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Existing Vegetation Classification and Mapping Technical Guide Version 1.0

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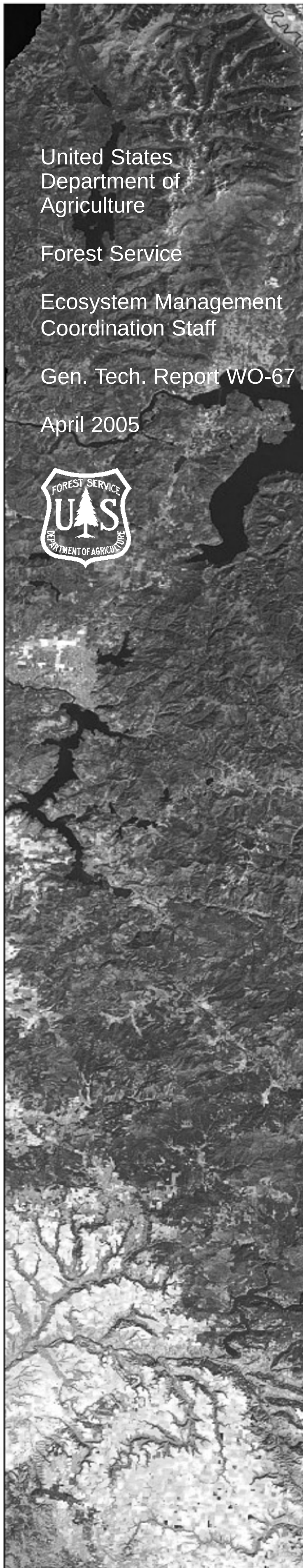

USDA

Existing Vegetation Classification and Mapping Technical Guide Version 1.0

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Table of Contents

Section 1. Existing Vegetation Classification and Mapping Framework

Section 2. Existing Vegetation Classification Protocol

Section 3. Existing Vegetation Mapping Protocol

List of Figures

List of Tables

Section 1. Existing Vegetation Classification and Mapping Framework

1.1 Introduction

The U.S. Department of Agriculture (USDA) Forest Service manages 156 national forests and 20 national grasslands. These 191 million acres represent a variety of landscapes and ecosystems. Classification and mapping of vegetation are fundamental to the stewardship, conservation, and appropriate use of these resources.

Existing vegetation is the plant cover, or floristic composition and vegetation structure, occurring at a given location at the current time. Existing vegetation is the primary natural resource at the heart of almost everything the Forest Service does and is the resource on which the agency spends the most money for inventories and assessments. Existing vegetation, however, has historically lacked consistent standards for classification and mapping. As a result, vegetation descriptions and maps have not been sharable across unit boundaries.

When classification and mapping of existing vegetation are undertaken, this protocol establishes Forest Service standards and procedures for those activities. This technical guide is authorized by the Forest Service Manual (FSM) 1940 and has been developed according to direction in the Forest Service Handbook (FSH) 1909.

Read section 1 of this technical guide to provide context before reading sections 2 or 3.

1.1.1 Organization of Technical Guide

Section 1 of this technical guide describes the agency business needs that require existing vegetation information and the strategy and concepts of the protocol. Section 1 also provides the overall context and strategy for sections 2 and 3. Section 2 addresses floristic classification of existing vegetation and the relationship of floristic vegetation types to the Federal Geographic Data Committee (FGDC) 1997 physiognomic classification standard. Section 3 describes hierarchical mapping of existing vegetation at multiple levels. For definitions of terms used in this guide, see the Glossary.

This guide does not address quantitative inventory or monitoring of existing vegetation. It also does not address classification or mapping of potential natural vegetation (PNV). PNV classification and mapping protocols will be addressed in other technical guides.

1.1.2 Vegetation Classification Standards

The FGDC National Vegetation Classification Standards (NVCS) established a hierarchical existing vegetation classification with nine levels (FGDC 1997). The seven upper levels are primarily based on physiognomy. The two lowest levels, alliance and association, are based on floristic attributes. The Forest Service vegetation classification protocol contained in this technical guide is compatible with the 1997 FGDC standards for physiognomic classification and is also as compatible as possible with the forthcoming FGDC floristic classification standards, which were drafted by the Ecological Society of America (ESA) Panel on Vegetation Classification (Jennings et al. 2004).

Section 1.3.1 defines associations and alliances. Sections 2.2.4 and 2.2.5 describe classification criteria for associations and alliances, respectively.

1.1.3 Vegetation Mapping Standards

No FGDC standard currently exists for vegetation mapping. This protocol provides standards for developing vegetation geospatial databases and associated maps at four hierarchical levels that support the various business functions of the Forest Service.

The four hierarchical map levels identified represent a gradient of thematic and spatial detail. The coarsest level is designed to efficiently meet broad analysis needs; the finest level is designed to provide more geographically precise and detailed vegetation information. The defined map levels will help determine the information generally necessary at various functional levels of the Forest Service and set expectations for data content, consistency, and accuracy. Section 1.3.2.2 describes each map level and summarizes general characteristics, related functional areas, and supported business requirements. Although local business needs may necessitate detailed mapping of nonvegetated areas, this protocol is not intended to provide comprehensive guidance on performing this task.

1.2 Background and Objectives

1.2.1 Existing Vegetation Information Uses

Ecosystem assessment and land management planning at national and regional extents require consistent standards for classification and mapping of existing vegetation. An existing standardized vegetation classification system provides a consistent framework for cataloguing, describing, and communicating information about existing plant communities. The Forest Service does not have the resources to develop a separate classification or map for every issue land managers face. Therefore, the Forest Service must describe and map fundamental units of vegetation that can be interpreted to address numerous inquiries. The net value of using standardized existing vegetation classifications and maps is improved efficiency, accuracy, and defensibility of resource planning, implementation, and activity monitoring. Hierarchical classification and multilevel mapping of existing vegetation provide the appropriate level of detail for each issue.

Existing vegetation classifications and maps provide much of the information needed to perform these tasks:

- Describe the variety of vegetation communities occupying an area.
- Characterize the effect of disturbances or management on species including threatened and endangered species and community distributions.
- Identify realistic objectives and related management opportunities.
- Document successional relationships and communities within PNV or ecological types.
- Streamline monitoring design and facilitate extrapolation of monitoring interpretations.
- Assess resource conditions, determine capability and suitability, and evaluate forest and rangeland health.
- Assess risks for invasive species, fire, insects, and disease.
- Develop and describe fire and fuels related analysis products (e.g., Fire Regime Condition Classes).
- Conduct project planning and watershed analyses, and predict activity outcomes at the project or Land and Resource Management Planning scales.
- More effectively communicate with Forest Service partners, stakeholders, and neighbors.

Implementation of Forest Service policies and regulations requires knowledge of current vegetation composition, structure, and patterns that are provided through existing vegetation classifications and maps. Some examples are listed below.

- Sustainability: Planning Rules (36 CFR 219)—Evaluating and describing current status of ecosystems and species diversity and viability.
- Suitability and capability: National Forest Management Act of 1976 (NFMA) (16 U.S.C. 1604[g])[3][b])—Evaluating and describing diversity of plant and animal communities based on the suitability and capability of the land area.
- Noxious weeds and undesirable plants inventory: FSM 2080.
- Rangeland management: FSM 2210, FSH 2209.13, chapter 90—Existing vegetation composition and structure is used in conjunction with PNV to determine ecological status, describe diversity of habitats, and describe desired future conditions.
- Threatened/endangered/sensitive species: FSM 2670—Description of current habitats for plant and animal species based on current vegetation composition, structure, and patterns.
- Benchmark analysis: FSM 1922.12—Benchmark analysis provides baseline data to formulate and analyze alternatives. Estimates of forests' physical, biological, and technical capabilities to produce goods and services require existing vegetation information. Analysis is conducted according to 36 CFR 219.12 (e)(1).

1.2.2 Relationship of Existing and Potential Natural Vegetation

Existing vegetation information alone cannot answer questions about successional relationships, historical range of variation, productivity, habitat characteristics, and responses to management actions. These questions can be addressed only by combining information about PNV, existing vegetation, and stand history. An existing vegetation classification inherently lacks information on the above topics because it describes the vegetation present at only a single point in time. The current plant community reflects the history of a site. This history often includes geologic events, geomorphic processes, climatic changes, migrations of plants and animals in and out of the area, natural disturbances, chance weather extremes, and numerous human activities. Because of these factors, existing vegetation seldom represents the potential under current environmental conditions.

PNV is "the vegetation…that would become established if all successional sequences were completed without interference by man under the present climatic and edaphic conditions." (Tüxen 1956, as cited in Mueller-Dombois and Ellenberg 1974). PNV classifications are based on existing vegetation, successional relationships, and environmental factors (e.g., climate, geology, soil) considered together. This approach requires understanding of species autecology and successional dynamics of plant communities. PNV classification uses information on structure and composition similar to that needed for existing vegetation classification, but with greater emphasis on composition and successional relationships.

Existing vegetation and PNV classifications and maps are both important, but address different questions. They are best viewed as complementary and synergistic, rather than mutually exclusive. Existing and PNV classifications can be done together as shown by Mueggler's (1988) classification of aspen forests in the Intermountain Region. Many people request existing vegetation information, but expect it to include environmental and successional relationships without fully understanding the implications. In reality, land managers need information about both existing and potential natural vegetation to assess resource conditions and evaluate management options.

1.2.3 Vegetation Classification Business Requirements

Classification is the process of grouping of similar entities together into named types or classes based on shared characteristics. Vegetation classification consists of grouping a potentially infinite number of stands or plots into relatively few vegetation types. A **vegetation type** is a named category of plant community or vegetation defined on the basis of shared floristic and/or physiognomic characteristics that distinguish it from other kinds of plant communities or vegetation. Definition of vegetation types makes meaningful generalizations about each type possible, thus reducing complexity and furthering communication while maintaining meaningful differences among types.

To meet the business requirements of the Forest Service, a floristic classification of existing vegetation must have the following qualities:

- The classification system must eventually encompass all plant communities on National Forest System (NFS) and adjoining lands.
- The classification system must be based on inherent vegetation attributes such as composition, dominance, physiognomy, and structure. Solely abiotic features cannot distinguish types.
- The classification system must be hierarchical with varying levels of detail available to address management issues and guide vegetation mapping at multiple levels.
- The classification system must employ a simple dichotomous key with unambiguous criteria so that all users can consistently identify the vegetation types.
- The classification categories must be based on collection and analysis of plot data to ensure that they are precisely defined and mutually exclusive.
- The classification categories must be clearly defined, exhaustive, and mutually exclusive to facilitate communication and sharing of information.

The above requirements constitute guiding principles for developing floristic vegetation types for use on NFS lands. These requirements are consistent with the FGDC's guiding principles for vegetation classification (FGDC 1997) listed in appendix 1A.

1.2.4 Vegetation Mapping Business Requirements

Vegetation mapping is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. Maps are the most convenient and universally understood means to graphically represent the spatial arrangement and relationships among features on the earth's surface (Mosby 1980). Accurate and up-to-date maps of existing vegetation are commonly used for inventorying, monitoring, and managing numerous resources on national forests.

Consistent mapping of vegetation types requires that a scientific classification of existing vegetation be developed first because classification defines the entities to be mapped. Any map based on vaguely defined types is inconsistent, hard to validate, and difficult to compare with other vegetation maps. The knowledge gained and organized through the classification process helps determine what spatial vegetation information is needed to address land management issues. (See tables 1.3 and 1.4 for more information on the relationship between classification and mapping.) Mapping may reveal gaps in a classification that require development of new vegetation types or refinement of existing types through additional data collection and analysis.

The most important part of designing and implementing a mapping project is establishing the mapping objectives in the context of the land management issues to be addressed. Selection of the level of vegetation type (e.g., association) and the structural characteristics (e.g., canopy cover) used to define the mapped categories are a direct function of vegetation mapping objectives. To meet the business requirements of the Forest Service, maps of existing vegetation must have the following qualities:

- The vegetation characteristics used as map unit design criteria and their thematic resolution must be appropriate for depiction at the selected map level, and the selected level must be appropriate for the attributes.
- The vegetation types or classes used in designing map units should be based on a classification of existing vegetation, as described in section 1.2.3.
- The floristic composition of map units must be described in terms of clearly defined existing vegetation types.
- At any given mapping level, the floristic resolution should be based on the level of the existing vegetation hierarchy needed to address management issues.
- To the degree possible, finer map units should be capable of aggregation into broader map units based on the vegetation classification hierarchy.
- The mapping system must be hierarchical with varying levels of detail available to address management issues at multiple scales over extensive areas.
- The map units must be mutually exclusive and exhaustive.
- The mapping process must be repeatable and consistent.
- The map product must be of suitable accuracy for its intended uses.

The above requirements constitute guiding principles for mapping existing vegetation on NFS lands.

1.2.5 Protocol Objectives

The objective of this technical guide is to provide direction for developing existing vegetation classification and map products that are consistent and continuous across the landscape and responsive to the business needs of the Forest Service. The Forest Service is directed to manage vegetation for a variety of social and economic purposes while maintaining the integrity of ecosystem components and processes at national, regional, and local scales. This direction requires standardized vegetation maps at multiple scales across all NFS lands. The most effective way to standardize vegetation mapping is to base map units at all scales on a standardized hierarchical vegetation classification. Doing so will enhance the ability of the Forest Service to aggregate maps across large geographic areas for spatial analysis of national, regional, or multiforest issues. Standardized vegetation classification and mapping will also facilitate developing and populating corporate databases.

1.3 Protocol Overview

The existing vegetation protocol consists of two distinct but related processes: classification and mapping. Vegetation classification defines and describes vegetation types based on physiognomy and floristic composition. Vegetation mapping spatially depicts the distribution and pattern of vegetation types and/or structural characteristics. Because of the limitations of mapping technology, a one-to-one relationship rarely exists between vegetation types and vegetation map units. Mapping entails trade-offs among resolution, accuracy (both thematic and spatial), and costs. The goal is constrained optimization, not perfection.

1.3.1 Vegetation Classification Concepts and Definitions

Classification is the process of grouping of similar entities together into named types or classes based on selected shared characteristics. Classification is a fundamental activity of science and an integral part of human thought and communication (Mill 1872, Buol et al. 1973, Gauch 1982). Classification is how we assimilate and organize information to produce knowledge. "When we have a definition for anything, when we really have studied its nature to the point where we can say that it is *this* and not *that*, we have achieved knowledge" (Gerstner 1980, as cited in Boice 1998). Classification is a form of inductive reasoning that "establishes general truths from a myriad of individual instances" (Trewartha 1968). Even if classification categories are conceptual or abstract rather than absolute facts, they serve to formulate general truths based on numerous observations.

A **class** is "a group of individuals or other units similar in selected properties and distinguished from all other classes of the same population by differences in these properties" (Buol et al. 1973). The properties selected as the basis for grouping individuals into classes are called **differentiating characteristics** (Buol et al. 1973). Two fundamental approaches to selecting differentiating characteristics exist; each approach produces a different kind of class (Mill 1872) and a different kind of classification (Buol et al. 1973, Pfister and Arno 1980, USDA Soil Survey Division 1999).

A **natural or scientific classification** is a classification in which the differentiating criteria are selected to "bring out relationships of the most important properties of the population being classified, without reference to any single specified and applied objective" (Buol et al. 1973). In developing a scientific classification, "all the attributes of a population are considered and those which have the greatest number of covariant or associated characteristics are selected as the ones to define and separate the various classes" (Buol et al. 1973). A set of classes developed through scientific classification is referred to as a **taxonomy** (USDA Soil Survey Division 1999). A **taxonomic unit** (or **taxon**) is a class developed through the scientific classification process, or a class that is part of a taxonomy.

A **technical classification** (or **technical grouping**) is a classification in which the differentiating characteristics are selected "for a specific, applied, practical purpose" (Buol et al. 1973, Pfister and Arno 1980). The resulting classes are called **technical groups**. In contrast to natural classifications, technical classifications are based on one or a few properties to meet a specific interpretive need instead of considering all the properties of the population.

This technical guide provides direction for developing floristic taxonomic units and technical groups based on vegetation structure. Both types of classes are used for a variety of analysis applications that support the business needs of the Forest Service.

1.3.1.1 Floristic Taxonomic Units

Vegetation classification consists of grouping a potentially infinite number of stands or plots into relatively few vegetation types. A **vegetation type** is a named class of plant community or vegetation defined on the basis of selected shared floristic and/or physiognomic characteristics that distinguish it from other classes of plant communities or vegetation. Vegetation types are taxonomic units developed through the scientific classification process described above. Scientific classification makes meaningful generalizations about each vegetation type possible, thus reducing complexity and furthering communication while maintaining meaningful differences among types (Pfister and Arno 1980). Members of a vegetation type (e.g., plots or stands) should be more similar to each other (in aggregate) than they are to members of other vegetation types. Three different levels of vegetation taxonomy are widely used in scientific vegetation classification: association, alliance, and dominance type. These levels are defined below.

An **association** (or **plant association**) is "a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy" (Jennings et al. 2004). The FGDC standard specifies that the term association "refers to existing vegetation, not a potential vegetation type." In other words, association does not necessarily refer to a climax plant community. This usage predominates in vegetation ecology (Krebs 1972, Mueller-Dombois and Ellenberg 1974, Barbour et al. 1980, Collinson 1988). In contrast, the Forest Service (USDA Forest Service 1991) and Natural Resources Conservation Service (NRCS) (USDA NRCS 1997) use the term "plant association" to refer to a climax or potential natural plant community, following Daubenmire (1968). The FGDC standard mandates that the terms "association" or "plant association" not be used to imply a climax plant community. Classifying PNV at the association level of vegetation taxonomy, however, is acceptable.

An **alliance** is "a vegetation classification unit containing one or more associations and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation" (Jennings et al. 2004). Because an alliance is a grouping of associations, plot data must be collected and analyzed and associations classified before alliances can be defined. Classification of alliances, therefore, requires the same level of data collection as classification of associations.

A **dominance type** is "a recurring plant community defined by the dominance of one or more species which are usually the most important ones in the uppermost or dominant layer of the community, but sometimes of a lower layer of higher coverage" (Gabriel and Talbot 1984 as cited in Jennings et al. 2004). Dominance types have been widely used in the development of map units where remote sensing imagery is the primary basis for map feature delineation. "Determining dominance is relatively easy, requiring only a modest floristic knowledge. However, because dominant species often have a geographically and ecologically broad range, there can be substantial floristic and ecologic variation within any one dominance type" (Jennings et al. 2004). Dominance types can be developed more rapidly than associations or alliances, but typically provide less information for land managers.

1.3.1.2 Structural Technical Groups

Structural classes are technical groups developed to provide the basis for analysis applications and specific management interpretations. This protocol addresses the use of structural classes to describe and map three attributes of vegetation structure: vegetated cover, tree canopy closure, and overstory tree diameter. These attributes are defined below. The technical groups or classes used to describe these attributes are presented in tables 3.5, 3.6, and 3.7, respectively.

Vegetated cover is the relative percentage of nonoverlapping vegetation cover, a bird's eye view as seen from above in a delineated area. Vegetated cover in a delineated area will not exceed 100 percent.

Tree canopy closure is the total nonoverlapping tree canopy in a delineated area as seen from above. The sum of all tree canopy cover within a delineated area will not exceed 100 percent. Tree canopy closure below 10 percent is considered a nontree type.

Overstory tree diameter is the mean diameter at breast height (4.5 feet, or 1.37 meters, above the ground) for the trees forming the upper or uppermost canopy layer (Helms 1998). Tree size class is determined by calculating the diameter (usually at breast height) of the tree of average basal area (Quadratic Mean Diameter [QMD]) of the top story trees that contribute to canopy closure, i.e., tree cover as seen from a bird's eye view from above. Top story trees are those trees that receive light from above and at least one side; these are the open grown, dominant, and codominant trees.

1.3.2 Vegetation Mapping Concepts and Definitions

Two fundamental mapping concepts are presented in the following sections and form the basis for the map product standards defined in section 3. These fundamental concepts are the relationship between vegetation classification and mapping and mapping at multiple levels to address differing information needs.

1.3.2.1 Relation of Vegetation Classification to Mapping

Consistent mapping of vegetation types requires that a vegetation classification be developed beforehand. **Vegetation mapping** is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. Patterns of vegetation types are best recognized after the types have been defined and described. Maps based on vaguely defined types are inconsistent, hard to validate, and difficult to compare with other vegetation maps.

A **vegetation map unit** is a collection of areas defined and named the same in terms of their component taxonomic units and/or technical groups (adapted from USDA Soil Survey Division Staff 1993). Vegetation map units can be based on physiognomic or floristic taxonomic units and structural technical groups, or combinations of these units or groups. These taxonomic units and technical groups provide the basis for vegetation maps that are consistent with the mapping objectives, appropriate for the map level being produced, and within the limitations of mapping technology. Selecting the vegetation types and structural classes to be depicted by the map is accomplished through the map unit design process.

Map units are designed to provide information and interpretations to support resource management decisions and activities. The **map unit design** process establishes the criteria used to aggregate or differentiate vegetation taxonomic units and technical groups to define map units. A map unit comprises one or more taxonomic units or technical groups. The criteria used to aggregate or differentiate within physiognomic types, floristic types, or structural classes to form map units depends on the purpose of, and the resources devoted to, any particular mapping project (Jennings et al. 2004). For example, map units designed to provide information on existing forest structure to characterize wildlife habitat or fuel condition would be based on a combination of tree canopy cover and overstory tree diameter technical groups. The map unit design process is more complex for vegetation types than for structural characteristics. The mapping standards for vegetation cover, tree canopy closure, and tree diameter described in section 3 represent general-purpose map unit designs for each structural characteristic at all map levels; although local information needs may occasionally require exceeding the standards.

Map units are depicted on maps within map features. **Map features** are individual areas or delineations that are nonoverlapping and geographically unique (e.g., polygon delineations or region delineations). Typically, one map unit is repeated across the landscape in many individual map feature delineations. The map feature delineation process should be based on the map units identified in the map unit design process. A more detailed discussion and examples of the relationship among taxonomic units/technical groups, map units, and map features are included in section 3.2.2.

1.3.2.2 Map Levels

Maps are developed and used at multiple resolutions and are best represented by a hierarchical series of map products. In this technical guide, these products are described as **map levels**. Four hierarchical map levels are identified that represent a gradient of thematic and spatial resolution. Table 1.1 illustrates the business requirements and applications, and table 1.2 presents characteristics of these map levels. The four map levels are as follows:

- **National.** National, the coarsest level in the map hierarchy, is intended to store and depict data at a nationwide or global extent. Map products at this level typically will have broad map classes and coarse spatial representation. Products at this level may be developed programmatically or aggregated from existing lower level products where feasible.
- **Broad.** Broad-level products are intended to support State, multistate, or regional information needs. Products at this level may be developed programmatically or aggregated from existing products.
- **Mid.** Mid-level products are intended to support forest and multiforest information needs including forest planning, forest/region resource assessment and monitoring, and fire/fuels modeling. Products at this level provide a synoptic and consistent view of existing vegetation across all ownerships within the map extent. They typically are developed programmatically from remotely sensed data and field data. Standard base-level maps, where they exist, should be considered for integration into mid-level map products.
- **Base.** Base-level products support local forest and district information needs and represent the highest thematic detail and spatial accuracy. Products at this level are needed for most project planning and implementation. Base-level information is the least likely of all levels to be spatially extensive due to the cost of development; however, it offers the most flexibility for upward integration within the map hierarchy. Products at this level are typically developed from large-scale, remotely sensed data and field data.

These four map levels will help to determine the information necessary for various organizational levels of the Forest Service and set the expectations for data content, consistency, accuracy, and development costs. The national level is intended to efficiently meet the broadest analysis needs; the base level is intended to provide geographically precise and detailed vegetation information.

Table 1.1. *Existing vegetation map levels, business requirements, and applications.*

Map Level	Forest Service program areas	Forest Service business requirements	Ecological unit hierarchy	Ecological analysis scale (range) ECOMAP 1997	Potential natural vegetation classification	Existing vegetation classification	Existing vegetation map unit design	Existing vegetation map product examples	Data sources/ Sampling protocols	Map Extent
1: National	Forest Inventory and Analysis (FIA), Resource Planning Act (RPA), International Forestry, Fire, Forest Health Monitoring (FHM)	National Strategic Inventory (FIA Phase I), Forest Cover, Forest and Rangeland Health/Sustainability	Division, province	1:30,000,000 to 1:5,000,000; gen poly size 10,000–100,000 sq. mi	Class and subclass	NVCS class and subclass, Major Land Renewable Resource Areas (MLRA)	National Land Cover Database, NVCS class and subclass	National Land Cover Database	Forest health Monitoring (FHM), FIA, National Research Institute (NRI)	National (millions of sq. mi)
2: Broad	RPA, FIA, Fire, FHM	Bioregional assessments, conservation strategies (region/subregion)	Section, subsection	1:7,500,000 to 1:250,000; gen poly size 10–1,000 sq. mi	Series	Dominance types, alliances (e.g., Society for Range Management [SRM)], Society of American Foresters [SAF] cover types)	Dominance type groups, alliance groups	SAF forest type map, Gap Analysis Program (GAP)	FHM, FIA, NRI	State or multistate or (20+ million acres)
3: Mid	Forest Planning and Monitoring, Fire, FIA	Forest/multiforest planning/monitoring, 4th/5th Hydrological Unit Code (HUC) Watershed Assessments, National Fire Plan Implementation (Forest Level) Forest and Rangeland Health Assessments, Terrestrial and Aquatic Habitat Assessments	Landtype association	1:250,000 to 1:60,000; gen poly size 1,000–10,000 acres	Series, climax plant association (sensu Daubenmire)	Dominance types, alliances, (associations optional where needed)	Dominance types, alliances, alliance groups and/or complexes, canopy cover groups, size/height groups (e.g., Vegetation Stand Structure [VSS])	R5 Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) California Wildlife Habitat Relationships (CWHR), R1 Satellite Image Land Classification (SILC) 1 and 3, GAP, National Wetlands Inventory (NWI)	FIA intensified plots, compartment exams, field training data plots	Forest or multiforest (50,000+ acres)
4: Base	Project Planning, Forest Plan Implementation, Land Treatments	Forest Plan Implementation Project Planning and Land Treatments, e.g.: • Fuel Treatments • Grazing Mgt. • Timber Mgt. • Habitat Mgt. Range Analysis Stand Exams Effectiveness Monitoring	Landtype, landtype phase	1:60,000 to 1:24,000; gen poly size < 1,000 acres	Climax plant associations and phases (sensu Daubenmire)	Alliances, associations	Alliances, association, association complexes, canopy cover classes, size/height classes, vertical and horizontal structure	Resource photo interpretation maps, stand maps (e.g., R8 Continuous Inventory of Stand Conditions [CISC], R2 Common Vegetation Unit [CVU],range allotment analysis maps	Stand exams, rangeland protocols, Terrestrial Ecological Unit Inventory (TEUI) integrated plots	5th/6th HUC Watershed or Project Area (< 50,000 acres)

Table 1.2. *Existing vegetation map levels and characteristics.*

Map Level	Typical map extent	Minimum mapping feature area (acres)	Suggested update frequency	Required physiognomic map attributes	Number of required total tree canopy closure classes	Number of required overstory tree diameter classes	Required floristic map attributes
National	National (millions of square miles)	500	5–10 years	Division, order, and class	0	None	None
Broad	State or multistate (20+ million acres)	20	5–10 years	Division, order, class, and subclass	3	None	Cover types and cover type groups
Mid	Forest or multiforest (50,000+ acres)	5	1–5 years	Division, order, class, and subclass	4	5	Cover types and regional dominance types
Base	5th/6th HUC watershed or project area (<50,000 acres)	5	1–5 years	Division, order, class, and subclass	10	7	Cover types, regional dominance types and alliances

The four map levels differ in thematic and spatial resolution. **Thematic resolution** is the level of categorical detail present in a given map unit; **spatial resolution** is the measure of sharpness or fineness in spatial detail. To the extent possible, a nested thematic and spatial relationship should exist between map levels for geographically coincident map products. Although a seamless data hierarchy currently may not be feasible across the entire agency, the objective is that maps developed across administrative units for similar purposes will be comparable and reliable for conjunctive analysis. Vegetation maps used by regional and national functions are expected to depict information consistent with local maps that follow this protocol. In practice, coarse data will sometimes be used locally and specific information used nationally, which emphasizes the need for data consistency and compatibility.

These four map levels are not intended to be the sole definitions of the vegetation map products required to meet the business needs of the Forest Service. The standards defined in section 3 for each map level are the minimal requirements to achieve each level and can be exceeded spatially and/or thematically. Informational requirements may dictate the need for a vegetation map that contains elements of two map levels (e.g., mid and base) or include information not identified in the standards section of this protocol. In other words, view these map levels as minimal standards, not constraints.

1.3.2.3 Relation of Map Levels to Map Scale

To differentiate the concepts of map level and map scale, a brief explanation of map scale is necessary. Based on historical use in a vegetation-mapping context, it has become easy to incorrectly use scale when referring to the detail depicted on a map. The term **scale** actually describes the proportion that defines the relationship of a map, image, or photograph to that which it represents, such as distance on the ground (Robinson et al. 1978). For example, on Forest Service primary base maps, a distance of 1 foot on the map represents 24,000 feet on the ground and is represented by the scale proportion of 1:24,000. Based on this definition, the term is only applicable when the representation is fixed, such as on a printed map or image. Scale is not valid for geospatial datasets that have no fixed representation. Because geospatial datasets are the standard map products defined in section 3, the term "map level" replaces scale when identifying vegetation datasets that can be effectively displayed at multiple scales but contain specific thematic and spatial resolution.

1.4 Roles and Responsibilities

Forest Service responsibilities for resource inventory and monitoring are outlined in FSM 1940.04. Specific roles and responsibilities for classification and mapping of existing vegetation are described below.

National

- Provide direction for classification and mapping of existing vegetation that meets the business needs of multiple disciplines.
- Develop classification and mapping standards for existing vegetation to facilitate compatibility of vegetation types and maps across regional lines.
- Ensure that corporate database systems support the existing vegetation business needs.
- Coordinate with the Forest Service Inventory and Monitoring (I&M) Framework and interagency classification and mapping activities.
- Support and evaluate regional implementation of existing vegetation classification and mapping to ensure compliance with national standards.
- Ensure that existing vegetation classification is consistent with FGDC-adopted standards.
- Provide direction on interim classification and mapping of vegetation before the FGDC floristic classification standard is completed.
- Ensure that regions are collecting data using approved NFS codes.
- Correlate vegetation types among regions, and ensure compatibility of descriptions across regional boundaries.
- Maintain a national existing vegetation classification Web site to facilitate correlation.

Regional

- Implement existing vegetation classification and mapping programs consistent with national standards and protocols, and develop regional supplements as needed.

- Develop existing vegetation classifications and maps to support resource assessments, forest plan revisions, resource monitoring, and other business requirements as scheduled in the regional strategic inventory plan.
- Coordinate with external cooperators and neighboring Regions to correlate vegetation types.
- Conduct field reviews to ensure consistency and quality during accomplishment of performance measures.
- Correlate vegetation types in the Region, maintain a list of types in the Natural Resource Information System (NRIS) database, and track the status of vegetation classification and mapping in the region.

Forest

- Implement the existing vegetation classification and mapping programs using national standards and protocols and regional supplements.
- Implement classification and mapping projects on schedule and within budget.
- Collect appropriate field data to classify existing vegetation according to FGDC standards.
- Provide quality control of data collection for classification and mapping projects; train field crews to collect data in a manner consistent with established national protocols.
- Conduct accuracy assessments of existing vegetation maps.
- Ensure that vegetation classification and mapping information is used appropriately in forest planning, assessments, and project implementation.
- Coordinate with local cooperators and neighboring Forest Service administrative units to correlate vegetation types and maps.
- Correlate vegetation types and track the status of vegetation classification and mapping in the forest.
- Publish final reports for vegetation classification and mapping projects.
- Enter and store all field-collected data in the NRIS database.

1.5 Relationship to Other Federal Programs and Standards

This section describes the relationship of the Forest Service existing vegetation protocol to the FGDC NVCS (FGDC 1997), other Forest Service I&M protocols, and other Federal and non-Federal programs.

All Federal agencies and programs that collect or produce vegetation data are under the policy jurisdiction of the FGDC. Relationships between these agencies and programs are governed by their joint accountability to the FGDC (OMB 1990, FGDC 1997).

1.5.1 Relationship to the FGDC National Vegetation Classification Standard

The protocol contained in this technical guide is designed to be compatible with the FGDC NVCS published in 1997. The objective of that standard is as follows:

> The overall objective of the National Vegetation [Classification] Standard (NVCS)…is to support the use of a consistent national vegetation classification to produce uniform statistics in vegetation resources from vegetation cover data at the national level. It is important that, as agencies map or inventory vegetated Earth cover, they collect enough data accurately and precisely to translate it for national reporting, aggregation, and comparisons. Adoption of the NVCS in subsequent development and application of vegetation mapping schemes will facilitate the compilation of regional and national summaries. (FGDC 1997).

