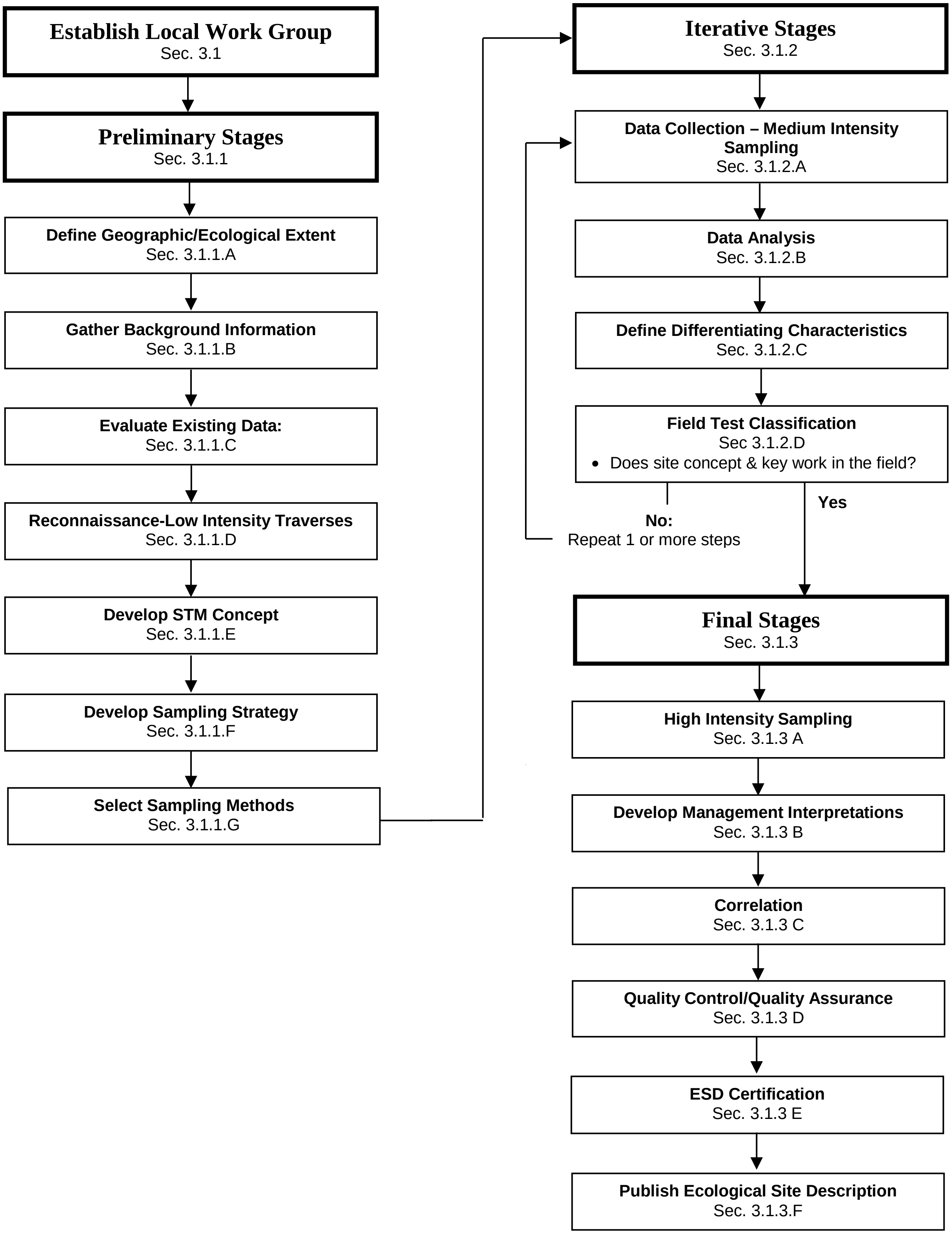
E. Certification

After the ESD is completed, and quality control and quality assurance measures have been met, the document is ready for certification. If a particular ESD pertains only to lands administered or serviced by a single agency, then a certification by that unique agency is sufficient for release to the public. If two or more agencies share responsibilities over land covered by a particular ESD, then all affected agencies will share signatory duties. Multiple signatures would be required, in this case, before the document should be released for use by both agency personnel and the public.

F. Publish the Ecological Site Description

Approved ecological site descriptions that have completed quality control and quality assurance reviews are to be published electronically in one national system, such as Ecological Site Information System (ESIS), which is supported by all agency partners. Approved ESDs are accessible to the agencies and public, and reports may be customized to meet individual needs.

Figure 3.1 Ecological Site Classification & Development Process



SECTION 3.2 Ecological Site Key

Keys to ecological sites are an important tool for accurate identification of ecological sites in the field. Although soil maps may indicate ecological sites associated with soil map units, individual ecological sites are not always spatially delineated within a map unit. In many situations, ecological sites may occur as one or more major components or as a minor inclusion of a map unit. A key is based on soil, site, and vegetation characteristics that differentiate ecological sites and facilitate identification of individual ecological sites within a map unit.

Areas without a soil survey may have ESDs. In these situations, an ecological site key will facilitate the identification of individual ecological sites.

A key may be constructed using a dichotomous format or by simply leading the reader through diagnostic characteristics. Since many ecological sites may represent a range of community phases, the key should be based on abiotic factors that are stable and not subject to change because of management or disturbance. Abiotic factors may include soil properties (i.e., texture, depth, presence of claypan, etc.), topographic features (i.e., landform, slope, aspect, slope position, elevation) or climate (i.e., precipitation zone, etc.). Indicator species that are persistent features of the site should also be included.

Ecological site keys should be developed for each MLRA. Similar MLRA's may have similar keys or even identical keys. Keys need to be cross-walked to ecological sections/subsections where the national hierarchical framework of ecological units is used by the FS. Examples of ecological site keys are contained in appendix D.

SECTION 3.3 Describing States and Community Phases of Ecological Sites

Descriptions of states and community phases should include data representing the influence of different disturbance regimes, seasonal differences, and differences between years on plant species, dynamic soil properties, and ecological processes. Descriptions based on a single plot are not adequate. Data from integrated plots should be used to describe community phases and states. The steps and process for understanding and documenting states and associated community phases is similar to that outlined for the classification of ecological sites.

Consideration must be given to many factors including the effects of:

- fire or lack of fire
- grazing or lack of grazing
- rodent activity
- insect activity
- soil erosion or deposition by wind and/or water
- drought or unusually wet periods
- variations in hydrology and storm events
- plant disease
- introduced plant and animal species

The following methods are used to describe characteristic states and community phases of an ecological site:

1. Review of historical accounts, survey and military records, and botanical literature of the area. The information may be combined with expert knowledge to develop vegetation state concepts.

2. Identification and evaluation of reference sites featuring similar community phases and associated soils.
   - Sample locations used to describe community phases and soils for the reference state should be exposed to natural disturbances regimes, within the natural range of variability.

   - When describing the community phases and soils for alternative states, sample locations should characterize the range of variability of the alternative state.

3. Data collected by soil scientists and vegetation specialists must be from the same location and preferably collected concurrently. See figure 3.1 and sections 3.1.1.G, 3.1.2.A, 3.1.2.B, and 3.1.3.A, for direction about sampling methods, data collection, and analysis associated with describing community phases associated with describing states.

   - Evaluation and interpretation of existing research and classification data dealing with the ecology, management, and soils can be used to support state and community phase characterization.

   - In situations where reference community phases cannot be confidently identified, historical references or data from other ecological sites with similar vegetation, soil, and climatic characteristics may be used as supporting data.

   - Evaluate and compare the same ecological site at various locations that have experienced different levels of management and disturbance to differentiate states.

SECTION 3.4 Data Storage

The data collected and used to support the classification, description, data extraction, and report generation ability of ESDs will be entered and stored in an appropriate database. Examples of existing databases include the Ecological Site Inventory Information System (ESIS) and the National Soil Information System (NASIS) within NRCS; the Natural Resources Information System (NRIS-Inventory and Mapping) within FS; and the Inventory Data System (IDS) within the BLM. The national interagency workgroup identified in section 1.0.D will develop policy and procedures for common data management.

SECTION 3.5 Ecological Site Naming Convention

The naming convention includes a common, descriptive abiotic name as well as a biotic plant community name (scientific and common name), and a site identification number (ID). The abiotic name can include modifiers (elevation, aspect, precipitation, etc.) as needed to adequately describe and differentiate the ecological site.

The biotic plant community name may be composed of up to three strata, consisting of a primary and a secondary tree, shrub and herbaceous species representing the reference community phase.

Biotic names shall contain both scientific and English common names. Vascular plant scientific names will follow the accepted name in USDA PLANTS database. Among the taxa that are chosen, those occurring in the same strata or growth form are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/).

The recommended naming convention is similar to the following example.

Site Name: Clay Loam Upland 13-17" precipitation zone (p.z.)
Artemisia tridentata ssp. wyomingensis / *Pascopyrum smithii* - *Bouteloua gracilis*
(Wyoming big sagebrush / western wheatgrass - blue grama)
Site ID: 035XF603

The Ecological Site Identification/Numbering System—The site ID consists of an eight-digit alpha numeric character code. The site ID begins with a three-digit number and followed by a one-digit letter (default is “X”) that designates the MLRA. Next comes a single-digit letter (default is “Y”) that designates the Land Resource Unit (LRU) or another State-designated subdivision of the MLRA. This is followed by a three-digit number, unique to the site—for example, 123XY987. Only one name and site ID will be given to a common ecological site that occurs within the same MLRA.

SECTION 3.5.1 Community Phase Naming Convention

Community phases should be named based on dominant overstory and understory species. When appropriate, plant communities recognized within the NVC may be used. When alternative naming conventions are used, the community phases that are data supported must be able to be crosswalked to vegetation types in the NVC. Minimum core vegetation data (canopy or foliar cover by species, growth form, and vertical strata; production by species) as mentioned in section 3.1.2.A, must be available to crosswalk community phases.

The following naming conventions and definitions are adapted from Federal Geographic Data Committee (2008). Community phase names shall contain both scientific and English common names in ESDs. However, STM diagrams should only display either the common or the scientific name. The relevant dominant and ecologically significant indicator species that are used in naming a community phase should be selected from the tabular summaries of the community phases. Dominant species and indicator species should include at least one from the dominant stratum of the plant community. Vascular plant scientific names will follow the accepted name in the USDA PLANTS database (USDA Natural Resources Conservation Service 1995), coupled with the specific date of observation of the website. Among the taxa that are chosen to name the community phases, those occurring in the same strata or growth form are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/). Taxa occurring in the uppermost stratum are listed first, followed successively by those in lower strata. The order of taxon names within stratum or growth form generally reflects decreasing levels of dominance, constancy, or other measures of diagnostic value.

SECTION 3.6 Revision of Ecological Site Descriptions

Analysis and interpretation of new information may reveal a need to revise or update ESDs. Because the collection of such information through resource inventories and monitoring is a continuous process, ESDs should be periodically reviewed for needed revision. It is especially important that ESDs be reviewed by all signatory agencies when new data on composition, production, or response to disturbance become available. Documented production and composition data, along with related soil, climate, and physiographic data, will be the basis of the ESD revisions. Changes need to be tracked through time, including former classifications and the descriptions of an ecological site and the previous names of the ecological site.

SECTION 4.0 Delineation and Mapping of Ecological Sites

Delineation of an ecological site is the process of determining where boundaries between different ecological sites occur. Delineation is the process of separating map units using consistent criteria (Winthers et al. 2005), which consist of multiple factors. In field application, these factors include observable landscape features such as soil morphology, texture and drainage class, indicator plant communities, landform position, slope, aspect, or elevation, and so forth. The criteria may differ according to specific map scale, and the importance of factors will vary depending on broader-scale influences such as macroclimate. For example, the importance of aspect becomes greater in moisture-limited climatic zones.

Ecological sites can be mapped using a number of approaches. One approach is to use existing map products to estimate ecological site occurrence. Maps produced through the National Cooperative Soil Survey (NCSS) are a primary information source across private, State, and many Federal lands. Terrestrial ecological unit inventories (TEUI) conducted on National Forests are another information source.

In areas where soils have been mapped as part of the NCSS, ecological site delineation depends on the relationship of ecological sites to soil map unit components. Ecological sites may be identified and delineated as single components where soils are mapped as soil consociations (generally Order 2 soil surveys). Many similar soil map unit components may be grouped into one ecological site. However, a single soil component (phase) of a named soil series will not occur in more than one ecological site.

Where soils are mapped as soil associations, soil complexes, or soil undifferentiated groups, individual ecological sites are identified, yet they may not be delineated separately (generally Order 3 or Order 4 soil surveys). In these situations, ecological sites are usually associated with the soil map unit delineation; however, the actual physical location of the ecological site within the soil map unit might not be identifiable.

In areas where TEUIs have been completed in accordance with NCSS standards, ecological sites may be identified at different levels of a spatial hierarchy (tables 1 and 2, app. A). At the finest level, ecological land-type phases can often be directly related to an ecological site, since both systems recommend incorporating use of the same biotic and abiotic factors in map unit design. At the land-type level, one or more ecological sites may occur, depending on the variability in local conditions.

Table 4. Relationship of soil survey intensity to ecological site delineation. Adapted from table 2-1 in USDA-Soil Survey Division Staff (1993). See table 1.1 of this document to see the relationships to the National Hierarchical Framework of Ecological Units and Soil Geography.

Soil Survey Order	**Map Scale**	**Minimum Delineation Size (acres)**	**Kinds of Map Units**	**Map Unit Components (soils)**	**Map Unit Components (ecological sites)**
2^{nd} Order (Intensive; general agriculture, urban planning)	1:12,000 – 1:31,680	1.4 – 10.0	Mostly soil consociations	Soil series phase	Single ecological site associated with soil series phase.
3^{rd} Order (Extensive; range, community planning)	1:20,000 – 1:63,360	4.0 – 40.0	Mostly soil associations or soil complexes	Soil series or soil series phase	Multiple ecological sites may be associated with soil map unit components. Individual ecological sites in a soil association or soil complex are not delineated within the soil map unit.
4^{th} Order (Extensive; general land-use potential and land management)	1:63,360 – 1:250,000	40.0 – 623.0	Mostly soil associations	Soil series or taxa above the series	Ecological sites are generally not delineated at this soil survey order.

Depending on the availability and quality of soil surveys or TEUIs, these areas previously mapped as part of the NCSS, present an opportunity to utilize geospatial technologies to delineate and map ecological sites. Maps of soil polygons sharing common soil properties can be combined with other spatial information not considered in the original map unit design. Morphometric characteristics of aspect or slope position, or important differences in bedrock or surficial geology, for example, can be combined with soil property polygons to render unsupervised ecological site delineation. An example of a GIS application that would be useful in delineating and mapping ecological sites is the Terrestrial Ecological Unit Inventory (TEUI) Geospatial Toolkit (Fisk et al. 2007, Benton 2008).

In areas where ecological sites are being developed in conjunction with the initiation of a new soil survey, TEUI, or update of an existing soil survey, attributes used to develop ecological sites should be incorporated in map unit design. This approach uses existing information, classification results, or expert knowledge in establishing ranges of characteristics in mapping legends.

SECTION 4.1 Ecological Sites and Ecological Unit Hierarchy Mapping

There is increasing recognition that cross-scale relationships and factors are important to understanding ecosystem processes and influences on patterns at different spatial and temporal scales. Knowledge about hierarchical relationships is needed to better understand and describe ecosystem dynamics associated with ecological sites (Bestelmeyer et al. 2011). An ecological unit hierarchy provides a framework for characterizing landscapes and cross-scale ecosystem processes. They also provide a framework for assessing resource conditions at multiple scales and addressing indirect, direct, and cumulative effects of management activities (Cleland et al. 1997).

Bestelmeyer et al. (2009) discusses the use of a spatial hierarchy to structure inventory and to identify cross-scale interactions. The levels of the hierarchy in Bestelmeyer et al. (2009) are similar and easily related to the National Hierarchical Framework of Ecological Units (Cleland et al. 1997) (see appendix A). Middle levels stratify landscapes within climate zones into distinct soil-geomorphic systems (SGSs), capturing soil-geomorphic relationships encompassing mosaics of ecological sites. Landscape and land-type ecological units in Cleland et al. (1997) and Winthers et al. (2005) are comparable to SGSs described by Bestelmeyer et al. (2009) to describe the landscape context, relationships, and cross-scale processes. At the ecological site level, an ecological site is considered a spatial unit associated with distinct soils and topographic positions within a landscape (e.g., soil-geomorphic system, land-type ecological unit), linked to soil map unit components (e.g., soil series phase) or land-type phase ecological units. Ecological sites can be associated with the land-type association, land type, and land-type phase ecological units at the landscape and land-unit planning and analysis levels of the hierarchy.

SECTION 5.0 Contents of Ecological Site Descriptions

This section highlights each element of an ESD (see app. E). Each element will be described by both required and recommended information. Agencies using this template may add additional requirements for their own use, but will not remove any element from the site description.

A. Ecological Site Characteristics

1. Site Name:

<u>Required:</u> The naming convention includes a common, descriptive abiotic name as well as a biotic plant community name (scientific and common name). The abiotic name can include optional modifiers (elevation, aspect, precipitation, etc.) as needed to adequately describe and differentiate the ecological site.

The biotic name may be composed of up to three strata, consisting of a primary and a secondary tree, shrub, and herbaceous species representing the reference community phase. Biotic names shall contain both scientific and English common names. The relevant dominant and diagnostic species that are used in naming the reference community phase should be selected from the tabular summaries. Vascular plant scientific names will follow the accepted name in the USDA PLANTS database. Among the taxa that are chosen, those occurring in the same strata or growth form are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/).

The recommended naming convention is similar to the following example.

<u>Site Name:</u> Clay Loam Upland 13-17" p.z. (precipitation zone)
Artemisia tridentata ssp. wyomingensis / *Pascopyrum smithii* - *Bouteloua gracilis*

(Wyoming big sagebrush / western wheatgrass - blue grama)
Site ID: 035XF603

Recommended: None

2. Site ID:

Required: The site ID consists of an eight-digit alpha numeric character code. The site ID begins with a three-digit number and followed by a one-digit letter (default is "X") that designates the MLRA. Next comes a single-digit letter (default is "Y") that designates the LRU or another state-designated subdivision of the MLRA. This is followed by a three-digit number, unique to the site—for example, 123XY987. Only one site ID will be given to a common ecological site that occurs within the same MLRA.

Recommended: None

3. Hierarchical Classification Relationships

Required: List the name (and code, if applicable) of the higher land classification element. This would include classification systems such as the MLRA (USDA Natural Resources Conservation Service 2006) and the Ecological Subregions: Section or Subsection (McNab et al. 2007) of the National Hierarchical Framework of Ecological Units (Cleland et al. 1997).

Recommended: None

B. Physiographic Features

Required: Describe the position of the site on the landscape. Physiographic features include landscape, landform, geology (lithology, stratigraphy), aspect, site elevation, slope, water table, flooding, ponding, and runoff class. Use standard physiographic terminology and definitions from the National Soil Survey Handbook (USDA Natural Resources Conservation Service 1996) and Field Book for Describing and Sampling Soils (Schoeneberger et al. 2002). Document the capability of the site to generate runoff, receive runoff from other sites, or both receive and generate runoff.

Recommended: None

C. Climatic Features

Required: Climatic information will be developed and included in the description of the site. Include climatic features that typify the site, relate to its potential, and characterize the dynamics of the site: storm intensity, frequency of catastrophic storm events, drought cycles. Climatic features include frost-free period, freeze-free period, mean annual precipitation, monthly moisture and temperature distribution, and location of climate stations. If climate data exist, include information (averages and ranges) from throughout the entire area where the ecological site occurs. Climate data may be extrapolated using climate models (e.g., Parameter-elevation Regressions on Independent Slopes Model (PRISM)). Distinguish between information that is supported by weather station data and information that is extrapolated from existing weather stations (for example, PRISM data). Include a link to local weather stations if available. Many sites occur in areas without appropriate climate station data.

Recommended: None

D. Influencing Water Features

Required: Describe any water features existing on the site or adjacent wetland/riparian ecological sites that influence the vegetation and/or management of the site: streams, springs, wetlands, or depressions. Use terminology associated with the Cowardin Wetland Classification (Cowardin et al. 1979) and Rosgen Stream Classification (Rosgen 1996).

Recommended: None

E. Representative Soil Features

Required: Describe the inherent soil properties that define a site as distinctive from other sites. Differentiate between inherent, attainable, and actual values for the selected properties as appropriate. Give special attention to properties that significantly affect plant-soil-water relationships and the site hydrology. Representative soil features that need to be described include: parent materials, surface and subsurface texture, surface and subsurface fragments, drainage class, hydrologic conductivity (permeability class), depth, electrical conductivity, sodium adsorption ratio, calcium carbonate equivalent, soil reaction (pH), and available water capacity.

Describe the soil and hydrologic rangeland health indicators that characterize the reference community phase: for example, extent of rills and gullies; extent of water flow patterns across the soil surface during overland flow; amount and patterns of pedestalling and terracettes caused by wind or water; size and frequency of wind-scoured areas susceptibility of the site to compaction; expected nature of the surface organic layer; and expected physical and chemical crusts that might be present.

Recommended: Provide a list of soil map unit components which are correlated to the ecological site.

F. States and Community Phases

1. Ecological Dynamics of the Site:

Required: Describe the general ecological dynamics of the site. Describe states based on growth form, life form, or functional group. Where appropriate, identify successional or seral stages. Describe the changes that are expected to occur because of variation in weather, and what effects this might have on the dynamics of the site. Identify the disturbances and disturbance intervals affecting site development (fire regime, fire dependent or not, native herbivory, and other disturbances). Other general information regarding the dynamics of the site in general should be included. Cite scientific literature and experts consulted in describing ecological dynamics of the site in the Other References section of the ESD (sec. 5.0.H.7).

Recommended: None

2. State-and-Transition Diagram:

Required: Include a diagram of the STM for the site. The diagram should include States, Community Phases, Community Pathways, Transitions, and Restoration Pathways. Label all parts of the STM. See section 2.0.C.1 for further guidance on components of STMs.

The assumptions, methods and supporting data or literature used in defining alternative states of STMs should be documented, peer reviewed, and further developed, if needed. These include careful description of the properties of reference and alternative states, description of the ecological mechanisms causing transitions and precluding recovery of reference or other states, the identification of evidence sources and assumptions, and the level of confidence in portions of the STM given the evidence.

Recommended: None

3. Photos:

Required: None

Recommended: One or more photos should be included for each state and/or community phase described in the STM for the ecological site. Landscape photos are desirable. However, consider adding other photos to capture unique properties of the site, such as vegetative structure, soil surface, etc. Photographs should focus on conveying characteristics of the natural landscape setting and should be free of people, livestock, vehicles, etc. If reference to scale is important use a tool such as a range pole.

4. Narrative:

Required: Describe each community phase and state identified in the STM diagram. Document whether the community phases are supported by empirical data or whether they are provisional communities. Describe the rationale for separating community phases in different states based on ecological processes. As a minimum, the narrative should describe the dynamics of the community phase and causes or triggers of community pathways and transitions. Identify and describe the thresholds between states. Provide information on the water cycle, nutrient cycle, and energy flow, and evaluation of the functioning of these ecological processes. Explain causes of shifts or changes, and relate how these changes will affect ecological functions. Describe changes in hydrologic and erosion characteristics of the site resulting from these shifts. Include descriptions of these elements: amount and distribution of expected litter, patterns of plant mortality, expected or measured changes to dynamic soil properties.

Recommended: None

5. Supporting Community Phase Documentation:

Required: For community phases supported by empirical data, document the number and type of plots used. For provisional community phases, document the source of information used as the basis for describing the community phase.

Recommended: Where permissible, identify the sampling site locations used to describe the community phases.

6. Community Phase Composition:

Required: For the reference community phase within the reference state, as well as all other data-supported community phases, a detailed species list will be entered and incorporated into plant association or constancy cover tables. Both common and scientific names and plant symbol will be included for all species. Plant scientific names and symbols will be obtained through the USDA PLANTS database (USDA Natural Resources Conservation Service 1995). If plant groups are used, plant groupings must identify whether individual species within the group will have a production limitation or whether a single species can account for the entire group allowable. Numerous items must be considered when placing plant species into groups for the purpose of ESD development. Items include kind of plant, structure, size, rooting structure, life cycle, production, niche occupied, and photosynthetic pathway. Plant groups could include cool-season tall grasses, cool-season midgrasses, warm-season tall grasses, warm-season midgrasses, warm-season short grasses, annual grasses, perennial forbs, biennial forbs, annual forbs, shrubs, half-shrubs, deciduous trees, evergreen trees, cacti, yucca and yucca-like plants, succulent forbs, and leafy forbs. This list is not exhaustive. Professionals describing sites may identify additional attributes and relationships that can be used to define useful groupings. For example, two or more groups of warm-season midgrasses may be described because of different niches and differences in production, structure, elevation, and climatic adaptations.

Recommended: Develop a detailed species composition list for all other community phases.

7. Annual Production:

Required: For the reference community phase within the reference state, as well as all other data-supported community phases, show the range of production by species (designating the range of variability for the species across the extent of the community phase) in two values (low and high), expressed in pounds air-dry weight/acre.

Recommended: To capture differences in annual production, by species across the extent of the community phase, it is recommended to collect annual production over multiple years for all other community phases.

8. Total Annual Production:

Required: For the reference community phase within the reference state, as well as all other data-supported community phases, show total annual production by growth form, expressed in pounds air-dry weight/acre, and the fluctuations to be expected during favorable, normal, and unfavorable years (climatic variability, primarily by precipitation). Total annual production is not to be confused with annual production by species above (see 7) which accounts for variability by species across the extent of the community phase.

Recommended: Collect total annual production for all other community phases described for the ecological site.

9. Canopy or Foliar Cover:

Required: For the reference community phase within the reference state, as well as all other data-supported community phases, use either canopy or foliar cover. Be sure to identify the type of cover and the data collection method. Methods should be standardized and documented. Summarize the range of canopy or foliar cover and constancy by species for each community phase.

Recommended: Include canopy or foliar cover estimates with line-intercept or line-point intercept methods for all other community phases described for the ecological site. Note the presence of rare plant species and whether or not they occurred on one, a few, many, or all sites sampled.

10. Structure:

Required: Characterize vertical structure for the reference community phase within the reference state, as well as all other data-supported community phases. Vertical structure will be collected by recording cover by growth form and vertical strata for each species (see section 3.1.3.A). Be sure to define both the height of the respective vertical strata, as well as the type of cover (canopy or foliar). Characterize horizontal structure for the reference community phase, as well as all other data-supported community phases. A combination of basal gaps, canopy gaps, canopy or foliar cover can be used to characterize horizontal structure. Horizontal structure is the distribution of vegetation patterns and gaps within an ecological site.

Recommended: Include both vertical and horizontal structure for all other community phases described for the ecological site.

11. Ground Surface Cover:

Required: For the reference community phase within the reference state, as well as all other data-supported community phases, record ground surface cover. Ground surface cover is the percentage of the ground surface actually occupied by bare soil, basal vegetation, litter, gravel, rock, or soil biological crust, including mosses and lichens.

Recommended: Include ground surface cover for all other community phases described for the ecological site.

12. Community Phase Growth Curves:

Required: None

Recommended: For the reference community phase within the reference state, as well as all other data-supported community phases, include a generalized chart or graph showing percent growth by month or season. Include growth curves for all other community phases described for the ecological site.

G. Ecological Site Interpretations

1. Animal Community:

Required: None

Recommended: Include information on landscape descriptions, area-sensitive species, transitory/migratory animals, invasive species, thresholds by animal species, species guilds, keystone species, aquatic elements/inclusions (e.g., mineral springs/seeps, riparian areas), essential habitat elements across plant communities, and potential species (e.g., extirpated, historical, incidental). Specific species related to a community phase should be described along with any known interactions. The following information, when provided, will be shown in the order listing lowest-to-highest trophic level: invertebrates, fish, reptiles/amphibians, birds, mammals, essential habitat elements, and variations impacting wildlife. General descriptions for use of the site by livestock, domesticated wildlife, wild horses, and burros should also be included. Suitability of this site for grazing, by kind and class of livestock, and potential management problems that exist (poisonous plants, topography, and physical barriers) should be described. Describe wildlife-livestock interactions and competition. Include forage preferences for livestock and wildlife by plant species and/or various parts of a plant species for each season of the year. Much of this information is likely more relevant at a higher order of land classification. If this information is contained in a description at a higher order, then a reference to that description is acceptable.

2. Hydrology Functions:

Required: None

Recommended: Indicate changes in hydrology functions that may occur with shifts in community phases within states. For each community phase, describe the changes in infiltration and runoff characteristics expected because of changes in plant species composition and soil surface characteristics. For example, when a plant community composition shifts from blue grama to buffalo grass, runoff is typically accelerated because of a change in plant growth form and root morphology characteristics. Information about water budgets for each community phase can be included.

3. Recreational Uses:

Required: None

Recommended: Indicate the potential uses that the site can support or that may influence the management of the site. List the plant species that have special aesthetic or landscape value. Be sensitive to disclosure of species affected by over harvesting. Much of this information is likely more relevant at a higher order of land classification. If this information is contained in a description at a higher order, then a reference to that description is acceptable.

4. Wood Products:

Required: None

Optional: Indicate use or potential use of significant species that may influence the management of the site. Describe the potential for woody species that have commercial value on sites where this is a management consideration.

5. Other Products:

Required: None

Recommended: Indicate the use or potential use of other products of the site. These may include such things as landscape plants, nuts and berries, mushrooms, and biomass for energy potentials. Be sensitive to disclosure of species affected by over harvesting.

H. Supporting Information

1. Associated Sites:

Required: Identify and describe other sites that are commonly located in conjunction with the site.

Recommended: None

2. Similar Sites:

Required: Identify and describe sites that resemble or can be confused with the site.

Recommended: None

3. Inventory Data References:

Required: Enter a listing of plots supporting the site identification. Record the data source (i.e., sample methods) and sample identification of each plot. This is a compilation of data types and numbers as described in section 5.0.F.5, Supporting Plant Community Phase Documentation. On non-Federal land, ensure privacy of the landowner by not listing specific locations.

Recommended: Enter a listing of inventory plots supporting the community phases in STMs in ecological site descriptions. On non-Federal land, ensure privacy of the landowner by not listing specific locations.

4. Agency/State Correlation:

Required: Enter the agencies and/or States which have reviewed and approved the site description.

Recommended: None

5. Type Locality:

Required: For Federal lands, enter the location of a typical example of the ecological site.

Recommended: For non-Federal lands, enter the location of a typical example of the site. Indicate township, range, section, or longitude, latitude, and specific location. On non-Federal land, ensure privacy of the landowner by not listing specific locations.

6. Relationship to Other Established Classification Systems:

Required: None

Recommended: Describe how the ecological site description may relate to other established classification systems. Crosswalk each data supported community phase to the existing vegetation type(s) in the National Vegetation Classification (NVC). Where applicable, include a description of how the ecological site is related to existing PNV classifications, habitat type classifications, and Biophysical Setting classifications. This information is particularly important on some Federal lands where other classification systems and mapping hierarchies are used in multilevel or above site-level resource assessments, land and resource management planning, and monitoring.

7. Other References:

Required: Record other reference information used in site development or in understanding ecological dynamics of the site.

Recommended: None

8. Rangeland Health Reference Sheet:

Required: Provide reference state conditions for the 17 indicators included in Interpreting Indicators of Rangeland Health (Pellant et al. 2005).

Recommended: None

I. Site Description Approval

1. Authorship:

Required: Record the original authors' names and date. Record any revisions with authors' names and date.

Recommended: None

2. Site Approval:

Required: Indicate site approval by the appropriate authorized agency representative before final distribution. Record the approver's name, date, and agency affiliation.

Recommended: None

GLOSSARY

At-Risk Community Phase—A community phase that can be designated within the reference state and also in alternative states. This community phase is the most vulnerable to transition to an alternative state.

Canopy Cover—The percentage of ground covered by a vertical projection downward of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included. It may exceed 100 percent. Canopy cover is synonymous with crown cover.

Community Pathway—Community pathways describe the causes of shifts between community phases. Community pathways can include the concepts of episodic plant community changes as well as succession and seral stages. Community pathways can represent both linear and non-linear plant community changes. A community pathway is reversible, attributable to succession, natural disturbances, short-term climatic variation, and facilitating practices such as grazing management.

Community Phase—A unique assemblage of plants and associated dynamic soil property levels that can occur within a state.

Constancy—The percentage of plots in a given data set that a taxon occurs in (Jennings et al. 2009).

Dominant Species—Plant species or species groups that exert considerable influence upon a community by its size, abundance or coverage.

Ecological Resilience—1) Amount of change or disruption in functioning of ecological processes (nutrient cycling, hydrologic cycle, energy flow, succession) caused by disturbance(s) that is required to transform a community phase or a state from one community phase to another community phase or from one state to another state. 2) Also, has been defined not as a quantity of change but as a rate of change . . . ecological resilience is the rate of recovery of pre-disturbance(s) functioning of ecological processes of a community phase or a state, after disturbance(s).

Ecological Site (ES)—An ecological site is a conceptual division of the landscape, defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances.

Ecological Site Classification—The process used to identify and define distinct ecological sites.

Ecological Site Descriptions (ESD)—The documentation of the characteristics of an ecological site. The documentation includes the data used to define the distinctive properties and characteristics of the ecological site; the biotic and abiotic characteristics that differentiate the site (i.e., climate, physiographic, soil characteristics, plant communities); and the ecological dynamics of the site that describes how changes in disturbance processes and management can affect the site. An ESD also provides interpretations about the land uses and ecosystem services that a particular ecological site can support and management alternatives for achieving land management.