1.5.1.1 History and Authority of FGDC

Office of Management and Budget (OMB) Revised Circular A-16 established the FGDC in 1990. Its mission is to "promote the coordinated development, use, sharing, and dissemination of surveying, mapping, and related spatial data" (OMB 1990). The FGDC is authorized to "establish, in consultation with other Federal agencies and appropriate organizations, such standards…as are necessary to carry out its government wide coordinating responsibilities" (OMB 1990).

Executive Order Number 12906 (Clinton 1994) designates the FGDC as the lead organization to coordinate the development of the National Spatial Data Infrastructure (NSDI), which is defined as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data." This Executive Order authorizes the FGDC to develop the standards required to implement the NSDI and requires Federal agencies to meet those standards. The gravity of this responsibility is best demonstrated with excerpts from Executive Order 12906:

> NOW, THEREFORE, by the authority vested in me as President by the Constitution and the laws of the United States of America … it is ordered as follows: … Federal agencies collecting or producing geospatial data … shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that *meets all relevant standards adopted through the FGDC process* [emphasis added] Executive Order Number 12906 (Clinton 1994).

1.5.1.2 Types of FGDC Standards

The FGDC establishes two kinds of standards: data and process (FGDC 1996). **Data standards** "describe objects, features or items that are collected, automated, or affected by activities or functions of agencies…. Data standards are semantic definitions that are structured in a model" (FGDC 1996). **Process standards** "describe how to do something, procedures to follow, methodologies to apply, procedures to present information, or business rules to follow to implement standards" (FGDC 1996). Five types of data standards and 10 types of process standards exist (FGDC 1996). Those relevant to existing vegetation classification are as follows:

- **Data classification standards** "provide groups or categories of data that serve an application…. Examples are wetland and soil classifications" (FGDC 1996). In other words, a data classification standard specifies and defines a set of categories that must be used, or crosswalked to, by Federal agencies. The physiognomic levels of the NVCS (FGDC 1997) are a data classification standard.
- **Classification methodology standards** "are the procedures to follow to implement a data classification standard. It (sic) describes how data are analyzed to produce a classification" (FGDC 1996). Classification methodology standards specify how to develop a classification rather than specifying the categories of the classification. The floristic levels of the NVCS (FGDC 1997) will be addressed by a classification methodology standard.

1.5.1.3 FGDC National Vegetation Classification Standard Overview

The FGDC NVCS establishes a hierarchical existing vegetation classification with nine levels. The top seven levels are primarily based on physiognomy. The two lowest levels, alliance and association, are based on floristic attributes. Appendix 1B provides an overview of the NVCS physiognomic hierarchy. Appendix 1C contains a draft key to the five highest physiognomic levels.

The NVCS provides data classification, content, and collection standards for the seven physiognomic levels of the NVCS. It specifies and defines the vegetation categories making up the physiognomic hierarchy and requires Federal agencies to collect the data attributes needed to identify the physiognomic categories. The FGDC Vegetation Subcommittee is currently in the process of revising the physiognomic levels of the NVCS (FGDC 2001a).

The NVCS provides minimal classification methodology, data collection, and quality assurance standards for the floristic levels of the hierarchy. According to the NVCS, "A comprehensive list of the nation's floristic level vegetation types is currently a goal to be pursued in the long term application of this standard" (FGDC 1997). The full development of the floristic classification methodology standards is currently underway as Part II of the current standard (FGDC 2001b). The ESA Panel on Vegetation Classification has drafted the standards (Jennings et al. 2004).

1.5.1.4 FGDC National Vegetation Classification Requirements

The NVCS provides the reason for a national vegetation classification standard:

> The purpose of the national standard is to require all federal vegetation classification efforts to have some core components that are the same across federal agencies to permit aggregating data from all federal agencies. The NVCS does not prevent local federal efforts from doing whatever they want to meet their specific purposes. *NVCS does require that when those local efforts are conducted, they are conducted in ways that, among whatever else they do, they provide the required core data* [emphasis added] (FGDC 1997).

The NVCS further notes that "the adopted standards must be followed by all federal agencies for data collected directly or indirectly (through grants, partnerships, or contracts)" (FGDC 1997). The FGDC physiognomic data requirement clearly applies to all protocols that involve classification or mapping of vegetation types. It also applies to any inventory or monitoring protocol that identifies or documents vegetation types: "The NVCS requires federally supported vegetation classification activities to collect data in ways that permit the data to be useful for creating a classification according to NVCS requirements" (FGDC 1997).

This Forest Service protocol contained in this technical guide requires the collection of all vegetation attributes (i.e., "core data") needed to crosswalk field plots to the physiognomic categories of the NVCS (FGDC 1997). It does not require using the FGDC physiognomic categories due to their impending revision (FGDC 2001a). The FGDC-required physiognomic attributes are described in section 2.4.2 of this technical guide.

The NVCS does not establish floristic data standards because "Currently the policy for applying the standard is only through the formation level" (FGDC 1997). The floristic data requirements of this protocol have been coordinated as closely as possible with the proposed FGDC floristic classification methodology standard as drafted by the ESA Panel on Vegetation Classification (Jennings et al. 2004). All vegetation attributes required by this protocol are described in section 2.4 of this technical guide.

Future FGDC revisions of the physiognomic levels of the NVCS and formal FGDC adoption of a floristic classification methodology standard may necessitate revision of this technical guide. Section 1.6 describes the revision procedures.

1.5.1.5 FGDC Classification and Forest Service Business Needs

The Forest Service is directed by the Forest and Rangeland Resource Planning Act of 1974 to inventory all forest land of the United States and by the National Forest Management Act of 1976 to inventory all national forests. For inventory purposes, forest land is defined as those lands having at least 10-percent stocking, or formerly having such tree cover, and occupying an area of at least 1 acre in size (USDA Forest Service 2002). For mapping, the agency defines forest land as having 10-percent canopy closure of trees. This mapping definition, adopted as an interagency standard with the development of the U.S. Geological Survey (USGS) Land Use Land Cover Classification System (Anderson et al. 1976), is also consistent with the International Forestry definition of forest land (UN-ECE/FAO 1997).

The NVCS physiognomic class of closed canopy forest is defined as 60- to 100-percent tree canopy closure, and the open tree canopy as 25 to 60 percent canopy closure. Both classes are clearly forest lands by the Forest Service standard. Because of the gap from 10- to 25-percent tree canopy closure, an additional physiognomic class is needed to meet the Forest Service business need related to forest inventory, monitoring, and land management planning. For this technical guide, a physiognomic mapping category of sparse tree canopy, defined as 10- to 25-percent tree canopy closure, will be added to the physiognomic class level.

Additionally, arid shrublands in the Western United States are commonly classified as shrubland types, having shrub cover of at least 5 percent (Hironaka et al. 1983, Mueggler and Stewart 1980). In acrid ecosystems, 5- to 10-percent shrub cover has been found to be ecologically significant in the classification and management of grasslands (Daubenmire 1970). NVCS physiognomic standards fail to recognize these two critical percent breaks at the physiognomic class level, using 25- to 100-percent cover for both the shrubland and dwarf shrubland classes. To meet the inventory, mapping, and management business needs of the Forest Service, mapping categories for shrubland and dwarf shrubland will be redefined as shrub- or dwarf-shrub-dominated lands with 10- to 100-percent shrub cover. Trees must be less than 10-percent canopy closure.

For grasslands, an additional physiognomic map category of herbaceous shrub steppe will be added and defined as herbaceous life form dominated with at least 10-percent cover, and shrub and or dwarf shrub life form of at least 5-percent but less than 10-percent cover. The cover requirements for the herbaceous physiognomic class will also be reduced and redefined for mapping as herbaceous-life-form-dominated land with at least 10-percent cover. Tree, shrub, and/or dwarf shrub life forms must be less than 10 percent cover. Using a 10-percent or lower cover break for shrubland and grassland types is consistent with the National Park Service, for which several recent vegetation alliance and association level classifications have been completed for Devils Tower (WY) and Tuzigoot (AZ) National Monuments, as well as Badlands National Park, SD (USGS and NPS, 2002).

These modifications and additions to the NVCS physiognomic class level will allow the mapping of critical vegetation map unit categories necessary to fully meet the business needs of the agency.

1.5.2 Relationship to Other Forest Service Inventory and Monitoring Protocols

The overall objective of Forest Service I&M protocols "is to provide the ecological, social, and economic information necessary for the Forest Service to achieve its mission to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations" (USDA Forest Service 2002). Inventory and monitoring of natural resources provide the ecological information required by the Forest Service mission. In this context, inventory and monitoring are two overarching processes:

- **Inventory** is the systematic acquisition, analysis, and organization of resource information needed for planning and implementing land management (adapted from USDA NRCS 1997).
- **Monitoring** is the systematic collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives (adapted from SRM 1989).

These two overarching processes comprise specific activities designed to answer basic resource questions. These questions and activities are described in table 1.3, which illustrates the overall structure of the Forest Service Inventory and Monitoring Framework.

Table 1.3. *I&M framework.*

Overarching I&M process	Basic resource question	Specific I&M activity
Inventory—The systematic acquisition, analysis, and organization of resource information needed for planning and implementing land management. (adapted from USDA NRCS 1997)	**What is it?**	**Classification**—The grouping together of similar entities into named types or classes based on shared characteristics.
	Where is it?	**Resource Mapping**—The delineation of the geographic distribution, extent, and landscape patterns of resource types or attributes.
	How much is there?	**Quantitative Inventory**—The objective quantification of the amount, composition, condition, and/or productivity of resource types or parameters within specified levels of statistical precision. (adapted from Helms 1998)
Monitoring—The systematic collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives. (adapted from SRM 1989)	**How is it changing over time?**	**Dynamic Sampling**—The collection and analysis of resource data to measure changes in the amounts, spatial distribution, or condition of resource types or parameters over time. (adapted from Helms 1998)
	Is it moving toward or away from management objectives?	**Evaluation**—The comparison of dynamic sampling results to management objectives consisting of predetermined standards, expected norms, threshold values, and/or trigger points.

The inventory process includes three fundamental activities: classification, resource mapping, and quantitative inventory. These activities produce basic information about ecosystems and/or individual resources. These accumulated data and organized knowledge are necessary to provide a credible scientific basis for establishing land management objectives that are biologically and physically attainable.

The monitoring process includes dynamic sampling and evaluation. Dynamic sampling measures changes in resources over time (Helms 1998). Evaluation compares these changes to management objectives, threshold values for sustainability, and/or trigger points that initiate specific management actions. The evaluation criteria and the sampling methods are based on the body of knowledge produced by the inventory process.

Classification and mapping of existing vegetation are related to quantitative vegetation inventory and vegetation monitoring. Table 1.4 describes each of these activities in terms specific to vegetation (instead of the generic terms in table 1.3), explains the relationships between them, and lists other vegetation protocols and processes that are related to these four existing vegetation activities. These include classification and mapping of PNV and historic vegetation, several Terrestrial Ecological Unit Inventory (TEUI) processes, and specific existing vegetation monitoring and quantitative inventory protocols.

The sampling methods employed by the protocols listed in table 1.4 should be as similar as possible to facilitate information sharing and simplify development of corporate

Table 1.4. *Relationships of existing vegetation I&M activities to other Forest Service activities.*

	Existing vegetation classification	Existing vegetation mapping	Quantitative vegetation inventory	Vegetation monitoring
Basic questions	What is it?	Where is it?	How much is there?	Is it changing toward or away from management objectives?
Task or activity	Develop and describe vegetation types; create keys to distinguish between types.	Delineate geographic distribution, extent, patterns, and juxtaposition of vegetation types and/or attributes.	Estimate the amount of each vegetation type or the values of vegetation attributes, in a specific area.	Detect changes over time in amounts of vegetation types or values of vegetation attributes, and compare them to management objectives.
Relationships between processes	Classification is a prerequisite for each of the other three processes. The other processes, especially mapping, can help validate and refine a classification.	Use a standard vegetation classification to develop a map legend and to design map units.	An inventory of vegetation types requires that a classification be developed first. An inventory can be generated from a map by summing acres of map units, polygons, or components.	Knowledge gained through classification, mapping, and quantitative inventory helps develop evaluation criteria and monitoring methods. Repeated mapping or inventory can provide monitoring data.

Table 1.4. *Relationships of existing vegetation I&M activities to other Forest Service activities. (continued)*

	Existing vegetation classification	Existing vegetation mapping	Quantitative vegetation inventory	Vegetation monitoring
Related activities or processes	• PNV classification • Ecological type classification • Historic vegetation classification	• PNV mapping • Landtype association (LTA) mapping • Landtype mapping • Landtype phase mapping • Historic vegetation mapping • Fire regime condition class mapping	• FIA • Common stand exam • Riparian inventory • Old growth inventory • Range inventory	• Forest health monitoring • Range monitoring • Riparian monitoring • Invasive weed monitoring • Threatened and endangered species (TES) plant monitoring

vegetation databases. Table 1.5 presents a generalized comparison of the sampling approaches used in classification, mapping, quantitative inventory, and monitoring of vegetation. It describes the kinds of attributes collected, selection of sampling locations, and precision of sampling method.

Table 1.5. *Comparison of sampling approaches for existing vegetation I&M activities.*

	Existing vegetation classification	Existing vegetation mapping	Quantitative vegetation inventory	Vegetation monitoring
Task or activity	Develop and describe vegetation types; create keys to distinguish between types.	Delineate geographic distribution, extent, patterns, and juxtaposition of vegetation types and/or attributes.	Estimate the amount of each vegetation type, or the values of vegetation attributes, within a specific area.	Detect changes over time in amounts of vegetation types or values of vegetation attributes, and compare them to management objectives.
Example attributes:	• Physiognomy • Floristics • Composition • Structure	• Vegetation types • Plant size classes • Canopy cover	• Vegetation types • Plant size classes • Canopy cover • Productivity • "Health indicators"	• Vegetation types • Plant size classes • Canopy cover • Productivity • "Health indicators"
Sample location method	**Subjective** Uniform stand and site conditions; not ecotonal. **Objective** Systematic placement along environmental gradients, or random placement	**Subjective** Representative of a polygon or map unit. **Objective** Systematic or random placement in a polygon or map unit.	**Subjective** **Usually not appropriate.** **Objective** Random or systematic placement to provide statistical reliability.	**Subjective** Located in benchmark or key areas of concern. **Objective** Located randomly or systematically in key areas.
Sampling methods	Reconnaissance or intensive. Vegetation and environmental data required for identifying relationships.	Reconnaissance or intensive. Vegetation and environmental data usually collected.	• Usually intensive. • Usually requires only vegetation data. • Methods depend on objectives.	• Usually intensive. • Data collected depends on what is being monitored.

1.5.2.1 Relationship to Forest Service TEUI Protocol

To provide the ecological context for making land management decisions, use the existing vegetation classification protocol and TEUI protocol together. Existing vegetation classification and maps describe current vegetation composition, structure, and patterns. TEUI provides ecological type classifications and defines land units where response to disturbance processes and land management actions are expected to be similar based on PNV and physical site characteristics (e.g., geology, climate, soil, and topography).

Existing vegetation classifications and maps, when combined with ecological type classifications and ecological unit maps, provide land managers a context for evaluating ecological conditions and resource values (e.g., wildlife habitat, forage, watershed conditions, and timber) and selecting appropriate land management practices based on ecosystem capability. Bourgeron et al. (1994) consider relationships between biotic components and abiotic factors important for predicting management response of ecosystems and landscapes under various management scenarios. Bailey et al. (1994) describe the importance of combining existing vegetation maps with ecological unit maps delineating land areas with similar potential for management to effectively assess ecosystem health in land use planning.

Predicting vegetation response or change as a function of various management scenarios or natural disturbance regimes requires associating existing vegetation classifications with TEUI ecological type classifications and describing successional relationships and dynamics. This requires classifying and describing the plant communities or vegetation states that may be associated with an ecological type. State and transition diagrams and succession models are being used by a variety of resource managers and specialists to predict vegetation change in response to disturbance processes or management practices. The state and transition diagram (Westoby et al. 1989, Stringham et al. 2001) is used to describe how different disturbances or management practices (e.g., fire, flooding, grazing, and insects), or stresses (e.g., drought, increased precipitation, climate change, and variability) affect changes or transitions from one plant community or state to another. Using this existing vegetation classification protocol in development of state and transition models facilitates prediction of changes in vegetation composition, structure, and pattern. This improves the utility of TEUI for evaluation and determination of desired vegetation objectives.

Information derived from combining existing vegetation classification, descriptions, and maps with TEUI provides the basis for selecting suitable areas for land use activities, identifying and prioritizing areas for restoration activities, evaluating various land management alternatives, and predicting the affects of a given activity on ecosystem health and resource condition. Existing vegetation classification and maps describe the range of vegetation composition, structure, and plant diversity associated with ecological types. This information can be used by land managers to assess and describe existing and potential resource conditions, define and describe desired vegetation conditions, describe outcomes resulting from various management prescription scenarios, and communicate environmental affects of land management planning alternatives.

Section 2 of this technical guide describes the methods used to develop vegetation types that can be used to describe the plant communities and states associated with ecological types that are developed according to the Terrestrial Ecological Unit Inventory Technical Guide.

1.5.3 Relationship to Other Federal Programs and Standards

All Federal agencies are required by Executive Order 12906 (Clinton 1994) to comply with FGDC standards (see section 1.5.1.1). Coordination of existing vegetation classification efforts among agencies is possible only to the extent that each agency complies with the NVCS (FGDC 1997). As lead agency for the NSDI vegetation theme (OMB 1990) and chair of the FGDC Vegetation Subcommittee (FGDC 1997), the Forest Service must make every effort to include all relevant Federal agencies in the development and implementation of the NVCS.

1.5.4 Relationship to Non-Federal Programs and Standards

FGDC standards are mandatory only for Federal agencies, but non-Federal governments and private organizations are encouraged to participate in the continued development of the NVCS (OMB 1990, Clinton 1994, FGDC 1997). As lead agency for the NDSI vegetation theme (OMB 1990) and chair of the FGDC Vegetation Subcommittee (FGDC 1997), the Forest Service must make every effort to include all interested non-Federal organizations in the development and implementation of the NVCS.

1.6 Change Management

Process

This technical guide will be updated periodically based on interdisciplinary consultations and the results of testing the products of the guide. Stimuli for change will include results of national and regional field reviews, usage, and recommendations submitted to the national program manager from the field.

Supplements

Supplementation of the protocol is delegated to regions but not to forest and grassland supervisors. Regions may supplement the information in this technical guide with methods or guidance required for meeting specific issues or needs of the Region, and as FGDC standards and other programs change.

Review

A cadre of experts will conduct a periodic review to determine how and when to make changes. The classification and mapping protocols will be refined through a process of peer review. This will be a continuous process coordinated by the Washington Office Ecosystem Management Staff.

Update Schedule

After the protocol is finalized, the Existing Vegetation Mapping Technical Guide will be updated as directed by the Washington Office Ecosystem Management Staff.

Section 2. Existing Vegetation Classification Protocol

2.1 Purpose

The purpose of this protocol is to produce a consistent classification of existing vegetation across National Forest System lands that is compatible with the Federal Geographic Data Committee (FGDC) National Vegetation Classification Standard (NVCS) and meets business needs of the Forest Service. In the long term, this requires classification of associations and alliances. In the short term, some business needs can be met through classification of dominance types as provisional alliances (see section 2.2.5). This protocol provides standards and guidelines for collection, analysis, and interpretation of data to classify and describe associations, alliances, and interim dominance types based on the guiding principles enumerated in section 1.2.3.

2.2 Planning and Design

In this section: *Overview of the vegetation classification process, classification concepts, association and alliance criteria, and standards for documentation and correlation of vegetation types*

The FGDC NVCS (1997) indicates that "classification methods should be clear, precise, where possible quantitative, and based upon objective criteria…. Classification necessarily involves definition of class boundaries." Kuchler (1973) states, "A scientific classification must have definable units, described with the greatest possible precision and consistency; there must be no exception to the rule."

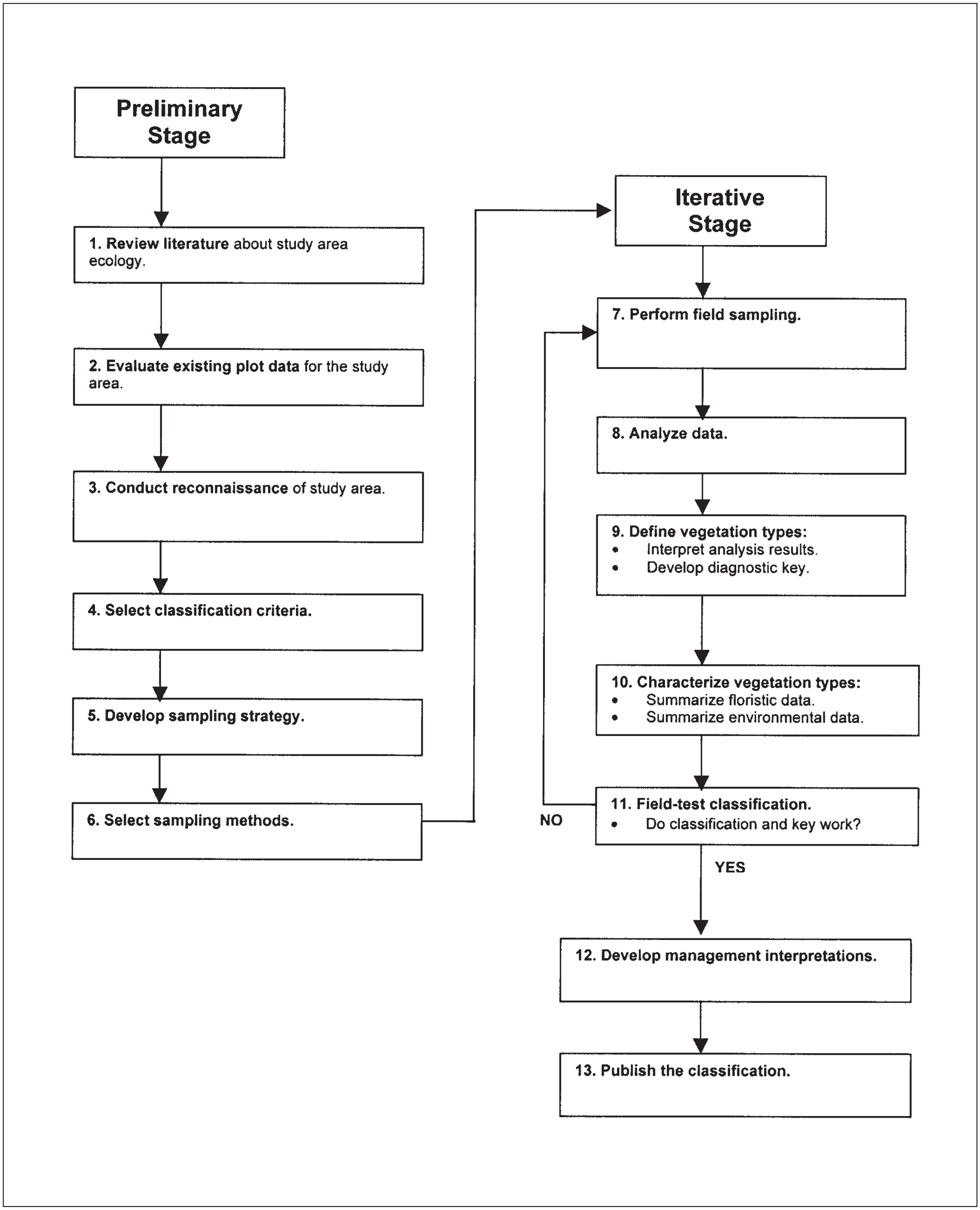
2.2.1 Vegetation Classification Process

The process of classifying vegetation types consists of a preliminary stage (ideally) performed once and an iterative stage usually repeated until the classification project is completed. The process is outlined below, followed by a short discussion of each step. Figure 2.1 is a diagram of the classification process.

Preliminary Stage

1. **Review literature** relevant to the ecology of the study area.
2. **Evaluate available plot data** for the study area.
3. **Conduct reconnaissance** of the study area.
4. **Select classification criteria** and descriptive attributes based on the purpose and taxonomic level of the classification.

Figure 2.1. *Flow diagram of vegetation classification process.*



5. **Develop a sampling strategy** consistent with the classification criteria that will encompass the full range of environmental factors in the survey area.
6. **Select sampling methods** based on the classification criteria and descriptive attributes.

Iterative Stage

7. **Conduct field sampling** using the strategy and methods developed above.
8. **Analyze data** using techniques consistent with the classification criteria.
9. **Define vegetation types** by interpreting the analysis results and developing a diagnostic key.
10. **Characterize vegetation types** by summarizing floristic and environmental data.
11. **Field-test** the diagnostic key and vegetation type descriptions.

Note: If the classification is inadequate, return to step 6 or 7, and repeat the cycle. If it does work well and meets documentation standards, continue with step 12.

12. **Develop ecological interpretations** for each vegetation type.
13. **Publish the classification,** and add types to the Forest Service corporate database.

The iterative stage of the classification process is often referred to as **successive refinement** because it involves repeated cycles of knowledge, questions, and observations. Successive refinement is the basic working approach of community ecologists (Pfister and Arno 1980, Gauch 1982). The preliminary stage of classification provides the starting knowledge for the first iteration of successive refinement.

2.2.1.1 Preliminary Stage

Literature review, data evaluation, and reconnaissance (steps 1 through 3) constitute preparation for a classification project. They are essentially the same for associations, alliances, and dominance types. Steps 4 through 6 produce a project plan for classification development. Classification criteria and sampling approach differ for each level of floristic classification (sections 2.2.4 and 2.2.5).

1. **Review literature.** The first step in developing a vegetation classification is reviewing the ecological literature relevant to the study area. Types of information include the following:
   - **Synecological**—Previous classifications of existing or potential vegetation from adjacent areas. This includes vegetation data from the survey area, such as range analysis transects and timber inventory plots.

- **Autecological**—Literature on the physiology and life cycles of the predominant plant species and their responses to environmental factors, natural disturbances, herbivory, and management activities.
- **Vegetation History**—Literature describing historic natural and human-caused disturbances of the vegetation in the study area or adjacent areas. Ideally this includes information on the severity and extent of past disturbances, their effects on vegetation, and responses of individual species.
- **Botanical**—Taxonomic keys and species lists for the survey area and adjacent areas. This should include synonymous plant names and their authors, which may be needed to interpret the above literature.
- **Climatic**—Precipitation maps, precipitation and snowfall data, air temperature data, and soil moisture and temperature data (if available).
- **Geologic**—Literature on geologic parent materials, geomorphic processes, and physiography of the study area, ideally including maps.
- **Soils**—Soil surveys, Terrestrial Ecological Unit Inventories (TEUI), or other studies in the survey area. Studies from adjacent areas also may be useful, especially if they address soil-vegetation relationships.
- **Hydrologic**—Studies of surface and subsurface water sources and flows in relation to the study area. Data on water chemistry, including pH.
- **Zoological**—Natural history and current and historical distribution and abundance of vertebrates and invertebrates that may affect the distribution, abundance, and condition of plant species in the study area. This should include information on herbivores (e.g., ungulates), keystone species (e.g., beavers), and other species that may influence vegetation.

2. **Evaluate existing plot data.** In addition to relevant literature, review all plot data available for the study area and evaluate its usefulness to the vegetation classification project. Some plot data may be used directly to help develop the classification; others may be useful only to help stratify the area for reconnaissance or sampling. Other plots may provide descriptive data, such as site index or forage production, if they can be assigned to a vegetation type after the classification is completed. Examples of data include TEUI plots, range inventory and monitoring plots, stand exams, and Forest Inventory and Analysis (FIA) plots.

3. **Conduct reconnaissance.** Reconnaissance consists of rapidly traversing the study area looking for general features of the landscape and vegetation, such as predominant plant species, geologic parent materials, landforms, and climatic patterns (Daubenmire 1968). Reconnaissance provides an “on-the-ground” look at the same factors mentioned in the literature review. Reconnaissance may include field-checking

the accuracy and/or relevance of pre-existing plot data (step 2). The intensity, or level of detail, employed in reconnaissance determines which sampling strategies (step 5) can be used validly (Mueller-Dombois and Ellenberg 1974).

4. **Select classification criteria.** The purposes of the intended classification are important considerations in selecting classification criteria. Determine which vegetation attributes will potentially be classification criteria and what additional data are needed for descriptive purposes or to derive management interpretations. For example, if managers want timber productivity estimates for each vegetation type, timber productivity data must be collected on at least a subset of the plots. Classification criteria for associations and alliances are described in sections 2.2.4 and 2.2.5, respectively. This step usually includes selection of analysis techniques appropriate for the classification criteria chosen.

5. **Develop sampling strategy.** The sampling strategy determines how samples will be distributed over the study area and what criteria will be used to locate sample plots. Use the major environmental gradients identified through literature review and reconnaissance to stratify the survey area for sampling. At a minimum, stratify the study area by elevation, landform, slope, aspect, geology, parent material, and vegetation patterns noted during reconnaissance (see section 2.3). Locate individual sample plots in areas of uniform vegetation and environment (FGDC 1997, Jennings et al. 2004).

6. **Select sampling methods.** Sampling methods are selected based on the classification criteria and descriptive attributes chosen for the project. The major concerns in plant community sampling are plot size, plot shape, and methods for measuring or estimating species abundance. If similar vegetation has been classified in adjacent areas, seriously consider the sampling methods used in those studies. As noted in step 4 above, other plot data uses may require collecting additional attributes. Keep such additional attributes to a minimum because they increase the time needed to sample a plot, thereby reducing the number of plots available to develop the classification. Sampling methods are described in section 2.4.

2.2.1.2 Iterative Stage

The iterative stage implements the project plan developed in the preliminary stage. Gauch (1982) recommends performing a pilot study to refine the sampling and data analysis methods. The first year of a classification project usually serves as a pilot study, even if this was not intended. Refining the criteria and methods requires revisiting steps 4, 5, and 6 of the classification process and revising the project plan. Carefully document any changes made. Iterative refinement of a classification can continue or be reinitiated during vegetation mapping.

7. **Perform field sampling.** Field sampling consists of collecting data in accordance with the sampling strategy using the chosen sampling methods.

8. **Analyze data.** The analysis procedures used by community ecologists are designed to detect patterns and relationships in a dataset, filter out noise, and eliminate outliers (Gauch 1982). **Patterns** include repeating coordinated species abundances and groups of samples with similar species composition. The patterns reflect **relationships** between plant species or between species and environmental factors. **Noise** is noninterpretable variation in species abundances that obscures patterns and relationships in the dataset. Sources of noise include chance distribution and establishment of seeds, disturbance effects, microsite variation, outliers, and misidentification of species. An **outlier** is a sample with low similarity to all other samples in a dataset.

9. **Define vegetation types.** Defining vegetation types requires interpreting the results of data analysis in light of the biology of the species involved and the inherent limitations of the numerical techniques used. The process of reducing noise and eliminating outliers may require deleting certain species and plots from the dataset and repeating the analyses. Eventually, this process groups the samples in the dataset into tentative vegetation types. Use the attributes that distinguish each group to develop a diagnostic key for field identification of the preliminary vegetation types. The key is tested on the entire dataset and revised as needed. See section 2.7 for vegetation type description requirements.

10. **Characterize vegetation types.** Characterization entails describing the properties and components of a category or class. After the vegetation types are defined, species composition and environmental data are summarized to characterize the types. A vegetation type description describes the central concept of the type and the range of variation within the type. Such descriptions require several samples per type.

11. **Field-test classification.** Field-testing of the classification uses the key and descriptions in the field to identify vegetation types. This often is performed concurrently with field sampling during the next iteration of the classification process. The iterative stage of the classification process is complete when the descriptions and keys work well in the field for a variety of end users, and each type is adequately documented. Ideally, the relationships of vegetation types to environmental factors and disturbances are also documented. Correlation by the regional ecologist and peer review by other ecologists must be incorporated into this step.

12. **Develop management interpretations.** Management interpretations describe characteristics of each vegetation type that are relevant to land use and management decisions. Some interpretations depend solely on attributes of the existing vegetation, and others are a function of successional relationships to other vegetation types. After the classification system is finalized, management interpretations for each vegetation type are developed and a complete description of each type is written. As land managers use the classification in conducting projects, they will obtain additional information on how each vegetation type responds to various treatments. A vegetation classification provides a way to organize this new information and retrieve it for application to future projects.

13. **Publish the classification.** After the classification is complete, publish a report that includes vegetation type descriptions, diagnostic keys, and documentation of the sampling and analysis methods used to develop the classification. For more details on the contents of the report, see section 2.7. To provide scientific credibility, peer review of the final manuscript is required and publication in a refereed forum is preferred. The regional ecologist should oversee the peer review process and ensure that new vegetation types are added to the corporate database.