Ecological Type—A category of land with a distinctive (i.e., mappable) combination of landscape elements. The elements making up an ecological type are climate, geology, geomorphology, soils, and potential natural vegetation. Ecological types differ from each other in their ability to produce vegetation and respond to management and natural disturbances (Winthers et al. 2005).

Foliar Cover—The percentage of ground covered by a vertical projection downward of the aerial portion of plants. Small openings in the canopy and intraspecific overlap are excluded. Foliar cover is always less than canopy cover. It may exceed 100 percent.

Indicator species —A species whose presence, abundance, or vigor indicates certain environmental conditions. Indicator species may represent either qualitative or quantitative distinctions between types (Winthers et al. 2005).

Integrated Plots—Plots in which vegetation, soil, and other physical data, are collected concurrently, for the purposes of classifying ecological sites and classifying plant community phases in ecological site descriptions.

Naturalized Plant Community—A plant community that is dominated by naturalized exotic plant species and is a relatively stable community resulting from secondary succession after disturbance. Annual grasslands of California are an example of a naturalized plant community (adapted from USDA Natural Resources Conservation Service 1997, amended 2003; Habich 2001).

Potential Natural Community—A potential natural community is a biotic community that would become established on an ecological site if all successional sequences were completed without interference by humans under contemporary environmental conditions. The potential natural community recognizes past influences by humans, including past land use and including exotic species of plants or animals. Human influence is excluded from the present onward to eliminate the complexities of future management. A potential natural community explicitly recognizes that naturalized exotic species may persist in the final stage of secondary succession and that succession after disturbance does not always reestablish the original vegetation (adapted from Habich 2001).

Potential Natural Vegetation—The plant community that would become established if all successional sequences were completed without human interference under contemporary environmental and floristic conditions, including those created by man (Tuxen 1956, as cited in Mueller-Dombois and Ellenberg 1974, and modified by Winthers et al. 2005).

Rangeland—Land on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangelands include natural grasslands, shrublands, savannas, many deserts, tundra, alpine communities, marshes, and meadows (Society for Range Management 1998).

Reference Community Phase—The reference community phase is identified as that community phase which exhibits the characteristics of the reference state, and contains the full complement of plant species that historically occupied the site (Bestelmeyer et al. 2010, Briske et al. 2008). The reference community phase formed as a result of interacting environmental gradients, natural disturbance regimes, and physiological characteristics of species comprising the community. It is the community phase in the reference state that is used to classify an ecological site.

Reference state—A reference state is recognized in each state-and-transition model that describes the ecological potential and natural or historical range of variability of the ecological site.

Restoration Pathways—Restoration pathways describe the environmental conditions and practices that are required to recover a state that has undergone a transition.

State—A state is a suite of community phases and their inherent soil properties that interact with the abiotic and biotic environment to produce persistent functional and structural attributes associated with a characteristic range of variability (adapted from Briske et al. 2008).

State-and-Transition Model—A method to organize and communicate complex information about the relationships between vegetation, soil, animals, hydrology, disturbances (fire, lack of fire, grazing and browsing, drought, unusually wet periods, insects and disease), and management actions on an ecological site.

Thresholds—Conditions sufficient to modify ecosystem structure and function beyond the limits of ecological resilience, resulting in the formation of alternative states (Briske et al. 2008).

Transition—Transitions describe the biotic or abiotic variables or events, acting independently or in combination, that contributes directly to loss of state resilience and result in shifts between states. Transitions are often triggered by disturbances including natural events (climatic events or fire) and/or management actions (grazing, burning, fire suppression). They can occur quickly as in the case of catastrophic events like fire or flood, or over a long period of time as in the case of a gradual shift in climate patterns or repeated stresses like frequent fires.

Triggers—Events, processes, and drivers that initiate a transition to an alternative state.

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APPENDIX A. Relationship of Ecological Classification and Mapping Systems

A number of ecological classification and mapping systems are currently used by various agencies and organizations. These systems are designed to provide information specific to an agency's or organization's land and resource management mission and business needs. Most systems strive to understand the inherent biological and physical potential of the land in terms of the capability to support desired resource values, as well as the response of the land to management actions or disturbance regimes.

Many of the classification systems are part of a nested hierarchy that address ecosystem relationships at multiple spatial scales, and provide information appropriate for different levels of planning and analysis (table 1). The upper (broader spatial scale) planning and analysis levels in the hierarchy are based on general relationships and described in broad terms, (e.g., regional or continental climate patterns, soil order or great group) while the lower (finer spatial scale) planning and analysis levels are described in finer detail, using specific soil, vegetation, and/or landform characteristics associated with a site (e.g., soil series, soil series phase, plant association).

There is a distinction between classification and mapping systems. Classification is a formal process of organizing ecosystem elements into naturally occurring classes or categories. Mapping utilizes classifications to develop map unit legends to estimate the spatial distribution of ecosystem elements (i.e., components) or integrated multifactor ecosystem classes that occur across the landscape (Winthers et al. 2005). Mapping includes a map unit design process to establish relationships between classification and mapping. Map units do not necessarily have a one-to-one relationship with classification units. Often it is necessary to include two or more classification units into a single map unit because of the heterogeneity or mosaic nature of vegetation and soil features on any given landscape. Through the map unit design process, decisions are made about the thematic and spatial level of map detail, which classified components comprise each map unit, and what delineation criteria will be used to differentiate map units (Winthers et al. 2005).

Driscoll et al. (1984) describes two kinds or approaches to ecological classification for assessing natural resources, integrated and component, or ecosystem element. Integrated classification unites elements of the land (i.e., vegetation, soil, landform, climate, and water) to describe a united entity. Integrated classifications express the interactive character of the land's elements as a unit in relation to surrounding land units in a spatial hierarchy. Integrated ecological classifications are based on known functional relationships among land elements. Examples of integrated classification and mapping systems include the lower levels (land unit) of the NHFEU (Cleland et al. 1997), the ecological type classification (Winthers et al. 2005), and ecological systems (Comer et al. 2003).

Component or ecosystem element classifications describe parts of the land (i.e., soil, vegetation, landform, water, and climate) separately, with each element as an entity based on their primary characteristics. Examples of component or ecosystem element classifications include Soil Taxonomy (USDA Soil Survey Staff 1999), Potential Natural Vegetation Classification Hierarchy (Brewer and Pfister 2006, Brohman and Bryant 2005, Driscoll et al. 1984) and the NVCS (Federal Geographic Data Committee 2008). An ecosystem element classification approximates integrated land classification as the classification of each element may consider integration of physical and biotic factors. For example, effects of moisture and temperature are considered in soil and vegetation classifications, such as boreal forests (forests developed in cool climates) and Aridisol soils (soils formed in aridic climates). Further integration is accomplished by selecting classification criteria from several ecosystem element classifications to form a new ecological entity. Examples of ecosystem classifications and mapping derived through the combination of ecosystem element classifications are the upper levels of the NHFEU (i.e., Domain, Division, Province, Section, Subsection) (Cleland et al. 1997).

Table 1 arrays different ecological classification systems and ecological mapping systems used by the FS, NRCS, BLM, and NatureServe. The table provides context for where ecological sites and their descriptions reside within hierarchical planning and analysis levels (which themselves represent various spatial scales). Ecological sites are associated with land unit planning and analysis level, where fine spatial scale ecosystem elements are used to characterize ecosystems. Ecological sites are appropriate for fine scale planning and analysis and are roughly equivalent to ecological types associated with land type phases, plant associations, and habitat type phases.

Table 1. Relationships of ecological classification and mapping systems across various hierarchical planning and analysis levels.

	Ecological Classification Systems				Ecological Mapping Systems		
Hierarchical Planning and Analysis Levels	**Ecosystem Classification NRCS and BLM**	**Ecosystem Classification FS[1, 2]**	**Potential Natural Vegetation Hierarchy[6]**	**National Vegetation Classification (NVC)[5]**	**National Hierarchical Framework of Ecological Units[1]**	**NRCS Soil Geography Hierarchy[3]**	**NatureServe Ecological Systems[7]**
Continental and Region (Ecoregion)	NA	Macro Climate PNV Series Groups[1]	PNV Groups, Sub-classes	Formation/Division	Domain, Division, and Province (1:5,000,000-1:30,000,000)	Land Resource Region (LRR)/Common Ecological Region (1:7,500,000)	Macro-ecosystem scale
Subregion	NA	Macro Climate, Physiography, PNC – Series, Formation	Plant Series; Formation	Division/ Macrogroup	Section (1:3,500,000) and Subsection (1:250,000)	Major Land Resource Area (MLRA) (1:3,500,000) Land Resource Unit (LRU)/Common Resource Area (CRA) (1:1,000,000) General Soil Map (1:250,000)	
Landscape (watershed—5th unit of Hydrologic Unit Code)	Biophysical Settings (BLM)	Geomorphology Geology, Relief, Biophysical Settings, Potential Natural Community (PNC) Series; Ecological type[2]	Plant Series; Habitat Type Group	Group/Alliance; (Dominance Type[4])	Landtype Association (1:60,000)	NA	Ecological Systems (Meso-ecosystem Scale)
Land Unit (subwatershed—6th unit of Hydrologic Unit Code), grazing allotment, farm/ranch)	NA	Ecological type[2]	Potential Plant Association; Habitat type	Association/ Alliance	Landtype (1:24,000)	Detailed Soil Map (1:24,000)	Micro-ecosystem Scale
	Ecological Site	Ecological type[2]	Potential Plant Association Phase; Habitat type phase	Association	Landtype Phase (< 1:12,000)	Soil Series, Soil Series Phase (1:12,000)	
Individual Sample Sites	Vegetation plot and soil pedon	Sample site (soil pedon/ vegetation plot)[2]	Vegetation plot	Vegetation plot	Integrated Plot	Soil Pedon	NA

[1] Map scale from: NHFEU (Cleland et al. 1997)
[2] Terrestrial ecological unit inventory technical guide indicates soil series can be incorporated into landtype phase (see table 3.1 in Winthers et al. 2005)
[3] USDA Natural Resources Conservation Service 2006. MLRA definitions 12/15/2005, Soil Geography Hierarchy, http://soils.usda.gov/survey/geography/hierarchy/index.html
[4] Existing vegetation classification and mapping technical guide (Brohman and Bryant 2005)
[5] National Vegetation Classification Standard, version 2 (Federal Geographic Data Committee 2008)
[6] An ecological land classification framework (Driscoll et al. 1984)
[7] Ecological Systems of the United States: A Working Classification of US Terrestrial Systems (Comer et al. 2003)

Forest Service Ecological Classification and Unit Mapping

The FS utilizes ecological classification and mapping to classify ecological types and map ecological units at multiple spatial scales. Ecological units are relatively stable environments associated with repeating patterns of landscape elements (e.g., geology, climate, landform, topographic feature, vegetation, soils), with similar combinations of ecological sites and types as map unit components (Winthers et al. 2005). They delimit areas of similar biological and physical potentials at different levels of resolution (i.e., continental to land unit) within a nested hierarchy (Cleland et al. 1997).

The NHFEU (Cleland et al. 1997) outlines eight levels of ecological unit classification and mapping which support four planning and analysis levels used by the FS (table 2). The hierarchy provides a framework for describing and assessing ecosystems from continental to local scales.

Ecoregion and subregion are the two upper planning and analysis levels typically used for national and regional assessments and planning. Domain, division, and province are ecological units used to describe and communicate ecosystem processes in regional and national assessments and planning (Cleland et al. 1997). Mapping and classification criteria used for these broad ecological units include continental climatic regimes and physiography (Winthers et al. 2005). Section and subsection are ecological units used in regional assessments and planning (Cleland et al. 2007). Mapping and classification criteria used for these regional ecological units include regional climate, geomorphic processes, topography, and stratigraphy (Winthers et al. 2005). Section and subsection ecological units are roughly at the same spatial scale as Major Land Resource Areas and Land Resource Units (table 1).

Landscape and land unit are the two lower planning and analysis levels used by the FS for local assessments and planning. At the landscape planning and analysis level, land-type association ecological units describe and communicate ecosystem processes for forest-wide and watershed analysis and planning. Differentiating criteria for land-type associations and associated ecological types include broad patterns of soil families or soil sub groups, potential natural vegetation series (i.e., vegetation series), geomorphic processes, landforms, geology, and local climate. Land-type association ecological units are roughly at the same map unit size as map units in a 4th order soil survey (table 2).

Land type and land-type phase ecological units at the land unit planning and analysis level are used to describe and communicate ecosystem processes at local scales for project, small landscape (subwatershed) analysis and planning, resource inventories, and effectiveness monitoring. Land types are roughly at the same map unit size as map units in a 3rd order soil survey and land-type phases are roughly at the same map unit size as map units in a 2nd order soil survey (see table 2). Land types and land-type phases are characterized by repeating patterns of one or more ecological types. Ecological unit inventories are designed and completed in cooperation with the NRCS and meet the mapping conventions and soil classification standards of the NCSS (Winthers et al. 2005, Cleland et al. 1997).

Table 2. Relationship of land-type association, land type, and land-type phase ecological units of the NHFEU, to associated ecological type criteria, ecological sites, and soil survey classification and mapping.

National Hierarchical Framework of Ecological Units Components[4]	**Ecological Type Criteria**	**Ecological Site Correlation**	**Soil Taxonomic Unit Component (SRI)**[1,3,6]	**Soil Survey/ Soil Resource Inventory (SRI) Order**[1,3]	**NRCS Soil Geography Hierarchy**[5] **and Soil Map Unit Components**[1]
Subregion: Section (1:3,500,000) and Subsection (1:250,000)	Regional climate, geology, geomorphology, soil great groups and subgroups,	Land Resource Unit	NA	5th Order	Land Resource Units 1:250,000 – 1:1,000,000 or smaller
Land-type association (1:60,000 – 1:250,000)	Climate, geology, geomorphology, soil great groups and subgroups, potential vegetation series and subseries	NA	Phases of soil families or soil subgroups	4th Order	General Soil Map (1:63,360 - 1:250,000)
Land type (1:24,000 – 1:60,000) One (i.e., soil consociation) or more ecological types (i.e., soil association or soil complexes)	Potential natural vegetation, soils, local climate, geomorphology, surficial geology, and hydrology. Based on integrated field plot sample	Correlated with soil series and differences in species composition of the reference community phase. Mapped as soil series, soil associations, or soil complexes.	Phases of soil series or soil families	3rd Order	Detailed soil map mostly of soil series, soil associations, or soil complexes. (1:20,000 - 1:63,360)
Land-type phase (<1:24,000) One (i.e., soil consociation); sometimes more than 1 ecological type (i.e., soil association or soil complexes)	Potential natural vegetation, soils, local climate, geomorphology, surficial geology, and hydrology. Based on integrated field plot sample	Correlated with soil series, soil series phase, and reference community phase. Mapped as single soil series, some soil associations.	Soil series, Soil series phase	2nd Order	Detailed soil map mostly single soil series, soil series phase, some soil associations (1:12,000 – 1:31,680)
NA	NA	Correlated with soil series phase and reference community phase. Mapped as single soil series phase.	Soil series phase	1st Order	Detailed soil map, mostly single soil series phase map units (1:15,840 or larger)

[1] USDA Soil Survey Division Staff (1993).

[2] Terrestrial Ecological Unit Inventory Technical Guide indicates soil series can be incorporated into landtype phase (see table 3.1 in Winthers et al. 2005).
[3] USDA Forest Service (1991b)
[4] Map scale from: NHFEU (Cleland et al. 1997)
[5] USDA Natural Resources Conservation Service 2006. MLRA definitions 12/15/2005, Soil Geography Hierarchy http://soils.usda.gov/survey/geography/hierarchy/index.html
[6] USDA Soil Survey Staff (1999)

An ecological type is similar to an ecological site at the land unit level (e.g., landtype phase, soil series phase). It is a category of land with a distinctive (that is, mappable) combination of landscape elements. The elements making up an ecological type are climate, geology, geomorphology, soils, and potential natural vegetation. Ecological types differ from each other in their ability to produce vegetation and respond to management and natural disturbances (Winthers et al. 2005). An ecological type classification is associated with the landscape and land unit planning and analysis levels of the hierarchy. As components of land-type associations, ecological type classifications describe relationships between broader landscape elements. Geomorphology is a primary differentiating criteria, rather than soil properties. Local climate (modified by elevation, aspect), geology, parent material, soil subgroups, and vegetation series are also used as differentiating criteria for land-type association ecological types. As components of land type and land-type phase ecological units, local site relationships become more important as differentiating criteria. Primary differentiating criteria are soil properties, local climate modified by terrain (slope, aspect, elevation), parent material (surficial geology), potential natural vegetation, hydrology, and geomorphology.

Ecological type classifications are derived through analysis of field data comprised of integrated plots to determine which site characteristics or properties best differentiate the types. Integrated plots include data about the geology, geomorphology, soil properties, and potential natural vegetation of a sample site. Ecological type classifications and descriptions, where completed, can provide information useful in the formation and documentation of ecological site concepts and descriptions. Information and associated data they provide can help stratify the landscape along environmental gradients, define plant-soil-site relationships, identify differentiating factors between ecological sites, and provide additional supporting documentation for ecological site descriptions.