2.2.2 Classification Approaches and Concepts

Two fundamentally different approaches are used to develop classifications. The “top-down” or divisive method subdivides a group of objects based on differences among them. Most divisive classifications use differences that are readily apparent to define the categories. The “bottom-up” or agglomerative method defines types by grouping objects together based on shared characteristics. This method accommodates and often requires detailed observations of the objects to be classified. Table 2.1 compares these two approaches to classification.

A classification can be either hierarchical or nonhierarchical. Both assign objects to classes based on shared attributes; hierarchical classifications also group those classes based on shared attributes. A hierarchy enables objects to be compared at various levels of detail and expresses relationships between individual objects. A simple hierarchy can assist in organizing and accessing information. A hierarchy may be better suited for describing and mapping vegetation at multiple geographic scales (FGDC 1997); however, the order in which criteria are used in the hierarchy greatly affects the usefulness of the classification.

Table 2.1. *Two approaches to hierarchical classification.*

Divisive approach (top-down)	**Agglomerative approach (bottom-up)**
Subdivides a group of objects to create types.	Groups individual objects together to create types.
Focuses on differences.	Focuses on similarities.
Generally uses one or few classification criteria.	Often uses many classification criteria.
Usually requires little observation of objects.	Often requires detailed observation of the objects.
Usually based on a simple dataset.	Usually based on a complex dataset.
Best suited for large sets of objects.	Best suited for small sets of objects.
Works best over large areas; is less useful for small areas.	Works best in small areas; often breaks down for large areas.
Upper level units are usually more clearly defined than lower level units.	Lower level units are usually more clearly defined than upper level units.
Often used to express and clarify known relationships and patterns.	Usually used to detect unknown relationships and patterns, or to quantify known relationships.
Resulting classification tends to be conceptual and *a priori*.	Resulting classification tends to be empirical and *a posteriori*.

2.2.3 Vegetation Classification Criteria

Developing a classification system involves selecting criteria for defining and differentiating categories. The criteria used depend on the purpose of the classification. Another consideration in selecting classification criteria is the number of attributes used to assign an object to a group. A single factor, a few factors, or many factors may be used to classify objects. Top-down classifications are usually based on few attributes; bottom-up classifications typically incorporate many attributes. Vegetation classification systems have generally used two types of criteria—physiognomic and floristic.

2.2.3.1 Physiognomic Criteria

Physiognomic classifications subdivide vegetation into categories based on gross differences in life form and vegetation structure. They are usually developed with a top-down approach and work best at broad scales. Physiognomic classifications typically have few factors and require relatively little data; however, physiognomic categories are inherently broad. Examples include terms such as forest, shrubland, and meadow.

Physiognomy is the overall appearance of a kind of vegetation (Daubenmire 1968, Barbour et al. 1980). Physiognomy is the expression of the life forms of the dominant plants and vegetation structure (Mueller-Dombois and Ellenberg 1974, Barbour et al. 1980). **Life form** includes gross morphology (size, woodiness), leaf morphology, life span, and phenological (or life cycle) phenomena (Barbour et al. 1980). **Structure** is "the spatial arrangement of the components of vegetation" (Lincoln et al. 1998). Structure is a function of plant size and height, vertical stratification into layers, and horizontal spacing of plants (Mueller-Dombois and Ellenberg 1974). Physiognomy refers to the general appearance of the vegetation; structure describes the spatial arrangement of plants in more detail. “Physiognomy should not be confused with structure” (Mueller-Dombois and Ellenberg 1974).

2.2.3.2 Floristic Criteria

Floristic classifications emphasize the plant species comprising the vegetation instead of life forms or structure. Floristic classifications are based on community composition and/or diagnostic species. In practice, most floristic classifications incorporate life form or vegetation layers to some degree. Floristic classifications can be developed using a top-down (e.g., dominance types) or bottom-up (e.g., associations) approach, but the latter is more commonly used (see table 2.1). Floristic classifications work better than physiognomic classifications at finer scales and generally require more data to develop.

Community composition is the kinds, absolute amounts, or relative proportions of plant species present in a given area or stand. Community composition can be described qualitatively or quantitatively. The latter may use either absolute amounts or relative proportions of the plant taxa present. Express the amount of each plant taxon as percent cover (FGDC 1997, Jennings et al. 2004). Differentiate these three approaches using the following terms:

- **Floristic composition** is “a list of the plant species of a given area, habitat, or association” (Lincoln et al. 1998). It provides a qualitative description of a plant community.
- **Absolute composition** is a list of the absolute amounts of each plant species present in a given area or stand. Express the amount of each plant taxon as absolute percent cover.
- **Relative composition** is a list of the proportions of each plant species relative to the total amount of all species present in a given area or stand. Express the proportion of each plant taxon as relative percent cover.

Floristic composition alone provides less ecological information than a quantitative description of community composition (Daubenmire 1968, Greig-Smith 1983). Absolute composition is more informative than relative composition. As Daubenmire (1968) states:

> It is more important to know that species A has 12 percent coverage in a stand than that it provides 75 percent of the total plant cover. Only the absolute values give an insight into the capacity of the environment to support vegetation.

A list of plant species is included in absolute or relative composition; species amounts or proportions, however, cannot be derived from floristic composition. Relative composition can be derived from absolute composition, but not vice versa. Plot data that include absolute composition provide the greatest flexibility for developing a floristic vegetation classification.

Diagnostic species are "any species or group of species whose relative constancy or abundance can be used to differentiate one [vegetation] type from another" (Jennings et al. 2004). This definition implies that diagnostic species must be determined empirically through analysis of plot data (Mueller-Dombois and Ellenberg 1974). Identifying diagnostic species is an inherent part of classifying associations and alliances. Diagnostic species include dominant, differential, character, and indicator species, defined below:

- **Dominant species**—"the species with the highest percent of cover, usually in the uppermost… layer" (Kimmins 1997, as cited in Jennings et al. 2004). Dominant species represent a quantitative difference in composition between vegetation types. Two stands or types may have identical floristics but differ in dominant species.
- **Differential species**—a plant species that because of its greater constancy and/or abundance in one vegetation type than another, can be used to distinguish the two types (adapted from Jennings et al. 2004). A differential species serves to distinguish between two vegetation types.
- **Character species**—"a species that shows a distinct maximum concentration (quantitatively and by presence) in a well-definable vegetation type" (Mueller-Dombois and Ellenberg 1974). A character species shows "a distinctive accumulation of occurrences in only one [vegetation] type" (Jennings et al. 2004). A character species distinguishes one vegetation type from several others.
- **Indicator species**—"a species whose presence, abundance, or vigor is considered to indicate certain environmental conditions" (Gabriel and Talbot 1984, as cited in Jennings et al. 2004). Indicator species may represent a qualitative or quantitative distinction between community types.

Dominant species are generally self-evident. Other diagnostic species are typically determined empirically through analysis of species abundances and environmental data; however, they may be selected *a priori* if their ecology is well understood. Grouping plots based on species composition usually occurs by using multivariate procedures that objectively search for groups of species that occur together repeatedly across the landscape. The diagnostic value of a species may change across its geographic range due to genetic variation, compensating environmental factors, or changes in associated species.

Habitat is not a classification criterion for existing vegetation, but is important for descriptive and interpretive purposes. **Habitat** is "the combination of environmental or site conditions and ecological processes (such as disturbances) that influence the community" (Jennings et al. 2004). The distributions of diagnostic species along environmental gradients may be used to evaluate the utility of a classification.

2.2.3.3 Vegetation Cover Concepts

Abundance of plant species can be measured in numerous ways, but the standard measure for vegetation classification purposes is percent cover. Cover is a meaningful attribute for nearly all plant life forms, which enables their abundances to be evaluated in comparable terms (Daubenmire 1968, Mueller-Dombois and Ellenberg 1974). Percent cover can be defined generically as "the vertical projection of the crown or shoot area to the ground surface expressed as…percent of the reference area" (Mueller-Dombois and Ellenberg 1974). The use of crown or shoot area results in two definitions of cover:

- **Canopy cover** is "the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings in the canopy are included" (SRM 1989, USDA NRCS 1997).
- **Foliar cover** is "the percentage of ground covered by the vertical projection of the aerial portion of plants. Small openings in the canopy and intraspecific overlap are excluded" (SRM 1989). Foliar cover is the vertical projection of shoots, i.e., stems and leaves.

Foliar cover is usually less than, and never greater than, canopy cover (Daubenmire 1968, SRM 1989). Neither can exceed 100 percent for a single species, but both can total more than 100 percent for all the species in a plot or stand due to overlap between species (Daubenmire 1968). Canopy cover or canopy closure for a single life form or layer also cannot exceed 100 percent. For example, tree canopy closure and total vegetation canopy cover as described in section 3.222 cannot exceed 100 percent.

Foliar cover and canopy cover are "not necessarily correlated" (Daubenmire 1968) for either a species or a plant community. All Forest Service vegetation sampling for classification purposes *must* use canopy cover, not foliar cover, for the following reasons:

- Canopy cover better estimates the "area that is directly influenced by the individuals of each species" (Daubenmire 1968).
- Canopy cover, or canopy closure, is easier to estimate from aerial photos than foliar cover and is more likely to correlate with satellite image analysis. A classification based on canopy cover is better suited for mapping vegetation than one based on foliar cover.
- The majority of Forest Service legacy data for vegetation classification uses canopy cover instead of foliar cover.

2.2.4 Association Criteria

An **association** is "a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy" (Jennings et al. 2004). Based on this definition, associations are classified primarily based on community composition and diagnostic species. Physiognomy and structure are secondary criteria that are often correlated with floristics because life form is constant for most species. Although habitat is not a classification criterion for existing vegetation, habitat information is needed to describe the environmental range of an association. An association with a wide environmental range may be of little interpretive value for conservation and management. Environmental data are also required to work out successional relationships among associations and relate existing vegetation to potential natural vegetation (PNV).

Because diagnostic species are determined empirically through numerical analysis, vegetation plot data for classification of associations must include a complete species list with canopy cover estimates for each species. Physiognomic data must also be collected so that associations can be grouped later into alliances and related to the physiognomic levels of the NVCS (FGDC 1997, Jennings et al. 2004). The minimum amount of plot data needed for classifying associations is described in section 2.2.6.1.

2.2.5 Alliance Criteria

An **alliance** is "a vegetation classification unit containing one or more associations and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation" (Jennings et al. 2004). Because an alliance is a grouping of associations (FGDC 1997), plot data must be collected and analyzed and associations classified before alliances can be defined. Classification of alliances requires the same vegetation plot data as classification of associations.

The standard approach to classifying alliances is to aggregate associations from the bottom up based on plot data. When immediate business needs require alliance-level information before completing classification of associations, an interim top-down approach to classifying "alliances" may be needed.

The FGDC NVCS (1997) states, "The diagnostic species used to determine…the alliance…are primarily the dominant species." Provisional alliances, therefore, may be defined by dominant species in the uppermost layer. The Ecological Society of America (ESA) Vegetation Classification Panel describes this approach as follows:

> Under data-poor conditions, new alliances may be provisionally identified through quantitative analysis of data on species in the dominant stratum (e.g. comprehensive tree layer data in forests), combined with information on the habitat or ecology of the plots. Alliance types developed through such incomplete data fail to meet the highest standards for defining floristic units.... To improve the confidence in these units, it is necessary to redefine them through analysis of full floristic information, such as plots that represent all of the associations that may be included in the alliance (Jennings et al. 2004).

Provisional alliances, as described above, are equivalent to dominance types. A **dominance type** is a recurring plant community "defined by the dominance of one or more species which are usually the most important ones in the uppermost or dominant layer of the community, but sometimes of a lower layer of higher coverage" (Gabriel and Talbot 1984, as cited in Jennings et al. 2004).

Dominance types are most simply defined by the single species with the greatest amount of canopy cover in the uppermost layer. Dominance types based on multiple species require more rigorous data analysis. Classification of dominance types requires canopy cover estimates for the species in the uppermost vegetation layer and the physiognomic attributes of the NVCS (FGDC 1997). These data are relatively easy to acquire and may be obtained from existing information, such as stand exams or FIA plots. Observational or anecdotal information can be used to help develop dominance types, but by itself is inadequate to define differentiating criteria.

Published vegetation types that may serve as provisional alliances include the following:

- Provisional alliances of the International Classification of Ecological Communities (ICEC), originally published by The Nature Conservancy (Anderson et al. 1998) and currently maintained by NatureServe (2004).
- Society of American Foresters (SAF) forest cover types based on plurality of basal area (Eyre 1980). SAF types apply only to stands with 25 percent or more canopy cover of trees.
- Society for Range Management (SRM) rangeland cover types based on "the present vegetation that dominates the aspect or physiognomy of an area" (Shiflet 1994). SRM types apply primarily to nonforested vegetation.

The utility of these published classifications as provisional alliances must be evaluated locally. If none are suitable, a local dominance type classification may be developed.

2.2.6 Classification Standards

Establishment of a new association, alliance, or dominance type requires that the vegetation type be adequately sampled and clearly distinguished from other vegetation types through written type descriptions and a diagnostic key. Proposed associations and alliances must be evaluated through peer review and correlation and may then become established through approval of the regional ecologist or designated vegetation data steward. Dominance types must be correlated and approved by the regional ecologist or designated vegetation data steward.

2.2.6.1 Sample Size

This Forest Service protocol requires a minimum of 10 plots to provide a reasonable description of the range of variation and characteristics of an association, alliance, or dominance type. Gauch (1982) recommends a minimum of 5 to 10 plots to establish and characterize a vegetation type. The plots should be well distributed over the geographical and ecological ranges of the type. Broadly distributed types may require more than 10 plots to adequately sample their geographical and ecological ranges. Under special conditions (e.g., difficulty of access), fewer than 10 plots may be used to describe a vegetation type, but under no conditions should a type be based on less than three samples. The regional ecologist must approve any exemption from the sample size requirement. These sample size requirements are based on preferential sampling, as described in section 2.3.2.

2.2.6.2 Diagnostic Keys

A dichotomous key to the vegetation types is required. A dichotomous key is simpler to use and understand than a key with multiple choices. There should be only two choices at each decision point so that the user has only to select one or the other. Figure 2.2 presents a simple example of a dichotomous key.

It should be noted that diagnostic keys generally do not exist for the published dominance types described in section 2.2.5 (ICEC alliances, SAF cover types, and SRM cover types). Consistent use of these dominance types will require development of national or regional keys. Such keys will require field-testing and refinement; e.g., see the key to sagebrush alliances developed by Reid et al. (2002).

Figure 2.2. *Dichotomous key example.*

Key to Woodland Dominance Types		
1a.	Quaking aspen (*Populus tremuloides*) the dominant tree present	**QUAKING ASPEN D.T.**
1b.	Not as above	2
2a.	Bigtooth maple (*Acer grandidentatum*) the dominant tree present	**BIGTOOTH MAPLE D.T.**
2b.	Not as above	3
3a.	Gambel oak (*Quercus gambellii*) the dominant tree present	**GAMBEL OAK D.T.**
3b.	Not as above	4
4a.	Curlleaf mountain-mahogany (*Cercocarpus ledifolius*) the dominant tree present	**CURLEAF MOUNTAIN-MAHOGANY D.T.**
4b.	Not as above	5
5a.	Junipers (*Juniperus* spp.) with or without various pinyon pines (*Pinus* spp.) the dominant tree species present	**JUNIPER-PINYON WOODLAND D.T.**
5b.	Not as above	**UNIDENTIFIED WOODLAND TYPES**

2.2.6.3 Correlation of Vegetation Types

The regional ecologist must correlate associations, alliances, and dominance types. Correlation requires a manuscript that minimally includes vegetation type descriptions, a diagnostic key, and descriptions of sampling and analysis methods. In addition to the manuscript, the following information is required for correlation of association and alliances:

- Synthesis tables (summaries of constancy and mean cover by species for each type).
- Association tables (individual plot data for each type).
- A map showing all plot locations for each vegetation type.

Regional ecologists may require additional information for correlation at their discretion.

2.3 Sampling Strategy

In this section: *Stratification of study area and plot location approaches*

Random or systematic sampling across a study area is inefficient and costly because a very dense set of sample points is required to include the variation inherent in the landscape (Mueller-Dombois and Ellenberg 1974, Gauch 1982). The study area should be stratified to optimize the distribution of samples and reduce the number of samples required.

2.3.1 Stratification of Study Area

Stratification of the study area may be based on environmental factors, vegetation patterns, or a combination of both. Environmental factors can be used to stratify the study area in an objective manner for vegetation classification. Stratification based solely on vegetation cover is always subjective (Mueller-Dombois and Ellenberg 1974) and can potentially bias the resulting classification.

Environmental factors useful for stratification include elevation, slope, aspect, climatic factors, geologic parent materials, soils, and hydrologic conditions. The first three factors can be generated from digital elevation models (DEMs). Maps of climatic factors created by the PRISM or Daymet models are available online; for PRISM, visit http://www.ocs.orst.edu/prism/prism_new.html, and for Daymet, visit http://www.forestry.umt.edu/ntsg/bioclimatology/daymet/.

For classification of associations, the use of vegetation cover for stratification should be limited to obvious physiognomic types and dominance types to minimize bias. Stratification into finer vegetation units requires detailed knowledge of the study area based on intensive reconnaissance (Mueller-Dombois and Ellenberg 1974).

2.3.2 Plot Location

Plots may be located in sampling strata either preferentially (Gauch 1982, Jennings et al. 2004) or objectively (Mueller-Dombois and Ellenberg 1974). Preferential sampling locates plots in areas with relatively uniform physiognomy, floristic composition, and environmental conditions. Objective sampling locates plots systematically or randomly in strata. The objective approach is also called representative sampling (Jennings et al. 2004).

Preferential sampling should locate plots "subjectively without preconceived bias" (Mueller-Dombois and Ellenberg 1974). This means that plots are carefully selected for homogeneity of vegetation and environment, but are not selected because they "fit" a preconceived community type. Selection of "typical" stands or rejection of "degraded" or "atypical" stands may introduce bias unnecessarily and lead to erroneous conclusions (Mueller-Dombois and Ellenberg 1974).

Homogeneity is a matter of subjective judgment because no stand is absolutely homogenous, and homogeneity is dependent on plot size (Mueller-Dombois and Ellenberg 1974, Gauch 1982). No completely objective way exists to evaluate homogeneity, but the following guidelines have been successfully used by ecologists for many years (Mueller-Dombois and Ellenberg 1974, Gauch 1982):

- The plot should not include any obvious change in physiognomy.
- The predominant taxa in each vegetation layer should be consistently distributed across the plot.
- The plot should not encompass any abrupt changes or obvious gradients in environmental factors, such as slope, aspect, geologic parent materials, or soil depth, moisture, or texture.

The data to be collected on each plot may place further restrictions on plot location. For example, if site index is to be measured on each plot, samples cannot be located in stands that lack suitable site trees. For example, an otherwise acceptable stand may be rejected for sampling because the trees are infected with mistletoe.

Representative sampling employs systematic or random location of plots in strata, but rejection criteria may be necessary to avoid sampling obvious ecotones, which are of limited use for classifying vegetation. The "gradsect" technique, or gradient-directed sampling, is one example of this approach (Austin and Heylingers 1991, as cited in Jennings et al. 2004). This technique is a form of stratified random sampling that may be cost effective for sampling vegetation patterns along environmental gradients (Gillison and Brewer 1985).

As long as rejection criteria are defined ahead of time, the objectivity of the sampling will be maintained. The rejection criteria listed above for preferential sampling also apply to representative sampling. Representative sampling should be used when the stratification units are large and variable or when statistical support for conclusions is desired (Mueller-Dombois and Ellenberg 1974), which may accommodate additional business needs.

2.4 Sampling Methods

In this section: *Plot size and shape, life forms and layers, species data requirements, canopy cover estimation, environmental data, metadata, and FGDC physiognomic requirements*

The ocular macroplot, or relevé (Mueller-Dombois and Ellenberg 1974, Jennings et al. 2004), sampling method is the fastest and most efficient sampling approach for vegetation classification.

The ocular macroplot procedure consists of the following steps:

1. Mark the plot boundaries.
2. Record environmental attributes.
3. Record plot location, preferably by global positioning system (GPS) and metadata.
4. List all the plant species present in the plot.
5. Estimate canopy cover for each species by layer (also height and diameter class if desired).
6. Estimate canopy cover, height, and diameter class of required life forms and layers.
7. Obtain required FGDC physiognomic field plot data.

Photographs of the plot and its landscape setting are strongly recommended. Appendix 2A provides instructions and example field forms for the ocular macroplot vegetation sampling method.

The cover-frequency (USDA Forest Service 2002b) and line intercept (USDA Forest Service 2002d) methods are useful for calibrating ocular cover estimates. They produce data generally suitable for floristic classification, but require much more time and effort than the ocular macroplot method. Both methods miss many species when compared with macroplot sampling (Jennings et al. 2004). The cover-frequency and line intercept methods are not compliant with the FGDC NVCS because they do not accommodate all the physiognomic attributes required to crosswalk data to the NVCS physiognomic hierarchy

2.4.1 Plot Size and Shape

Plots should be small enough to be efficient, yet large enough to include most of the species present in the community. Presampling tests should be conducted by listing the species present in a set of nested plots of increasing area. The required minimum plot size

Table 2.2. *Commonly used macroplot sizes.*

Standard plot area	Equivalent plot area	Plot dimensions Radius of circular plot	 Side of square plot	Default plot dimensions or shape	Temperate vegetation types where commonly used
50 m²	~1/80 ac	4.0 m 13.1 ft	7.1 m 23.2 ft	5 x 10 m rectangular	Riparian shrubland Riparian herbland Alpine vegetation Grassland
100 m²	~1/40 ac	5.6 m 18.5 ft	10.0 m 32.8 ft	10 x 10 m square	
375 m² **(legacy only)**	~1/11 ac	10.9 m 35.9 ft	19.4 m 63.5 ft	circular	Low-diversity forest Shrubland Grassland Riparian forest and woodland Riparian large shrubland
400 m² 37.0 ft	~1/10 ac 65.6 ft	11.3 m	20.0 m	20 x 20 m square	
1/10 ac	~405 m²	11.4 m 37.2 ft	20.1 m 66.0 ft	circular	
500 m²	~1/8 ac	12.6 m 41.4 ft	22.3 m 73.3 ft	circular	
800 m²	~1/5 ac	16.0 m 52.4 ft	28.3 m 92.7 ft	20 x 40 m rectangular	Forests with widely spaced large trees
1/5 ac	~810 m²	16.1 m 52.7 ft	28.4 m 93.3 ft	circular	
1000 m²	~1/4 ac	17.8 m 58.5 ft	31.6 m 103.7 ft	20 x 50 m rectangular	High-diversity forests
2500 m²	~3/5 ac	28.2 m 92.5 ft	50.0 m 164.0 ft	50 x 50 m square	Old growth forests with very large trees

can then be determined from a species area curve, i.e., by plotting number of species against plot size. A plot meets the minimal area requirements when enlarging the plot adds no or very few new species. Plots larger than the minimal area provide acceptable data but are less efficient in terms of the time required to sample the plot. If plots are too small, floristic data will not be adequate for developing a vegetation classification.

Minimal area, as defined above, varies widely by general vegetation type (Mueller-Dombois and Ellenberg 1974, Barbour et al. 1980, Gauch 1982). Table 2.2 shows several common plot sizes and the temperate vegetation types in which they are commonly used. The smallest of these sizes that meets the minimal area criterion generally should be used for a classification project. One of these sizes should be used unless minimum area determination indicates a larger plot is needed or the vegetation being sampled occurs in patches smaller than these sizes.

Adjusting the plot shape to fit in the homogeneous area to be sampled is acceptable. Staying in a homogeneous area is more important for classification work than the shape of the plot. The plot shape (square, rectangular, or circular) is up to the user, but the entire plot should fit in the vegetation stand. Plot size should not be adjusted on steep slopes to avoid overestimating canopy cover as compared to plots on level ground (Mueller-Dombois and Ellenberg 1974). For instructions for recording plot area and dimensions, see appendix 2A.

2.4.2 Identification of Life Forms and Layers

Canopy cover of major life forms is required to describe vegetation structure, to cross-walk plot data and vegetation types to the FGDC physiognomic hierarchy (FGDC 1997, Jennings et al. 2004), and to meet additional Forest Service business needs. Life forms required for Forest Service business needs are described below. Addition life forms required for FGDC compliance are described in section 2.4.9.1.

2.4.2.1 Required Life Forms

Percent canopy cover must be estimated for each of the following life forms. Percent canopy cover of any life form is the percentage of the plot area included in the vertical projection of the outermost perimeter of the natural spread of foliage of plants of that life form (section 2.2.3.3). Canopy cover of any single life form cannot exceed 100 percent.

Trees

Woody plants that generally have a single main stem and have more or less definite crowns. In instances where life form cannot be determined, woody plants at least 5 meters in height at maturity will be considered trees (adapted from FGDC 1997).

Shrubs

Woody plants that generally exhibit several erect, spreading, or prostrate stems which give it a bushy appearance. In instances where life form cannot be determined, woody plant less than 5 meters in height at maturity will be considered shrubs (adapted from FGDC 1997).

Dwarf-shrubs—Caespitose, suffrutescent, creeping, matted, or cushion-forming shrubs that are typically less than 50 cm tall at maturity due to genetic and/or environmental constraints (adapted from FGDC 1997). Does not include shrubs less than 50 cm tall due to young age or disturbance.

Herbs

"Vascular plants without significant woody tissue above the ground…with perennating buds borne at or below the ground surface" (FGDC 1997). Includes graminoids, forbs, ferns, club mosses, horsetails, and quillworts.

Graminoids—Nonaquatic flowering herbs with relatively long, narrow leaves and inconspicuous flowers with parts reduced to bracts. Includes grasses, sedges, rushes, and arrowgrasses (adapted from FGDC 1997).

Forbs—Nonaquatic, nongraminoid herbs with relatively broad leaves and/or showy flowers (adapted from FGDC 1997). Includes both flowering and spore-bearing, nongraminoid herbs.

Appendix 2A, section 2A.2.2 includes instructions for recording canopy cover by life form on the Vegetation Composition field form.

2.4.2.2 Required and Optional Tree Layers

For trees, canopy cover, predominant tree height, predominant crown height, and predominant diameter by layer are used to describe vegetation structure to provide a rough picture of past stand dynamics, and to crosswalk to the FGDC physiognomic hierarchy. For detailed instructions on recording these attributes on the Vegetation Composition form, see appendix 2A, section 2A.2.4.2. Percent canopy cover, predominant tree height, predominant crown height, and predominant diameter (section 2.4.2.3, below) must be estimated for the tree overstory and regeneration layers. Recognition of these layers is dependent on the potential height growth of the tree species making up the stand. For this purpose, **dwarf trees** are defined as trees that are typically less than 12 meters tall at maturity due to genetic and/or environmental constraints. Examples include pinyon pines, junipers, and mountain mahogany.

Overstory (TO)

Trees at least 5 meters in height that make up the forest canopy or dwarf trees that have attained at least half of their (site-specific) potential height growth and make up the forest canopy.

Regeneration (TR)

Trees less than 5 meters in height or dwarf trees that have attained less than half of their (site-specific) potential height growth and are clearly overtopped by the overstory layer.

The overstory layer may optionally be subdivided into the following sublayers to describe vegetation structure in more detail:

- **Supercanopy (TOSP)**—Scattered overstory trees that clearly rise above the main canopy.
- **Main Canopy (TOMC)**—Dominant and codominant overstory trees that receive direct sunlight from above.
- **Subcanopy (TOSB)**—Overstory trees clearly overtopped by, and separate from, the main canopy, but taller than the regeneration layer.

Use these divisions to mentally subdivide the overstory. All sublayers may not be present. Record percent canopy cover, the predominant or prevailing tree height, predominant crown height, and the predominant diameter of each sublayer. For example, a stand may have a main canopy of dominant/codominant trees mostly 20 meters tall and a subcanopy of younger trees predominately 8 meters tall.

The tree regeneration layer may optionally be divided into the following sublayers:

- **Saplings (TRSA)**—Regenerating trees less than 5 meters in height but taller than 1.4 meters (4.5 feet) *or* regenerating dwarf trees taller than 1 meter (3.3 feet).
- **Seedlings (TRSE)**—Regenerating trees less than 1.4 meters (4.5 feet) in height *or* regenerating dwarf trees less than 1 meter (3.3 feet) tall.

Some studies may choose to subdivide seedlings into established and nonestablished classes. The criteria for established seedlings may vary by species and region. Required and optional tree and shrub layers are summarized in table 2.3.

Table 2.3. *Summary of tree and shrub layers.*

Life form	Required layers	Optional sublayers
Trees (T)	Overstory (TO)	Supercanopy (TOSP) Main canopy (TOMC) Subcanopy (TOSB)
	Regeneration (TR)	Sapling (TRSA) Seedling (TRSE) Established (TRSEE) Nonestablished (TRSEN)
Shrubs (S)		Tall shrubs (ST) Medium shrubs (SM) Low shrubs (SL)

2.4.2.3 Optional Shrub Layers

Total percent canopy cover, predominant shrub height, and crown height may optionally be estimated for the following shrub layers:

- **Tall Shrubs (ST)**—Shrubs greater than 2 meters in height. (Includes shrubs more than 5 meters in height but clearly multistemmed.)
- **Medium Shrubs (SM)**—Shrubs 0.5 to 2 meters in height.
- **Low Shrubs (SL)**—Shrubs less than 0.5 meter in height.

The low shrub layer includes FGDC's dwarf shrub life form in addition to shrubs that are less than 0.5 meter tall due to young age or disturbance. Tall and medium shrubs are subdivisions of FGDC's shrub life form. For more information, see section 2.4.9.1.

2.4.3 Species Identification

A list of all vascular plant species identifiable at the time of sampling is required on all vegetation classification plots. Identification of vascular plants to the subspecies or variety level may be required for some projects. Include plants if their crowns overhang the plot area, even though their root systems may not be in the plot area, except when sampling narrow riparian communities. In such riparian communities, do not include overhanging trees rooted outside the community (across an ecotone) in the species list.

Floristic classification requires accurate plant identification. Correct species identification is more important than accuracy in cover estimates. Overlooking or misidentifying a species is a more serious error than estimating cover as 5 percent when a measurement would show it to be 3 percent. Field employees must be well qualified and/or trained in species identification, use of accepted scientific floras, and proper collection of unknown species for later identification.

Botanical nomenclature should follow a standard flora for the geographic area being sampled. The floras used should be identified in any products (e.g., publications, database) produced by a classification project and included in the project metadata. Codes for plant species must follow the PLANTS database (USDA NRCS 2002).

Any plant that cannot be identified to the species level should be collected for later identification. Assign a collection number to the specimen and record the number on the field form along with other required information (e.g., percent cover, life form).

2.4.4 Species Canopy Cover Data

Estimate the total canopy cover of each species using the procedure described in section 2.4.5. For a tree species, estimate its canopy cover in the overstory and regeneration layers in addition to total cover for the species. Assign each species in the macroplot an appropriate life form and life form modifier as defined in section 2.4.9.1. Each species can belong to one life form only.

Estimating canopy cover for each tree species in each optional sublayer is recommended but not required. Estimating canopy cover provides approximate relative age distributions for tree species (Daubenmire 1968, Mueller-Dombois and Ellenberg 1974), which can be used to roughly describe past succession in the stand. Because size-age relationships are not constant, interpret such data with caution and supplement it with actual age data (Harper 1977).

2.4.5 Canopy Cover Estimation

Canopy cover is the percentage of the plot surface area covered by the periphery of the foliage of the plants. Do not use cover classes. Estimate percent canopy cover of each species, life form, layer, or size class in the plot as follows:

- Use 0.1 as “trace” for items present but clearly less than 1-percent cover.
- Estimate to the nearest 1 percent between 1- and 10-percent cover.
- Estimate to at least the nearest 5 percent between 10- and 30-percent cover.
- Estimate to at least the nearest 10 percent for values exceeding 30-percent cover.

In the species list, do not record species that do not occur in the plot, but are present in the stand. Information from outside the plot can be recorded in field notes, but cannot legitimately be used in data analysis. A consistent plot size is an important assumption for most community data analysis procedures; using species data from outside the plot violates this assumption. If sampling is consistently missing ecologically meaningful species, use a larger plot size.

Table 2.4 lists commonly used plot sizes and the dimensions of squares representing 1 percent and 5 percent of the plot area. Canopy cover can be consistently estimated by walking through a macroplot and counting the number of 1- or 5-percent units of a species present in the plot. Canopy cover for life forms, layers, or size classes can be similarly estimated. Crosscheck estimates with each other for consistency and to help account for overlap between layers in a life form or species, species in a layer, and so forth. It may be helpful to complete cover estimates for each species and the items in table 2.3 before estimating cover for the required FGDC life forms in section 2.4.9.1.

Data collection personnel must calibrate their estimates of cover. Ocular estimate calibration should be conducted at the beginning of inventory projects and periodically throughout the life of the project. Field data collection personnel may calibrate their

Table 2.4. *Plot sizes and dimensions of squares equaling 1- and 5-percent of the plot.*

Plot size (area)	Side of a 1-percent square	Side of a 5-percent square
50 m^2	0.7 m 2.3 ft	1.6 m 5.2 ft
100 m^2	1.0 m 3.3 ft	2.2 m 7.3 ft
400 m^2	2.0 m 6.6 ft	4.5 m 14.7 ft
0.01 acre	2.0 m 6.6 ft	4.5 m 14.7 ft
0.2 acre	2.8 m 9.3 ft	6.4 m 20.9 ft
1,000 m^2	3.2 m 10.4 ft	7.1 m 23.2 ft

ocular estimates by periodically sampling with cover-frequency transects or line intercept methods (USDA Forest Service 2002b and 2002d). When using the line intercept method for calibration, measure canopy cover, not foliar cover (Daubenmire 1968). Quick comparison of cover estimates can be made by having personnel independently estimate cover for a few species in a plot and comparing their results. If necessary, the process may be repeated until all personnel produce similar results.

2.4.6 Plant Height and Diameter Data

Record the predominant plant height and crown height, including unit of measure, for any tree or shrub layer present in the macroplot. **Crown height** for trees is the vertical distance from ground level to the lowest whorl with live branches in at least three of four quadrants around the stem. Crown height for shrubs is the vertical distance from ground level to the lowest live foliage or branches. The minimum and maximum height of each layer are optional attributes. Predominant height is optional for the other life forms in section 2.4.2.1. Predominant height for each species in each layer is also useful, but optional, information. For instructions on determining predominant plant height and crown for trees and shrubs, see appendix 2A, sections 2A.2.4.2 and 2A.2.4.3.

The predominant diameter at breast height (d.b.h.) or root collar (d.r.c.) must be recorded for each tree layer. Record the diameter to the nearest inch rather than using diameter classes; classes can be assigned later. For instructions for measuring predominant diameter and recording it on the Vegetation Composition form, see appendix 2A, section 2A.2.4.2.

2.4.7 Environmental Attribute Data

Plot data used to classify existing vegetation must include floristic composition and structural attributes. Supplemental data describing abiotic characteristics and disturbance processes must be collected to understand landscape vegetation patterns, relationships among plant communities, and successional dynamics and pathways. Such data are also necessary if the vegetation classification is to be used to evaluate ecological status and resource conditions.

The minimum required environmental attributes for floristic classification of existing vegetation are elevation, slope gradient (percent), slope aspect (in degrees azimuth), and ground cover. In riparian vegetation, the fluvial geomorphic surface should also be described. Recommended additional information includes landform, slope position, slope shape, and geologic parent material. Appendix 2A provides guidelines for describing elevation, slope gradient and aspect, ground cover, slope position, and slope shape. Guidelines for describing landform and geologic parent material can be found in the *Terrestrial Ecological Unit Inventory Technical Guide* (Winthers et al. 2004).

Although not collected in the field, attach climatic data to plot records for data analysis and description of vegetation types; use national climate coverages such as DayMet and PRISM or local weather station data.

2.4.8 Metadata

The term **metadata** refers to "data about the data." Metadata include information about how the data were collected and the original intended use of the data. Metadata are necessary to support proper analysis and application of the data. Ecologists should review metadata for reliability and applicability before using data from other sources.

In the past, this information often was in hard copy form, if written at all, and difficult to track down when sharing data. A minimum set of electronic metadata must accompany all plot data and be input for a project before any plot data can be entered into the Natural Resource Information System (NRIS) database system. This ensures that basic metadata will always be stored with the dataset and is accessible to all users.

2.4.8.1 Project Metadata

Project metadata describe how a set of data was collected. Examples include the following:

- **Project Name**—Assign a specific name and purpose of the data gathering/data analysis project. Include references to specific floras used to support plant species identification as well as other references that may have been used, such as existing classifications, sample design references, and photography or imagery sets.
- **Protocol**—Documents the protocol followed (e.g., FSH 1909 Existing Vegetation Classification and Mapping Protocol).
- **Methods**—Describes the specific method or type of sample used to collect the data. For example, the ocular macroplot method may be used for collecting vegetation attribute, and the cover frequency or line-intercept methods may have been used for ocular cover calibration. A separate method may have been used to collect optional tree measurement data (e.g., variable radius plot sampling).
- **Sample Design—**Documents the sample design used for the plots in a specific project. Sample design attributes include how the sample units were selected and the size of the plot. Additional attributes to support cover frequency and line intercept methods include number of transects, length of transects, and number and size of frames along the transects.

2.4.8.2 Plot Metadata

Metadata attributes that vary from plot to plot are included as fields on the General Site Form in appendix 2A. These include a unique site ID, project name, date of collection, examiners, location information, and air photo information. Whenever measurements are taken (e.g., elevation, height, diameter), the appropriate unit of measure (feet, meter) must accompany the value and be stored with the data.

2.4.9 FGDC Physiognomic Crosswalk Attributes

The FGDC NVCS requires that federally funded vegetation classification plot data include the attributes needed "to classify units down through the physiognomic levels of [Division, Order,] Class, Subclass, Group, [Subgroup,] and Formation." The FGDC physiognomic hierarchy is being revised, however, and the Subgroup and Formation levels are not clearly defined (see appendix 1B). This protocol, therefore, does not require field collection of attributes needed to classify FGDC Groups, Subgroups, and Formations at this time.

Because of the above situation, the FGDC requirements are reduced to the following:

1. Use the key in appendix 1C to key out the plot to FGDC subclass in the field, and record the subclass on the General Site Data form.
2. Record a life form and life form modifier for each species on the plot using the lists in tables 2.5 and 2.6, respectively.

Requirement 1 enables plot data to be quickly crosswalked to the division, order, class, and subclass levels of the FGDC hierarchy. If needed, the group, subgroup, and formation can usually be determined from individual species cover data.

Requirement 2 allows for rapid summarization of species data by life form. The life forms and life form modifiers in tables 2.5 and 2.6 are intended to facilitate the assignment of plots to categories of the pending revision of the FGDC physiognomic hierarchy.

These requirements will be revised on completion of the revised FGDC physiognomic hierarchy.

Table 2.5. *Required FGDC life forms.*

Life form code	Name and definition
T	**Tree**—A woody plant that generally has a single main stem and a more or less definite crown. In instances where life form cannot be determined, woody plants at least 5 m in height at maturity will be considered trees (adapted from FGDC 1997).
S	**Shrub**—A woody plant that generally has several erect, spreading, or prostrate stems that give it a bushy appearance. In instances where life form cannot be determined, woody plants less than 5 m in height at maturity will be considered shrubs (adapted from FGDC 1997). Includes dwarf shrubs and woody vines.
H	**Herb**—A vascular plant without perennial aboveground woody stems, with perennating buds borne at or below the ground surface (Whitaker 1970, FGDC 1997). Includes forbs, graminoids, and herbaceous vines.
N	**Nonvascular**—A plant or plant-like organism without specialized water or fluid conductive tissue (xylem and phloem). Includes mosses, liverworts, hornworts, lichens, and algae (adapted from FGDC 1997).
E	**Epiphyte**—A vascular plant that grows by germinating and rooting on other plants or other perched structures and does not root in the ground (adapted from FGDC 1997).
L	**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 (Gerwing 2004), typically exceeding 5 m in height at maturity.

Table 2.6. *Required FGDC life form modifiers.*

Life form code	Life form modifier code	Name and definition
T	TBD	**Broad-leaved deciduous tree**—A tree with leaves that have well-defined leaf blades that are typically greater than 645 square mm (1 sq in) in area and seasonally loses all its leaves and becomes temporarily bare-stemmed (FGDC 1997).
	TBE	**Broad-leaved evergreen tree**—A tree with a branching crown and leaves that have well-defined leaf blades that are typically greater than 645 square mm (1 sq in) in area and has green leaves all year round (FGDC 1997).
	TN	**Needle-leaved tree**—A tree with slender, elongated leaves or with small overlapping leaves that usually lie flat on the stem (FGDC 1997). Includes scale-leaved as well as needle-leaved trees, and deciduous as well as evergreen.
	TS	**Sclerophyllous tree**—A tree with relatively small, usually evergreen leaves that are stiff and firm, and retain their stiffness even when wilted (FGDC 1997, Whitaker 1970).
	TU	**Succulent tree**—A tree or arborescent plant with fleshy stems or leaves with specialized tissue for the conservation of water (FGDC 1997). Includes cacti, Joshua trees, euphorbias, and others more than 5 meters in height at maturity.
S	SD	**Dwarf-shrub**—A caespitose, suffrutescent, creeping, matted, or cushion-forming shrub that is typically less than 50 cm tall at maturity due to genetic and/or environmental constraints (adapted from FGDC 1997). Does not include shrubs less than 50 cm tall due to young age.
	SBD	**Broad-leaved deciduous shrub**—A shrub that is typically more than 50 cm tall at maturity with leaves that have well-defined leaf blades that are typically greater than 645 square mm (1 sq in) in area and seasonally loses all its leaves and becomes temporarily bare-stemmed (FGDC 1997).
	SBE	**Broad-leaved evergreen shrub**—A shrub with a branching crown that is typically more than 50 cm tall at maturity with leaves that have well-defined leaf blades that are typically greater than 645 square mm (1 sq in) in area and has green leaves all year round. (FGDC 1997).
	SM	**Small-leaved shrub**—A shrub that is typically more than 50 cm tall at maturity with leaves that have well-defined leaf blades that are typically less than 645 square mm (1 sq in) in area (FGDC 1997). Includes evergreen and deciduous shrubs with small leaves.
	SN	**Needle-leaved shrub**—A shrub that is typically more than 50 cm tall at maturity with slender, elongated leaves or with small overlapping leaves that usually lie flat on the stem (FGDC 1997). Includes scale-leaved as well as needle-leaved shrubs, and deciduous as well as evergreen.
	SC	**Sclerophyllous shrub**—A shrub with relatively small, usually evergreen leaves that are stiff and firm, and retain their stiffness even when wilted (FGDC 1997, Whitaker 1970).
	SU	**Succulent shrub**—A shrub or shrub-like plant with fleshy stems or leaves with specialized tissue for the conservation of water (FGDC 1997). Includes cacti less than 5 meters in height at maturity.
H	HA	**Aquatic herb—**A flowering or nonflowering herb structurally adapted to live floating or submerged in an aquatic environment. Does not include emergent herbs such as cattails and sedges (FGDC 1997, Jennings et al. 2003).
	HF	**Forb**—A nonaquatic, nongraminoid herb with relatively broad leaves and/or showy flowers. Includes both flowering and spore-bearing, nongraminoid herbs.
	HFF	**Flowering forb**—A forb with relatively broad leaves and showy flowers. Does not include graminoids, ferns, or fern-likes.
	HFS	**Spore-bearing forb**—A nonflowering, spore-bearing forb. Includes nonaquatic, nonwoody ferns, club mosses, horsetails, and quillworts.
	HG	**Graminoid**—A nonaquatic, flowering herb with relatively long, narrow leaves and inconspicuous flowers with parts reduced to bracts. Includes grasses, sedges, rushes, and arrowgrasses.
N	NB	**Bryophyte**—A nonvascular, nonflowering, photosynthetic plant that bears leaf-like appendages or lobes and attaches to substrates by rhizoids. Includes mosses, liverworts, and hornworts (Abercrombie et al. 1966).
	NA	**Alga**—A nonvascular, photosynthetic plant with a simple form ranging from single- or multi-celled to a fil amentous or ribbon-like thallus with relatively complex internal organization (Abercrombie et al. 1966).
	NL	**Lichen**—An organism generally recognized as a single plant that consists of a fungus and an alga or cyanobacterium living in symbiotic association (FGDC 1997).

2.5 Data Storage

In this section: *Date storage requirements and data cleaning methods*

Store project data, plot data, and vegetation type data that are collected or derived as part of this existing vegetation classification protocol in the Forest Service NRIS database. Follow formats and procedures for data storage developed in coordination with NRIS.

All required attributes in this protocol will be supported in NRIS and follow national standards. Support means that data entry and edit forms will be provided that include lookup lists of standard codes. Applications and reports will be developed that use this information. All optional attributes recognized in the national protocol will be accommodated in NRIS. Data entry screens and database fields and standard codes will be available to hold this information. Corporate tools, however, will be driven largely by corporate or required data. Data collected at a region's discretion beyond the required and optional attributes listed in this technical guide may not necessarily be accommodated in NRIS and may not follow a national standard. Coordinate with regional and national stewards on such matters.

Label archival materials associated with the classification project, such as maps, photos, reports, and plot data sheets, with the project name and store them together in an accessible and protected location.

2.5.1 Data Cleaning

Review data for completeness and obvious errors before entering it in the corporate database. The NRIS database makes extensive use of data validation techniques against standard codes, units of measure, value range checks, and required fields that will also promote consistent data entry and error checking. After data are entered in the NRIS database, several common methods can be used to check data for additional errors.

Query the species cover data table for a list of species codes and associated scientific names. By examining this list, the classifier will find errors in species code entry if names of species not recognized or known to occur in the study area appear on the list. NRIS tables will not allow the entry of a nonexistent species code.

Query the appropriate table for lists of other pieces of data collected (e.g., plot slope, tree heights) and examine the lists to find obvious data entry errors that would not be disallowed by lookup table restrictions. For example, one could enter a plot slope of 180 percent, but the reviewer may know that no plot in the study could possibly have a plot slope of 180 percent.

Query the data table containing all the site identifiers against each table containing data about the site to see if these other tables contain records for all plots sampled.

Typographic errors may occur in individual plots and must be visually checked against plot card data.

2.6 Data Analysis

In this section: *Data analysis concepts and guidelines*

The analysis procedures used by community ecologists are designed to detect patterns and relationships in a dataset, filter out noise, and eliminate outliers (Gauch 1982). An **outlier** is a sample with low similarity to all other samples in a dataset. **Patterns** include repeating coordinated species abundances and groups of samples with similar species composition. The patterns reflect **relationships** between plant species or between species and environmental factors. **Noise** is noninterpretable variation in species abundances that obscure patterns and relationships in the dataset. Sources of noise include chance distribution and establishment of seeds, local disturbances, microsite variation, outliers, and misidentification of species.

No particular analysis process or method produces a vegetation classification. The available techniques simply produce information that an ecologist uses to help define vegetation types. The results of data analysis must be interpreted in light of knowledge of the biotic and abiotic factors influencing plant species distributions in the study area. Integrating all this information is the job of the ecologist and cannot be automated.

Jennings et al. (2004) state, "Various methods are available for identification of environmental and floristic pattern from matrices of species occurrence in filed plots. The substantial menu of available analytical methods allows individual researchers to select those methods that provide the most robust analyses for the available data" (e.g., Braun-Blanquet 1932, Mueller-Dombois and Ellenberg 1974, Jongman et al. 1995, Ludwig and Reynolds 1988, Gauch 1982, Kent and Coker 1992, McCune and Medford 1999, McCune et al. 2002, and Podani 2000). That ecologists understand the concepts and mathematics of each method to appropriately interpret the analysis results is also critical (Pielou 1984).

Multivariate analysis techniques examine the behavior of more than one dependent variable in a set of parameters. In the case of vegetation analysis, species presence and species cover values may be used to compare and group individual plots. Floristic data is often complemented by environmental or other abiotic parameters, such as soil texture, elevation, slope, azimuth, and mean annual or seasonal precipitation values.

Four fundamental approaches are widely used for vegetation analysis: tabular analysis, clustering, gradient analysis, and ordination (Jennings et al. 2004). Tabular analysis involves the sorting of a matrix of plots and species in an effort to detect recurring groups of species, identify diagnostic species, and group similar plots together. Such a table is referred to as an association table. Clustering methods may be divisive—separating the data into progressively narrower groupings through differences between plots, or agglomerative—deriving clusters of plots that share common features. Both methods are sometimes used sequentially to assess the adequacy of the associations developed by the first method. When environmental parameters are included in the dataset, direct gradient analysis may be applied to examine the groupings or clusters of plots along environmental gradients. A variety of software packages provide these types of analyses in various combinations.

Regardless of the analytical methods used, document proposed associations using synthesis and association tables to facilitate peer review and correlation of vegetation types (see section 2.2.6.3). A synthesis table displays constancy and mean canopy cover for each vegetation type. An association table displays individual plot data for each vegetation type. Both are invaluable for diagnostic key development and peer review.

Tables 2.7 and 2.8 show examples of synthesis and association tables using data from big sagebrush plant associations on the Bridger-Teton National Forest (Tart 1996, Svalberg et al. 1997). To save space, both examples represent only partial tables. Table 2.7 is a synthesis table that summarizes late and mid-seral plots for six plant associations. It displays diagnostic species and species with high constancy in at least one association, rather than a complete species list. Table 2.8 is a partial association table for the same six plant associations. It displays only the diagnostic species for the late seral plots in each association. A complete association table would display 140 plots and more than 300 plant species. These plant associations were developed using ordination of floristic data and tabular analysis of both floristic and environmental data (Tart 1996). Plant codes follow the Natural Resources Conservation Service (NRCS) PLANTS database.

2.7 Reporting

In this section: *Naming and description of vegetation types, and vegetation type metadata*

2.7.1 Naming Vegetation Types

The purpose of naming the taxonomic units in a classification is to create a unique, consistent identifier for the unit. Naming conventions for taxonomic units must include short name, scientific name, and common name. This approach facilitates communication and tracking of the types in databases, maps and reports, and among a variety of potential audiences. Naming approaches must be coordinated at the regional and national levels (preferably by the regional ecologist) to provide consistency.

Use a descriptive approach to naming that uses a combination of dominant and diagnostic species to name the type. “The names of dominant and diagnostic taxa are the foundation of the association and alliance names” (Jennings et al. 2004). For names of associations and alliances, include at least one or more species names from the uppermost layer of the type. For alliances, use taxa from lower layers sparingly. Among the

Table 2.7. *Synthesis table for vegetation classification example*

Species	ARTRP4 -PUTR2 /ELSP3 (n=30)		ARTRP4 /FEID -ELSP3 (n=60)		ARTRV2 /FEID -ELSP3 (n=17)		ARTRV2 /ELTR7 (n=16)		ARTRS2 /ELTR7 (n=6)		ARTRS2 /TRSP2 (n=11)	
Species	**Con**	**Cov**	**Con**	**Cov**	**Con**	**Cov**	**Con**	**Cov**	**Con**	**Cov**	**Con**	**Cov**
Diagnostic species												
BASA3	**67**	**3**	58	3	24	1	6	tr				
PUTR2	**93**	**8**	**67**	**6**								
ARTRP4	**100**	**24**	**100**	**22**	18	2						
ELSP3	**100**	**25**	**88**	**14**	**88**	**7**						
ARTRV2	3	tr	5	tr	**100**	**26**	**100**	**29**	17	2	18	1
FEID	40	1	**97**	**17**	**100**	**28**	**100**	**30**	**100**	**31**	**100**	**26**
POGR9			7	tr	47	tr	**81**	**1**	**83**	**2**	**100**	**3**
ELTR7	3	tr	7	tr	18	tr	**88**	**3**	**100**	**4**	**100**	**10**
GEVI2			8	tr	41	tr	44	tr	50	1	**82**	**4**
ARTRS2									**100**	**27**	**100**	**24**
TRSP2			3	tr			6	tr	33	tr	**73**	**3**
CARA6							13	tr	17	tr	**73**	**3**
Species with 50 percent constancy in at least one association												
POSE	50	1	45	1	35	1	6	tr				
PHLO2	57	1	32	tr	41	tr	19	tr				
SYOR2	57	tr	47	1	29	tr	13	tr			9	tr
COUMP2	**70**	**tr**	**63**	**1**	24	tr						
CHVI8	**63**	**1**	50	tr	29	tr	6	tr				
STCO4	**87**	**4**	53	2	47	2	6	tr				
HEUN	10	tr	17	tr	53	2	13	tr			9	1
ANMI3	37	1	45	1	**94**	**3**	**81**	**3**	**67**	**3**	55	1
ERUM	50	tr	**60**	**2**	**100**	**6**	**94**	**4**	**100**	**3**	**73**	**4**
STLE4	33	2	18	tr	24	1	50	2	50	1	9	tr
ARCO5	7	tr	40	tr	59	1	**63**	**1**	50	1	36	tr
KOMA			17	tr	**76**	**2**	**63**	**1**	50	1	9	tr
CAOB4	10	tr	12	tr	**65**	**2**	**63**	**1**	**67**	**2**	9	tr
TAOF	13	tr	13	tr	53	tr	38	tr	50	tr	36	tr
GETR			7	tr	53	tr	**88**	**2**	**83**	**1**	27	1
ACMIL3			8	tr	**71**	**1**	**75**	**1**	**100**	**1**	**91**	**2**
SWRA			3	tr	41	tr	**75**	**1**	**83**	**1**	**64**	**1**
DAIN			3	tr	29	tr	**69**	**2**	50	1	18	1
PHMU3	17	tr	20	tr	18	tr	56	1	33	tr	9	tr
ANSES	3	tr	7	tr	35	tr	50	tr	**83**	**tr**	45	tr
STNEN2	7	tr	20	tr	35	1	44	1	**67**	**1**	45	1
HEHO5					6	tr	13	tr	**67**	**1**	27	tr
LILE3			2	tr	24	tr	25	tr	50	tr		
BRAN	3	tr	3	tr	12	tr	44	tr	50	tr	18	tr
LIFI									17	tr	55	3

Bold text **60-**percent constancy
Black text 25–59-percent constancy
Gray Text ≤ 24-percent constancy

Table 2.8. *Association table for vegetation classification example.*

Grp	Plot No.	BASA3	PUTR2	ARTRP	ELSP3	FEID	ARTRV	POGR9	ELTR7	GEVI2	ARTRS	TRSP2	CARA6
1	J1810V	6		40	35	0							
	J1811V	5	7	30	30								
	J1814B	4	8	10	20	3							
	J1817B	3	3	10	30		3						
	BLEL01		7	20	45								
	H2001V		20	25	40								
	K2102V		20	20	20	2							
2	H1608B	10		8	17	23							
	G1306V	2		25	22	28			0				
	F1225B	10		10	30	5				0			
	F1214B	1	1	20	10	25							
	G1316B	10	1	17	40	0							
	G1705B	7	8	11	15	8							
	H1804B	1	5	17	25	15							
	I1705V	10	0	30	20	10							
	I1706V	3	7	17	20	10							
	I1712V	0	8	27	12	25							
	I1720B	4	6	18	20	5							
	I1723B	5	2	10	0	40							
	K1901V	1	10	35	30	15							
	I1902V		30	45	19	12							
	I1711B			30	7	35				0			
3	E0704B			5	15	20	25	0					
	F1001V			1	15	35	24			1			
	F1220B				15	35	20						
	E0915B				20	15	35	0					
	E0507B				0	50	30	0		0			
	F1202V					40	35						
4	E0509B					45	25						
	R2805N					20	20	1	15				
	F1002B					40	30	1	3	1			
	F1204B					40	35	1	0	0			
	F0202V					40	30	0	0			0	
	E0703B					40	35	0	4	0			0
5	D0422B					40		1	10		37		
	D0218B					30		0	5		45	0	
	D0436N					25		4	5	2	12		
6	B0608B					30	10	1	10	2	15	2	2
	D0804B					30	5	2	20	25	25	2	2
	D0605B					40		0	15	0	11	4	2
	D0607V					35		2	6	4	29		
	Q2706V					10		1	25		30	5	

Group	Association short name	Association long name
1	ARTRP4-PUTR2/ELSP3	*Artemisia tridentata* var. *pauciflora—Purshia tridentata/Elymus spicatus*
2	ARTRP4/FEID-ELSP3	*Artemisia tridentata* var. *pauciflora/Festuca idahoensis—Elymus spicatus*
3	ARTRV2/FEID-ELSP3	*Artemisia tridentata* var. *vaseyana/Festuca idahoensis—Elymus spicatus*
4	ARTRV2/ELTR7	*Artemisia tridentata* var. *vaseyana/Elymus trachycaulus*
5	ARTRS2/ELTR7	*Artemisia tridentata* ssp. *spiciformis/Elymus trachycaulus*
6	ARTRS2/TRSP2	*Artemisia tridentata* ssp. *spiciformis/Trisetum spicatum*

taxa chosen to name the type, those of the same life form (tree, shrub, herb, or nonvascular) are separated by a hyphen (-); those of differing life forms are separated by a slash (/). Taxa occurring in the uppermost layer are listed first, followed successively by those in lower layers. Within the same life form, the order of names generally reflects decreasing levels of dominance, constancy, or diagnostic value of the taxa. Ensure that plant codes (i.e., plant symbols) for vascular plant taxa used in type names follow the USDA-NRCS PLANTS database. Table 2.9 provides several naming conventions examples.

Table 2.9. *Examples of vegetation type names.*

Short name	Scientific name	Common name
ABGR/LIBO2	*Abies grandis*/*Linnaea borealis*	Grand fir/twinflower
TSHE-ABGR/CLUN	*Tsuga heterophylla-Abies grandis*/*Clintonia uniflora*	Western hemlock-Grand fir/queencup beadlily
ARTRP4/FEID-ELSP3	*Artemisia tridentata* var. *pauciflora*/*Festuca idahoensis-Elymus spicatus*	Mountain big sagebrush/Idaho fescue-bluebunch wheatgrass

2.7.2 Vegetation Type Descriptions

A necessary product of the vegetation classification process is a standardized taxonomic description of the alliance, association, or dominance type. A taxonomic description defines the floristic boundaries of the vegetation type and describes the characteristics that distinguish it from other vegetation types. A taxonomic description includes the following elements:

- **Type Concept.** A description of the distinguishing characteristics of the vegetation type. This should include the diagnostic species that distinguish the type from others and a general description of physiognomy including major life forms and layers.

- **Geographic Distribution.** A description should include the geographic distribution of the vegetation type by State or national forest.

- **Vegetation Data.** Plant taxa used in describing a vegetation type should be referred to by a binomial Latin name as well as a common name. Provide a table of plant taxa, with constancy (percent of plots in which a given species or subspecies occurs), average percent canopy cover, and range of percent cover of each taxon included in the type. Clearly indicate diagnostic species in the constancy/cover table. Specify the main life forms in each type, including height and percent cover of each life form or layer, as applicable. The sample size for the type must also be included.

- **Environmental Data.** Provide information on site conditions, such as climate, elevation, slope aspects, slope steepness, topographic slope position, landforms, geologic parent materials, and soils. Describe the range and the central tendency of these attributes.

- **Vegetation Dynamics.** A description should include the successional and disturbance factors that influence the type. Note its successional relationship to other types, if known.

- **Management Interpretations.** Descriptive information relevant to management options and limitations, such as timber productivity, wildlife habitat values, forage productivity, species diversity, and structural diversity.

- **Hierarchy.** State the placement of the association, alliance, or dominance type in the FGDC physiognomic hierarchy from division through group.

- **Supporting Data.** Specify plot data used in the analysis of the type, including the number of plots used and the method of analysis used for determining the vegetation type.

- **Comparison to Other Types.** Describe how the vegetation type compares to other similar described types. Include references for those types.

2.7.3 Vegetation Type Metadata

Data that support the description of specific vegetation types (i.e., alliances and associations) can be stored directly in the corporate database. Examples include the type name, any coding convention, publication reference, examiners, supporting plot list, type concept, and summary data, such as species cover and constancy.

Certain classification systems that are national in scope are distributed with the corporate NRIS database to support plot, polygon, or map unit data where needed. All vegetation types from the following three existing vegetation classification systems are distributed and managed nationally in the NRIS database:

- All levels of the FGDC physiognomic classification.
- Society of American Foresters Cover Types.
- Society of Rangeland Management Cover Types.

Section 3. Existing Vegetation Mapping Protocol

3.1 Purpose

The purpose of the protocol that this technical guide describes is to define specific data standards and provide guidelines for a mapping methodology associated with four map levels. The four levels are intended to meet a full range of business requirements from national to subforest geographic extents.

3.1.1 Background and Specific Objectives

Consistent map products currently exist in widely scattered locations across the agency and were developed in the absence of national standards. The objective of this technical guide is to provide direction for the development of consistent and continuous existing vegetation map products at the four hierarchical levels. Successful implementation of these standards and guidelines will allow appending of existing vegetation maps at the appropriate level and facilitate consistent and comparable analyses in and across forests, Regions, and the Nation. Additionally, consistent vegetation maps at ecologically based extents (e.g., ecological sections) are important to serve the forest, multiforest, regional, and national business requirements.

The protocol contained in this technical guide identifies data standards and provides guidelines for map project planning, design, development, and assessment; field and aerial photography data; and metadata/documentation. The intent of this protocol is not to be directly prescriptive regarding methods for project planning and product development; however, numerous specific methodological considerations are provided as references for the planning and implementation of the mapping process. To determine the most cost-effective and appropriate means for meeting existing vegetation information needs is the role of program and project managers. At the beginning of each primary subsection, a bulleted synopsis summarizes the included content.

3.1.2 Business Requirements

In this section: *The relationship of significant business functions to map levels*

Business requirements are the basis for identifying the fundamental data elements of the map unit design process. These business requirements are determined through an information needs assessment. Localized Forest Service and cooperators' business requirements may be factored into the definition of standard data elements, as well as additional data elements in existing vegetation map products.

Table 3.1. *Existing vegetation map levels supporting Forest Service business.*

Map level	Representative business requirements
National	National strategic inventory
All levels	Land management planning
All levels	Cooperative program support
All levels	Post-fire assessment
Broad, mid	Multiforest/bioregional planning
Broad, mid, base	Forest risk assessment
Broad, mid, base	Rangeland assessment
Broad, mid, base	Cumulative effects analysis
Broad, mid, base	Viability assessment
Mid, base	Forest plan monitoring
Mid, base	Forest/regional fuels assessment
Mid, base	Ecosystem assessment by watershed
Base	Project planning, monitoring, and evaluation

Table 3.1 identifies a number of business functions common across the Forest Service. The standard map units and map features identified in this section of the technical guide are shared among these business functions. In addition to the standard map units defined in this guide, specific business functions can drive the definition of regional or local standards. Additional local standards may include greater thematic detail, supplemental data elements, or finer spatial resolution. As part of a mapping project plan, carefully consider the map level most likely to provide the required information. Mapping additional elements will require additional resources.

In table 3.1, a number of Forest Service business requirements are related to the map levels typically required to support those functions. Many of those functions occur at several Forest Service organizational levels and are often supported by different map products. The map product levels defined in section 1.3.2.2—national, broad, mid, and base—are intended to support the basic information needs that exist throughout the Forest Service and define a relationship between the map products that support those needs.

3.1.3 Products

In this section:

- *Map product format and content*
- *Desirable byproducts of mapping*

The primary product at each level of mapping will be a geospatial database and Federal Geographic Data Committee (FGDC)-compliant metadata. The base-level map product will be a vector format geospatial database; the three remaining levels in the map hierarchy are optionally raster or vector format. These map products must meet the specified standards, be geographically continuous in the area of interest, and contain the data attributes identified in tables 3.3 through 3.7.

Data sources and deliverable byproducts of a mapping process may include the following: remotely sensed data, including satellite imagery and aerial photography, digital elevation models (DEMs), interim map products (e.g., image classifications, delineated polygons), and field reference data.

3.2 Planning, Design, Development, and Assessment

This section elaborates on the project planning and map unit design outlined in section 3.1.1. Map standards will subsequently be defined for the spatial and thematic data attributes of the four levels of vegetation maps. Individual concepts of map unit design are detailed in the subsections below.

3.2.1 Project Management

In this section: *Steps for planning a mapping project*

Project management is the planning, organizing, and managing of resources—personnel, equipment, time, money, and data—to accomplish a defined objective.

Successful project management requires a clear definition of project objectives, identification of all tasks needed to reach the objectives, proper allocation of resources to accomplish tasks, and constant monitoring of task accomplishments and resource expenditures.

3.2.1.1 Information Needs Assessment Process

To start an information needs assessment, gathering general information about the requirements of planned natural resource projects and relate these needs to specific business requirements for a vegetation map. Information gathering activities may include the following:

- Identify the project needs:
  - Specify the project area (e.g., watershed, forest, ecosection).
  - Specify the objectives of the project (e.g., analysis objectives and interpretation needs).
  - Include the overall project goals and the expected individual products/activities in the list of objectives.
  - Consider the objectives in the context of time, budget, and staff constraints.
- Identify the data requirements:
  - Conduct preliminary research to locate and examine applicable existing vegetation data and other ancillary data.

- Evaluate existing information for factors such as currency, minimum standards compliance, attributes needed to meet project requirements, and correlation or relevance to the area of interest.
- Determine the need for developing and/or acquiring new datasets. This may include digitizing, purchasing imagery, and other procurement methods.
- Consider issues of scale, resolution, precision, and accuracy of the required data.
- Identify the level and types of vegetation classification to be mapped based on analysis objectives and interpretation needs.

- Identify analytical needs:
  - Determine the analytical methods to satisfying the project objectives.
  - Determine the types of programs, models, or algorithms required for processing and analysis.

3.2.1.2 Identify Resources Needed for Mapping

If the information needs assessment results identify human and information processing resources as requirements, develop an acquisition plan. The following items are identified for inhouse mapping. These same factors can be used to develop a government estimate of costs for outsource contracting for a vegetation map.