At the land unit planning and analysis level ecological types are similar to ecological sites because both describe and communicate information about the lands capability to support similar vegetation, and the lands response to management actions and disturbance regimes. Soils and abiotic factors, together with vegetation, are used to differentiate ecological types and ecological sites. Classification of ecological types and ecological sites differs in some key aspects. Ecological type classifications are defined at multiple spatial scales and are applicable at both the landscape and land unit planning and analysis levels of the hierarchy. However, criteria for differentiation of ecological types vary across the spatial scales. Ecological sites are associated to a single spatial scale, the site level. In terms of spatial scale, ecological types and ecological sites are most comparable at the land-type phase and 1st and 2nd order soil survey levels.

Relationship to Habitat Type Classifications

Habitat types have historically been defined as all parts of the land surface supporting, or capable of supporting, the same kind of climax plant association (Daubenmire 1978). Habitat type classifications have been developed and used extensively in the western United States to define and describe differences in land capability for land and resource management analysis and planning. Wellner (1989) noted that 127 habitat type classifications for forests and rangelands had been published in the western United States between 1970 and 1987. Habitat type classifications differ from potential natural vegetation classifications in that habitat type classifications include two components, vegetation and associated abiotic characteristics. The vegetation component is defined by potential natural vegetation (i.e., late successional or potential plant association), thus the vegetation component is a potential natural vegetation classification. In practice, however, habitat types have been developed for fire-dependent ecosystems based on dominant seres, not the endpoint of succession in the absence of disturbance. For example, habitat types have been developed for jack and red pine ecosystems (Kotar et al. 2002), which originated from and are maintained by relatively frequent crown or surface fire regimes. In Montana and northern Idaho, Pfister and Arno (1980) considered 70-year-old forested sites as late successional communities for interpreting and describing ecological potential, that is, sites where understory species composition has achieved stability with the environment. Jensen (1990) similarly considered minimally disturbed sites to classify and describe ecological potential for grassland and shrubland types. The abiotic component is comprised of climate, soils, terrain, and landform. Together, the potential natural vegetation community and the abiotic components define the environmental setting or the habitat type. An underlying premise of habitat type classification is that vegetation is the integrated expression of the environment that reflects the environmental potential of a land area (Pfister 1989).

Habitat types differ from ecological sites in that soils are not explicitly used to differentiate habitat types, which are differentiated on the basis of indicator species. Soils information is often included in habitat type descriptions as part of the environmental setting description. More detailed investigation and documentation of the relationship of key soil properties to indicator species is needed to meet ESD standards.

Relationship with Ecological Systems and Biophysical Settings

Ecological systems is a mid-level ecosystem classification and mapping system developed by NatureServe to address information needs in support of assessments of ecological integrity and biological diversity, and to inform conservation and resource management decisions. Ecological systems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes (e.g., fire, flooding etc.) (Comer et al. 2003). Spatially, they are defined as mesoscale ecosystems. They are somewhat comparable to land-type associations but are more narrowly defined as a landscape unit intermediate between the group and the alliance level of the NVC (table 1). They are a broader land unit than an ecological site, being focused on landscape elements and patterns rather than site-level ecosystem element relationships. Ecological systems use plant associations (i.e., plant associations within the NVC, which are existing vegetation types) which co-occur as a differentiating criteria. In addition to existing vegetation types, other factors to differentiate ecological systems include disturbance regimes, substrates (i.e., soil, geology), and environmental gradients (i.e., local climate, desert, arid grassland, montane, alpine zones). Conversely, disturbance regimes are not differentiating criteria for ecological sites, ecological types, nor land-type association ecological units.

Biophysical Settings, a classification used to map fire regimes, uses the scale and nomenclature of ecological systems in describing vegetation communities at the time of European settlement (LANDFIRE 2010). Within LANDFIRE, unique STM's were developed for each Biophysical Setting which depicts development stages, successional pathways, and natural disturbance effects in the absence of human interference.

Relationship with the National Vegetation Classification

The United States Federal Geographic Data Committee developed a geospatial data standard called the National Vegetation Classification (Standard) (Federal Geographic Data Committee 2008). The purpose of the Standard is to support the development and use of a consistent national vegetation classification system for the United States and its Trust Territories. The U.S. National Vegetation Classification allows uniform statistics to be generated about vegetation resources in the United States, based on vegetation data gathered at local, regional, or national levels. The Standard requires that agencies be able to crosswalk other vegetation classifications to the NVC to facilitate the compilation of regional and national summaries.

In addition, ***all federal vegetation classification efforts must meet core data requirements that are the same across all Federal agencies*** to permit aggregation of data from all Federal agencies. The NVCS will require that vegetation inventory units crosswalk to the NVC. Therefore, the composition of any vegetation inventory unit has to be describable in terms of one or more vegetation types within the NVC. The NVC contains a standardized list of vegetation types in each of several hierarchical levels, with the most detailed hierarchical levels characterized by vegetation types that are floristic (plant species) based. The NVCS and NVC apply to existing vegetation and existing vegetation types, regardless of their relationship to potential natural vegetation.

Ecological sites contain differing kinds and amounts of vegetation that are categorized into community phases. Community phases are floristic and are existing vegetation types. Therefore, ecological sites are subject to necessary crosswalking to the NVC. Community phases that are data-supported and not provisional need minimum data to be collected to facilitate crosswalking of community phases to vegetation types in the NVC. Specifically, minimum data associated with plots used to classify ecological sites, and data associated with plots used to identify community phases that can exist on ecological sites will need to be collected.

The NVC does not replace classification of vegetation types (community phases) in an ecological site classification. Therefore, community phases identified in ecological sites do not have to be named exactly as vegetation types in the NVC. However, by whatever means community phases are identified for ecological sites, minimum data associated with those community phases must be available so that each community phase can be crosswalked to one or more existing vegetation types in the NVC.

Ecological Site Relationship with National Cooperative Soil Survey (NCSS)

The National Soil Survey Handbook (NSSH) (USDA Natural Resources Conservation Service 1996) establishes responsibility for planning soil surveys on rangeland. Soil scientists and vegetation specialists (ecologists or rangeland management specialists) and cooperating agencies will work together to map soils and ecological sites in rangeland areas. Essential activities include development of soil survey work plans, determination of soil mapping unit composition, preparation of map legends, determination of mapping intensity, and necessary field reviews.

The NSSH, part 627.02 (USDA Natural Resources Conservation Service 1996), describes the delineation of major landform units and landform components as a preliminary procedure in field mapping. The next step is the identification, description, and classification of the kinds of soils associated with the landform components.

A soil map unit is a collection of areas defined and named the same in terms of their soil components and is uniquely identified on a soil map as a delineation (USDA Soil Survey Division Staff 1993). Map unit design establishes relationships between soil-landscape elements, ecological site characteristics (as defined by the classification), and soil taxonomic unit to define map unit components. There are four kinds of soil map units: soil consociations, soil associations, soil complexes, and soil undifferentiated groups (USDA Soil Survey Division Staff 1993). Soil consociations are soil map units composed of a single component (i.e., soil series, soil series phase) that makes up at least 75 to 85 percent of the map unit. Soil associations and soil complexes are soil map units that may have two or more major dissimilar components which together make up 75 to 85 percent of the map unit and consistently occur together. Major components of a soil association can be delineated at larger scales, while components of soil complexes cannot be delineated separately. Soil undifferentiated groups are soil map units that consist of two or more components that do not consistently occur together. They may be grouped together, however, because of some common map feature (landform, topography) that may determine similar management interpretations. Regardless of map unit kind, soil map units may contain 15 to 25 percent inclusions of dissimilar components.

Mapping scale, soil survey order, and kinds of map unit delineations have a bearing on whether ecological sites are delineated or how precise or general the delineations may be. Ecological sites may be identified and delineated as single components where soils are mapped as soil consociations (generally order 2 soil surveys). Where soils are mapped as soil associations, soil complexes, or soil undifferentiated groups, individual ecological sites are identified, yet they may not be delineated separately (generally order 3 or order 4 soil surveys). In these situations, ecological sites are usually associated with the soil map unit delineation; however, the actual physical location of the ecological site might not be identifiable from the soil map. Ecological sites associated with the different soil components within map units with multiple components are expressed as a percent of the map unit soil taxonomic composition.

Ecological site delineation depends on the relationship of ecological sites to the order of soil survey mapping. There is a many-to-one relationship between soil series phase and ecological sites. This is represented most frequently at order 2 soil survey mapping. Many similar soil taxonomic components may be grouped into one ecological site. However, a single soil component (phase) of a named soil series will not occur in more than one ecological site.

Broadly mapped soil components (i.e., soil series or higher taxonomic units, soil family, in an order 3 soil survey), may include more than one ecological site.

Order 3 mapping describes individual soil and plant map unit components at soil association or soil complex levels. This requires that map unit descriptions be developed that describe each soil association component and assign locations and percentages to each. Individual ecological sites must be described at a level equivalent to the individual components of the order 3 soils map. Where order 2 soil surveys are completed and ecological site interpretations have been made, boundaries of ecological sites can generally be determined directly from the soil map.

APPENDIX B. Example of Growth Forms That Could Be Used To Categorize Plant Species Cover (adapted from Federal Geographic Data Committee 2008).

Growth Form	Definition
Trees	Woody plants that generally have a single main stem and have more or less definite crowns. In instances where growth form cannot be determined, woody plants equal to or greater than 5 meters (m) in height at maturity shall be considered trees.
Shrubs	Woody plants that generally exhibit several erect, spreading, or prostrate stems which give it a bushy appearance. In instances where growth form cannot be determined, woody plants less than 5 m in height at maturity shall be considered shrubs.
Herbs	Vascular plants without significant woody tissue above the ground, with perennating buds borne at or below the ground surface. Includes graminoids, forbs, ferns, club mosses, horsetails, and quillworts.
Nonvascular	A plant or plant-like organism without specialized water or fluid conductive tissue (xylem and phloem). Includes mosses, liverworts, hornworts, lichens, and algae.
Floating	Rooted or drifting plants that float on the water surface.
Submerged	Rooted or drifting plants that by-and-large, remain submerged in the water column or on the aquatic bottom.
Epiphyte	A vascular or nonvascular plant that grows by germinating and rooting on other plants or other perched structures, and does not root in the ground.
Liana	A woody, climbing plant that begins life as terrestrial seedlings but relies on external structural support for height growth during some part of its life, typically exceeding 5 m in height or length at maturity.

APPENDIX C. Example of Vertical Strata That Could Be Used To Categorize Plant Species Cover (adapted from Federal Geographic Data Committee 2008)

Stratum	Definition
Tree	The layer of vegetation where woody plants are typically more than 5 m in height, including mature trees, shrubs over 5 m tall, and lianas. Epiphytes growing on these woody plants are also included in this stratum.
Shrub	The layer of vegetation where woody plants are typically more than 0.5 m tall but less than 5 m in height, such as shrubs, tree saplings, and lianas. Epiphytes may also be present in this stratum. Rooted herbs are excluded even if they are over 0.5 m in height, as their stems often die back annually and do not provide a consistent structure.
Herb	The layer of vegetation consisting of herbs, regardless of height, as well as woody plants less than 0.5 m in height.
Nonvascular (Ground)	The layer of vegetation consisting of nonvascular plants growing on soil or rock surfaces. This includes mosses, liverworts, hornworts, lichens, and algae.
Floating	The layer of vegetation consisting of rooted or drifting plants that float on the water surface.
Submerged	The layer of vegetation consisting of rooted or drifting plants that by-and-large remain submerged in the water column or on the aquatic bottom. Emergent plant growth forms are excluded (for example, cattails would be placed in the herb stratum).

APPENDIX D. Example Ecological Site Key

Soil Based Key
To the Ecological Sites within the 16-20 inch Precipitation Zone within the AZ1 Land Resource Unit within
Major Land Resource Area (MLRA) 41, Southeastern Arizona Basin and Range

Major Land Resource Area (MLRA) 41, Southeastern Arizona Basin and Range, is found in southeastern Arizona and southwestern New Mexico within the Mexican Highland Section of the Basin and Range Province of the Intermontane Plateaus.

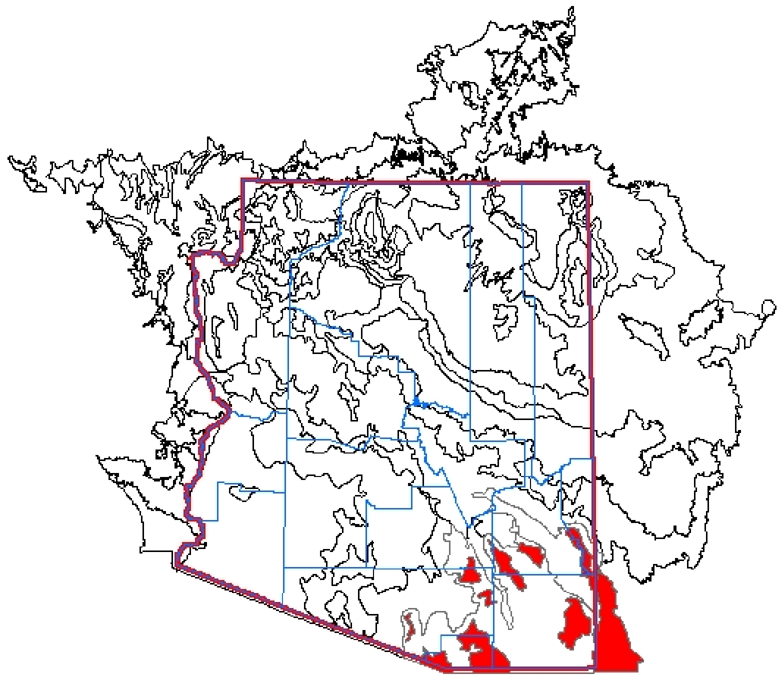
The climate of the area is warm (thermic) and dry to wet (typic aridic to typic ustic). Elevations range from 2600 feet to 10,700 feet or more in the higher mountainous areas found within the MLRA.

The MLRA is separated into three Land Resource Units (LRU's), the 41.AZ1 – Mexican Oak-Pine Forest and Oak Savannah, the 41.AZ2 – Chihuahuan – Sonoran Desert Shrubs LRU, and the 41.AZ3 – Chihuahuan – Sonoran Semidesert Grasslands LRU. This key example displays only one of the three LRU's, the 41.AZ1, Mexican Oak – Pine Forest and Oak Savannah, and displays one of the three precipitation zones, 16-20 precipitation zone within that LRU:

Land Resource Unit 41.AZ1

Mexican Oak-Pine Forest and Oak Savannah

LRU 41.AZ1 – Mexican Oak-Pine Forest and Oak Savannah	
Elevations range from 4500 to 10,700 feet and precipitation ranges from 16 to 30 inches. Vegetation includes Emory oak, Mexican blue oak, Arizona white oak, one-seed juniper, alligator juniper, sacahuista, California bricklebush, skunkbush sumac, Arizona rosewood, wait-a-bit mimosa, sideoats grama, blue grama, purple grama, wooly bunchgrass, plains lovegrass, squirreltail, and pinyon ricegrass. The soil temperature regime ranges from thermic to mesic and the soil moisture regime ranges from aridic ustic to typic ustic. This unit occurs within the Basin and Range Physiographic Province and is characterized by numerous mountain ranges that rise abruptly from broad, plain-like valleys and basins. Igneous and metamorphic rock classes dominate the mountain ranges and sediments filling the basins represent combinations of fluvial, lacustrine, colluvial and alluvial deposits.	