- Identify the processing system requirements:
  - Consider whether existing hardware and software are appropriate and adequate for performing project tasks and producing output products.
  - Determine whether the datasets are in the proper format.
  - Determine the types of preprocessing, processing, and postprocessing operations that must be performed.
  - Consider whether the available data storage is adequate for processing and archiving.
- Identify the project's staffing requirements:
  - Determine the availability of appropriate staff.
  - Determine the need to obtain outside expertise (e.g., programmers, remote sensing specialists, resource specialists, or statisticians).
  - Calculate the time needed to locate outside expertise in the context of project budget and schedule.
  - Consider training needs of project staff.

3.2.1.3 Vegetation Mapping Project Plan, Schedule, and Budget

Maintain and update the vegetation mapping project plan as a written document throughout the duration of the project. At a minimum, the project plan should contain these four elements:

1. The abstract summarizes the project to facilitate communication to interested parties.
2. The technical design clearly and specifically fulfills these requirements:
   - State project objectives and identify output products.
   - State the methods and data sources to be used.
   - Break the workload into identifiable tasks.
   - Estimate effort, in hours, and type of personnel and skills by task.
   - Estimate resource needs including costs, personnel, and equipment needed by task.
   - Identify material and services needed by task.
   - Assess risk of failure by task and provide contingency plans for high-risk tasks.
   - State the data standards to be followed.
   - Include a quality control process and accuracy requirements.

   The breakdown of tasks in the technical design is particularly important. Tracking individual tasks is much easier than trying to manage the whole project as a whole. The task breakdown is also used to monitor progress and budget. Assessing risks and formulating contingency plans are also important to the technical design. Typical risks for vegetation mapping projects include the following:

   - Problems related to using new or untried technology.
   - Probability that primary data for certain geographic areas are not available.
   - Probability of delay in acquiring imagery or other data.
   - Budget and schedule overruns.
   - Problems related to the logistical challenges of fieldwork.
   - Training or hiring of skilled personnel.
   - Failure to meet specified accuracy standards.
3. The project schedule is constructed from the technical design as follows:
   a. Start with the time required for each task as listed in the technical design.
   b. Determine which tasks are concurrent and which are sequential.
   c. Consider the availability of personnel.
   d. Consider constraints related to fieldwork, access to computers, and availability of data.
   e. Include time for contingency plans.
   f. Develop the final schedule.
4. The project budget is calculated by assigning costs to each task identified in the technical design. Make sure to include salaries, travel and training costs, equipment and material needs, and required outside services, as well as personnel time.

3.2.2 Map Standards

In this section:

- *Requirements for map unit keys*
- *Thematic map accuracy requirements*
- *Spatial map accuracy requirements*
- *Definition of standard map attributes*
- *Minimum map feature*
- *Map update cycles*

3.2.2.1 Map Unit Keys

Before developing the map, classification schemes for each map unit standards and any additional data attributes must be developed. Map keys define mutually exclusive map units in each classification scheme. Ensure that map units are clearly identifiable through the mapping process and on the ground. Physiognomic and floristic map keys must reference the appropriate information source specific to the mapping project (i.e., all vegetation associations used to define the desired map units). Map keys must also contain specific logic for defining and differentiating each physiognomic, floristic, and structural map unit.

3.2.2.2 Map Attributes

Existing vegetation maps are based on the areal extent of the map features, the associated physiognomic and floristic composition attributes, and attributes for structural characteristics. This technical guide identifies vegetation characteristics common to many of the business needs previously identified. The four attributes described below—physiognomic, floristic composition, floristic map, and structural characteristic—are standard for the base, mid, and broad levels. Additional attributes may be necessary to meet local information needs and will be defined by regional and/or forest program managers. Locally specific standards will apply across their logical geographic extents to ensure data consistency.

Physiognomic and Floristic Composition Attributes

Physiognomic and Floristic Composition. Physiognomic and floristic composition are the fundamental components of a vegetation map. The National Vegetation Classification Standards (NVCS) (FGDC 1997) defined a hierarchical system for arranging these components into taxonomic units, which is the foundation for the map hierarchy described in this technical guide. When the NVCS was adopted as an FGDC standard in 1997, the standard described the physiognomic and floristic composition components. Two floristic levels, alliances and associations, were defined. Standards were provided for the physiognomic portion of the hierarchy only.

To further develop NVCS, the Ecological Society of America (ESA), through a memorandum of understanding with the FGDC, established a vegetation classification panel (ESA 1999). In May 2002, the ESA vegetation panel submitted Standards for Associations and Alliances of the U.S. National Vegetation Classification (Jennings et al. 2004). The

ESA document states that "Consistent with FGDC principles, the standards here for floristic units relate to vegetation classification and are not standards for the identification of mapping units. Nevertheless, types defined using these standards can be mapped and can be used to design useful map units subject to the limitations of scale and mapping technology." The ESA-proposed standards for associations and alliances, along with the 1997 NVCS physiognomic standards, form the basis for the mapping standards identified in this technical guide. All map units are assumed to fit somewhere in this classification hierarchy, regardless of whether they are included in the FGDC classification.

Landscape features dominated by land uses (e.g., urban areas) and water bodies are to be mapped as nonvegetative, if they do not meet the minimum standard for vegetative cover. Mapping continuous areas requires using land use and cover as well as vegetation classification systems. Although many areas of the national forests could be mapped using map units defined by vegetation physiognomic classification only, sparsely vegetated and nonvegetated areas mapped by this classification only provide little information to the map user. Adding land cover label assignments such as water, barren land, or snow, would be more informative. Urban and agricultural land use dominated areas will classify, more often than not, as vegetated condition. Land use can be mapped for vegetative conditions alone; however, having additional information related to the land use enables map users to answer questions, such as the amount and location of urban forests or agricultural vineyards. For an illustration of the intersection between land use/land cover and physiognomic class and subclass, see appendix 3G.

Each map level requires a minimum degree of compositional detail. The national level requires the least detail, and the base level the greatest. At a minimum, the most detailed classification of map units must equal or exceed the least detail required map unit at the next level higher in the map hierarchy. As an example, table 3.3A lists dominance type as the most detailed floristic category required for the mid level; the base level requires more detailed alliances. This ensures that a given map product will aggregate up to the next level and still meet the required compositional detail at that level. At each level in the map hierarchy, every category above the lowest required category is also required.

The FGDC NVCS requires floristic map units based on vegetation types from a fully documented and adopted existing vegetation classification system. The lack of near term availability of adopted FGDC vegetation classifications, however, may limit the ability to develop floristic map units. Additionally, identified business needs may influence the level of floristic detail defined in the map key. Technological limits and resource constraints also may preclude the development of the full range of taxonomic units identified to meet business requirements. In all cases, map units and associated keys must reference the classification system documents on which they were based. Where an adopted FGDC existing vegetation classification system is available but map detail is more generalized, base floristic map units on and reference that classification system.

Tables 3.3A through 3.4 identify the required (R) or optional (O) hierarchical categories of physiognomic and floristic composition for each level of map product. Table 3.4 offers an example of classes for the listed attributes of the hierarchy. The FGDC document FGDC-STD-005—Vegetation Classification Standard, available at www.fgdc.gov/standards/status, is the source for physiognomic categories.

Continuous Land Cover Mapping and Land Use Classes. Landscape features dominated by land uses (e.g., urban areas) and water bodies are mapped as nonvegetated in the physiognomic hierarchy if they are less than the minimum standard for vegetative cover. Mapping continuous areas, however, requires using land use and cover as well as vegetation classification systems. Therefore, land cover and land use classes defined in the Anderson 1 classification system (Anderson et al. 1976) are required for nonvegetated areas. Although many areas of the national forests could be mapped using map units defined by vegetation physiognomic classification only, sparsely vegetated and nonvegetated areas mapped solely as such provide little information to the map user. Land cover labels such as water, barren land, or snow are more informative and allow for the most integrated representation of vegetated and nonvegetated landscapes.

Land use labels in vegetated polygons are not a required component of the mapping protocol; however, information needs may dictate the codevelopment of land use and existing vegetation map labels. Urban and agricultural land use dominated areas will usually classify as a vegetated condition. Although many land uses can be mapped for their vegetated conditions alone, additional information related to the land use enables map users to answer questions such as the amount and location of urban forests or agricultural vineyards. For an illustration of the intersection between land use/land cover and physiognomic class and subclass, see appendix 3G.

Table 3.2 depicts a simplified relationship between the Anderson 1 land use/land cover classification system and physiognomic classes.

Physiognomic Classes. Tables 3.3A through 3.3D identify the NVCS physiognomic levels that are required attributes at each mapping level.

Floristic Composition. Floristic composition is a fundamental attribute of existing vegetation maps comprising associations and alliances. Alliances and associations are classification standards, not map unit standards for the labeling of map features. Nevertheless, vegetation alliances and associations defined using classification standards can be used to design map units subject to the limitations of scale and mapping technology (Jennings et al. 2004).

The association is the most basic unit of vegetation in the NVCS. The NVCS defines an association as “a recurring plant community with a characteristic range in species

Table 3.2. *Relationship between Anderson 1 and FGDC physiognomic class.*

FGDC Physiognomic class	**Anderson 1 land use land cover**								
	Urban or built-up land	Agricultural land	Range land	Forest land	Water	Wetland	Barren land	Tundra	Perennial snow or ice
Closed tree canopy—forest	X	X		X		X			
Open tree canopy—savannah	X	X		X		X			
Shrubland	X	X		X		X		X	
Dwarf shrubland	X		X			X		X	
Herbaceous—shrub steppe	X	X	X			X		X	
Herbaceous grassland	X	X	X			X		X	
Nonvascular						X	X	X	
Sparsely vegetated	X	X					X		
Nonvegetated	X				X		X		X

Note: Herbaceous—shrub steppe is added as a Forest Service addition to the NVCS.

Table 3.3A. *Physiognomic map attributes.*

Physiognomic Classification Category	**Map level**			
	National	Broad	Mid	Base
Physiognomic order[a]	R	R	R	R
Physiognomic class[a] woody vascular plants (tree/shrub) required; herbaceous and nonvascular optional	R	R	R	R
Physiognomic subclass[a] woody vascular plants (tree/shrub) required, herbaceous and nonvascular optional	O	R	R	R

[a] Reflects NVCS physiognomic hierarchy with modifications necessary to meet the Forest Service business requirements (see section 1.5.1.5 for details).
Note: R=required; O=optional.

Table 3.3B. *Physiognomic classes—order.*

Name	**Definition**
NVCS order—vegetated division	
Tree dominated order	Areas where tree life form (National Resources Conservation Service [NRCS] plants growth habit has at least 10-percent cover in the uppermost strata during the peak growing season).
Shrub dominated order	Areas where shrub and/or subshrub life forms are at least 10-percent cover in the uppermost strata.
Herbaceous/nonvascular dominated order	Areas where herbaceous and/or nonvascular life forms are at least 10-percent cover in the uppermost strata.
No dominant life form order	Areas where vegetation cover is at least 1 percent, but the area does not classify as tree, shrub, or herbaceous/nonvascular dominated.
NVCS Order—nonvegetated division	
Nonvegetated order	Nonvegetated order usually associated with open water or land use dominated, human-modified land, such as heavy industrial, commercial, and transportation facilities.

composition, specific diagnostic species, and a defined range in habitat conditions and physiognomy or structure" (Jennings et al. 2004). Because the delineation of associations requires identification of understory species that are not present in the upper canopy, direct use of associations is appropriate only where the mapping effort includes extensive ground observations.

The NVCS specifies that floristic alliances are abstract units of vegetation determined by the floristic characteristics shared among associations and the physiognomic-ecological characteristics of the higher levels of the classification. Thus, the alliance is defined as a grouping of associations with a characteristic physiognomy and habitat and that share one or more diagnostic species that, as a rule, are found in the uppermost or dominant stratum of the vegetation.

The development of existing vegetation map units based on NVCS require the availability of alliance descriptions, based on verified associations, developed from appropriate field plot data as described in section 2 of this technical guide, and is required for base-level mapping. Because the ESA-proposed standards for associations and alliances have not been formally adopted as part of the NVC, many years may pass before a comprehensive

Table 3.3C. *Physiognomic classes—class.*

NVCS class—vegetated (as modified by NFS for minimum life form cover requirements)	
Name	**Definition**
Tree dominated order	
Closed tree canopy	Tree life form dominated land with at least 60-percent canopy crown closure. Tree life form is defined by NRCS PLANTS Master growth habit for tree.
Open tree canopy	Tree life form dominated land with at least 25-percent but less than 60-percent canopy crown closure. Tree life form is defined by NRCS PLANTS Master growth habit for tree.
Sparse tree canopy	Tree life form dominated land with at least 10-percent but less than 25-percent canopy crown closure. Tree life form is defined by NRCS PLANTS Mastergrowth habit for tree. *This class is a Forest Service addition to NVCS Order*.
Shrub dominated order	
Shrubland class	Tall shrub life form dominated land with at least 10-percent cover. Less than 10-percent tree cover may be present.
Dwarf shrubland class	Subshrub life form dominated land with more than 10- percent cover of subshrubs. Less than 10-percent tree and/or tall shrub cover may be present.
Herbaceous and nonvascular dominated order	
Herbaceous—shrub steppe class (optional)	Herbaceous life form dominated land with at least 10-percent cover, and shrub and/or subshrub life form of at least 5-percent but less than 10-percent cover. *This class is a Forest Service addition to NVCS Order.*
Herbaceous—grassland class	Herbaceous life form dominated land with at least 10-percent cover. Tree, shrub, and/or subshrub life forms must be less than 10-percent cover.
Nonvascular class (optional)	Nonvascular life form dominated land with at least 10-percent cover. Tree, shrub, subshrub, and grass life forms must be less than 10-percent cover.
No dominant life form order	
Sparsely vegetated class	Total vegetative cover at least 1 percent but less than 10 percent. Vegetation is scattered or nearly absent; total vegetation cover, excluding crustose lichens (which can sometimes have greater than 10-percent cover) is generally 1 to 10 percent.

Table 3.3D. *Physiognomic classes—subclass.*

NVCS subclass—vegetated	
Name	**Definition**
Subclass for tree, shrub, and subshrub dominated classes	
Evergreen vegetation subclass	Evergreen vegetation associations in which evergreen plants generally contribute 75 percent or more to the total dominate plant cover. Evergreen species are woody plant species that have green leaves all year round or a plant that in xeric habitats has green stems or trunks and never produce leaves.
Deciduous vegetation subclass	Deciduous vegetation associations in which deciduous woody plants generally contribute 75 percent or more to the total dominate plant cover. Deciduous species are woody plants that seasonally lose all their leaves and become temporarily bare-stemmed.
Mixed evergreen-deciduous vegetation subclass	Tree life form dominated land with at least 10-percent but less than 25-percent canopy crown closure.
Subclass for herbaceous dominated classes	
Perennial graminoid subclass (optional)	Perennial graminoid vegetation associations, graminoids that persist for several years, and species generally contributing to more than 50 percent of the herbaceous vegetation.
Perennial forb subclass (optional)	Perennial forb vegetation associations, forbs (including ferns and biennials) that persist for several years, and species, generally contributing to more than 50 percent of the herbaceous vegetation.
Annual graminoid and/ or forb subclass (optional)	Herbaceous life form dominated land with at least 10-percent cover, and shrub and/or subshrub life form of at least 5-percent but less than 10-percent cover. *This class is a Forest Service addition to NVCS Order.*
Hydromorphic rooted vegetation subclass (optional)	Hydromorphic rooted vegetation of nonemergent graminoids or forbs, structurally support by water, and rooted in substrate (e.g., pond weeds and water lilies).
Subclass for nonvascular dominated classes	
Bryophyte subclass (optional)	Bryophytes (including mosses, hornworts, and liverworts) vegetation generally dominates the nonvascular cover.
Lichen subclass (optional)	Lichens (foliose or fruticose) generally dominate the nonvascular cover.
Alga subclass (optional)	Algae generally dominate the nonvascular cover.
Subclass for sparsely vegetated classes	
Consolidate rock subclass (optional)	Consolidated rock with sparse vegetation, such as cliffs, outcrops, lava flows, bedrock.
Boulder, gravel, cobble, or talus subclass (optional)	Tallus/scree slopes, rock flats of boulders, cobble, or gravel with sparse vegetation.
Unconsolidated material subclass (optional)	Unconsolidated material (soil, sand, and ash), such as sand dunes, sand flats, sand beaches and shores, agriculture field-bare soil, nonagriculture disturbed areas, tidal mud flats
Urban or built-up subclass (optional)	Meets Anderson Level 1 land use classification for urban and built-up land but has sparse vegetation. Residential buildings, commercial and industrial complexes, transportation and utilities, paved-over areas.

Table 3.4. *Floristic map attributes.*

Floristic Classification Category	**Map level**			
	National	Broad	Mid	Base
Cover types and type groups (SAF/SRM)	O	R	R	R
Dominance types (locally defined)	O	O	R	R
Alliances[a]	O	O	O	R
Associations[a]	O	O	O	O

[a] Currently defined levels of the NVCS hierarchy; see section 1.5.1.5 for details.
Note: R=required; O=optional.

set is available across the country to serve as a basis for map unit design. To ensure that existing vegetation maps meet FGDC standards, use verified and peer-reviewed associations and derived alliances for the development of map units.

Interim approaches exist for defining existing vegetation map units in the guiding principles of the NVC. These approaches for mid-level mapping include using provisional associations and alliances maintained in the NatureServe classification database (NatureServe 2001), with key components available on the NatureServe Web site (www.natureserve.org/explorer), as well as regionally developed dominance type classification systems. Other acceptable alternatives for broad level mapping include using cover types including the Society of American Foresters (SAF) forest types (Eyre 1980) and the Society for Range Management (SRM) cover types (Shiftlet 1994) to develop the floristic characteristics of map units.

Dominance types have been widely used in the development of map units where remote sensing imagery is the primary basis for map feature delineation. As described in Jennings et al. (2004):

> "Under the dominance approach, vegetation types are classified on the basis of dominant plant species found in the uppermost stratum. Determining dominance is relatively easy, requiring only a modest floristic knowledge. However, because dominant species often have a geographically and ecologically broad range, there can be substantial floristic and ecologic variation within any one dominance type."

Dominance types provide a simple method of classification based on the floristic dominant (or group of closely related dominants) as assessed by some measure of importance such as biomass, density, height, or leaf area cover (Kimmins 1997). They represent one of the lowest levels in several published classification hierarchies" (e.g., Cowardin et al. 1979, Brown et al. 1980).

Cover types are typically based on the dominant species in the uppermost stratum of existing vegetation. Forest cover types developed by the Society of American Foresters (SAF) are based on the tree species that may by one or more species, having a plurality of basal area as measured from ground plots" (Eyre 1980). For rangelands, the SRM recently developed cover types based on the plurality of canopy cover by dominant species (Shiftlet 1994).

In most cases, the map unit descriptions will be parallel to the classification hierarchy established as stated in the ESA Vegetation panel report (Jennings et al. 2004). In this guide, these will be referred to as "homogenous type" map units. However, as Jennings and others (2004) have suggested, "It is important to remember that, while vegetation varies continuously in time and space, classification partitions that continuum into discrete units, primarily for practical reasons. …[Map unit design] approaches, particularly those that aggregate alliances and associations using vegetation physiognomy as criteria may be more practical for some uses. For example, in using the NVC alliance class as a target for vegetation mapping by the Gap Analysis Program (GAP) (Jennings 2000), not all alliance types can be resolved. In such cases, alliance types are aggregated into map units of 'compositional groups' or 'ecological complexes' Although not part of the NVC standard, such alternative approaches would result in units of vegetation that are just as 'legitimate.'" Similar situations may arise as the Forest Service attempts to implement mapping standards based on the NVC. In this technical guide, the term **vegetation complexes** is used as analogous to ecological complexes.

- **Homogenous types** are map units composed of a homogenous condition of vegetation or uniform type; a map unit composed of a single alliance or dominance type, at least 85 percent of the area in a polygon.
- **Compositional groups** are map units composed of alliances or dominance types that are spatially discrete but cannot be discriminated into separate map units by spectral signatures or landscape indices, such as slope, aspect, and elevation. For example, in the Southern United States compositional groups have been proposed in the GAP to accommodate mixed vegetation dominated by southern yellow pine.
- **Vegetation complexes** are map units distinguished from compositional groups in that the spatial closeness of the alliances or dominance types prevents discrimination of separate map features. In North Carolina, for example, pocosin wetlands are spatially heterogeneous with pond pine woodlands intermixed with several evergreen shrubland alliances in such close proximity that they cannot be delineated separately yet form ecologically and spatially repeating patterns across the landscape.

Mapping units developed from the NVC apply to all existing vegetation regardless of successional stage or cultural influence. In many areas of the country, forests and other wild land environments may be intermixed with agricultural lands, recreational developments, and other developed areas where the vegetated cover meets the standards for mapping existing vegetation. Descriptions of these vegetative cover types are not included or are poorly represented in the NVC provisional associations and alliances or the SAF cover types. Some of these cover types may be included in SRM cover type descriptions. In many cases, existing vegetation map units will have to be defined to describe these portions of the landscape. Map unit descriptions will also need to be developed for areas where the extent of emergent aquatic vegetation or an exotic plant species is dominant and covers an area in excess of extent identified for a minimum map feature.

Figure 3.1 shows an example of map units and attributes in a map feature starting at the top of the hierarchy.

Figure 3.1. *Map units and attributes in a map feature example.*

Division: Vegetated
- Order: Tree dominated
- Class: Closed tree canopy
- Subclass: Evergreen forest
- Cover type (SAF): Douglas fir
- Dominance type (R5-CALVEG): Douglas fir
  - Alliance: Douglas fir forest—Bigleaf maple
- Association: Douglas fir—Bigleaf maple-hazelnut

Structural Characteristic Attributes

Tree Canopy Closure. Tree canopy closure is defined in this technical guide as the total nonoverlapping tree canopy in a delineated area as viewed from above. (Note that tree canopy closure is not defined by a hemispherical projection as viewed from below.) Tree canopy closure less than 10 percent is considered a nontree polygon. Table 3.5 identifies tree canopy closure breaks that are required for base, mid, and broad level maps. Canopy closure breaks at 10 percent (base-level) represent feasibly mapped approximations of a continuous canopy variable and offer the greatest flexibility for user-specified aggregation. The tree canopy closure breaks are consistent with the physiognomic class breaks for vegetation. Any additional divisions necessary to meet local requirements must be subdivisions of the categories listed in table 3.5.

Overstory Tree Diameter Map Units. Overstory tree diameter class is defined in this technical guide as any intervals into which a range of tree diameters may be divided for classification (Helms 1998). In this protocol, the mean diameter at breast height (d.b.h.) (4.5 feet, or 1.37 meters, above the ground) is calculated for the trees forming the upper or uppermost canopy layer (Helms 1998). This mean can be calculated as the Quadratic

Table 3.5. *Total tree canopy closure map units.*

Canopy closure categories (%)	Map level			
	National	Broad	Mid	Base
0				R
1–9.9		R	R	R
10–19.9				R
20–29.9			R	R
30–39.9				R
40–49.9	O	R	R	R
50–59.9				R
60–69.9				R
70–79.9		R	R	R
80–89.9				R
90–100				R

Note: R=required; O=optional.

Table 3.6. *Overstory tree diameter map units.*

<table>
<tr><th rowspan="2">Canopy closure categories (%)</th><th colspan="4">Map level</th></tr>
<tr><th>National</th><th>Broad</th><th>Mid</th><th>Base</th></tr>
<tr><td>0–4.9</td><td rowspan="7">O</td><td rowspan="7">O</td><td>R</td><td>R</td></tr>
<tr><td>5–9.9</td><td>R</td><td>R</td></tr>
<tr><td>10–19.9</td><td>R</td><td>R</td></tr>
<tr><td>20–29.9</td><td>R</td><td>R</td></tr>
<tr><td>30–39.9</td><td rowspan="3">R</td><td>R</td></tr>
<tr><td>40–49.9</td><td>R</td></tr>
<tr><td>50+</td><td>R</td></tr>
</table>

Note: R=required; O=optional.

Mean Diameter (QMD) or as basal-area-weighted mean diameter. Table 3.6 identifies tree diameter class breaks that are mandatory for base- and mid-level mapping. Developing tree size map units at the broad and national levels is optional. Additional categorical breaks required to meet local requirements in the mid- and base-levels must aggregate to the standard tree diameter categories.

3.2.2.3 Thematic Accuracy

Conduct accuracy assessments of the defined map attributes as a standard part of the mapping process. These assessments should focus on the thematic content of the map and are not required to determine spatial accuracy of map feature delineations. Apply the spatial accuracy standards addressed in section 3.2.2.5 primarily to the data sources used to develop the maps and are not part of a thematic accuracy assessment.

Accuracy standards are addressed at two levels: (1) minimum accuracy required for a national corporate vegetation layer, and (2) ideal accuracy goals based on what can feasibly be obtained. Increased floristic and structural categorical detail and/or increased mapping difficulty usually result in a higher probability of map error. Realistic accuracy standards account for the degree of difficulty in mapping due to the nature and detail of each attribute. For example, physiognomy is less detailed and considered less difficult to map than the other map attributes and, therefore, has higher accuracy standards associated with it. Mapping feasibility, however, does not take precedence over the need for accuracy standards that ensure a useful product. Map attributes, required and optional, that do not achieve the minimum accuracy standard should populate a national corporate database structure. The inability to achieve the accuracy standards, however, does not require the disposal of map products that are the result of significant investment.

An objective evaluation of map accuracy results will illustrate the nature and magnitude of map error. A process should then be identified to improve accuracy on substandard map units. Documentation to alert users of the limited utility that may exist as a result of low accuracy may also be necessary. A map improvement process will comprise one or more approaches including remapping and redesign of the map units. Remapping should logically target the map attributes or map units in question and may require a change in mapping methodology. Redesigning map units based on mapping feasibility also provides an opportunity to achieve accuracy standards (see section 3.2.3), typically through class aggregation. Aggregating classes to map units that are broader than the standard for the desired map level, however, effectively represents a shift to a coarser map level. A map product, therefore, may not uniformly meet the accuracy standards for a given map level. In a hypothetical example, a map meets base-level standards for tree canopy closure but only achieves floristic accuracy standards for dominance types. In this case, the map would be considered a mid-level map that exceeds the minimum standard for tree canopy closure.

To determine map accuracy, several approaches can be taken, some of which are covered in section 3.2.2.3. The assessment methods used should be documented and the results of all methods reported. The basis for determining compliance with the accuracy standards will be, by default, a standard error matrix unless otherwise stated in the accuracy assessment documentation. Regional vegetation data stewards will need to determine the adequacy of a given accuracy assessment method for determining standards compliance.

Table 3.7 lists accuracy goals and standards for the required data attributes at each map level. Accuracy percentages refer to overall weighted accuracy for each map attribute.

Table 3.7. *Map attribute accuracy goals and requirements.*

Vegetation map attribute	**Map level**			
	National goal standard (%)	Broad goal standard (%)	Mid goal standard (%)	Base goal standard (%)
Physiognomic order	80–70	90–80	90–80	90–80
Physiognomic class	80–70	90–80	90–80	90–80
Physiognomic subclass		90–80	90–80	90–80
Alliance		80–65	85–65	85–65
Association		80–65	85–65	85–65
Cover type		80–65	85–65	85–65
Dominance type		80–65	85–65	85–65
Tree canopy closure		80–65	85–65	80–65
Tree diameter class			80–65	80–65

3.2.2.4 Minimum Map Feature

Minimum map feature is the term used to describe the smallest size polygon required in a map. A homogeneous area must be delineated in a map if this area is equal to or greater in areal extent than the minimum map feature standard for each map level. Stated another way, no differing condition, as defined by the map unit design, that is greater in area than the minimum map feature can be left as an unmapped inclusion in a larger polygon. Depending on technical feasibility and business need, it may be necessary to map features smaller in areal extent than the minimum map feature standard.

Table 3.8 defines the minimum map feature standard for each of the map levels.

Table 3.8. *Minimum map feature standard.*

	Map level			
	National	Broad	Mid	Base
Minimum map unit (MMU) (acres)	500	20	5	5

3.2.2.5 Georegistration

Each level of the map hierarchy is intended to cover a general analysis scale and/or business function area. Correspondingly, a measure of spatial precision and accuracy is implied at each level. Spatial precision is generally determined by the data sources and methods used to develop a map. Guidelines for appropriate data sources and methods are outlined in section 3.24. Map scale equivalencies are established for each map level (i.e., base = 1:24,000, mid = 1:100,000). Obtain the geospatial positioning accuracy of imagery and ancillary datasets used to derive the existing vegetation maps from the data provider. The geospatial positioning accuracy of intermediate and final geospatial datasets produced during the development of an existing vegetation map and any input datasets will be calculated according to the standard defined in *Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data* (FGDC-STD-007.3-1998).

The National Standard for Spatial Data (NSSDA) is a data usability standard that defines the process for calculating and reporting the geospatial positioning accuracy of the data. The data producer is required to determine and report the accuracy of their datasets according to NSSDA. The NSSDA uses root-mean-square error (RMSE) at the 95-percent confidence level to determine positional accuracy of datasets in ground units. The accuracy is be tested by comparing the planimetric coordinates of a minimum of 20 well-defined points in the dataset with coordinates of the same points from an independent source of higher accuracy. If the positional accuracy of a dataset by the prescribed procedure cannot be determined, the NSSDA identifies three alternatives for determining positional accuracy: deductive estimate, internal evidence, and comparison to source. Using these alternatives is most appropriate for estimating the positional accuracy of ancillary datasets from external sources. Do not use these alternatives to determine the positional accuracy of the primary imagery sets used in producing existing vegetation maps. Digital orthophotos are generally the best source of control points for assessing the accuracy of existing vegetation maps. Table 3.9 identifies the horizonal geospatial positioning accuracy standards for existing vegetation maps (datasets).

Table 3.9. *Horizontal accuracy requirements.*

	Map level			
	National	Broad	Mid	Base
Map scale	1:1,000,000	1:250,000	1:100,000	1:24,000
Horizontal accuracy	± 1666 ft	± 416 ft	± 166 ft	± 40 ft

3.2.2.6 Update Schedule

Vegetation composition and structure are dynamic; changes in vegetation regularly require refreshing existing vegetation maps. Each map level has an associated temporal scale that determines the frequency of map maintenance. In the extent of the time identified, a given map product will be updated to account for changes in vegetation that have typically resulted from sudden disturbance, such as fire, insect- and disease-caused mortality, silvicultural treatments, or rapid growth. Gradual successional changes are more difficult to identify and may need to be accounted for over longer time frames. Section 3.4.3 includes additional information on map maintenance.

Business needs and resource constraints will also play a role in determining the update cycle. A time range is listed for each map level to allow flexibility in planning map maintenance. Map products with a hierarchical relationship should be on a coordinated schedule to ensure that updates in the most detailed map are incorporated into upper level maps in a timely fashion. Table 3.10 lists the temporal scale or update period for each map level.

Table 3.10. *Map update frequency.*

	Map level			
	National	Broad	Mid	Base
Temporal scale	5–10 years	5–10 years	1–5 years	1–5 years

3.2.2.7 Metadata

FGDC-compliant metadata will accompany map products developed at each level of the hierarchy. Section 3.4 includes additional information on metadata content and format.

3.2.3 Map Design

In this section:

- *Process for designing map units based on physiognomic, floristic, taxonomic units and structural technical groups*
- *Determining map feature size and delineation method*

Map design involves two fundamental processes. The first process, map unit design, identifies the vegetation characteristics to be mapped and assembles or develops classification keys for each map attributes used to describe those characteristics. Map unit design establishes the relationship between vegetation classification and mapping. The second process, map feature design, identifies the spatial characteristics and structure of the map. Both processes are implemented to comply with vegetation map standards and adopted vegetation classifications. Section 3.2.3.3 provides hypothetical examples to illustrate these process relationships.

3.2.3.1 Map Unit Design

As described in section 1.3.2, the relation of vegetation classification to mapping provides the basis for map unit design. **Classification** is the process of grouping of similar entities into named types or classes based on selected shared characteristics. (Section 1.3 includes a detailed explanation of the nature of vegetation classification.) **Vegetation mapping** is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. Patterns of vegetation types cannot be recognized until the types have been defined and described. Consequently, consistent mapping of vegetation types requires that a vegetation classification be developed beforehand. Any mapping based on vaguely defined types will be inconsistent, hard to validate, and difficult to compare with other vegetation maps.

The mapping standards for existing vegetation defined in this section include five types of classifications. The physiognomic and vegetation type classifications are based on floristic characteristics; the total vegetation canopy cover, tree canopy cover, and tree size classifications are based on structural characteristics. The physiognomic and vegetation type classification systems consist of associated sets of **taxonomic units** that are the basic set of classes or types that comprise the classification systems. Similarly, the total vegetation canopy cover, tree canopy cover, and tree size classifications consist of associated sets of **technical groups** that are the basic sets of classes that comprise the classification systems. Taxonomic units and technical groups represent a conceptual description of ranges and/or modal conditions in vegetation characteristics. These taxonomic units and technical groups should provide the basis for vegetation maps that are consistent with the mapping objectives, appropriate for the map level being produced, and within the limitations of mapping technology. Establishing the relationship between these vegetation classifications and map products depicting them is accomplished through the **map unit design** process.