Land Resource Unit 41.AZ1, Mexican Oak – Pine Forest and Oak Savannah, Ecological Site List for 16-20” PZ

Site ID Number	Site Name
041XA101	Clayey Swale16-20" p.z.
041XA102	Granitic Hills16-20" p.z.
041XA103	Limestone Hills16-20" p.z.
041XA104	Limy Slopes16-20" p.z.
041XA105	Limy Upland16-20" p.z.
041XA107	Loamy Slopes16-20" p.z.
041XA108	Loamy Upland16-20" p.z.
041XA109	Clay Loam Upland16-20" p.z.
041XA110	Sandy Loam Upland16-20" p.z.
041XA111	Volcanic Hills16-20" p.z.
041XA112	Sandy Wash, QUEM, QUAR
041XA113	Sandy Bottom, PLWR2, POFR2
041XA114	Loamy Bottom16-20" p.z.
041XA117	Granitic Upland16-20" p.z.
041XA126	Clayey Upland16-20" p.z.
041XA127	Sandy Loam Upland16-20" p.z.Deep

Key to Ecological Sites found in the 16-20" PZ within Land Resource Unit 41.AZ1, Mexican Oak-Pine Forest and Oak Savannah

I. Flooded (bottom position, flooded from the valley-side or over-bank)

A. Soils with a perennial high water-table (3-15 ft.)

1. Soils sandy and gravelly with redox features –
Sandy Bottom, PLWR2, POFR2 (041XA113)

2. Soils loamy to clayey with redox features - Cienega **

B. Soils with seasonal (summer) water table (3-15 ft.) –

1. Soils sandy loam to clay loam - Loamy Bottom (041XA114)

C. Soils without a high water table (3-15 ft)

1. Soils sandy - Sandy Wash, QUEM, QUAR (041XA112)

2. Soils sandy loam to clay loam - Loamy Bottom (041XA114)

3. Soils clayey (vertic) - Clayey Swale (041XA101)

II. Not Flooded (upland position, receives only precipitation)

A. Slopes less than 15%

1. Soils calcareous throughout

a. Soils shallow (less than 20 inches deep)

1. Soils with a lime cemented hardpan –
Limy Upland (041XA105)

b. Soils moderately deep to deep (30 to 60 inches)

2. Soils with an argillic horizon - Loamy Upland, limy **

2. Soils non calcareous in upper 10 inches

a. Soils shallow (less than 20 inches deep)

1. Soils underlain by granite, schist, rhyolite bedrock -
Granitic Upland (041XA117)

b. Soils moderately deep to deep (30 to 60 inches)

1. Soils without an argillic horizon

a. Soils loamy fine sand to sandy loam –
Sandy Loam Upland, Deep (041XA127)

2. Soils with an argillic horizon

a. Soils with sandy loam surface 4 in. or thicker
Sandy Loam Upland (041XA110)

b. Soils with sandy loam surface less than 4 in.
Loamy Upland (041XA108)

c. Soils with clay loam surface (not vertic) -
Clay Loam Upland (041XA109)

d. Soils with a clayey surface (vertic) –
Clayey Upland (041XA126)

B. Slopes greater than 15%

1. Soils shallow (less than 20 inches deep)

a. Soils calcareous throughout

1. Soils over limestone parent materials – Limestone Hills (041XA103)

b. Soils non calcareous

1. Soils over granite, schist, gneiss, rhyolite (acid igneous) - Granitic Hills (041XA102)

2. Soils over basalt, andesite, welded tuff (basic igneous) - Volcanic Hills (041XA111)

2. Soils moderately deep and deep (30 to 60 inches)

a. Soils calcareous throughout

1. Soils dark colored in the surface 5 inches (10YR, 4/2) – Limy Slopes (041XA104)

b. Soils non calcareous in the upper 10 inches

1. Soils sandy loam to clay loam – Loamy Slopes (041XA107)

2. Soils clayey - Clayey Slopes **

** These sites may occur, but have not yet been confirmed

APPENDIX E. Example Ecological Site Description

ECOLOGICAL SITE DESCRIPTION

(Portions of this ecological site description have been fabricated for presentation purpose in an effort to display the applicable contents of an ESD as defined in the Interagency ESD handbook)

ECOLOGICAL SITE CHARACTERISTICS

Site Name: Deep Sand Savanna 13-16 P.Z.

Artemisia filifolia/*Andropogon hallii-Schizachyrium scoparium,* (sand sagebrush/sand bluestem-little bluestem)

Site ID: 045CY999

Hierarchical Classification Relationships:

Major Land Resource Area (MLRA) 045C-Central New Mexico Highlands. This MLRA lies within the Sacramento Section of the Basin and Range Province of the Intermontane Plateaus. It is characterized by block-faulted ranges separated by intermountain basins. Tablelands and mesas are capped by sedimentary rocks. Many local terraces are near small streams. Steep escarpments and breaks are common. Elevation generally ranges from 5,000 to 7,400 feet (1,525 to 2,255 meters). In some mountainous areas, however, it is more than 8,500 feet (2,590 meters).

Crosswalk MLRA 045C with Ecological Subregions:

Section M313B—Sacramento-Monzano Mountains
Section M315A—Pecos Valley

Physiographic Features

This site occurs as coarse-textured eolian and alluvial sediments on upland plains. Slopes are nearly level to gently undulating, generally less than 5 percent. Low stabilized hummocks or dunes may occur. Exposure varies but is not significant. Elevations range from 4,500 to 7,200 feet above sea level.

Landform: (1) Plain

(2) Sand sheet

	Minimum	Maximum
Elevation (feet):	4500	7200
Slope (percent):	0	5
Slope Shape:	Linear	
Hillslope – Profile Position:	Not applicable	
Water Table Depth (inches):		
Flooding:		
Frequency:		
Duration:	None	None
Ponding:		
Depth (inches):		
Frequency:		
Duration:	None	None
Runoff Class:	Negligible	Medium
Aspect:	No Influence on this site	

Climatic Features

Climatic features are of the general area within which the Deep Sand Savanna ecological site is located, and do not necessarily apply to exact locations of the Deep Sand Savanna ecological site.

The climate of the area is semi-arid continental. The average annual precipitation ranges from 13 to 16 inches. Variations of 5 inches, more or less, are common. Seventy-five percent of the precipitation falls from April through October. Most of the summer precipitation falls in the form of high-intensity, short-duration thunderstorms. Drought (less than 75% of average annual precipitation) years occur about 1 in 10 years.

Distinct seasonal changes and large annual and diurnal temperature changes characterize temperatures. The average annual temperature is about 50 degrees F with extremes of –29 degrees F in the winter and 103 degrees F in the summer.

Both temperature and precipitation favor warm-season, perennial plant species. However, about 40 percent of the precipitation falls at a time favorable for cool-season plant growth. This allows the cool-season species to occupy an important component in this site. Because of the coarse texture of the soil, the plant community can respond rapidly to any precipitation during the frost-free season. Strong winds blow from February through June, drying the soil during a critical stage for plant growth and causing the soil to blow, which can damage plants.

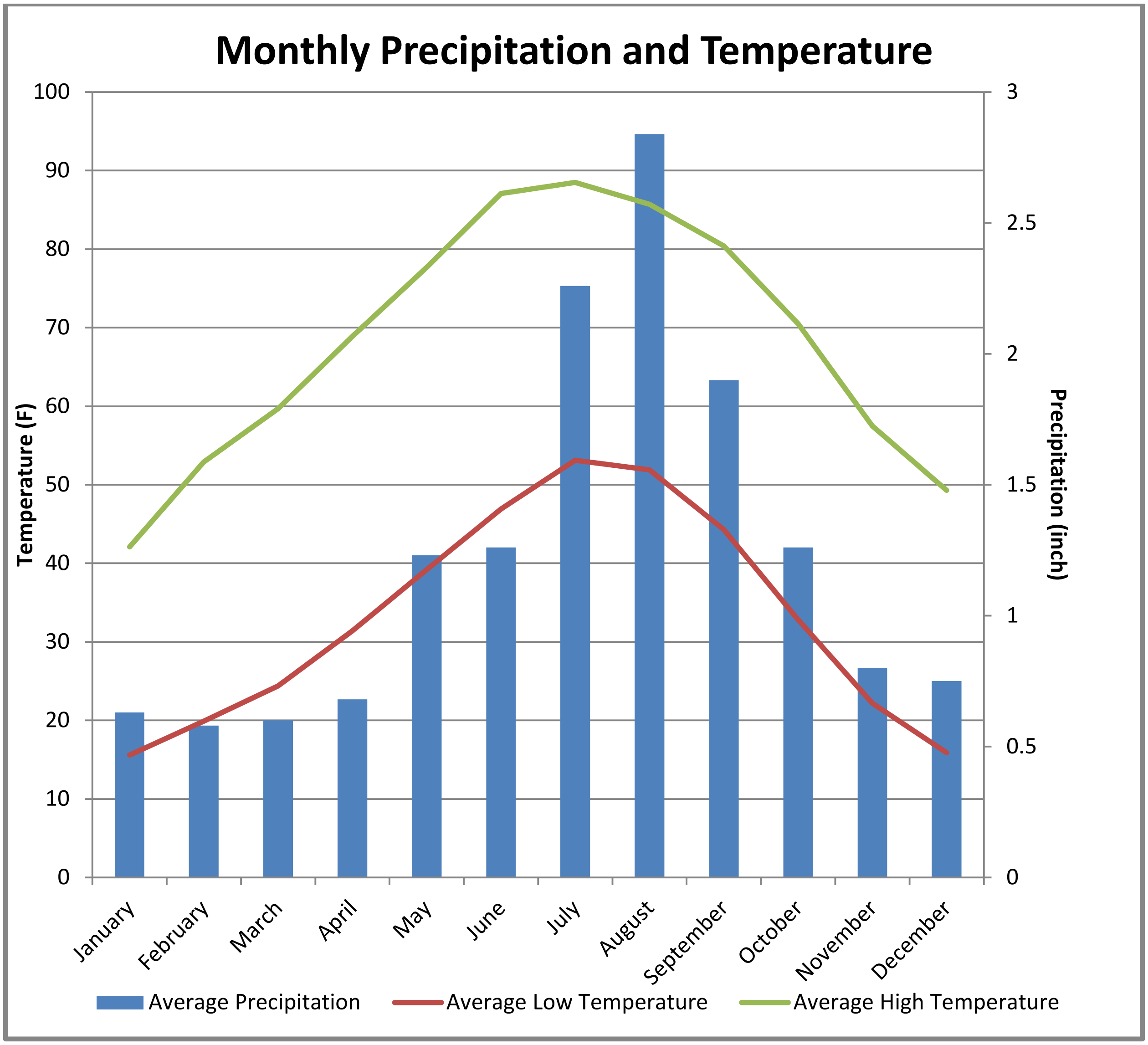
The average frost-free period varies between 131 and 173 days, with at least 50% of the years having a frost-free period within that range. The average freeze-free period varies between 155 and 187 days, with at least 50% of the years having a freeze-free period within that range. The last killing frost typically occurs in early May and the first killing frost typically occurs in early October.

	Minimum (days)	Maximum (days)
50% Probability Frost-Free Period (32.5^{o}F or greater)	131	173
50% Probability Freeze-Free Period (28.5^{o}F or greater)	155	187

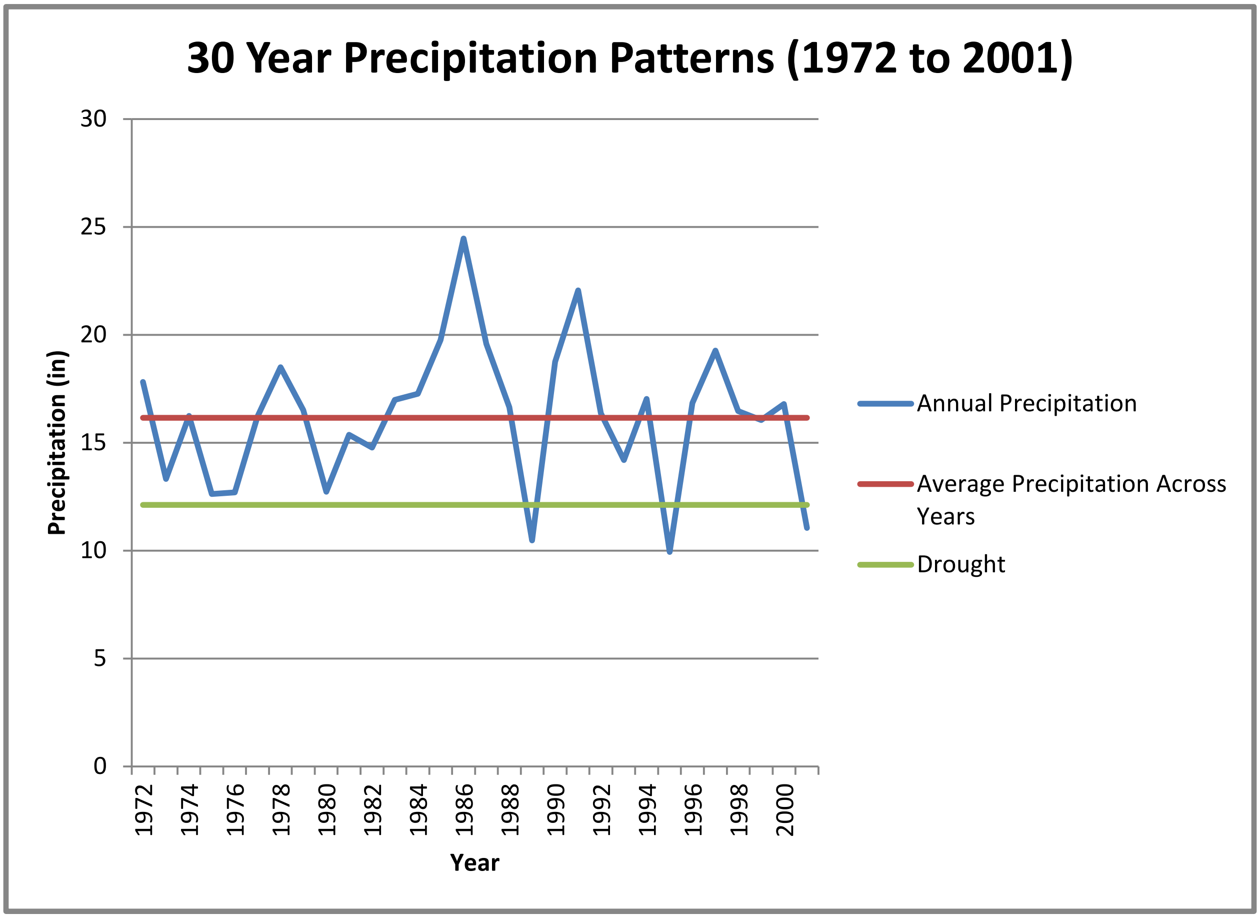
Mean Annual Precipitation: 13.0 to 16.0 inches per year

Monthly Precipitation (inches) and Temperature (^{o}F) Distribution

		Temperature	
Month	Average Precipitation	Average Low	Average High
January	0.63	15.6	42.1
February	0.58	19.9	52.9
March	0.60	24.4	59.7
April	0.68	31.4	68.9
May	1.23	39.2	77.7
June	1.26	46.9	87.1
July	2.26	53.1	88.5
August	2.84	51.9	85.7
September	1.90	44.3	80.4
October	1.26	32.8	70.5
November	0.80	22.2	57.5
December	0.75	15.9	49.3



Monthly Precipitation and Temperature
Temperature (F)
Precipitation (inch)
100
90
80
70
60
50
40
30
20
10
0
3
2.5
2
1.5
1
0.5
0
January
February
March
April
May
June
July
August
September
October
November
December
Average Precipitation
Average Low Temperature
Average High Temperature



Referenced Climate Stations

Clines Corners 7 SE, NM
Corona 11 SSW, NM
Estancia, NM
Gran Quivira Natl. Monument, NM
Mountainair, NM
Vaughn, NM

Influencing Water Features

This site is not influenced by water from a wetland or stream.

Wetland Description:	System	Subsystem	Class
(Cowardin System)	None		

Representative Soil Features

The soils on this site are deep and excessively drained. Key features that typify the site are: surface textures that are of loamy fine sand or fine sandy loams; soils that extend to a depth of 60 inches or more; soil surface stability class ratings of 3.5 to 4.5 in interspaces, and soil surface stability ratings of 4 to 5 under shrub or grass plant canopies; soils are rapidly permeable and have a low water-holding capacity. The average soil organic matter (SOM) is 1 to 3%. Surface runoff is very slow. Drying of the surface is fast and soil-blowing hazard is high.

Characteristic Soils Are: Flugle, Mespun, Otero, Palma, Trail

Parent Materials:
Kind: Eolian deposits
Origin: Sandstone and Shale

Surface Texture: (1) Loamy fine sand
(2) Fine sandy loam
(3) Loamy sand

Subsurface Texture Group: Loamy

	Minimum	Maximum
Surface Fragments <=3" (% Cover):		
Surface Fragments > 3" (% Cover):		
Subsurface Fragments <=3" (% Volume):	15	35
Subsurface Fragments > 3" (% Volume):	15	35

Drainage Class: Well drained To Excessively drained
Permeability Class: Moderately slow To Rapid

	Minimum	Maximum
Depth (inches):	60	72
Electrical Conductivity (mmhos/cm):	0	4
Sodium Absorption Ratio:		
Calcium Carbonate Equivalent (percent):		
Soil Reaction (1:1 Water):	6.1	8.4
Soil Reaction (0.01M CaCl2):		
Available Water Capacity (inches):	3.0	6.0

States and Community Phases

Ecological Dynamics of the Site

A state-and-transition model was developed using archeological and historical data, professional experience, and scientific studies. A brief summary of the information used is included here. The model was refined using professional experience and expert knowledge gained from 1990 to 2012. Scientific knowledge gained from long term and expanded studies (Shaver 2010b) and scientific and historical literature was also used.

In the early 1600's Gran Quivira (Jumano Pueblo) may have had as many as 1,000 inhabitants. These people traded with the Pueblo peoples in the Rio Grande valley to the west, the Comanche in the east and the Apache in the south. Vivian (1961) quotes Spanish documents in which Nicolas de Aguilar, a Spanish "Encomendero", in 1663 states:
"It has never been possible to keep livestock in said Pueblo because there is not water, for what there is comes only from wells which are a quarter of a league (~850 – 900 m) from the place, forty or fifty estados (~70 - 85 m) in depth. And therefore it costs a great deal to get water and it makes a lot of work for the Indians in obtaining it, and the wells are exhausted and there is an insufficient water supply for the people, for their lack of water is so great they are accustomed to save their urine to water the land and to build walls."

Excavations of the ruin of Gran Quivira show that over half of the animal bones found were blacktailed jackrabbit (*Lepus californicus*) and pronghorn antelope (*Antilocapra americana*). Desert cottontail rabbits (*Sylvilagus audubonii*), domestic and wild sheep (*Ovis* spp), mule deer (*Odocoileus hemionus*), domestic horse (*Equus caballus*) and bison (*Bison bison*) were also present in much smaller amounts. Trace amounts of bones were found from various birds, cougar (*Felis concolor*), gray fox (*Urocyon cinereoargenteus*) and black-tailed prairie dog (*Cynomys ludovicianus*) (Vivian 1961). The indication is that native herbivory prior to European influence, and even after Spanish reconquest and colonization in 1692, was mainly by lagomorphs and pronghorn antelope.

This area has historically been described as grassland with few junipers dotting the landscape. One-seed juniper (*Juniperus monosperma*) was confined to ridge tops and the foot slopes of adjoining mountains (Bandelier 1884, Horgan 1954, McLeullough 1982). While not specific to the peoples of the Jumano Pueblo, Stewart (2002) states that the Apache, Navajo and Pueblo inhabitants of this area used fire as a management tool for hunting, to draw game into the area, for clearing crop fields and to increase the yield of grass seeds used for grain. Other authors support this contention with fire frequencies for the area ranging from 4 – 20 years (Allen 1989, Baisan and Swetnam 1997, Frost 1998). This fire regime would be frequent enough to create and maintain a grassland aspect and herbaceous dominated plant community. Wright (1990) indicated that fires every 10 – 30 years kept juniper on shallow, rocky, rough places. He also indicated that non-sprouting junipers less than four feet tall are readily killed by ground fires of herbaceous fuel. Dwyer and Pieper (1967) show that one-seed juniper less than four feet tall were killed with a ground fire.

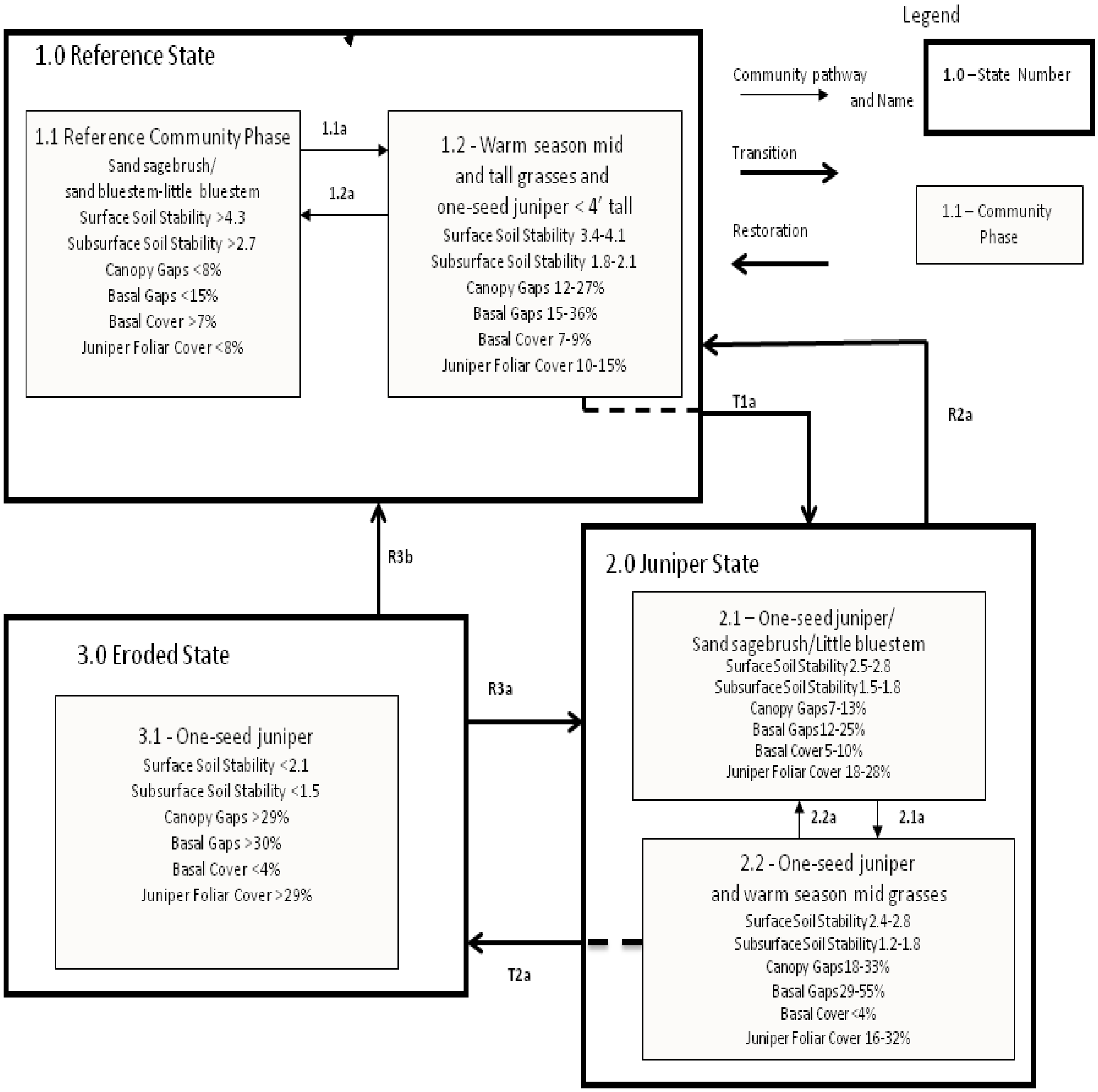
Given this description, it is very unlikely that large numbers of domesticated or native herbivores were grazing in this region until the Anglo expansion into New Mexico occurred in the mid 1800's. It is estimated that there were several hundred thousand head of sheep in New Mexico from 1788 onward to about 1870 (Denevan 1967). Domestic livestock grazing increased rapidly following Anglo expansion. From 1870 to 1890 sheep numbers increased to around 5 million state wide (Denevan 1967). Cattle numbers were approximately 137,000 in 1880 and reached 1.3 million by 1889. Numbers of sheep and cattle increased from the 1880s to the end of World War I and have been decreasing since 1920 (Schickedanz 1980). In 1906 there were approximately 1 million cattle and 6 million sheep in New Mexico. By 1979, cattle had increased to 1.5 million, while sheep had decreased to 600,000. This historical increase in livestock numbers undoubtedly impacted the natural disturbance regime of frequent fires by lessening the frequency, and increasing the pre-Anglo low levels of herbivory. Many studies have linked juniper expansion to increased livestock and decreased fire frequency (Jameson 1962, Johnsen 1962, Arnold 1964, Arnold et al. 1964, White 1965, Jameson 1967, Jameson 1970, Clary and Jameson 1981, Pieper 1983, Miller and Wigand 1994, Allen and Breshears 1998, Lanner and Van Devender 1998).

Historical information and existing data (Shaver 2010a, 2010b) indicate these physical and environmental conditions have led to ecological dynamics that have produced an ecological site characterized by tall and mid warm season grasses. Warm and cool season mid and short grasses were the sub-dominant plant functional groups on this ecological site. Observation indicates the forb component was variable depending on timing and amount of precipitation and with the season. The woody plant component was both spatially and temporally variable depending on time since the last fire, but was always a minor component of the plant community (Allen 1989, Baisan and Swetnam 1997, Frost 1998, Stewart 2002). The production of a continuous fine fuel load and resulting fires were important negative feedbacks that limited the abundance of the woody components and maintained an herbaceous dominance on the site. The resilience of the ecological site was maintained by the continued input of organic matter primarily from root turnover of the herbaceous species (Gill and Jackson 2000) and herbaceous litter. Development and maintenance of stable soil aggregates is a function of the interactions of soil microbes and organic inputs, and the continuation of herbaceous litter production and root turnover. The resulting soil aggregate stability is integral to the negative feedback mechanisms responsible for ecological resilience. High soil aggregate stability provides optimal rates of infiltration, water holding capacity, aeration and mineral cycling, which maintains herbaceous production. Herbaceous production provides for a uniform distribution of soil nutrients and water throughout the soil profile (Schlesinger et al. 1990). This uniform distribution maintains uniform organic matter inputs (Kemper and Koch 1966, Tisdall and Oades 1982, Goldberg et al. 1988, Topp et al. 1996, Bird et al. 2007) and strengthens the resilience of the site to the periodic fires that were necessary to control the establishment and increase of one-seed juniper.

As European settlement progressed, domestic livestock numbers increased rapidly and the resulting grazing pressure decreased fine fuel for fires (Savage and Swetnam 1990, Swetnam et al. In Press). One-seed juniper increased in density and cover with an increase in the time since the last fire, also causing a decrease in herbaceous production (Jameson 1962, Johnsen 1962, Arnold 1964, Arnold et al. 1964, White 1965, Jameson 1967, Jameson 1970, Clary and Jameson 1981, Pieper 1983, Miller and Wigand 1994, Allen and Breshears 1998, Lanner and Van Devender 1998). Decreased herbaceous production caused a decline in organic matter inputs, resulting in lowered soil aggregate stability (Tisdall and Oades 1982). As herbaceous production and cover were reduced and bare ground and erosion increased, fine fuels for fire became inadequate and resilience was weakened. Soil moisture, nutrients and organic matter decreased in the interspaces and increased under the trees and shrubs (Padien and Lajtha 1992, Davenport et al. 1996, Weltzin and McPherson 1997, Breshears and Barnes 1999, Reid et al. 1999, Bird et al. 2002, McIntyre and Tongway 2005, Bestelmeyer et al. 2006, Bird et al. 2007). Decreased herbaceous production and organic matter in the interspaces likely decreased soil aggregate stability, infiltration, water holding capacity and mineral cycling. As the redistribution of resources continued the strength of the feedback mechanisms began to shift and site resilience decreased.

Plant interspaces continued to lose resources resulting in a lower proportion of root biomass available for annual turnover (Gill and Jackson 2000) further concentrating resources under the one-seed juniper. Gill and Jackson (2000) discussed the difference in root turnover from grasses and shrubs and state that the turnover from woody plants is much less proportionately than that of grasses. When juniper increases, the resulting reallocation of underground resources is well documented (Padien and Lajtha 1992, Davenport et al. 1996, Weltzin and McPherson 1997, Breshears and Barnes 1999, Reid et al. 1999, Bird et al. 2002, McIntyre and Tongway 2005, Bestelmeyer et al. 2006, Bird et al. 2007). This change develops abiotic feedback mechanisms controlled by wind and water erosion, leading to desertification that builds very strong resilience feedback mechanisms and resistance to change (Schlesinger et al. 1990, Whisenant 1999, Bestelmeyer et al. 2006).

State and Transition Diagram



Reference State 1.0

The reference state consist of two community phases, 1.1 and 1.2, each being maintained by frequent fire (6 to 20 year fire frequency) and weather fluctuations (drought and wet years). Community phase 1.1 is designated as the reference community phase while community 1.2 is the most at-risk community phase when bare ground increases and organic matter inputs decline.

Indicators: High perennial grass cover and production. Litter accumulation.

Feedbacks: Organic matter inputs allow for increased soil moisture, production, root turnover and litter increasing soil surface stability.

Reference Community Phase 1.1

***Artemisia filifolia/Andropogon hallii-Schizachyrium scoparium* (Sand Sagebrush/Sand Bluestem-Little Bluestem)**

Reference Community Phase 1.1

The description for community phase 1.1 is based on data from medium and high intensity sampling. This community phase is characterized by an open stand of pinyon and/or one-seed juniper with grass understory. The overstory tree canopy cover ranges from 1 to 10 percent. Both warm/cool season mid and tall grasses characterize the understory grasses. Sand bluestem and little bluestem are the most common and abundant grass species in the understory. Sand sagebrush is the most common and abundant understory shrub. Other shrub species occur in minor amounts. Half-shrubs and forbs are a minor part of the community phase. The open stand of pinyon and juniper at one time may have been maintained by natural fire. The foliar cover for overstory tree is less than 8 percent (see Plant Species Composition table).

Other uncommon grasses that could appear on this site include: switchgrass, mesa dropseed, alkali sacaton, threeawns, sandhill muhly, purple lovegrass, ring muhly, bottlebrush squirreltail, western wheatgrass, plains bristlegrass, green sprangletop, littleseed ricegrass, and prairie junegrass.

Other woody plants include: feather dalea, cholla, ephedra, winterfat, rubber rabbitbrush, broom snakeweed, fourwing saltbush, yucca, and algerita. Other forbs include: tansymustard, locoweed, redstem milkvetch, scarlet globemallow, mariola, sand verbena, goldenrod, and threadleaf groundsel.

Reference Community Phase Plant Species Composition:

Reference Community Phase Composition Table grouped by Growth Form, Functional Group membership, annual production, foliar cover, and constancy and canopy cover for common species found in the reference community phase. Production and foliar cover values are derived from high intensity sampling. Canopy cover values derived principally from medium intensity sampling.

					Annual Production (lbs/ac)		**Foliar Cover**		**Constancy/Canopy Cover Sample Number: 10**		
										Canopy Cover	
Group Number	**Functional Group Name**	**Common Name**	**Symbol**	**Scientific Name**	**Low**	**High**	**Low**	**High**	**Constancy**	**Range**	**Mean**
1-Tree					**35**	**75**				**1-10**	**5**
		one-seed juniper	JUMO	*Juniperus monosperma*	35	75	3	8	100	1-7	5
		pinyon pine	PIED	*Pinus edulis*	35	75			80	1-3	1
Shrub/Vine										**0 – 5**	**3**
2 – Evergreen Shrubs					**35**	**75**					
		sand sagebrush	ARFI2	*Artemisia filifolia*	35	75	2	3	100	5 – 15	10
		fourwing saltbush	ATCA2	*Atriplex canescens*	10	55	1	3	80	1 - 15	5
		algerita	MATR3	*Mahonia trifoliolata*	10	35	0	1	50	1 - 3	1
		yucca spp.	YUCCA	*Yucca*	10	25	0	1	30	1 - 3	1
3 – Deciduous Shrubs					**32**	**75**					
		oak spp.	QUERC	*Quercus*	22	40	0	3	50	1 - 10	5
		skunkbush sumac	RHTR	*Rhus trilobata*	10	35	0	2	50	1 - 3	1
		thistle cholla	CYDA4	*Cylindropuntia davisii*	0	30	0	1	50	1 - 3	1
Grass/Grasslike										**1-60**	**50**
4 –Warm Season Tall Grasses, Dense					**250**	**400**					
		sand bluestem	ANHA	*Andropogon hallii*	200	285			100	10 – 30	20
		little bluestem	SCSC	*Schizachyrium scoparium*	250	425			100	10 – 40	30
		Indiangrass (yellow)	SONU2	*Sorghastrum nutans*	50	75			80	1 – 5	3
		big bluestem	ANGE	*Andropogon gerardii*	105	160			80	5 – 20	10
5 –Warm Season Tall Grasses, Open					**50**	**250**					
		cane bluestem	BOBA3	*Bothriochloa barbinodis*	100	150			30	5 - 20	10
		prairie sandreed	CALO	*Calamovilfa longifolia*	25	100			10	1 - 5	3
6 - Mid Grasses					**40**	**100**					
		sideoats grama	BOCU	*Bouteloua curtipendula*	40	100			40	1 – 5	3
7 – Other Mid Grasses					**10**	**200**					
		spike dropseed	SPCO4	*Sporobolus contractus*	50	125			40	1- 5	3
		sand dropseed	SPCR	*Sporobolus cryptandrus*	40	160			40	1 - 5	3
		giant dropseed	SPGI	*Sporobolus giganteus*	24	60			40	1 - 5	3

8 -- Other Mid Grasses					**105**	**158**					
		blue grama	BOGR2	*Bouteloua gracilis*	0	80			30	1 - 3	1
		needleandthread	HECO26	*Hesperostipa comata*	32	53			30	1 - 3	1
		New Mexico feathergrass	HENE5	*Hesperostipa neomexicana*	0	26			30	1 - 3	1
		galleta	PLJA	*Pleuraphis jamesii*	0	40			20	1 - 3	1
9 -- Other Mid Grasses					**5**	**20**					
		black grama	BOER4	*Bouteloua eriopoda*	53	105			60	1 - 5	3
10 – Other Mid Grasses					**5**	**20**					
		Indian ricegrass	ACHY	*Achnatherum hymenoides*	5	20			60	1 - 3	1
11 - Forb					**0**	**55**				**1 – 5**	**3**
		winterfat	KRASC	*Krascheninnikovia*	5	10			100	1 - 3	2
		sand verbena	ABRON	*Abronia*	0	10			80	1 - 3	1
		wooly loco	ASMO7	*Astragalus mollissimus*	0	3			50	1 - 3	1
		broom snakeweed	GUSA2	*Gutierrezia sarothrae*	0	40			50	1 - 5	3

Community Pathway 1.1a

Community Pathways: Characterized by time since last fire and fluctuations in weather. Community pathway 1.1a is driven by time since last fire or by a series of dry years followed by wet years. As time since the last fire increases, the opportunity for one-seed juniper seedling establishment increases. A series of dry years that decreases herbaceous production, cover and organic matter input into the soil, when followed by a wet cycle allow opportunity for one-seed juniper seed germination and establishment, and the development of community phase 1.2.