A **vegetation map unit** is a collection of areas defined and named the same in terms of their component taxonomic units and/or technical groups (adapted from USDA Soil Survey Division Staff 1993). These vegetation map units can be based on the taxonomic units and technical groups of physiognomic, floristic, or structural classifications or combinations of these. Map units are designed to provide information and interpretations to support resource management decisions and activities. The map unit design process establishes the criteria used to aggregate or differentiate vegetation taxonomic units and technical groups to establish corresponding map units. Therefore, a mapping unit comprises one or more taxonomic units and/or technical groups from one or more specific classifications. The criteria used to aggregate or differentiate within physiognomic types, vegetation types, or structural classes to form mapping units depends on the purpose of and resources devoted to any particular mapping project (Jennings et al. 2003). For example, map units designed to provide information on existing forest structure to characterize wildlife habitat or fuel condition would be based on a combination of tree canopy cover technical groups and overstory tree diameter technical groups. The map unit design process is more complex for floristic classifications than for relatively simple structural classifications. The mapping standards for vegetation cover, tree canopy closure, and tree diameter described in this section represent general purpose map unit designs for each structural classification at all map levels, although local information needs may occasionally require exceeding the standards.

Map units are depicted on maps in individual areas or delineations that are nonoverlapping and geographically unique referred to as **map features** (e.g., polygon delineations or region delineations). The map feature delineation process should be based on the map units identified in the map unit design process. Typically, one map unit is repeated across the landscape in many individual map feature delineations.

Map unit design identifies the collection of map features that share a common definition and label based on their vegetative characteristics (USDA Soil Survey Division Staff 1993). Each map unit differs, in some respect, from all others in a geographic extent. Map units are used as map attributes in a geospatial database. Map units are composed of one or more taxonomic units and/or technical groups that are differentiated in a map unit design process and characterized in map unit descriptions. Map units generalize all possible vegetation conditions to the smallest number that meets the intended analysis objectives of the map and are feasible to produce with available resources and technology. All map units of interest need to be identified to map vegetation and land cover across the landscape (Gong and Howarth 1992). Careful planning of the map unit design process is necessary to establish an adequate foundation for a mapping project (Lachowski et al. 1995).

Table 3.11. *Technical group, map unit, and map feature relationship example.*

Total vegetation canopy cover classification		**Total vegetation canopy cover mid-level**	
Canopy cover technical groups (%)	**Map unit design process** converts technical map units	**Canopy cover map units**	**Map feature delineation process** spatially depicts map units
0		Sparse vegetation	
1–9.9			
10–19.9		10–29.9-percent canopy cover	
20–29.9			
30–39.9		30–59.9-percent canopy cover	
40–49.9			
50–59.9			
60–69.9		60–79.9-percent canopy cover	
70–79.9			
80–89.9		80–100-percent canopy cover	
90–100			

The first logical step in map unit design is to identify taxonomic units and/or technical groups from existing classifications that pertain to each map unit. Classification keys that may have been developed as part of an existing vegetation classification should be assembled and used as the foundation for determining floristic map units. Based on the availability of adopted vegetation classifications and the validity of historical classification systems, using existing classification keys may be useful to map vegetation composition. In the absence of existing classification keys that meet national and regional standards, new keys will need to be developed.

Map Unit Design Process

When a new map unit design is required to meet local analysis needs that are not met by the national standard definitions, find a balance of idealized need and resource constraint. To achieve this balance, take the following steps:

1. **Define the user needs.** The ideal level of detail and the intended use of the data must be clearly defined.
2. **Identify the resources available.** Consider personnel, time, budget, existing data, and management approval as the critical resources.
3. **Identify the source image data to be used.** Be aware of the relationship between the source data and the analysis objectives and possible limitations inherent in a given data type with respect to the desired level of information. A specific consideration would be the ability or inability of an image data type to discern individual floristic categories defined in the classification scheme.
4. **Formalize the design of the map units.** Following the design of the map units, map unit keys, and descriptions are developed. The logic of the map unit design is defined in a dichotomous key for the map units. The key illustrates the hierarchical and mutually exclusive relationship of all map units. See appendix 3A for examples of map unit keys associated with several vegetation characteristics. Map unit descriptions are developed to describe the taxonomic unit composition of each map unit.

Elements of Quality Map Unit Design

At a minimum, a map unit design must be the following:

- **Exhaustive.** The map units that result from the design process must account for the full range of conditions of interest found in the project area. In addition to the vegetation classifications addressed by the protocol contained in this technical guide, other land cover classifications needed to meet analysis objectives should be included (e.g., urban, agriculture, barren, and water).
- **Mutually exclusive.** Any specific vegetation condition must be assignable to one and only one map unit.
- **Field applicable.** The logic in the map unit design must be applicable to field observations and/or field sampled data.

3.2.3.2 Map Feature Design

Map feature design identifies the spatial characteristics and structure of individual areas or delineations on a map. Specific map features are nonoverlapping and geographically unique and may contain more than one thematic element (map units). Two key components of map feature design are setting the size of the minimum map feature and determining how the map features will be delineated. The term "minimum map feature," as used in this technical guide, is analogous to minimum map unit (MMU) as used widely in the past. National standards for the minimum map feature at each map level have been established and are described in section 3.2.2. Keep in mind that local business needs may dictate the delineation of smaller landscape features, such as small water bodies or riparian areas, below the size of minimum map feature standard.

Determine the Minimum Map Feature

1. **Define the user needs.** The ideal level of detail and the intended use of the data must be clearly defined.
2. **Identify the source image data to be used.** Consider the ability or inability of the source image data to discriminate vegetation/landscape features considered important in step 1.
3. **Determine the methodology to use for feature delineation.**

Methods for map feature delineation are described in greater detail in section 3.2.4.

3.2.3.3 Map Design Examples

This section provides several simple map design examples to illustrate the map unit design and map feature design process relationships.

Example 1

A mapping project is proposed where the user identifies the need for a geospatial database and map product depicting order-level physiognomic type taxonomic units. The map unit design process determines that map units can be developed to directly correspond to the taxonomic units. These relationships are listed in table 3.12. Note that the taxonomic class

Table 3.12. *Physiognomic type classification taxonomic units and map units.*

Physiognomic type classification	Physiognomy map
Order-level taxonomic units	**Order-level mapping units**
Vegetation not dominant	Sparse vegetation
Tree dominated	Tree vegetation
Shrub dominated	Shrub vegetation
Herb dominated	Herbaceous vegetation
Nonvascular dominated	Nonvascular vegetation

"vegetation not dominant" is designed to also include areas with less than 1-percent vegetation. Figure 3.2 illustrates map features depicting these map units.

Example 2

A mapping project is proposed in which the user identifies the need for a geospatial database and map product depicting dominance type taxonomic units. The map unit design process identifies map units that are consistent with the user needs and can be produced within the limitations of mapping technology. Table 3.13 lists these relationships. Figure 3.3 illustrates map features depicting these map units.

Figure 3.2. *Physiognomic types.*

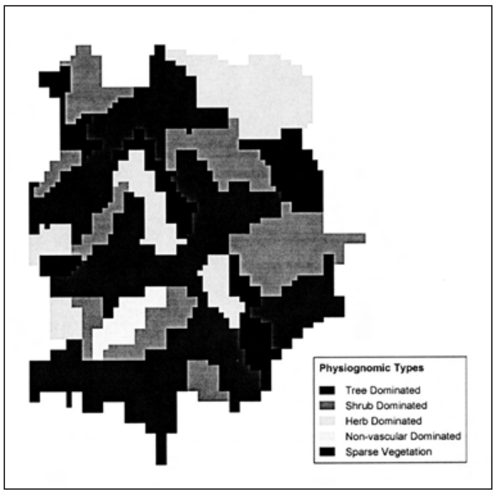


Figure 3.3. *Dominance types.*

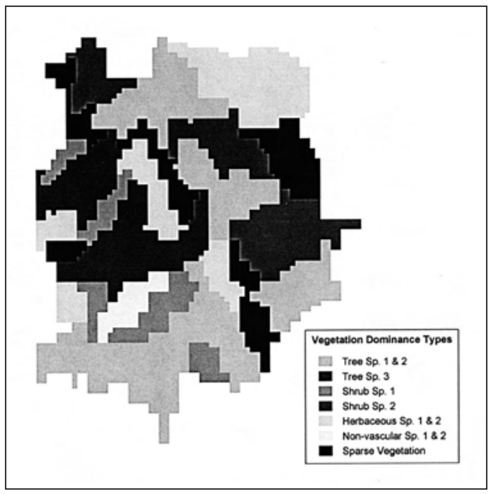


Table 3.13. *Dominance type classification taxonomic units and map units.*

Dominance type classification	**Dominance type map**
Taxonomic units	**Mapping units**
Tree SP. 1 Tree SP. 2	Tree SP. 1 and 2
Tree SP. 3	Tree SP. 3
Shrub SP. 1 Shrub SP. 2	Shrub SP. 1
Herbaceous SP. 1 Herbaceous SP. 2	Herbaceous SP. 1 and 2
Nonvascular SP. 1 Nonvascular SP. 2	Nonvascular SP. 1 and 2
Sparse vegetation	Sparse vegetation

Example 3

A mapping project is proposed where the user identifies the need for a geospatial database and map product depicting tree canopy cover technical groups. The map unit design process identifies the mid-level map units described by the protocol contained in this technical guide as appropriate for the user needs and consistent with current mapping technology. Table 3.14 lists these relationships. Figure 3.4 illustrates map features depicting these map units.

Example 4

A mapping project is proposed where the user identifies the need for a geospatial database and map product depicting dominance type taxonomic units as well as tree canopy cover technical groups. The map unit design process recognizes that these map units are a combination of the map units from examples 2 and 3 and, therefore, are all unique combinations of the two sets. Table 3.15 lists these relationships.

Figure 3.5 illustrates map features depicting these map units.

Examples 1 through 4 represent simple single-purpose mapping projects in which the relationships between the taxonomic units and technical groups of the classifications and map units of the map product are fairly direct. In practice, however, most mapping projects

Figure 3.4. *Tree canopy cover.*

Figure 3.5. *Combined dominance type and tree canopy cover.*

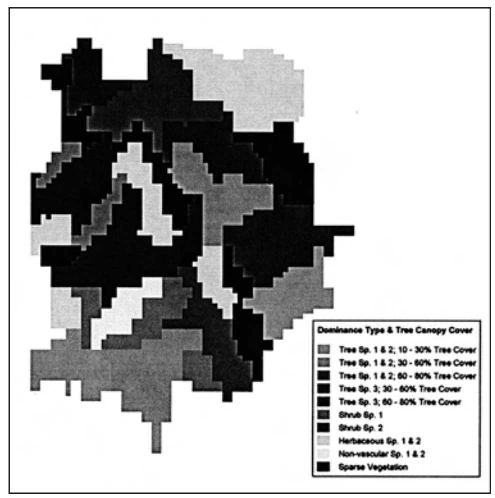


Table 3.14. *Tree canopy cover classification technical groups and map units.*

Tree canopy cover classification	**Tree canopy cover map**
Tree canopy cover technical groups (%)	**Tree canopy cover mapping units**
0 1–9.9	Sparse vegetation
10–19.9 20–29.9	10–29
30–39.9 40–49.9 50–59.9	30–59.9
60–69.9 70–79.9	60–79.9
80–89.9 90–100	80–100

Table 3.15. *Combined dominance type and tree canopy cover classification map units.*

Dominance type cover	Tree canopy cover	Combined dominance type and tree canopy
Mapping units	**Mapping units (% canopy cover)**	**Mapping units (% canopy cover)**
Tree SP. 1 and 2	10–29.9	Tree SP. 1 and 2; 10–29.9
	30–59.9	Tree SP. 1 and 2; 30–59.9
	60–79.9	Tree SP. 1 and 2; 60–79.9
	80–100	Tree SP. 1 and 2; 80–100
Tree SP. 3	10–29.9	Tree SP. 3; 10–29.9
	30–59.9	Tree SP. 3; 30–59.9
	60–79.9	TREE SP. 3; 60–79.9
	80–100	TREE SP. 3; 80–100
Shrub SP. 1	No tree canopy cover	SHRUB SP. 1; no tree canopy cover
Herbaceous SP. 1 and 2	No tree canopy cover	Herbaceous SP. 1 and 2; no tree canopy cover
Nonvascular SP. 1 and 2	No tree canopy cover	Nonvascular SP. 1 and 2; no tree canopy cover
Sparse vegetation	No tree canopy cover	Sparse vegetation; no tree canopy cover

are implemented to meet more general purposes. In most cases, mapping projects produce geospatial databases that contain all the map units (physiognomic, floristic, and structural) that are included in this protocol for any given level of mapping. This will generally require differentiating and delineating map features based on complex map unit design criteria that incorporate all the taxonomic units and technical groups from all the vegetation classifications being mapped. When the delineation of each map feature is based on all applicable vegetation classifications (physiognomic, floristic, and structural) the resulting geospatial database provides a flexible tool for a wide variety of analysis objectives.

3.2.4 Map Product Development and Assessment

In this section:

- *General overview of the mapping process*
- *Steps to producing mid and base-level vegetation maps*
- *Technical discussion of data sources and mapping methods used in the production of vegetation maps*

The information in section 3.2.4 is presented in a format analogous to three tiers of a pyramid. The top tier provides an overview of the general process categories that comprise an entire mapping project. The second tier summarizes the activities performed in each of those processes specifically for mid- and base-level map development. The third and most technical tier presents a number of methodological considerations for performing mapping activities. These considerations are based on existing and former mapping efforts in the Forest Service and are intended to provide insight into appropriate data sources and technologies currently available for map development. These considerations are neither exhaustive nor the only means for implementing vegetation mapping. Project managers and analysts should conduct a thorough mapping process investigation.

The three-tiered approach in this section's organization is designed to make this technical guide useful to a broad audience with varying levels of need for understanding the mapping process. Program managers may only need a general process outline to understand basic resource requirements whereas a mapping analyst requires a more technical understanding of the data and technologies applied.

3.2.4.1 Vegetation Mapping Overview

Producing a vegetation map to the standards specified in this document is a multidisciplinary activity. Beginning with classification of the vegetation communities described in section 2 through the finalization of a geographical information systems (GIS) database and associated metadata, a series of processes must be completed using the skills contained in several resource and technical fields (e.g., vegetation ecologist, field forester, GIS technician, remote sensing specialist/photogrammetrist). When considered at its most basic level, vegetation map production can be summarized by the following process categories.

1. Identify mapping project based on information need.
2. Identify the mapping system and its relevant components.
3. Develop a project plan.
4. Assemble the resources necessary to produce a map including people, hardware/software, and data.
5. Perform the actual mapping tasks.
6. Conduct an accuracy assessment.
7. Build GIS database and associated metadata.
8. Update data on a cyclical basis.

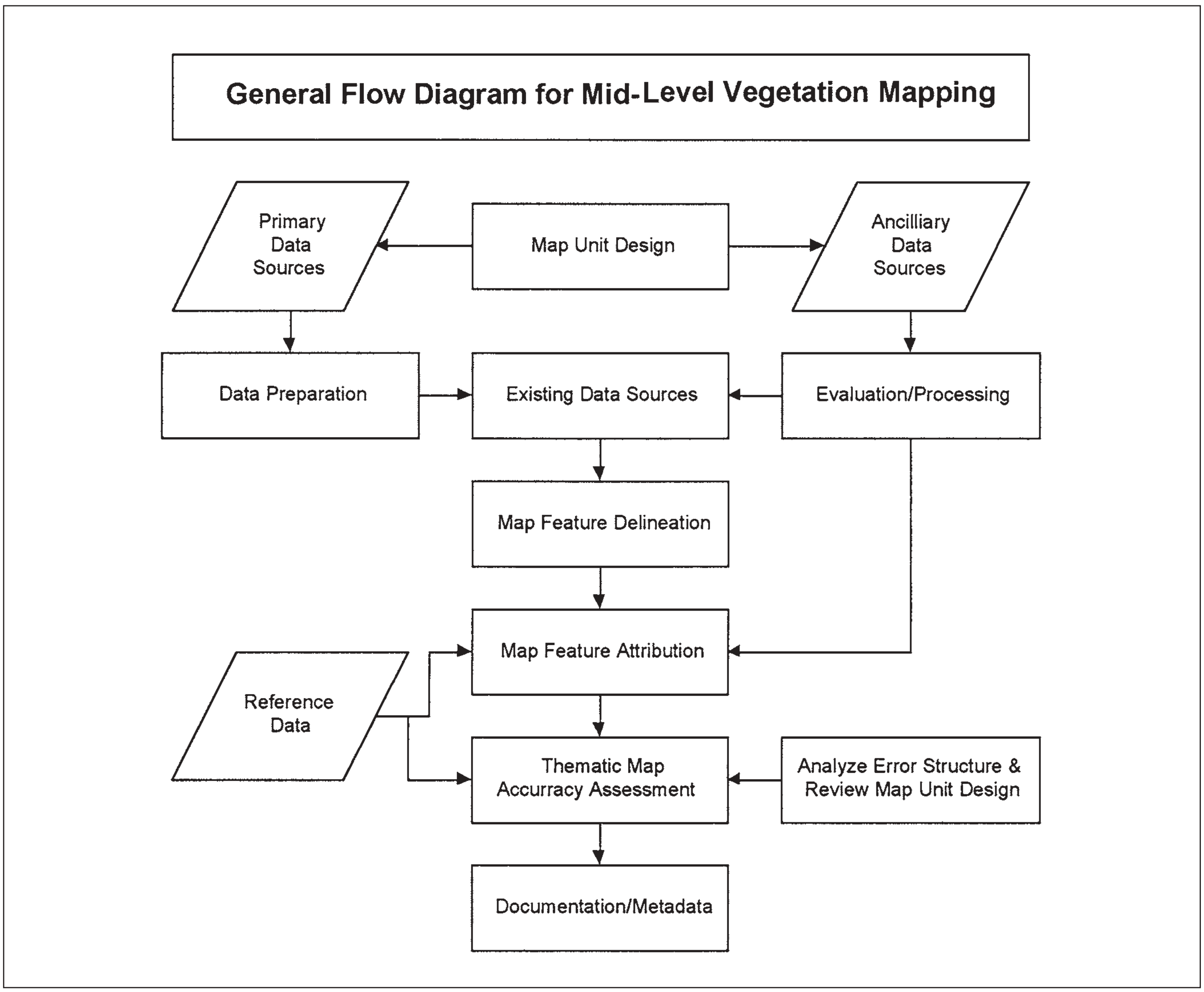
Timeframes for accomplishing the processes related to initial map production are dependent on geographic extent, map level, and resource availability. To be successful, mapping projects may easily span more than 1 year and represent a significant commitment of resources. Furthermore, these products should be viewed as "living maps" to be maintained on a regular basis versus one-time investments that will quickly become outdated and have limited value for resource monitoring.

Map product development and assessment are discussed in more detail for mid- and base-level map products than for broad and national level products. Many of the same methods identified for the mid-level and/or through the aggregation of finer level maps meeting the specified standards can be used to develop broad- and national-level map products. Step-based processes for producing mid- and base-level maps are illustrated and summarized in the following sections.

3.2.4.2 Produce a Mid-Level Existing Vegetation Map

Figure 3.6 illustrates the processes necessary to develop a mid-level map product that meets the map standards identified in section 3.2.2. Processes for mapping additional attributes required at the regional or local level will need to be identified and described by the local data stewards. Appendix 3C includes examples of mid-level mapping protocols in operational use in the agency.

Figure 3.6. *Map Product Development and Assessment Mid-Level Vegetation Mapping.*



Steps to Produce a Mid-Level Vegetation Map

The steps below are presented in the general chronological order in which they occur, although variation in mapping methods and availability of existing data and resources may alter the progression in a given project.

Step 1: Design map units. Identify existing floristic classifications for plant associations or dominance types for the area being mapped. Identify plant associations or dominance types that are to be mapped as compositional groups or vegetation complexes map units.

Step 2: Acquire and prepare the necessary data. Identify and acquire primary and ancillary data appropriate for mid-level map development (table 3.16). Process the primary data to ensure adequate geospatial registration and data content. Evaluate and process ancillary data to ensure appropriate scale, georegistration, and extent.

- Acquire and process appropriate primary image data to be used for delineation and classification:
  - Radiometric correction.
  - Geometric correction.
  - Terrain correction.
  - Generate derivative data—e.g., Normalized Difference Vegetation Index (NDVI), Principal Component Analysis (PCA), texture.
  - Mask imagery to subproject processing areas in project area extent.
- Gather ancillary data, determine utility, and process for project use:
  - Consider the appropriate resolution and/or scale of capture.
  - Reproject to desired projection, if necessary.
  - Clip/mask to project area extent.
  - Generate derivative layers—e.g., slope/aspect, hillshade, layer buffers.

Table 3.16. *Mid-level mapping methods.*

Map attribute	Appropriate mapping methods
Physiognomic order	Generalized from Physiognomic class
Physiognomic class	Generalized from cover or dominance type
Physiognomic subclass	Supervised/unsupervised image classification
Cover type (e.g., SRM/SAF)	Spatial modeling based on ecological predictors and existing cover type, augmented with image classification
Dominance type	Spatial modeling based on ecological predictors and existing physiognomic class, augmented with image classification
Total vegetation cover	Supervised/unsupervised image classification
Tree canopy closure	• Supervised/unsupervised image classification • Image based modeling • Hybrid classification (classification-plot regression)
Tree diameter	• Supervised/unsupervised image classification • Hybrid classification (classification-plot regression)
Anderson 1 class[a]	Supervised/unsupervised image classification

[a] Required for polygons with less than 10-percent total vegetation cover.

Step 3: Delineate vegetation and landscape features. Delineate continuous patches of similar vegetation composition and structure based on primary data source and consistency with the map unit design. Use computer-based systematic methods of generating polygons (image segmentation) or integrate/aggregate from existing base-level maps. Section 3.2.4.4 includes additional information on image segmentation and thematic aggregation.

- Prepare inputs for image segmentation:
  - Layer stack segmentation inputs (image bands, image derivatives, and ancillary data).
- Integrate base-level maps where they exist:
  - Aggregate detailed map units to required level in the classification hierarchy.
  - Aggregate below minimum map features to required minimum map feature size, if necessary, using adjacency and similarity logic.

Step 4: Assemble and collect reference data required for mapping and accuracy assessment. Gather existing plot data and/or collect new plot and/or photointerpretation data and summary observation data to use for computer training, model development, interim map assessment, and final accuracy assessment.

- Assemble existing plot data and evaluate for sample intensity and data content to determine utility for development or assessment.
- Collect new plot data and/or photointerpretation data for map development or accuracy assessment.
- Conduct rapid assessments to gather extensive summary data for training, ecological model rule development, and interim map assessments.

Step 5: Assign attributes to map features (polygons). Map each standard attribute independently in a hierarchical process, applying appropriate image classification and/or modeling techniques (table 3.16). Map more general attributes (subclass) first and subsequently use as stratification for tree-specific attributes (dominance type, canopy closure, and size) to increase process efficiency. Field and/or photographically review and correct map units for nonsystematic error.

- Map standard attributes:
  - Classify imagery for subclass and edit results.
  - Classify imagery for Anderson 1 land cover types.
  - Classify imagery to total vegetation cover.
  - Model/classify dominance types in mapped subclass categories.
  - Classify structure in mapped subclass categories.
  - Map additional attributes.

Step 6: Move maps into a corporate database format and apply crosswalks to complete the database hierarchy and link to other classification systems. Combine independently mapped attributes into a corporate database structure (appendix 3F) and audit/rectify database anomalies. Apply crosswalks to populate upper levels of the hierarchy and additional classification systems identified for local needs.

- Create a single geospatial database containing all mapped attributes.
- Add remaining database elements of the corporate database structure.
- Apply crosswalks to populate upper levels of the hierarchy and additional classification systems.
- Overlay with other GIS layers to populate additional attributes.
- Audit the database and spatial layer for substandard anomalies, GIS errors, and illogical map attribute combinations.

Step 7: Conduct a map accuracy assessment. Using an independent reference dataset, compare labeled reference data to map labels to generate error matrixes for each map attribute/class. Consider generating fuzzy set accuracy assessments in addition to standard error matrices.

- Assemble independent reference dataset: Calculate attribute labels from data.
- Compare labeled reference data with map labels for each attribute:
  Evaluate spatial relationships of reference data to map features to determine the validity of individual reference data records for map assessment.
- Generate error matrices.
- Analyze error structure relative to the map unit design to identify possible aggregation or other changes to improve accuracy.

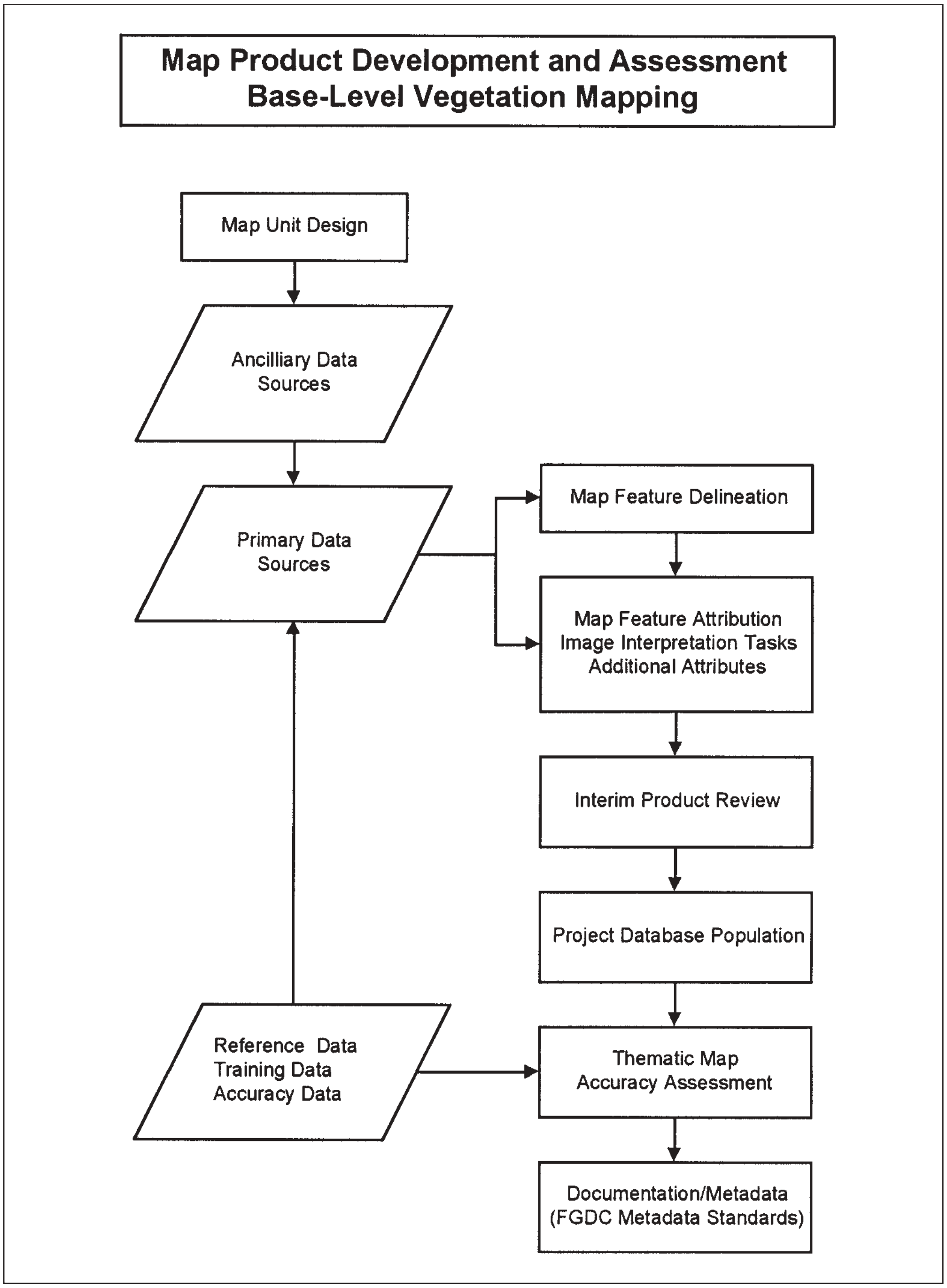
Step 8: Finalize FGDC-compliant and additional metadata.

- Populate FGDC-compliant metadata template (appendix 3E).
- Compile additional compendium of more detailed source data and methods documentation created during the mapping process.
- Create archive of project data backups and documentation.

3.2.4.3 Produce a Base-Level Map

Figure 3.7 illustrates the processes necessary to develop a base-level map product meeting the map standards identified in section 3.2.2. Processes for mapping additional attributes required at the regional or local level will need to be identified and discussed by the local data stewards.

Figure 3.7. *Map Product Development and Assessment Base-Level Vegetation Mapping.*



Steps to Produce a Base-Level Vegetation Map

The steps below are presented in the general chronological order they occur, although variation in mapping methods and availability of existing data and resources may alter the progression in a given project.

Step 1: Design map unit. Identify appropriate floristic classification of plant associations and alliances in the area to be mapped. Determine which, if any, plant associations will be mapped as compositional groups or vegetation complexes map units. If formal classifications for some or all the existing vegetation do not exist, complete vegetation sampling and classification before proceeding with mapping.

Step 2: Acquire and prepare the necessary data. Identify and acquire primary and ancillary data appropriate for base-level map development (table 3.17). Evaluate and process ancillary data to ensure appropriate scale, georegistration, and extent.

- Acquire primary photo/image data:
  - Appropriate photo scale to identify map attributes.
  - Orthorectify digital data, if necessary.
- Gather ancillary data, determine utility, and process for project use:
  - Consider appropriate resolution and/or scale of capture.
  - Reproject to desired projection system if necessary.
  - Clip/mask to project area extent, including buffer.
  - Generate derivative layers—e.g., slope/aspect, hillshade, layer buffers.

Table 3.17. *Base-level mapping methods.*

Map attribute	Appropriate mapping methods
Physiognomic order	Generalized from physiognomic class
Physiognomic class	Generalized from plant alliances
Physiognomic subclass	Photo/image interpretation with field observations
Cover type	Generalized from plant alliances
Dominance type	Generalized from plant alliances
Alliances	Spatial modeling based on ecological predictors (e.g., topography, climate, geology) and existing physiognomic type, augmented with photo/image interpretation and field observation
Associations	Field observation
Total vegetation cover	Photo/image interpretation with field observations
Tree canopy closure	Photo/image interpretation with field observations
Tree diameter	Photo/image interpretation with field observations
Anderson 1 class	Photo/image interpretation with field observations

Step 3: Assemble and collect reference data necessary for mapping and accuracy assessment. Gather existing plot data and/or collect new plot and summary observation data to be used for interpreter calibration, model development, interim map assessment, and final accuracy assessment.

- Assemble existing plot data and evaluate it for sample intensity and data content to determine utility for development or assessment.
- Collect new plot data for map development or accuracy assessment.
- Conduct rapid assessments to gather extensive summary data for ecological model rule development and interim map assessments.

Step 4: Delineate vegetation and landscape features. Delineate continuous patches of similar vegetation composition and structure based on primary data source. Delineations are determined through photography and/or image interpretation and registered to a digital image base. Feature delineation and attribution can occur simultaneously for map attributes that are readily interpreted on large-scale photography.

- Calibrate interpretation analyst based on reference data and mensurational guides that illustrate crown densities and diameters at various photo scales.
- Delineate vegetation stands or patches containing uniform or evenly distributed vegetation structure and top layer species composition. Digitize delineations over a digital image base.
- Adjust delineations for species composition, if necessary, based on field observations.

Step 5: Assign attributes to map features (polygons). Map each standard attributes that can reliably be interpreted from stereoscopic photography and associated high-resolution imagery (table 3.17). Attributes not reliably mapped from image/photointerpretation should be mapped based on field observation.

- Map standard attributes:
  - Interpret photography/imagery for subclass and label polygons.
  - Interpret photography/imagery for tree canopy closure.
  - Interpret photography/imagery for tree diameter class.
  - Interpret photography/imagery for Anderson 1 land cover types and label polygons.
  - Interpret photography/imagery for total vegetation cover.

Label polygons with vegetation alliances based on modeling, photograph/image interpretation, and field observation.

- Map additional attributes.

Step 6: Move maps into a corporate database format and apply crosswalks to complete the database hierarchy and link to other classification systems. Combine mapped attributes in a corporate database structure (appendix 3F) and audit/rectify database anomalies.

- Create a single geospatial layer containing all mapped attributes as separate database elements.
- Add remaining database elements of the corporate database structure.
- Apply crosswalks to populate upper levels of the hierarchy and additional classification systems identified for local needs.
- Overlay with other GIS layers to populate additional attributes not related to vegetation.
- Audit the database and spatial layer for substandard anomalies, GIS errors, and illogical map class combinations between attributes.

Step 7: Conduct a map accuracy assessment. Using an independent reference dataset, compare labeled reference data to map labels to generate error matrices for each map attribute/class. Consider generating fuzzy set accuracy assessments in addition to standard error matrices.

- Assemble independent reference dataset. Calculate attribute labels from data.
- Compare labeled reference data with map labels for each attribute. Evaluate spatial relationship of reference data to map features to determine the validity of individual reference data records for map assessment.
- Generate error matrices.

Step 8: Finalize FGDC-compliant and additional metadata. Populate FGDC metadata template (appendix 3E).

- Populate FGDC-compliant metadata template.
- Compile additional compendium of more detailed source data and methods documentation created during the mapping process.
- Create archive of project data backups and documentation.

3.2.4.4 Principles of Map Product Development and Assessment

Existing Information Sources

Vegetation mapping across the range of map levels outlined in the protocol described in this technical guide is primarily accomplished through the use of remotely sensed image data. These data can be acquired from airborne or spaceborne platforms and can be in photographic or digital form. A brief explanation of remote sensing systems, common remote sensing data sources, and the methods used to extract thematic information will provide insights into the similarities and differences of vegetation mapping approaches based on photographic or digital data.

"Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by [a] device that is not in contact with the object, area, or phenomenon under investigation" (Lillesand and Kiefer 1987). The remote sensing data sources noted in this section are the products of complex systems. Although a thorough description of these systems and the energy-matter interactions that affect the basic nature of these data is beyond the scope of this protocol. To understand the differences in how information is extracted from these data and how this information relates to the attributes and standards for vegetation maps, however, requires a brief overview. For detailed descriptions, refer to Campbell (1987), Lillesand and Kiefer (1987), and Jensen (1996).

In their simplest form, the complex matter/energy interactions involved in passive electromagnetic remote sensing are described by three basic processes: (1) energy from the sun propagates through the atmosphere where it (2) interacts with earth surface features and (3) is retransmitted through the atmosphere and becomes available to a remote sensing device. The atmosphere has a substantial effect on the intensity and spectral composition of energy available to remote sensing system. These effects result primarily from atmospheric scattering and absorption. Spaceborne sensors are changed more by the atmosphere than the airborne sensors because their energy source passes through the full thickness of the atmosphere twice. Energy incident on any earth surface feature will have various portions reflected, absorbed, and/or transmitted. The proportions of energy that are reflected, absorbed, and/or transmitted vary for different surface features and provide the basis for distinguishing different types of features in an image. Because of the nature of the matter/energy interactions, two features may be indistinguishable in one portion of the electromagnetic spectrum and easily distinguished in another. Many remote sensing devices are designed to use this variable response and collect data in several specific regions of the electromagnetic spectrum. A number of multispectral image data sources are included in this section's description of potential remote sensing data sources. The other data sources collect data, color and panchromatic, only in the visible portion of electromagnetic spectrum.

All the primary remote sensing data sources described are passive sensors of electromagnetic energy; that is, they all rely on the sun as their source of energy and sense/record data in various portions of the electromagnetic spectrum. These data are digitally recorded in the form of pixels and photographically recorded on crystals or grains of silver halide. A pixel is defined as "a two-dimensional picture element that is the smallest nondivisional element of a digital image." For the purposes of describing the ground resolution of these remote sensing data and discussing the extraction of information, a pixel and a grain of silver halide are reasonably analogous; both represent the smallest nondivisible element and an integrated signal of some area on the ground.

Development of map products at all levels depends on the acquisition of primary and ancillary data sources. Primary data sources are those from which a map is directly derived; ancillary data sources are used to support development and verification of the map.

Primary Data. Primary data sources are most often continuous data that depict an uninterpreted image of surface condition at some moment in time. Many primary data sources are logically used for map feature delineation and population. These include satellite based multispectral and panchromatic imagery, as well as true color, infrared, and panchromatic digital and hardcopy aerial photography.

Table 3.18 lists commonly available examples of satellite borne sensor data that can be used as a primary image data source. Table 3.19 lists minimum photographic scales recommended for detecting and measuring various vegetation characteristics commonly

Table 3.18. *Available digital image data types.*

Data type	Coverage (swath width) (km)	Spatial resolution (meters)	Spectral resolution[1]	Temporal resolution (days)	Appropriate map level
Landsat Multispectral Scanner (MSS)	185	82	G, R, NIR	N/A	Broad, national
Landsat TM 5, 7	185	6 at 30; 1 at 60; 1 at 15 (Landsat 7 only)	B, G, R, NIR, MIR; TIR	16	Mid, broad, national
SPOT 2	60	3 at 20; 1 at 10	G, R, NIR	Pointable (< 5)	Mid, broad
SPOT 4	60	4 at 20; 1 at 10	G, R, NIR, MIR	Pointable (< 5)	Mid, broad
SPOT 5	60	4 at 10, 1 at 5, 1 at 2.5	B, G, R, NIR MIR	< 5	Base, bid
Indian Remote Sensing Satellite 1B (IRS-1B); (Live Internet Spectral Scanner [LISS 1]); LISS 2	145; 74	4 at 72.5 4 at 36.25	B, G, R, NIR	22	Broad, national
European Remote Sensing Satellite 1, 2 (ERS-1,2); (Active Microwave Instrumentation [AMI]); (Along Track Scanning Radiometer [ATSR])	100	1 at 26 (Radar) 4 at 1,000	Far Infrared; B, G, R, NIR	35	Broad, national
Resurs-01-3	600	4 at 160 1 at 700	B, G, R, MIR, TIR	21	Broad, national
National Oceanic and Atmospheric Administration (NOAA); (Advanced Very High Resolution Radiometer [AVHRR])	2,700	5 at 1,100	G, R, MIR Thermal	Daily	National
IRS-P4 (Ocean Colour Monitor [OCM])	1,420	8 at 360	MIR	2	National
IKONOS	11	4 at 4 1 at 1	B, G, R, NIR	1–3	Base, mid
IRS-1C, D	142; 70	3 at 23; 1 at 70; 1 at 5.8	G, R, NIR, SWIR	24	Base, mid, broad
RADARSAT	500	1 at 9-100 (Radar)	Far Infrared	3	Mid, broad, national
China-Brazil Earth Resources Satellites 1 (CBERS-1); (Charge coupled device [CCD]); (Wide Field Imager [WFI]) Infrared Multispectral Scanner (IRMSS)	113 120 900	5 at 20 2 at 260 3 at 80, 1 at 160	B, G, R, NIR, MIR, thermal	26	Mid, broad, national
Terra (Moderate Resolution Imaging Spectroradiometer [MODIS]); (Multiangle Imaging Spectroradiometer [MISR]); (Advanced Spaceborne Thermal Emission and Reflection Radiometer [ASTER])	2,330 360 60	2 at 250, 5 at 500, 29 at 1,000; 4 at 250; 3 at 15, 6 at 30, 5 at 90	B, G, R NIR, MIR, thermal; B, G, R, NIR; SWIR, VNIR, thermal	Daily	Mid, broad, national
OrbView-2	2,800	8 at 1,130	6 visible, 2 NIR	Daily	National
Orb View-3	8	4 at 4, 1 at 1	B, G, R, NIR	< 3	Base, mid
Quickbird 2	17	4 at 2.5, 1 at 0.65	B, G, R, NIR	1–4	Base, mid
Earth Observing 1 (EO-1) (Advanced Land Imager [ALI]) (Hyperion) (Linear Etalon Imaging Spectrometer Array Atmospheric Corrector [LAC])	37 7.6	1 at 10, 9 at 20; 220 at 30; 256 at 250	B, G, R, NIR, MIR; Hyperspectral—visible to MIR; Hyper—MIR to SWIR	7	Mid, broad, national

[1] B=blue, G=green, R=red, NIR=near infrared, MIR=mid infrared, TIR=thermal infrared, SWIR=short wave infrared, VNIR=visible near infrared/short wave.

Table 3.18. *Available digital image data types. (continued)*

Data type	Coverage (swath width) (km)	Spatial resolution (meters)	Spectral resolution[1]	Temporal resolution (days)	Appropriate map level
Earth Resources Observation Systems B1 (EROS-B1)	12.7	1 at 0.82	Panchromatic	Daily	Base
Aqua (MODIS) (Advanced Microwave Scanning Radiometer [AMSR])	2,330	2 at 250, 5 at 500, 29 at 1,000; 1 at 5	B, G, R, NIR, MIR, Thermal, Far infrared	< 4	National
Sea-viewing Wide Field-of-view Sensor (SeaWiFS)	1,502	8 at 1,100	B, G, R, NIR, MIR, Thermal	1	National

[1] B=blue, G=green, R=red, NIR=near infrared, MIR=mid infrared, TIR=thermal infrared, SWIR=short wave infrared, VNIR=visible near infrared/short wave.

Table 3.19. *Photographic scales and resolution necessary for vegetation mapping.*

Data requirements (map units)	Ground resolution (m)	Minimum scale (IR, CIR)[a] detection measurement	Minimum Scale BW[b], color) detection measurement	Appropriate common scale (IR, CIR[a], BW[b], color)
Vegetated cover				
Tree stands	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Tree species	0.1	1:3,200 1:1,600	1:5,000 1:2,500	Special project
Tree stand height class	0.3	1:12,500 1:6,400	1:20,000 1:9,600	1:12,000 1:12,000/1:16,000
Tree stand mean diameter	0.3	1:12,500 1:6,400	1:20,000 1:9,600	1:12,000 1:12,000/1:16,000
Tree stand crown closure	0.3	1:12,500 1:6,400	1:20,000 1:9,600	1:12,000 1:12,000/1:16,000
Shrub stands	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Shrub species	0.3	1:12,500 1:6,400	1:20,000 1:9,600	1:12,000 1:12,000/1:16,000
Shrub stand height class	0.3	1:12,500 1:6,400	1:20,000 1:9,600	1:12,000 1:12,000/1:16,000
Shrub stand form class	0.3	1:12,500 1:6,400	1:20,000 1:9,600	1:12,000 1:12,000/1:16,000
Forb stands	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Grass stands	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Nonvegetated cover				
Rock	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Barren	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Water	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000
Land use	3	1:184,000 1:92,000	1:320,000 1:160,000	1:60,000 1:40,000

[a] IR=infrared, CIR=color infrared. [b] BW=panchromatic.

mapped. Other noncontinuous remotely sensed data are available—e.g., lidar (light detection and ranging—but are difficult to apply as a primary source for the development of continuous vegetation information, although they may be effectively used in conjunction with continuous data sources.

When selecting an appropriate data source, consider several basic principles that relate the grain of data to the size and shape of the vegetation/landscape elements that constitute the pattern of interest. When the pattern of interest is smaller than the grain of the data, the pattern cannot be detected. When the pattern of interest is much larger than the grain of the data, that pattern can be well represented, provided it can be recognized in those data. This is particularly true when the pattern is composed of spectrally homogenous units organized in regular shapes (shape index approaching 1:1 and/or a fractal dimension approaching 1) (Nellis and Briggs 1989, Turner et al. 1989, Cullinan and Thomas 1992, Simmons et al. 1992, and Ryherd and Woodcock 1996). For example, a minimum map unit of 5 acres represented by approximately 22 Thematic Mapping (TM) pixels, 75 Systeme Probatoire d'Observation de la Terre (SPOT) high resolution visible imaging system (HRV) pixels, and 20,000 digital orthophoto pixels that is essentially homogeneous would be detectable and reasonably well characterized by any of these remote sensing data sources.

As the grain of the data interacts with the grain of the vegetation pattern, it creates a problem referred to as boundary pixels. Boundary pixels are those pixels that are not completely filled by one homogenous class of scene object, in this case vegetation. If the area on the ground is relatively uniform, the integrated signal and the resulting digital number are reasonable representations of the area. The problem is created by pixels that represent an area that contains the boundary of two or more features that differ in brightness. The integrated signal of this area becomes an average of the two conditions and may not represent either condition well. If a given map unit is irregular in shape (high edge: interior ratio; shape index much greater than 1:1, and/or a fractal dimension much greater than 1), the proportions of boundary pixels increase relative to nonboundary pixels. A similar condition develops when the pixels comprising an object are not spectrally homogenous. This pattern of heterogeneity results in difficulty segmenting the image into regions (Ryherd and Woodcock 1996).

Selection of primary data sources for map production must be based on the ability of the data to delineate and identify the standard and any supplemental map units. For example, using a 1-kilometer ground resolution satellite image will not allow for the delineation of map units that meet the minimum map feature standard defined for mid-level maps. A variety of satellite remote sensing data sources are available with highly variable spatial, temporal, and spectral characteristics. Similarly, a wide range of aerial photography data sources are available that also vary in their spatial, temporal, and spectral characteristics. A single primary data source may not be adequate to delineate a complete population of all map units. The map producer may need several primary data sources to develop a complete map product. Subsequent factors determining selection of primary data sources include data availability, quality, and cost. Other considerations should include currency and temporal coincidence of image data.

Data Preparation. Prepare digital imagery for processing through the proper registration and correction of raw data, with the objective of increasing the accuracy and interpretability of the image before image classification. Three important image-preprocessing steps (correction types) follow:

1. Radiometric correction accounts for variations in the image resulting from sensor anomalies or environmental conditions, such as haze, so that image values represent as closely as possible the true reflectance of land cover features. This step is optional

and depends on the severity of the image defects and/or the project's need to show true reflectance values.

2. Geometric correction reorients the image to compensate for the Earth's rotation and variation in the satellite's position and altitude. This process may also include positioning or warping an image in a map projection system so that accurate measurements can be made. This step is necessary if the resulting classification products are used in GIS with other georeferenced information layers.
3. Terrain correction adjusts the image for the relief distortion with the help of digital elevation data. Terrain correction is recommended if precise location is required and the study area has relief differences greater than 500 feet.

Ancillary Data. Other data sources are available to use to support map unit delineation and map unit population. These include vertical aerial photography, videography, digital orthophoto quads, DEM, historical vegetation data and maps, other ecologically related data and maps (e.g., soils and hydrography), and disturbance and land use information (e.g., fire history, silvicultural treatments, urban succession). Consider the scale of capture associated with an ancillary data source relative to the desired level of detail in the map product and scale of the source data. For example, it may not be appropriate to rely on a 1:100,000-scale hydrographic layer to help map riparian related vegetation types at the mid-level. Conversely, at the mid-level, a 1:24,000 DEM can greatly enhance the ability to map the distribution of vegetation types constrained by elevation. Also consider using multiple ancillary datasets or map layers that vary greatly in scale. Spatial and thematic accuracy may vary considerably between sets of information. Spatial coregistration may be necessary to appropriately use two or more independent layers as inputs into the same process.

Map Feature Delineation

Criteria are established to use when spatially differentiating map features between map units. Those criteria describe structural, floristic, and physiognomic characteristics of the vegetation to be mapped, as well as nonvegetated landscape elements. In the context of the protocol described in this technical guide, the delineation of map features depicting the vegetation configuration across the landscape representing elements of vegetation pattern can be synonymous with landscape patch delineation or stand delineation. The term "patch," as defined in Forman (1995), is "a relatively homogenous nonlinear area that differs from its surroundings." This definition is consistent with other common reference texts, including Picket and White (1985) and Forman and Godron (1986), and also with the common use of the term in the landscape ecology literature (Hartgerink and Bazzaz 1984, Scheiner 1992). Patch can specifically describe forested patches, nonforest vegetation patches, rock/barren patches, or water patches.

In contrast, the term "stand" has long been used to refer to the basic unit of forest management (Toumey 1937). It also has been used as the basic unit of mapping and inventory (Graves 1913). A stand is defined as "a community, particularly of trees, possessing sufficient uniformity as regards composition, age, spatial arrangement, or condition, to be distinguishable from adjacent communities, so forming a silvicultural or management entity." This definition, from the SAF's *Terminology of Forest Science, Technology, Practice, and Products* (Ford-Robertson 1971), is consistent with definitions in a variety of reference texts including Toumey (1937), Smith (1986), Oliver and Larson (1990), Lincoln et al. (1982), and the definition provided in the USDA Forest Service *Silvicultural Practices Handbook* (FSH 2409.17). Historically, most vegetation mapping completed by the agency has been conducted through delineation of forest stands. In the context of the protocol that this technical guide covers, the terms "patch" and "stand" may be synonymous depending on the degree that management considerations are incorporated into stand delineations along with compositional and structural characteristics. Because many past stand delineations contain multiple vegetation conditions and map units, they would be multiple map features in any new mapping effort.

Guidelines for Map Feature Delineation

Image Interpretation. Image interpretation is the systematic examination of image data. This frequently involves other supporting materials, such as maps and field observations (Lillesand and Kiefer 2000). "The basis for delineation of map units is normally discontinuities in texture (reflecting life form composition, stocking, tree crown size differences, and/or apparent tree height" (Stage and Alley 1973). If map feature delineation is completed with aerial photography, the process normally uses stereoscopic vertical aerial photography. This process involves transferring the photo delineations to a base map and converting to a digital form. An alternative image interpretation technique involves interpreting stereoscopic pair aerial photography in conjunction with high-resolution, digital imagery interpretation. An advantage of simultaneous onscreen delineation is the creation of an immediate digital product. Photographic and digital image interpretations without using stereoscopic photographic pairs suffer from the constraint of a one-dimensional depiction of vegetation cover. Image interpretation is the most intuitive form of map feature delineation but is also the most subjective and least cost effective.

Image Segmentation. As stated in Ryerd and Woodcock (1996), "Image segmentation is the process of dividing digital images into spatially cohesive units, or regions. These regions represent discrete objects or areas in the image." If map feature delineation is completed with digital imagery, the process typically uses data from spaceborne remote sensing platforms. The basis for map unit delineation is usually the segmentation and merging of raster data based on spectral characteristics and spatial arrangement. This segmentation and merging process is influenced by the variance structure of the image data and provides the modeling units that reflect life form composition, stocking, tree crown size differences, and other vegetation/land cover characteristics. Because the image data are geospatial data, the delineations do not have to be transferred to a base map. Image segmentation is the most objective and typically lowest cost approach to map feature delineation but is the farthest removed from human intuition. Image segmentation is most often used to develop mid and broad level map products because it offers substantial spatial detail in a consistent and repeatable fashion over large areas.

Thematic Aggregation. Thematic aggregation is the process of combining spatially distinct map features based on their categorical similarity and spatial arrangement. Thematic aggregation is not a stand-alone approach to feature delineation. Feature delineations generated at lower levels in the hierarchy, however, may preclude the need to directly delineate features at higher levels. If map features are derived through aggregation routines, a clear set of aggregation parameters or rules must be developed. Aggregation parameters must consider the thematic relationship of potentially merged features (e.g., the aggregation of two similar tree types is more desirable than the aggregation of a tree type and a nonvegetated class). Aggregation parameters are defined by thematic similarity and composition of the aggregated feature and are ideally based on a hierarchical classification scheme.

Aggregation as a means of feature delineation is most commonly applied at the coarsest map levels and, if applied at the mid-level, should only supplement more direct delineation techniques. Base-level mapping presumes that no finer continuous map product exists, and aggregation is not an applicable technique.

Map feature aggregation that have an areal extent below the minimum map feature standard should be performed using logic that aggregates based on thematic similarity of map unit attributes versus longest shared perimeter (e.g., opening the longest shared arc).

Table 3.20. *Data sources and methods for map feature delineation.*

Map level	Minimum map feature standard (acres)	Data sources	Delineation methods
National	500	Medium to coarse resolution multispectral or panchromatic imagery (30 m–1 km); existing broad or mid-level vegetation maps	Data aggregation of broad or mid-level maps; image segmentation
Broad	20	Medium resolution multispectral or panchromatic imagery (10–30 m), small scale photography (1:40,000–1:80,000), existing mid- and base-level maps	Data aggregation of mid- or base-level maps; image segmentation; image interpretation
Mid	5	Fine to medium resolution multispectral or panchromatic imagery (1–30 m), mid-scale photography (1:15,840–1:40,000), existing base-level maps	Image segmentation; image interpretation; data aggregation of base-level maps
Base	5	Fine resolution multispectral or panchromatic imagery (< 5 m), large scale photography (1:5,000–1:15,840)	Image interpretation

Tables 3.21A and 3.21B offer simple guidelines for developing a merge routine that will minimize the variability of a map unit in a map feature associated with merging adjacent features.

Map Feature Attribution

The process of mapping vegetation characteristics and assigning map unit labels or category to each map feature is referred to as **map feature attribution**. At a minimum, each map feature is attributed with a category from each standard map unit defined in section 3.2.2. The map feature attribution process is typically applied in two steps: (1) classifying the landscape in terms of the map units, and (2) labeling map features (polygons) with map attributes. Depending on the mapping methodology, these two steps can be applied simultaneously or successively. Image interpretation usually accomplishes these two steps simultaneously; image classification often separates these two steps into two distinct processes.

Table 3.21A. *Aggregation logic—if physiognomic order is different than any adjacent map feature.*

Adjacent feature	Below minimum feature—tree order	Below minimum feature—shrub order	Below minimum feature—herbaceous order	Below minimum feature—no dominant	Below minimum feature—non-vegetated
Tree order	Different	Merge second	Merge fourth	Merge fourth	Merge fourth
Shrub order	Merge first	Different	Merge third	Merge third	Merge third
Herbaceous order	Merge second	Merge first	Different	Merge second	Merge second
No dominant—sparse	Merge third	Merge third	Merge first	Different	Merge first
Nonvegetated	Merge fourth	Merge fourth	Merge second	Merge first	Different

Table 3.21B. *Aggregation logic—if physiognomic order is the same as at least one adjacent map feature.*

Map unit attribute	Priority	Herbaceous order	Herbaceous order	Herbaceous order
Floristics	1	Different—merge	N/A	N/A
Physiognomic subclass	2	Same	Different—merge	N/A
Physiognomic class	3	Same	Same	Different—merge

Map unit attribute	Priority	Shrub order	Shrub order	Shrub order	Shrub order
Shrub cover	1	Different —merge	N/A	N/A	N/A
Floristics	2	Same	Different—merge	N/A	N/A
Physiognomic subclass	3	Same	Same	Different—merge	N/A
Physiognomic class	4	Same	Same	Same	Different —merge

Map unit attribute	Priority	Tree order	Tree order	Tree order	Tree order	Tree order
Tree cover	1	Different—merge	N/A	N/A	N/A	N/A
Tree size	2	Same	Different—merge	N/A	N/A	N/A
Floristics	3	Same	Same	Different—merge	N/A	N/A
Physiognomic subclass	4	Same	Same	Same	Different—merge	N/A
Physiognomic class	5	Same	Same	Same	Same	Different—merge

Floristics in tables 3.21A and 3.21B refer to map units based on classification systems of cover type, dominance type, or plant alliances.

The methods used to map vegetation characteristics may vary by map attribute and level. As with the selection of image data sources, all possible methods are not appropriate across the range of map levels. The following section describes the appropriate methods used to map the standard attributes at the mid- and base-levels. The appendixes present specific examples of mapping methodologies that have been successfully used in the Forest Service. The standards defined in section 3.2.2 and the guidelines provided in conjunction with the associated examples should enable the development of a vegetation mapping work plan and/or the development of mapping contract specifications.

As previously described, vegetation mapping across the range of map levels outlined in the protocol covered in this technical guide is primarily accomplished by using remotely sensed image data. Map feature attribution is therefore a remote sensing classification or interpretation process. The methods explained herein apply to the base and mid-level map products based on the assumption that broad and national level maps are generalizations of the mid-level map features and will be generated by aggregating those data.

Many common textbooks on digital image processing of satellite remote sensing data and interpretation of aerial photography cover the process of extracting information from remotely sensed data, or “decoding” information from raw uninterpreted images. Image classification of satellite remote sensing imagery and interpretation of aerial photography are analogous processes. Both processes are data models intended to represent complex natural systems. On the most basic level, the image interpretation and classification processes are essentially the same; both processes group similar objects and label them with some form of thematic information. Beyond this most basic level, however, each of these processes has some fundamental differences related to the basic remote sensing data, the analytical logic and methods, and the “tools” used to extract the information.

The following sections briefly outline and describe the image interpretation process (not limited to aerial photography interpretation) and the satellite image classification process. These two processes are explained together to illustrate their relationships. To remain within the scope of the protocol covered in this technical guide, the tasks for each process are only summarized. The basic task descriptions generally follow Avery (1977), Estes et al. (1983), Simonett et al. (1983), Campbell (1987), Lillesand and Kiefer (1987), Jensen (1996), and Lachowski et al. (1995 and 1996). Other textbooks and the remote sensing literature offer many minor variations on the basic tasks described. Similarly, the elements of image interpretation presented are also fairly common in the aerial photography interpretation literature

Elements of Image Interpretation. These elements, with some variation, are fairly common in the aerial photography interpretation literature (Avery 1977, Estes et al. 1983, Simonett et al. 1983, Campbell 1987, Lillesand and Kiefer 1987, Jensen 1996); most of them have analogies in satellite imagery classification.

- **Image tone** denotes the lightness, darkness, and/or color of a region in an image. Values for each cell in each band in multispectral data would be analogous. For more information, refer to remote sensing literature that relates primarily to this element.[4]

[4] Hixson, M.; Scholz, D.; Fuhs, N.; Akiyama, T. 1980. Evaluation of several schemes for classification of remotely sensed data. Photogrammetric Engineering and Remote Sensing. 46: 1547–1553, Strahler, A.H. 1980. The use of prior probabilities in maximum likelihood classification of remotely sensed data. Remote Sensing of Environment. 10: 135–163, Crapper, P.F.; Hynson, K.C. 1983. Change detection using Landsat photographic imagery. Remote Sensing of Environment. 13: 291–300, Crist, E.P.; Kauth, R.J. 1986. The tasseled cap de-mystified. Photogrammetric Engineering and Remote Sensing. 52: 81–86, Shasby, M.; Carneggie, D. 1986. Vegetation and terrain mapping in Alaska using Landsat MSS and digital terrain data. Photogrammetric Engineering and Remote Sensing. 52: 779–786, Fung, T.; LeDrew, E. 1987. Application of principal components analysis to change detection. Photogrammetric Engineering and Remote Sensing. 53: 1649–1658, Chavez, P.S.; Bowell, J.A. 1988. 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Photogrammetric Engineering and Remote Sensing. 56: 469–473, Mausel, P.W.; Kramber, W.J.; Lee, J.K. 1990. Optimum band selection for supervised classification of multispectral data. Photogrammetric Engineering and Remote Sensing. 56: 55–60, Wang, F.1990. Improving remote sensing image analysis through fuzzy information representation. Photogrammetric Engineering and Remote Sensing. 56: 1163–1169, Cetin, H.; Levandowski, D.W. 1991. Interactive classification and mapping of multi-dimensional remotely sensed data using n-dimensional probability density functions (nPDF). Photogrammetric Engineering and Remote Sensing. 57: 1579–1587, Cohen, W.B. 1991. Response of vegetation indices to changes in three measures of leaf water stress. Photogrammetric Engineering and Remote Sensing. 57: 195–202, Loveland, T.R.; Merchant, J.W.; Ohlen, D.O.; Brown, J.F. 1991. 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Satellite inventory of Minnesota forest resources. Photogrammetric Engineering and Remote Sensing. 60: 287–298, Collins, J.B.; Woodcock, C.E. 1994. Change detection using the Gramm-Schmidt transformation applied to mapping forest mortality. Remote Sensing of Environment. 50: 267–279, Coppin, P.R.; Bauer, M.E. 1994. Processing of multitemporal Landsat TM imagery to optimize extraction of forest cover change features. IEEE Geoscience and Remote Sensing. 60: 287–298, Green, K.; Kempka, D.; Lackey, L. 1994. Using remote sensing to detect and monitor land-cover and land-use change. Photogrammetric Engineering and Remote Sensing. 60: 331–337, Woodcock, C.E.; Macomber, S.; Ryherd, S.; et al. 1994. Mapping forest vegetation using Landsat TM imagery and a canopy reflectance model. Remote Sensing of Environment. 50: 240–254, Collins, J.B.; Woodcock, C.E. 1996. An assessment of several linear change detection techniques for mapping forest mortality using multitemporal Landsat TM data. 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Photogrammetric Engineering and Remote Sensing. 64: 293–300, Deppe, F. 1998. Forest area estimation using sample surveys and Landsat MSS and TM data. Photogrammetric Engineering and Remote. Sensing. 64: 285–292, Mickelson, J.G.; Civco, D.L.; Silander, Jr., J.A. 1998. Delineating forest canopy species in the northeastern United States using multi-temporal TM imagery. Photogrammetric Engineering and Remote Sensing. 64: 891–904, and Todd, S.W.; Hoffer, R.M. 1998. Responses of spectral indices to variation in vegetation cover and soil background. Photogrammetric Engineering and Remote Sensing. 64: 915–921.

- **Image texture** refers to the apparent roughness and smoothness of an image region created by the frequency of tonal change on the image. Texture is typically caused by the pattern of highlighted and shadowed areas as an irregular surface is illuminated from an oblique angle. Tonal change among groups of pixels would be analogous. For more information, refer to remote sensing literature that relates primarily to this element.[5]
- **Shadow** is especially an important clue in the interpretation of objects. Shadows of buildings, trees, and other objects reveal characteristics that are not obvious from the overhead view alone. Edges, such as forest boundaries, often have characteristic shadows.
- **Pattern** refers to the arrangement of individual objects into distinctive, recurring forms that permit recognition. The distinctive pattern of an orchard, baseball diamond, or drive-in theater makes them identifiable. A recurring pattern between adjacent pixels can be used as one of the features of a contextual classification of digital imagery. For more information, refer to remote sensing literature that relates primarily to this element.
- **Association** specifies characteristic occurrence of certain objects or features, usually without the strict spatial arrangement implied by pattern. The identification of a baseball diamond, for instance, is often associated with a school or park.
- **Shape** refers to the general form, configuration, or outline of individual objects. For example, lakes, rivers, timber harvest units, and center pivot irrigation fields all have shapes that can provide clear identification.
- **Size** of an object or feature is considered in relation to other objects on the image and to the photo scale.

[5] Haralick, R.M.; Shanmugam, K.; Dinsteim, L.H. 1973. Textural features for image classification. IEEE Transactions on systems, man, and cybernetics. SMC-3: 610–621, Vilnrotter, F.M.; Nevatia, R.; Price, K.E. 1986. Structural analysis of natural textures. IEEE Transactions on Pattern Analysis and Machine Intelligence. 8: 76–89, Nellis and Briggs 1989, Franklin, S.E.; Peddle, D.R. 1990. Classification of SPOT HRV imagery and texture features. International Journal of Remote Sensing 11: 551–556, Marceau, D.J.; Howarth, P.J.; Dubois, J.M.M.; Gratton, D.J. 1990. Evaluation of the grey-level co-occurrence matrix method for land-cover classification using SPOT imagery. IEEE Transactions on Geoscience and Remote Sensing. 28: 513–519, Peddle, D.R.; Franklin, S.E. 1991. Image texture processing and data integration for surface pattern discrimination. Photogrammetric Engineering and Remote Sensing. 57: 413–420, Cohen, W.B.; Spies, T.A. 1992. Estimating structural attributes of Douglas-fir/western hemlock forest stands from Landsat and SPOT imagery. Remote Sensing of Environment. 41: 1–17, Gong, P.; Marceau, D.J.; Howarth, P.J. 1992. A comparison of spatial feature extraction algorithms for land-use classification with SPOT HRV data. Remote Sensing of Environment. 40: 137–151, Kushwaha, S.P.S.; Kuntz, S.; Oesten, G. 1994. Applications of image texture in forest classification. International Journal of Remote Sensing. 15: 2273–2284, Cohen, W.B; Spies, T.A.; Fiorella, M. 1995. Estimating the age and structure of forests in a multi-ownership landscape of western Oregon, U.S.A. International Journal of Remote Sensing. 16: 721–746, Dikshit, O.; Roy, D.P. 1996. An empirical investigation of image resampling effects upon the spectral and textural supervised classification of a high spatial resolution multispectral image. Photogrammetric Engineering and Remote Sensing. 62: 1085–1092, Hay, G.J.; Niemann, K.O.; McLean, G.F. 1996. An object-specific image-texture analysis of H-resolution forest imagery. Remote Sensing of Environment. 55: 108–122, Ricotta, C.; Avena, G.C.; Ferri, F. 1996. Analysis of human impact on a forested landscape of central Italy with a simplified NDVI texture descriptor. International Journal of Remote Sensing. 17: 2869–2874, Ryherd and Woodcock 1996, Wulder, M.A.; Franklin, S.E.; Lavigne, M.B. 1996. High spatial resolution optical image texture for improved estimation of forest stand leaf area index. Canadian Journal of Remote Sensing. 22: 441–449, Jakubauskas, M.E. 1997. Effects of forest succession on texture in Landsat thematic mapper imagery. Canadian Journal of Remote Sensing. 23: 257–263, Wulder, M.A.; LeDrew, E.F.; Franklin, S.E.; Lavigne, M.B. 1998. Aerial image texture information in the estimation of northern deciduous and mixed wood forest leaf area index (LAI). Remote Sensing of Environment. 64: 64–76, Bian, L.; Butler, R. 1999. Comparing effects of aggregation methods on statistical and spatial properties of simulated spatial data. Photogrammetric Engineering and Remote Sensing. 65: 73–84, and Emerson, C.W.; N. S.N. LamQuattrochi D.A. 1999. Multi-scale fractal analysis of image texture and pattern. Photogrammetric Engineering and Remote Sensing. 65: 51–61.