One-seed juniper seedlings may increase in response to disturbances such as a series of dry years followed by wet years, or an interruption or delayed period from the normal fire frequency. A normal fire frequency allows ground fires to remove one-seed juniper seedlings and other established woody plants less than 1.5 meter in height. The site shifts from community phase 1.2 back to reference community phase 1.1.

As time since the last fire increases, the one-seed juniper increases in size and density and the site moves toward community phase 1.2. The negative feedback mechanisms associated with site resilience are weakened. Positive feedbacks associated with degradation increase, making community phase 1.2 the at-risk community phase in the Reference State.

Total Annual Production:

Total Annual Production (lbs/ac)

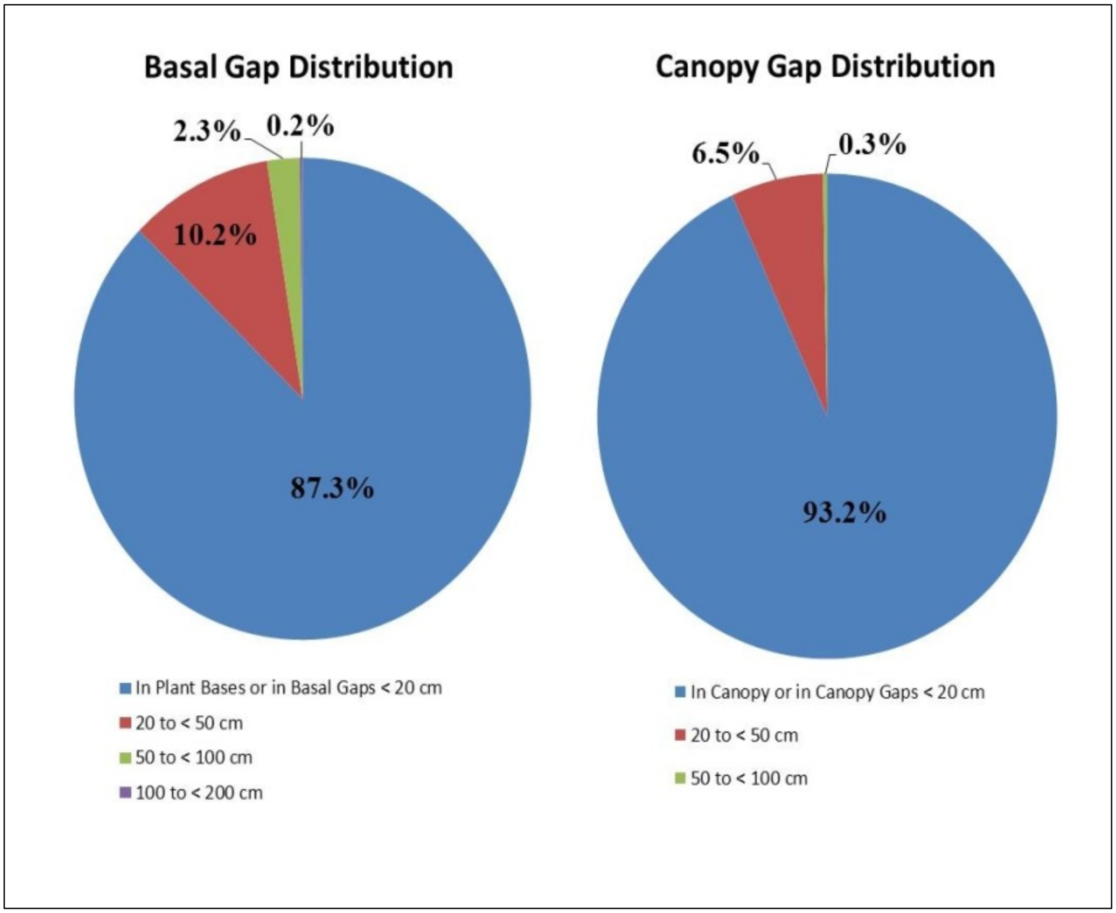
Year

Growth Form	Unfavorable	Normal	Favorable
Grass/Grasslike	475	700	1125
Forb	80	145	240
Shrub/Vine	5	20	35
Tree	75	150	300
Total:	635	1015	1700

Vertical Structure (percentages for each species are canopy cover)_

	Vertical Strata		
Species	Tree (> 5m height)	Shrub (> 0.5m to 5m height)	Herb (< 0.5m height)
One-seed juniper		1-2%	1-6%
Pinyon pine		0-1%	1-3%
Sand sagebrush		3-11%	2-4%
Oak spp.		1-8%	0-2%
Fourwing saltbush		1-11%	0-4%
Sand bluestem		2-5%	8-25%
Little bluestem		3-10%	7-40%
Big bluestem		2-5%	3-15%
Cane bluestem		1-5%	4-15%
Indiangrass		1-3%	2-7%

Horizontal Structure



Ground Surface Cover	Minimum	Maximum
Basal Cover	7%	14%
Litter	10%	20%
Surface Fragments > 0.25" and <= 3"		
Surface Fragments > 3"		
Bedrock		
Water		
Bare Ground	35%	40%
Biological Soil Crust		

Community Phase 1.2

<u>Warm season mid and tall grasses and one-seed juniper < 4' tall</u>

This community phase is provisional because a plant species list and plant abundance data are lacking.

Community phases, 1.1 and 1.2, are both maintained by frequent fire (6 to 20 year fire frequency) and weather fluctuations (drought and wet years).

Indicators: High perennial grass cover and production. Litter accumulation.

Feedbacks: Organic matter inputs allow for increased soil moisture, production, root turnover and litter increasing soil surface stability.

The average surface soil stability rating in community phase 1.2 was 3.7, well within the range for the Reference State, but the average subsurface soil stability rating was 1.9, at the low end of the Reference State range.

The following data is based on summarizing nine transects. Canopy gaps >200 cm and basal gaps >200 cm were 20% and 25% respectively, both within the range for the Reference State. Juniper foliar cover averaged 12%, inside the range of the Reference State but outside the range of the reference community phase. This data seems to indicate that this community phase 1.2 is at risk of crossing an ecological threshold.

Community Pathway 1.2a

This community pathway is driven by fire. Short fire frequency intervals allow ground fires that cause high mortality of one-seed juniper seedlings and established plants less than 1.5 meters tall.

Community pathway 1.2a represents the feedback mechanisms that maintain the resilience of the Reference State. As time since the last fire increases, the one-seed juniper in community phase 1.2 increases in size and density and the negative feedback mechanisms associated with site resilience weaken. Positive feedbacks associated with degradation increase, making this the at-risk community phase in the Reference State.

As the one-seed juniper increases in size and density, soil and water resources begin to concentrate under and around the juniper plants, reducing herbaceous production in the interspace areas. This reduction in herbaceous production increases gap size, reduces fine fuel for fires and reduces organic matter inputs for soil aggregate stability. This agrees with Archer (1989) who suggested that changes to natural disturbance regimes might cause increases in woody plants. Bestelmeyer et al. (2006) showed that as the size of bare patches increased, aggregate stability decreased. Shaver (2010b) showed that the results of herbicide treatment on these treated plots, although long lasting, were beginning to decline. This suggests that without the reintroduction of fire, the feedback mechanisms of increased organic matter inputs were not able to limit the increase or encroachment of one-seed juniper onto the site.

The resilience of the Reference State was weakened and the processes of infiltration, nutrient cycling, aggregate stability and annual production were nearing a threshold into the Juniper State.

Threshold values from the Reference State to the Juniper State for surface soil stability were between 3.4 and 2.8 and for subsurface soil stability at 1.8. Once the threshold is crossed, along the transition (T1a) the positive feedbacks for change become negative feedbacks strengthening the resilience of the Juniper State.

Transition - T1A

The triggers for this transition are the elimination of fire, and overgrazing, causing increased one-seed juniper canopy. The threshold values are as follows:

Increasing bare ground > 20%, and an increase in juniper canopy cover to 15%.

Slow variables and triggers for this transition are the elimination of fire attributable to decrease in fine fuels. The increasing canopies of juniper restrict or limit sunlight and moisture critical for herbaceous cover. The threshold values are: surface soil stability < 3.4, basal cover > 5%, juniper foliar cover > 15% and juniper > than 4' tall.

Juniper State 2.0

Juniper canopy cover controls the soil moisture, herbaceous production and organic matter inputs. Management practices applied to maintain current canopy cover and herbaceous production. Manipulation of shrub/tree species and prescribed fire and grazing management planned to maintain or improve warm season mid and tall grass production.

Indicators: Juniper foliar cover>15%, bare ground 35 to 50% summarized from line transect. Feedbacks: Juniper use of soil moisture, decreasing herbaceous production, decreasing organic matter inputs.

At-risk Community Phase: Either community phase 2.1 or 2.2 is at risk if juniper seedlings increase and canopy cover increases.

Community Phase 2.1

***Juniperus monosperma/Artemisia filifolia/Schizachyrium scoparium* (One-seed Juniper/Sand Sagebrush/Little Bluestem)**

The description for community phase 2.1 is based on data from medium and high intensity sampling.

Community Phase 2.1

This community phase consists of a tree overstory dominated by one-seed juniper (canopy cover 20-40%) and pinyon pine (canopy cover 5-10%). Sand sagebrush is the most common and abundant shrub species in the understory (canopy cover 5 -15%). The herbaceous layer contains a mix of tall and mid grass species with little bluestem (canopy cover 3-15%) being the most common and abundant grass species (see Plant Species Composition table).

Plant Species Composition:

Plant Species Composition Table grouped by Growth Form, Functional Group membership, annual production, foliar cover, and constancy and canopy cover for common species found in community phase 2.1. Foliar cover derived from high intensity sampling. Canopy cover values derived principally from medium intensity sampling.

					Annual Production (lbs/ac)		Foliar Cover		Constancy/Canopy Cover Sample Number: 15		
Group Number	Functional Group Name	Common Name	Symbol	Scientific Name	Low	High	Low	High	Constancy	Canopy Cover Range	Canopy Cover Mean
1-Tree										**15 - 45**	**25**
		one-seed juniper	JUMO	*Juniperus monosperma*	35	75	18	28	100	20 - 40	35
		pinyon pine	PIED	*Pinus edulis*	20	60			100	5 -10	8
Shrub/Vine										**5 - 15**	**10**
2 – Evergreen Shrubs					**35**	**75**					
		sand sagebrush	ARFI2	*Artemisia filifolia*	35	75	2	3	100	5 - 15	10

3 – Deciduous Shrubs					**32**	**75**					
		oak spp.	QUERC	*Quercus*	22	40	0	3	50	1 - 10	5
		skunkbush sumac	RHTR	*Rhus trilobata*	10	35	0	2	50	1 - 3	1
Grass/Grasslike										**1 - 30**	**15**
4 –Warm Season Tall Grasses, Dense					**100**	**220**					
		sand bluestem	ANHA	*Andropogon hallii*	10	30			80	1 - 5	3
		little bluestem	SCSC	*Schizachyrium scoparium*	50	85			100	3 - 15	10
5 –Warm Season Tall Grasses, Open					**0**	**30**					
		cane bluestem	BOBA3	*Bothriochloa barbinodis*	0	15			30	1 - 3	1
		prairie sandreed	CALO	*Calamovilfa longifolia*	0	25			10	1 - 3	1
6 -Mid Grasses					**0**	**40**					
		sideoats grama	BOCU	*Bouteloua curtipendula*	0	40			40	1 - 3	1
7 –Other Mid Grasses					**10**	**200**					
		sandhill muhly	MUPU2	*Muhlenbergia pungens*	10	50			60	1 - 3	1
8 – Other Mid Grasses					**105**	**158**					
		blue grama	BOGR2	*Bouteloua gracilis*	20	40			60	1 - 3	1
9 – Other Mid Grasses					**5**	**20**					
		perennial threeawn	ARIST	*Aristida*	15	45			60	1 - 5	3
		sixweeks grama	BOBA2	*Bouteloua barbata*	0	15			50	0 - 3	1
10 – Other Mid Grasses					**5**	**20**					
		Indian ricegrass	ACHY	*Achnatherum hymenoides*	0	10			60	1 - 3	1
		spike dropseed	SPCO4	*Sporobolus contractus*	0	30			40	1 - 3	1
		sand dropseed	SPCR	*Sporobolus cryptandrus*	0	40			40	1 - 3	1
11 - Forb					0	55				**1 – 5**	**3**
		Forb, annual	2FA		5	10			100	1 - 3	2

Community Pathway 2.1a

Community Pathway 2.1a is characterized by a decrease in shrub and herbaceous production and cover. Shrubs and tall grasses decrease or are eliminated. Juniper canopy cover increases as time lengthens since the last fire or since the last management action intended to reduce juniper canopy cover. Drought years followed by wet years will allow for increase in juniper establishment.

Total Annual Production:

Total Annual Production (lbs/ac)

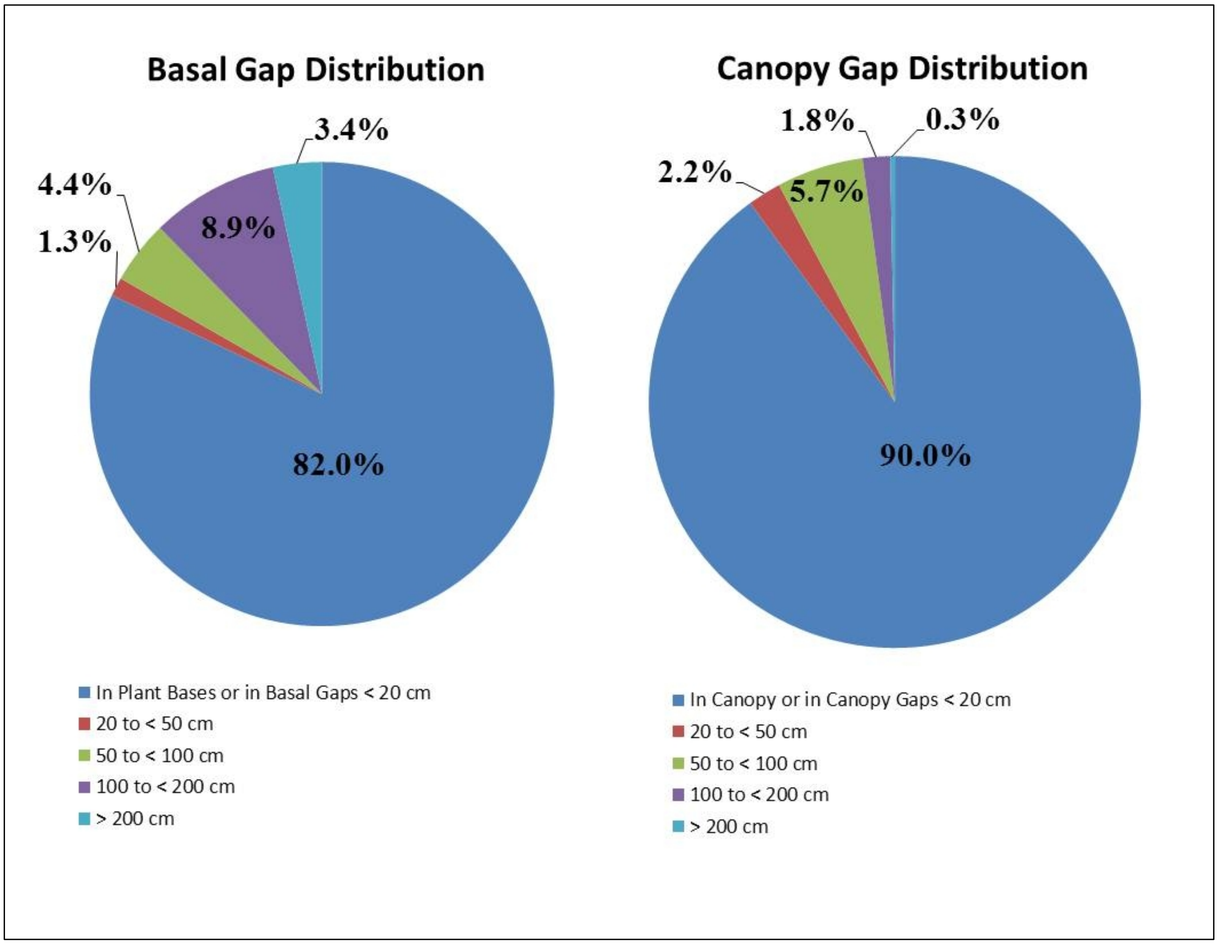
Year

Growth Form	Unfavorable	Normal	Favorable
Grass/Grasslike	330	425	585
Forb	100	300	400
Shrub/Vine	75	155	290
Tree	75	100	125
Total:	580	980	1400

Vertical Structure (percentages for each species are canopy cover)

	Vertical Strata		
Species	Tree (> 5m height)	Shrub (> 0.5m to 5m height)	Herb (< 0.5m height)
One-seed juniper	8-18%	10-17%	2-5%
Pinyon pine	3-5%	1-3%	1-2%
Sand sagebrush		4-12%	1-3%
Oak spp.	1-5%	0-3%	0-2%
Sand bluestem		0-2%	1-3%
Little bluestem		1-4%	2-11%

Horizontal Structure



Ground Surface Cover	Minimum	Maximum
Basal Cover	5%	10%
Litter		
Surface Fragments > 0.25” and <= 3”		
Surface Fragments > 3”		
Bedrock		
Water		
Bare Ground	35%	50%
Biological Soil Crust		

Community Phase 2.2

<u>One-seed juniper and warm season mid grasses</u>

This community phase is provisional because a plant species list and plant abundance data are lacking.

Community Phase 2.2

Community Pathway 2.2a

Management actions that decrease juniper canopy and increase herbaceous and shrub production. These can include prescribed burning, chemical or mechanical brush management, while grazing management is aimed at increasing production.

Transition - T2A

The trigger for this transition is the increase in juniper seedling establishment and/or juniper canopy cover. This is caused by management actions that lead to decreased herbaceous production and decreased organic matter inputs into the soil. This can also be caused by lack of management actions that actively reduce juniper canopy cover. Threshold values for this transaction are: Bare ground > 50% and soil surface stability <3.0.

Restoration Pathway - R2A

Removal of juniper foliar cover to < 15% with minimal soil surface disturbance. Grazing management that increases herbaceous production and favors the establishment and growth of warm season tall and mid grasses is essential for success of this pathway.

Eroded State 3.0

Active wind and water erosion taking place.

Indicators: Closed juniper canopy, soil surface stability indicators < 3.0, active wind and water erosion prevalent.

Feedbacks: Juniper use of all available moisture, elimination of organic matter inputs, decrease in soil surface stability

Community Phase 3.1

One-seed juniper

This community phase is provisional because a plant species list and plant abundance data are lacking.

Community Phase 3.1

Restoration Pathway - R3A

Management and restoration practices planned must decrease juniper foliar cover to < 30% with little or no surface disturbance. Grazing management must plan for increasing herbaceous production and allow for litter accumulation to improve organic matter inputs to stabilize soil surface.

Restoration Pathway - R3B

Management and restoration practices planned must decrease juniper foliar cover to < 15% with little or no surface disturbance. Grazing management must plan for increasing herbaceous production and allow for litter accumulation to improve organic matter inputs to stabilize soil surface.

Ecological Site Interpretations

Animal Community:

Habitat for Wildlife:

This ecological site provides habitat which supports a resident animal community that is characterized by mule deer, bobcat, coyote, blacktailed jackrabbit, desert cottontail, Stephen's woodrat, rock squirrel, pinyon mouse, scrub jay, blacktailed rattlesnake, and red spotted toad. The woody vegetation provides nesting opportunities for many bird species.

Plant Diet Preferences by Animal Kind: Months

Animal Kind: Mature Cow Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
big bluestem	*Andropogon gerardii*	Entire plant												
sand bluestem	*Andropogon hallii*	Entire plant												
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
prairie sandreed	*Calamovilfa longifolia*	Entire plant												
sunflower	*Helianthus annuus*	Entire plant	U	U	U	U	U	D	D	D	U	U	U	U
needleandthread	*Hesperostipa comata*	Entire plant	D	D	P	P	P	D	D	D	D	D	D	D
New Mexico feathergrass	*Hesperostipa neomexicana*	Entire plant	D	D	P	P	P	D	D	D	D	D	D	D
little bluestem	*Schizachyrium scoparium*	Entire plant	D	D	D	P	P	P	P	D	D	D	D	D
Indiangrass (yellow)	*Sorghastrum nutans*	Entire plant												

Animal Kind: Mature Deer

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	U	U	P	P	P	U	U	U	D	D	D	U
Bigelow's sagebrush	*Artemisia bigelovii*	Leaves												
sand sagebrush	*Artemisia filifolia*	Leaves												
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
black grama	*Bouteloua eriopoda*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
wild buckwheat	*Eriogonum*	Entire plant	U	U	D	D	D	D	D	D	U	U	U	U
sunflower	*Helianthus annuus*	Entire plant	U	U	U	U	U	D	D	D	U	U	U	U
oak spp.	*Quercus*	Leaves												
skunkbush sumac	*Rhus trilobata*	Leaves	P	P	P	D	D	D	D	D	D	P	P	P

Animal Kind: Mature Goats

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	U	U	P	P	P	U	U	U	D	D	D	U
Bigelow's sagebrush	*Artemisia bigelovii*	Leaves												
sand sagebrush	*Artemisia filifolia*	Leaves												
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
black grama	*Bouteloua eriopoda*	Entire plant	P	P	P	D	D	D	D	D	D	D	P	P
wild buckwheat	*Eriogonum*	Entire plant	U	U	D	D	D	D	D	D	U	U	U	U
sunflower	*Helianthus annuus*	Entire plant	U	U	U	U	U	D	D	D	U	U	U	U

oak spp.	*Quercus*	Leaves												
skunkbush sumac	*Rhus trilobata*	Leaves	P	P	P	D	D	D	D	D	D	P	P	P

Animal Kind: Mature Sheep

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	P	P	P	P	P	D	D	D	D	D	D	P
Bigelow's sagebrush	*Artemisia bigelovii*	Leaves												
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
black grama	*Bouteloua eriopoda*	Entire plant	P	P	P	D	D	D	D	D	D	D	P	P
wild buckwheat	*Eriogonum*	Entire plant	U	U	D	D	D	D	D	D	U	U	U	U
sunflower	*Helianthus annuus*	Entire plant	U	U	U	U	U	D	D	D	U	U	U	U
oak spp.	*Quercus*	Leaves												
skunkbush sumac	*Rhus trilobata*	Leaves	P	P	P	D	D	D	D	D	D	P	P	P

Legend: P = Preferred; U = Undesirable; D = Desirable

Hydrology Functions:

Soils were originally assigned to hydrologic soil groups based on measured rainfall, runoff, and infiltrometer data (Musgrave 1955). Since the initial work was done to establish these groupings, assignment of soils to hydrologic soil groups has been based on the judgment of soil scientists. Assignments are made based on comparison of the characteristics of unclassified soil profiles with profiles of soils already placed into hydrologic soil groups. Most of the groupings are based on the premise that soils found within a climatic region that are similar in depth to a restrictive layer or water table, transmission rate of water, texture, structure, and degree of swelling when saturated, will have similar runoff responses. Four (4) Hydrologic Soil Groups are recognized (A-D). For specific definitions of each hydrologic soil group see the National Engineering Handbook, Chapter 7, Part 630 Hydrology, or visit: http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=22526.wba The hydrologic soil groups are based on the following factors:

- intake and transmission of water under the conditions of maximum yearly wetness (thoroughly wet)
- soil not frozen
- bare soil surface
- maximum swelling of expansive clays

The slope of the soil surface is not considered when assigning hydrologic soil groups. In its simplest form, hydrologic soil group is determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable (such as a fragipan or duripan) or depth to a water table (if present).

The runoff curve numbers are determined by field investigations using hydrologic cover conditions and hydrologic soil groups.

Hydrologic Interpretations

Soil Series	Hydrologic Group
Flugle	B
Mespun	A
Otero	B

Palma	B
Trail	A

Recreational Uses:

This ecological site offers fair to good potential for hiking, horseback riding, nature observation, photography, camping and picnicking. Hunting for mule deer is fair and trapping for fur-bearing animals is good.

Wood Products:

This ecological site has a potential for wood products that are limited to fuelwood and fencing material. Although this is a limited potential, it may well be very economical. If this ecological site transitions to the juniper state or the eroded state as much as six to ten cords of fuelwood per acre may be harvested. Harvesting should be selective and done by hand cutting.

Other Products:

Grazing:

This ecological site is suitable for grazing by all kinds and classes of livestock during all seasons of the year. Because of the ecological site's potential to produce woody plants, it is very suited to browsing animals. Desirable forage plants are big bluestem, little bluestem, Indiangrass, sideoats grama, black grama, and New Mexico feathergrass,

Supporting Information

Associated Sites:

Site Name	Site ID	Site Narrative
Sand Hills 13-16" P.Z.	045CY099	Sand Hills ecological site will occur adjacent to and in association with Deep Sand Savanna ecological site. Sand Hills may occur as small to large islands scattered throughout the Deep Sand Savanna sites. Deep Sand Savanna sites will have greater production.
Loamy Sand 13-16" P.Z.	045CY092	Loamy Sand ecological sites typically occur at a lower position on the landscape.

Similar Sites:

Site Name	Site ID	Site Narrative
Deep Sand 12-16" P.Z.	045CY900	Deep Sand ecological site is very similar to the Deep Sand Savanna ecological site in plant community composition with production generally greater on Deep Sand Savanna sites. Deep Sand slopes may range from 1 to 8 % with the Deep Sand Savanna sites ranging from 1 to 5% and slightly undulating.

Inventory Data References:

Inventory data is based upon medium-intensity and high-intensity sampling of locations representing the ecological site concept. Other information incorporated into the ESD is from long-term observation of well-managed ranges, range inventory data, scientific studies, and numerous historical accounts of vegetation present at time of settlement. Several years of clipping data and numerous old range inventories have been reviewed (old New Mexico NRCS - Area 8 dated 06/18/75, and old Texas NRCS Area 21 dated 03/21/79). Photos by Joe Bob Quail.

Agency/State Correlation:

This ecological site has been correlated with the following states and/or agencies: Forest Service Southwest Region, BLM New Mexico, New Mexico/Texas NRCS.

Type Locality:

State: NM

County: Lincoln
Socorro
Torrance

Other References:

Data collection for this ecological site was done in conjunction with the progressive soil surveys within the Pecos-Canadian Plains and Valleys 70 Major Land Resource Area of New Mexico. This ecological site has been mapped and correlated with soils in the following soil surveys: Chaves, De Baca, Guadalupe, Lincoln, Sna Miguel, Santa Fe, Torrance.

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Rangeland Health Reference Sheet:

Reference Sheet

Author(s)/participant(s): Identify one or more authors

Contact for lead author: Identify the state and/or MLRA contact

Date: 3/12/2012 **MLRA:** 045C

Ecological Site: Deep Sand Savanna 13-16 P.Z. *Artemisia filifolia*/*Andropogon hallii-Schizachyrium scoparium, (*sand sagebrush/sand bluestem-little bluestem)

045CY999 This *must* be verified based on soils and climate and plant indicator species (see Ecological Site Description). Current plant community cannot be used solely to identify the ecological site.

Composition (indicators 10 and 12) based on: X Annual Production, Foliar Cover, Biomass

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Indicators. For each indicator, describe the potential for the site. Where possible, (1) use numbers, (2) include expected range of values for above- and below-average years for **each** community and natural disturbance regimes within the reference state, when appropriate and (3) cite data. Continue descriptions on separate sheet.

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1. **Number and extent of rills:** None on slopes less than 5%, and increasing only slightly beyond that range. After wildfires, extended drought, high-intensity summer thunderstorms, or combinations of these disturbances, rills may double in number. Healing should be rapid (within one year) after such an event.

2. **Presence of water flow patterns:** Water flow patterns may be few, but where present flow patterns are short and not connected. Flow patterns should only be present following intense storm events. Numerous obstructions can alter flow paths. Flow pattern length and numbers may double after wildfires, extended drought or combinations of these disturbances.

3. **Number and height of erosional pedestals or terracettes:** No pedestals or terracettes caused by water should occur on this site at reference condition. Wind caused pedestals are rare and only would be on the site after wildfires, extended drought or combinations of these disturbances. Slightly more pedestals would be expected where steeper sites deliver additional water from off-site after high-intensity summer thunderstorms. These would show signs of healing within 1 year after severe storm event.

4. **Bare ground from Ecological Site Description or other studies (rock, litter, standing dead, lichen, moss, plant canopy are not bare ground):** Expect 35 – 40% bare ground (less than 2

feet in diameter) in the intervals between natural disturbance events. Bare ground would be expected to increase to 60% the first year following wildfire and then decrease to pre fire levels within 2 to 5 years.

5. **Number of gullies and erosion associated with gullies:** Drainages where present are stabilized with native vegetation and should show no signs of active erosion.

6. **Extent of wind scoured, blowouts and/or depositional areas:** Wind erosion is minimal to nonexistent. Significant wind erosion would only be present following wildfire, extended drought or combinations of these disturbances. Wind scour, blowouts and/or depositional areas should be rare and only associated with disturbances (e.g. small mammal burrows, resting areas).

7. **Amount of litter movement (describe size and distance expected to travel):** Litter should be evenly distributed across site. Litter movement consists primarily of redistribution of fine litter (herbaceous plant material) in flow patterns for distances of not more than 1 meter. Litter movement over 5 feet may occur after wildfires, extended drought or combinations of these disturbances. Amounts and size of material moved may increase after high-intensity summer thunderstorms.

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** Stability class rating at 3.5 to 4.5 in interspaces at soil surface. Under plant shrub or grass plant canopy values will be 4 to 5. Values should be at the high range for fine textured soils. Soils with a surface layer of very coarse sand to fine gravel have stability values that range from 3.0 – 4.0.

9. **Soil surface structure and SOM content (include type and strength of structure, and A-horizon color and thickness):** The average Soil Organic Matter (SOM) 1 to 3%. Structure of the soils surface horizon is weak granular. Soil surface is stable and evidence of movement is very slight.

10. **Effect on plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Grasses should be uniformly distributed and runoff from sites is generally low. Surface runoff is slow and available water holding capacity is low. Diverse grass, forb, shrub functional/structural groups and diverse root structure/patterns reduces raindrop impact slows overland flow providing increased time for infiltration to occur. Extended drought reduces short and mid bunchgrasses causing decreased infiltration and increased runoff. This condition will self-correct in 2 to 5 years following disturbance unless a threshold has been crossed.

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):** No compaction layer should be present. There are no soil profile features in the top 9 inches of the soil profile that would be mistaken for a management induced soil compaction layer.

12. **Functional/Structural Groups (list in order of descending dominance by above-ground weight using symbols: >>, >, = to indicate much greater than, greater than, and equal to) with dominants and sub-dominants and "others" on separate lines:**
Dominants: Warm season tall bunchgrasses >> Warm season mid bunchgrass = evergreen shrub **Subdominants**: Warm season mid bunchgrasses > **Minor component**: evergreen trees > forbs = deciduous shrubs.

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13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** Plant mortality is typically minimal. Expect short/mid bunchgrasses mortality/decadence during or following drought. Most of the perennial plants in this community are long lived. Extended droughts would tend to cause relatively high mortality in short lived species such as bristlegrass. Shrub mortality would be limited to severe droughts. The combination of wildfires and extended droughts would cause even more mortality for several years following the fire than either disturbance functioning by itself would cause.

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14. **Average percent litter cover (%) and depth (inches):** The reference community phase averages 10% - 20% litter cover evenly distributed with a litter depth of 1/2 inch. After wildfires, extended drought, or combinations of these disturbances, litter cover and depth decreases to none immediately after the disturbance (e.g., fire) and dependent on climate and plant production increases to post-disturbance levels in one to five growing seasons.

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15. **Expected annual production (this is TOTAL above-ground production, not just forage production):** Unfavorable Production 635 lbs/ac; Normal Production 1015 lbs/ac; Favorable Production 1700 lbs/ac.

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16. **Potential invasive (including noxious) species (native and non-native). List Species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicator, we are describing what is NOT expected in the reference state for the ecological site:** Juniper, pinyon and oak are the greatest threat to dominate this site in the long term after disturbance (primarily following wildfire exclusion but also includes high human or herbivore impacts and extended drought). Pinyon and juniper and oak are most likely to retain dominance if allowed to alter natural fire regime.

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17. **Perennial plant reproductive capability:** All plant species should be capable of reproduction depending on water regime. All plants should be vigorous, healthy and reproductive depending on disturbance (e.g., drought). Plants should have numerous seed heads, vegetative tillers etc. The only limitations are weather-related effects, wildfire, and natural disease that may temporarily reduce reproductive capability.

Reference Sheet Approval:

Approval	Date
State Range Specialist	7/15/2012

Site Description Approval:

Authorship:

Author(s)	Date
____________________	24 July 2012

Site Approval:

Name	Date	Agency Affiliation
____________________	24 July 2012	Forest Service
____________________	24 July 2012	Natural Resources Conservation Service
____________________	24 July 2012	Bureau of Land Management