- **Site** refers to the topographic position, geographic location, or other biophysical environment factors; e.g., streams and rivers are positioned in valley floors and lookout towers are positioned on mountaintops or ridges. Other features occur only in some geographic locations, such as palm trees. This element could also refer to site characteristics such as potential vegetation setting. For more information, refer to remote sensing literature that relates primarily to this element.[6]

Image Interpretation for Base Level Mapping. High-resolution image interpretation completed by skilled interpreters is expected to comprise the basis for base-level vegetation maps. Extensive field data and validation are anticipated to be incorporated into this process. Depending on the thematic detail in the classification scheme for any given map product (i.e., plant associations versus alliances), the image interpretation task will involve various amounts of field validation sampling. This fieldwork may range from simple "ground truth" reconnaissance to a formal, two-stage sample design to a complete field-data based attribution of map delineations. Appendix 3B includes example of a structured aerial photointerpretation data gathering protocol in operational use in the agency.

Image/Photointerpretation Tasks

- Classification assigns objects, features, or areas to categories based on their appearance on the imagery.
- Enumeration refers to listing and counting discrete items visible on an image. Enumeration reports the numbers of classified items present in a defined area.
- Mensuration focuses on two kinds of measurement: (1) photogrammetry, or distance, height, volumes, and areas; and (2) photometry, the measurement of image brightness.
- Delineation outlines photomorphic patches or regions as they are observed on remotely sensed images. These areal units are characterized by specific tones and textures to identify edges or boundaries between separate areas.

Campbell (1987) describes five general image interpretation strategies that are likely to be incorporated into the base-level vegetation mapping process.

1. Using **field observations** to identify features on the imagery. This strategy has been employed to greater or lesser degrees by nearly all photointerpreters and provides

[6] Hutchinson, C.F. 1982. Techniques for combining Landsat and ancillary data for digital classification improvement. Photogrammetric Engineering and Remote Sensing. 48: 123–130, Cibula, W.G.; Nyquist, M.O. 1987. Use of topographic and climatological models in a geographical database to improve Landsat MSS classification for Olympic National Park. Photogrammetric Engineering and Remote Sensing. 53: 67–75, Janssen, L.L.F.; Jaarsma, M.N.; van der Linden, E.T.M. 1990. Integrating topographic data with remote sensing for land-cover classification. Photogrammetric Engineering and Remote Sensing. 56: 1503–1506, Bolstad, P.V.; Lillesand, T.M. 1992. Rule-based classification models: flexible integration of satellite imagery and thematic spatial data. Photogrammetric Engineering and Remote Sensing. 58: 965–971, Franklin, S.E.; Wilson, B.A. 1992. A three-stage classifier for remote sensing of mountain environments. Photogrammetric Engineering and Remote Sensing. 58: 449–454, Gong, P. 1996. Integrated analysis of spatial data from multiple sources: using evidential reasoning and artificial neural network techniques for geological mapping. Photogrammetric Engineering and Remote Sensing. 62: 513–523, Lakowski et al. 1997, Stoms, D.M.; Bueno, M.I.; Davis, F.W. et al. 1998. Map guided classification of regional land cover with multi-temporal AVHRR data. Photogrammetric Engineering and Remote Sensing. 64: 831–838.

reference or training data for most supervised and unsupervised classifications of satellite imagery.

2. **Direct recognition**, the application of the interpreter's accumulated experience, skill, and judgment to map features recorded on an image. An example would be the recognition of a golf course or baseball diamond on aerial photographs.
3. Interpretation by **inference**, using the visible distribution for a distribution that is not visible on the image. An example is interpretation of soil patterns, inferred from vegetation and topography, from aerial photographs. This strategy constitutes the vast majority of classifications of satellite imagery.
4. **Probabilistic interpretation**, which typically relies on the relationship between some element of image interpretation and the probable interpretation. Collateral (nonimage) information is commonly used in probabilistic interpretation.
5. **Deterministic interpretation**, where image characteristics and ground conditions are tied with quantitatively expressed deterministic relationships. A common example is using stereo photogrammetry to determine the height of an object on the photos.

Image Classification for Mid Level Mapping. Classification of medium-resolution image data (e.g., Landsat TM) is expected to comprise the basis for mid-level vegetation maps. These classifications are expected to be objective and repeatable methods that result in consistent map products.

Image Classification Task

- Radiometric correction is made for sensor system detectors when the system is not functioning properly. Radiometric correction is also made for atmospheric attenuation caused by scattering and absorption in the atmosphere and topographic attenuation.
- Geometric and terrain correction removes systematic and systematic geometric errors and makes the geometry of the image planimetric.
- Image classification logic and algorithm assign pixels to map units from these four general categories:
  - Unsupervised classification is the identification of natural groups or clusters in multispectral data with subsequent information map unit assignment.
  - Supervised classification is the process of using samples of known identity (i.e., pixels already assigned to information classes) to classify pixels of unknown identity.
  - Unsupervised/supervised hybrid classification is the combination of a supervised and unsupervised classification.
  - Ancillary data hybrid classification is the use of nonimage information with a supervised or unsupervised classification.
- Extract data from training (reference) sites selected from representative and relatively homogeneous land cover classes in the image. Collect spectral statistics for the modeling units representing each training site.

- Select appropriate bands using feature selection criteria to discriminate between classes and eliminate redundant information.
- If required, extract training statistics from final band selection.
- Extract thematic information and assign modeling units to map units or categories.
- Attribute delineated map features with thematic information.
- Correct for anomalous error in thematic information.
- Evaluate classification error using the remote sensing derived classification map and accuracy assessment (reference) data commonly summarized in an error matrix.

"The overall objective of image classification procedures is to automatically categorize all pixels in an image into land cover classes or themes….Typically, multispectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization" (Lillesand and Kiefer 2000). Four general analytical strategies exist for classifying digital remote sensing data into thematic map units or categories that are likely to be incorporated into the mid-level vegetation mapping process. All these general analytical approaches are often combined with manual classification of selected classes and/or manual edits of problem areas.

- Unsupervised classification to identify natural, spectral groups or spectral clusters in multispectral data. These clusters of data have unknown thematic content at the time they are created. The thematic labels are later assigned to the spectral statistical groups, often with some grouping or splitting of the original clusters.
- Supervised classification using samples of known identity (i.e., training data or pixels/regions already assigned to map units or categories) to classify pixels/regions of unknown identity. The training data establish the statistical relationships that comprise the basis for information class assignments to the most probable thematic class.
- Unsupervised/supervised hybrid classification. This hybrid approach combines the strengths of the two approaches and is common in vegetation mapping.
- Ancillary data hybrid classification combining nonimage information with a supervised and/or unsupervised classification. This strategy often applies ecological models to constrain the membership in thematic classes, thereby reducing error. An example of a simple ecological model would be to impose elevation ranges on classes that are not spectrally distinguishable but easily separated based on their biophysical setting.

Reference Data

Reference data collection is a vital part of vegetation mapping projects. Reference data is necessary to successfully complete a mapping project. Emphasize designing the reference data collection and identifying training and accuracy assessment sites.

Reference data collection refers to the effort expended to collect quantitative or qualitative data about ground features. Although field data collection is not always necessary, some type of reference data is needed to help interpret and/or assess accuracy during a mapping project. Reference data are frequently collected on the ground through field visits; several other techniques, however, are available for collecting this data. For example, interpreting aerial photographs or observation and taking notes from a helicopter or fixed-wing aircraft have been successful techniques for collecting reference data. Recently, airborne video cameras have been used. Data collection techniques depend on the level of detail needed to satisfy the requirements of the particular mapping project (Congalton and Biging 1992).

In remote sensing projects, reference data serve two primary purposes. First, reference data establish a link between variation on the ground and in the image. This link is necessary for assigning image modeling units (pixels or regions) to discrete land cover classes in the image classification process. Second, reference data help assess a map's accuracy.

Training data are representative areas of land cover that are identified on the satellite image and in the reference data source. In effect, training data are used to "train" the computer to assign information to a particular modeling unit. For example, a computer classification may separate a lake and a meadow on a satellite image based on spectral differences. The computer, however, will not be able to label lakes and meadows correctly until the appropriate reference information is supplied.

Accuracy assessment data, like training data, are samples of land cover and vegetation identified on the satellite image (classified image) and in the reference data source. Although training data are used in the image classification process, accuracy assessment data are used after the classification is completed to assess the accuracy of the final map. The accuracy of a classification is the degree to which the map's identification of various objects on the ground can be corroborated by the accuracy assessment data. For most projects, the same type of data is collected for training and accuracy data.

The most common sources of reference data for remote sensing projects are aerial photointerpretation and field data collection. Remote sensing projects commonly use photointerpretation as a primary source of reference data or to combine these two sources. Numerous references illustrate the development and use of reference data.[7] Many of these studies used photointerpretation in conjunction with field sampling; many others relied exclusively on the photointerpretation to provide these reference data.

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[7] Strahler, A.H. 1980. The use of prior probabilities in maximum likelihood classification of remotely sensed data. Remote Sensing of Environment. 10: 135–163, Shasby, M.; Carneggie, D. 1986. Vegetation and terrain mapping in Alaska using Landsat MSS and digital terrain data. Photogrammetric Engineering and Remote Sensing. 52: 779–786, Cibula, W.G.; Nyquist, M.O. 1987. Use of topographic and climatological models in a geographical database to improve Landsat MSS classification for Olympic National Park. Photogrammetric Engineering and Remote Sensing. 53: 67–75, Fung, T.; LeDrew, E. 1987. Application of principal components analysis to change detection. Photogrammetric Engineering and Remote Sensing. 53: 1649–1658, Chuvieco and Congalton 1988, Leprieur, C.E.; Durand, J.M. 1988. Influence of topography on forest reflectance using Landsat thematic mapper and digital terrain data. Photogrammetric Engineering and Remote Sensing. 54: 491–496, Franklin, S.E.; D.R. Peddle. 1990. Classification of SPOT HRV imagery and texture features. International Journal of Remote Sensing 11: 551–556, Janssen, L.L.F.; Jaarsma, M.N.; van der Linden, E.T.M. 1990. Integrating topographic data with remote sensing for land-cover classification. Photogrammetric Engineering and Remote Sensing. 56: 1503–1506, Marceau, D.J.; Howarth, P.J.; Dubois, J.M.M.; Gratton, D.J. 1990. Evaluation of the grey-level co-occurrence matrix method for land-cover

Independent of the source of reference data, promoting consistency between the training and accuracy assessment data is important. Training and accuracy assessment data should be of similar type and follow the taxonomic logic and data standards. For most projects, the same type of data is collected for training and accuracy assessment applications.

Thematic Map Accuracy Assessment

Accuracy assessments are essential parts of all remote sensing projects. First, they enable the user to compare different methods and sensors. Second, they provide information on the reliability and usefulness of remote sensing techniques for a particular application. Finally, and most importantly, accuracy assessments support the spatial data used in decisionmaking processes. Too often, vegetation and other maps are used without a clear understanding of their reliability. A false sense of security about the accuracy of the map may result in an inappropriate use of the map; important management decisions may be made on data with unknown and/or unreliable accuracy. Although quantitative accuracy assessment can be time consuming and expensive, it must be an integral part of any vegetation mapping project.

Quantitative accuracy assessment depends on the collection of reference data. Reference data is known information of high accuracy (theoretically 100-percent accuracy) about a specific area on the ground (the accuracy assessment site). The assumed-true reference data can be obtained from ground visits, photointerpretations, video interpretations, or some combination of these methods. In a digital map, accuracy assessment sites are generally the same type of modeling unit used to create the map. Accuracy assessment involves the comparison of the categorized data for these sites (i.e., modeling units) to the reference data for the same sites. The error matrix is the standard way of presenting results

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of an accuracy assessment (Story and Congalton 1986). This matrix is a square array in which accuracy assessment sites are tallied by their classified category in the image and their actual category according to the reference data (table 3.22). Typically, the rows in the matrix represent the classified image data, while the columns represent the reference data. The major diagonal, highlighted in the following table, contains those sites where the classified data agree with the reference data.

The nature of errors in the classified map can also be derived from the error matrix. In the matrix, errors (the off-diagonal elements) are errors of inclusion (commission errors) or errors of exclusion (omission errors). Commission errors appear in the off-diagonal matrix cells that form the horizontal row for a particular class. Omission error is represented in the off-diagonal vertical row cells. High errors of omission/commission between two or more classes indicate spectral confusion between these classes.

Useful measures of accuracy are easily derived from the error matrix:

- Overall accuracy, a common measure of accuracy, is computed by dividing the total correct samples (the diagonal elements) by the total number of assessment sites found in the bottom right cell of the matrix.
- Producer's accuracy, based on omission error, is the probability of a reference site being correctly classified. Producer's accuracy is calculated by dividing the total number of correct accuracy sites for a class (diagonal elements) by the total number of reference sites for that class located in the bottom cell in each column.
- User's accuracy, which is based on commission error, is the probability that a pixel on the map actually represents that category on the ground. User's accuracy is calculated

Table 3.22. *Error matrix example.*

		Reference data				
		Tree dominated	**Shrub dominated**	**Herbaceous/ nonvascular dominated**	**Sparsely vegetated**	**Row total**
Classified data	**Tree dominated**	**65**	4	22	24	115
	Shrub dominated	6	**81**	5	8	100
	Herbaceous/ nonvascular dominated	0	11	**85**	19	115
	Sparsely vegetated	4	7	3	**90**	104
	Column total	75	103	115	141	**434**

Overall Accuracy = 321/434 = 74 percent

Producer's Accuracy

Tree Dominated = 65/75 = 87 percent
Shrub Dominated = 81/103 = 79 percent
Herbaceous/Nonvascular Dominated = 85/115 = 74 percent
Sparsely vegetated = 90/141 = 64 percent

User's Accuracy

Tree Dominated = 65/115 = 57 percent
Shrub Dominated = 81/100 = 81 percent
Herbaceous/Nonvascular Dominated = 85/115 = 74 percent
Sparsely vegetated = 90/115 = 87 percent

by dividing the number of correct accuracy sites for a category by the total number of accuracy assessment sites, located in the far right cell of each row, that were classified in that category (Story and Congalton 1986).

Conducting an accuracy assessment is a multistep process whose successful completion requires a number of decisions and an awareness of the challenges previously described. Following are the general steps in accuracy assessment:

Step 1: Develop the sampling scheme. Many opinions exist on the proper sampling design to use with digital image classification. In most situations, random sampling (simple random or systematic random) without replacement and stratified random sampling will provide satisfactory results (see the discussion in Congalton 1991 and Stehman 1992). Random sampling often is not practical in the field, and stratified sampling requires collection of the accuracy assessment sites after the classification has been completed, which requires a second field effort. When photointerpretation is the primary reference data source, these limitations no longer apply. Regardless of the specific approach, all sampling schemes should contain an element of randomness to help eliminate interpreter's bias.

The appropriate sample number and size are other important considerations. The number of sample sites must be large enough to be statistically sound but not larger than necessary for the sake of efficiency. If overall accuracy is to be considered, more samples will be needed to examine the nature of errors in individual categories (the off-diagonal elements in the error matrix). A general rule of thumb is that at least 20 sites are required for each category in the classification. Congalton (1991) suggests 50 sites for each category and 75 to 100 sites per map unit for large areas with many categories. Evaluating the frequency distribution of class membership by attribute can make an estimate of the appropriate sample size.

The need for statistical validity must be balanced with practical considerations, such as time and budget constraints. Documentation should include an explanation of any statistical compromises made. Accuracy assessment sites are expensive and time consuming to delineate, characterize, and ground check. In determining the number of accuracy assessment sites to investigate, a tactical approach is recommended. Categories of particular importance may warrant more sites while relatively less important or easily mappable categories, such as snow and open water, may need fewer sites. Additionally, the proportion of field-visited to photointerpreted sites can be adjusted to balance statistical and practical considerations. For example, more photo sites may be collected than ground sites, and the ground-visited sites may be selected partly because of their accessibility.

Step 2: Choose the appropriate reference data. Reference data may be an existing map, existing resource inventory data, photointerpreted accuracy sites, or data collected on the ground. Because a major assumption in quantitative accuracy assessment is that the reference data are 100-percent correct, every effort should be made to secure the highest quality reference data. The analyst should be aware that, in many cases, reliable maps do not exist and inventory data are out of date. Often the available data are in a form that is incompatible with the classification scheme. To provide anything other than qualitative information, reference data must conform to the same classification scheme as the classified data.

Using photointerpretations as reference data requires taking special care. Photointerpreted sites have traditionally been accepted as 100-percent correct when used to assess the accuracy of digital classifications; however, as Biging and Congalton (1989) observed, perfect accuracy is rarely attributable to photointerpretations. To help minimize errors, apply the following principles: the date of the photos should be close to the date of the digital imagery; experienced interpreters familiar with both the vegetation and the classification scheme must conduct photointerpretations of accuracy sites; and to ensure the accuracy and consistency of the reference data, photointerpretations should be closely inspected.

Using precise ground measurements and/or photointerpretations as reference data is a frequent method of assessing the accuracy of the classified image. To minimize costs and maximize efficiency, data from accuracy assessment sites can be collected during the same field visit for collecting training site data. Accuracy assessment sites cannot be used as training sites. Additional photointerpreted sites can be collected after the field season, when the photointerpreters have experience with the project area. This combined approach can be a cost-effective means of acquiring accurate reference data.

Step 3: Delineate the accuracy assessment sites on the reference data. After the sampling scheme, sample size, and reference data are determined, the accuracy sites can be delineated. Because pinpointing the location is critical to determining the accuracy of the classified image, all assessment site locations must be precisely delineated on base maps, orthophotos, resource photographs, or collected with a global positioning system (GPS). For large projects, developing and maintaining a relational database is an efficient way of organizing and working with accuracy assessment data. Typically, accuracy assessment sites are delineated on resource photographs. Sites should be homogeneous with regard to map category and/or modeling unit (e.g., homogeneous crown closure class or homogeneous species mix). Unambiguous delineation rules must be established. Of utmost importance is that the sampling procedure be unbiased.

Step 4: Interpret the assessment sites from the reference data. As mentioned in step 2, accuracy assessment data must conform to the same classification scheme as the data used to produce the map. This is true regardless of whether field-verified or photointerpreted sites are used. The same labeling rules (classification key) used to assign labels to features in the map must be used to label accuracy assessment sites. To eliminate bias, the person collecting the reference data should be very familiar with the classification scheme, but not with the classified map. This person should have no prior knowledge of the map label for the corresponding accuracy assessment sites.

Step 5: Compile the classified data for accuracy assessment sites. Accuracy sites must be precisely located on the classified image or map coverage. Accuracy sites delineated on resource photography can be digitized directly over the satellite imagery or digital orthophotos. Sites with GPS data can be digitally transferred to the GIS. When cross-referencing the vegetation map with the accuracy assessment data, the accuracy assessment site may overlap more that one map feature. When this occurs, determine if the reference site data can be subdivided to follow map feature boundaries. The spatial accuracy of the reference data relative to the spatial accuracy of the map features must be considered. If the reference site data cannot be confidently assigned to one or more map features, it should not be used to for map accuracy. The goal is to develop a label for the accuracy assessment site to compare with the map feature label corresponding to the location of the reference site.

Step 6: Perform quality control. Although quality control is listed as a separate task, in practice it is an ongoing and iterative process. Errors in accuracy assessments will appear as errors in the classification, thereby resulting in an underestimation of the classification's accuracy. Some common errors include data entry mistakes, incomplete accuracy assessment forms, incorrect location of accuracy sites, incorrect interpretation of the accuracy site, and accuracy sites not entered into the database or missing from analysis.

Step 7: Build the error matrix. Tallying each accuracy site according to its accuracy assessment label and classification label creates the error matrix. Many commercial image-processing systems provide modules to create and analyze error matrices.

Step 8: Summarize and present accuracy assessment results. To prevent inappropriate uses, the error matrix and a discussion and analysis of the accuracy results should accompany any use of the classified map.

A relatively recent innovation in accuracy assessment is the use of fuzzy sets for accuracy assessments. Traditional accuracy assessment as described in section suffers from certain limitations. First, it assumes that each accuracy site can be unambiguously assigned to a single map category (Gopal and Woodcock 1994) when in reality it may be part of a continuum between map categories. Second, the traditional error matrix makes no distinction between magnitudes of error. For example, in a traditional error matrix, misclassifying “conifer forest” as “open water” carries the same weight as the error of misclassifying it as “conifer/hardwood mix.”

Fuzzy logic is designed to handle ambiguity and, therefore, should be considered for an accuracy assessment of complex or potentially ambiguous classification. Instead of assessing a site as correct/incorrect as in a traditional assessment, an assessment using fuzzy sets can rate a site as absolutely wrong, understandable but wrong, reasonable or acceptable match, good match, or absolutely right (Gopal and Woodcock 1994). The resulting accuracy assessment can then rate the seriousness of errors as well as absolute correctness/incorrectness. For a complete description of applying fuzzy sets to accuracy assessment, see Woodcock and Gopal (1992).

3.3 Field and Aerial Photography Data

In this section: *Identification of sources for data collection standards, protocols, and forms*

The collection and use of field data for map development can be a significant part of the mapping process. For the purposes of this technical guide, the term “field data” applies to measurements or direct observations made in the field while collecting reference data or making interim map assessments. These field data can exist in a number of formats but are typically characterized as plot level data or summary observations of a geographically specific area.

Similarly, the collection and use of aerial photography data for map development can also be a significant part of the mapping process. For the purposes of this technical guide, the term “aerial photo data” applies to data measured or interpreted from vertical aerial photography following the image interpretation process outlined in section 3.2.4.

The collection and notation of summary observations for interim map assessment is inherently a more subjective process, relying more on ocular estimation and interpretation than on measurement. This type of field data has limited application, but can be efficiently and cost effectively collected across broad geographic extents and is suitable for collecting training data and reviewing map products during the development stage. No standards currently govern the collection and storage of these data, nor is it the intent of this technical guide to direct their collection and storage. For the purposes of characterizing their utility and ensuring data consistency, however, section 3.3.5 outlines a field review approach.

3.3.1 Field Data Collection Standards and Methods

Standards (Common Stand Exam [CSE] Users Guide, V1.6) for the collection of plot level data for stand exams and vegetation inventories have already been established and are logically applied to data collection for mapping purposes (USDA Forest Service 2004a).

3.3.2 Field Data Forms

Field data forms are often used to record plot level data for stand exams and vegetation inventory data. These data can also be entered directly into a field data recorder.

3.3.3 Aerial Photo Data Collection Standards and Methods

A variety of aerial photointerpretation protocols have been used throughout the Forest Service in conjunction with remote sensing projects. Appendix 3B contains an example of an operational photointerpretation protocol applied to remote sensing reference data collection.

3.3.4 Aerial Photo Data Forms

Aerial photo data forms are often used to record data from photointerpretation. These data can also be entered directly into an electronic database or spreadsheet.

3.3.5 Field Reviews

Field reviews conducted for map assessment during the mapping process generally entail summarizing the vegetation composition and structure in a geographically specific manner. Often, notations about whether the map accurately characterizes or mislabels the vegetation are also included. This information is then used to refine systematic mapping processes (image classifications and ecological modeling rules) and edit map attributes for anomalous errors.

Collecting an adequate amount of information requires extensive review of the project area. In large project areas associated with the mid, broad, and national levels, this is usually a rapid assessment process requiring vehicle or aircraft travel. Base-level mapping projects may require walkthrough observations.

The interim map products are taken into the field as printed maps or a digital product on a laptop computer. Notes are taken about specific features in the map, noting the composition and structure. Correct map attributes can also be recorded but generally have less utility than basic data that can be categorized into multiple systems. Field review vegetation maps are more easily used when they include road systems, hydrography, and terrain characteristics. U.S. Geological Survey 7.5-minute base series maps can serve as an effective overlay on vegetation draft maps to provide this ancillary information.

3.4 Metadata/Documentation

Metadata have been established as a standard part of a final vegetation map product. The FGDC requires that metadata accompany digital map products; therefore, this technical guide provides metadata standards for existing vegetation maps. Metadata protocols contained herein are taken directly from the FGDC documents detailing the content and format of digital geospatial data.

3.4.1 Metadata Entry Methods and Verification

In this section: *FGDC metadata requirements for vegetation maps*

3.4.1.1 Metadata Required for Existing Vegetation Maps

FGDC Metadata Standards

Metadata or "data about data" describe the content, quality, condition, and other characteristics of data. The FGDC approved the Content Standard for Digital Geospatial Metadata (FGDC-STD-001) in June 1998.

Objective. The objective of the FGDC metadata standards is to provide a common set of terminology and definitions for the documentation of digital geospatial data. Other requirements specific to vegetation classification and mapping are provided in the FGDC-approved Vegetation Classification Standard (FGDC-STD-005) in June 1997.

Scope. Executive Order No. 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure*, was signed on April 11, 1994. Section 3, Development of a National Geospatial Data Clearinghouse, paragraph (b) states that "each agency shall document all new geospatial data it collects or produces, either directly or indirectly, using the standard under development by the FGDC, and make that standardized documentation electronically accessible to the Clearinghouse network."

The standard was developed from the perspective of defining the information required by a prospective user to determine the availability of a set of geospatial data, the fitness of the set of geospatial data for an intended use, the means to access the set of geospatial data, and to successfully transfer the set of geospatial data. Thus, the standard establishes the names of data elements and compound elements to be used for these purposes, the definitions of these data elements and compound elements, and information about the values that are to be provided for the data elements. The standard does not specify how this information is to be organized in a computer system or data transfer, or to transmit, communicate, or present this information to the user. *Content Standard for Digital Geospatial Metadata*, CSDGM Version 2—FGDC-STD-001-1998, on the FGDC website provides detailed instructions on developing FGDC metadata.

For a general interview approach for creating metadata, see appendix 3D. Appendix 3E contains a standard metadata template.

3.4.1.2 Specific Metadata Requirements in the FGDC Vegetation *Classification Standard*

"Agencies should record and make available the required FGDC metadata during the course of vegetation inventory, whether data has been gathered via remote sensing or fieldwork." This FGDC metadata includes but is not limited to the following items:

- Metadata for field (stand and plot) samples:
  - Data collectors: name and affiliation of investigators.
  - Date of fieldwork.
  - Field methods: plot design, date of observation/data collection, date of classification.
- Geographic coordinates:
  - Universal Transverse Mercator (UTM) or latitude/longitude coordinates of sample.
  - The data—North American Datum of 1927 (NAD27) or 1983 (NAD83).
  - Method of determination and estimation of location accuracy information in the form of ± X meters.
- Sampling design:
  - How, why, and how many sample sites were chosen (e.g., subjective, random, stratified).
  - Approximate extent of the stand sampled.
  - Where and how the data are stored.
- Metadata for remotely sensed samples:
  - Type of imagery (TM, SPOT, aircraft scanner, radar, CIR (color infrared), BW (panchromatic), video).
  - Source—mono, stereo, vertical, oblique.
  - Scale or resolution of imagery.
  - Date of imagery.
  - Methods used to classify type.
  - Method of imagery classification (visual or computer assisted).
  - Geographic coordinates (UTM or latitude/longitude coordinates) of samples:
    - ~ The datum—NAD27 or NAD83.
    - ~ Method of determination and estimation of location accuracy information in the form of ± X meters.

3.4.2 Database Structure Overview

In this section: *Reference to the corporate database structure for existing vegetation geospatial datasets*

Vegetation map products will be stored and maintained as geospatial databases containing the standard vegetation attributes, regional and local add-on attributes, and internal GIS database fields. Appendix 3F specifies the location and definition of standard and core-optional data fields required for existing vegetation map product. Valid values tables for the required fields are also included in appendix 3F.

3.4.3 Data Management

In this section: *Strategy for keeping vegetation maps current and applicable to monitoring*

3.4.3.1 Maintain Existing Vegetation Maps

Baseline Establishment

Critical to planning, inventory, and monitoring success is the establishment of consistent vegetation baseline information. Once established, vegetation changes and their causes can be determined. This information provides monitoring data to analyze the effects of change in condition of wildlife habitats, late successional old growth, forest health, mortality, growth, and standing forest volumes. Vegetation maps, when combined with ground-based inventory information, are fundamental to meet the needs of the Forest and Rangeland Resources Planning Act, Forest Resource Management Plans, bioregional assessments, and more localized watershed and project planning efforts.

Scheduling Updates

The goal for vegetation resource information is to have vegetation maps no more than 5 years old. Update map areas where changes to vegetation have occurred from various causes, such as regrowth, wildfire, harvest, insect and disease damage, vegetation treatments, agriculture, or built-out type conversions. Activity databases and change detection methods are helpful in identifying where updates need to occur and the causes of vegetation cover changes.

Coordinating Related Work Activities

When programming mapping or updating vegetation maps work, coordinate a schedule with others to acquire resource photography, satellite imagery, and vegetation resource information. Other work programs, such as surface fuels mapping, ground based inventory, and change detection monitoring programs, can be coordinated with vegetation mapping. Coordinating aerial photos and imagery acquisition contributes to the efficiency of all these efforts.

When developing a multiyear coordinated schedule for a region, consider using physiographic and administrative provinces, national forest acreages, current status of vegetation mapping, change detection, Forest Inventory Analysis (FIA) grid inventories, and land and resource management plan revision schedules. At the beginning of the cycle for an update area, plan to acquire aerial photography and imagery the summer before starting any mapping or change detection efforts. Next, schedule vegetation map updates and forest inventory remeasurements of changed areas. Finally, conduct trend analysis and monitoring by comparing baseline and update information. Yearly budgets need to be stable to keep scheduled activities on cycle. Programs can realize major cost savings only when current photos and imagery can be substituted for ground-based visits through interpretation. To achieve a coordinated cycle, baseline vegetation maps and FIA grid inventory plots need to be completed to a common standard and source dates in a province as much as possible, balancing workloads and budget constraints. By establishing a systematic update cycle for mapping and inventory, opportunities for partnerships outside of the national forests become more available with State and Federal agencies.

Tracking Changes Over Time

To understand vegetation changes on the landscape and its affect on related natural resources, track changes and their causes to compare with baseline inventories. Tracking imagery sources and dates of baseline maps as well as updating imagery sources and dates are necessary metadata. Cause of change is also important to know and aids in analysis of impacted resources, such as wildlife habitat and cumulative watershed impacts.

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Glossary

For some terms, one or more definitions are given, and often more than one is in common usage.

abiotic. Pertaining to the nonliving parts of an ecosystem, such as soil particles, bedrock, air, and water (Helms 1998).

absolute composition. List of the absolute amounts of each plant species present in a given area or stand. Express the amount of each plant taxon as absolute percent cover (FGDC 1997, Jennings et al. 2004).

abundance. The total number of individuals of a taxon or taxa in an area, volume, population or community often measured as cover in plants (Lincoln et al. 1998).

accuracy. The degree to which a measured quantity approaches the true value of what is being measured (Lincoln et al. 1998).

accuracy assessment. Process by which the accuracy or correctness of an image (or map) is evaluated.

accuracy assessment site. Site identified on a satellite image (or map) and on a reference dataset for the purposes of accuracy assessment of the image or map (Lachowski et al. 1996).

alliance. (1) A grouping of associations with a characteristic physiognomy and sharing one or more diagnostic species, which, as a rule, are found in the uppermost or dominant stratum of the vegetation (Jennings et al. 2004). (2) A physiognomically uniform group of associations sharing one or more diagnostic (dominant, differential, indicator, or character) species that, as a rule, are found in the uppermost stratum of the vegetation (FGDC 1997).

arc. In reference to GIS, within a spatial context, a locus of points that forms a curve that is defined by a mathematical expression (adapted from FGDC 1998).

association. (1) A recurring plant community with a characteristic range in species composition, specific diagnostic species, and a defined range in habitat conditions and physiognomy or structure (Jennings et al. 2004). (2) A physiognomically uniform group of existing vegetation stands that share dominant overstory and understory species. These occur as repeatable patterns across the landscape (adapted from FGDC 1997). (3) A plant community type of definite floristic composition, uniform habitat conditions, and uniform physiognomy (Flahault and Schröter 1910, as cited in Jennings et al. 2004). Definition 3 is the most authoritative; the Federal Geographic Data Committee (FGDC) modified it for existing vegetation, and the modification is followed in this technical guide.

association table. Summary of species data by plot for a given association. Association tables are essential to determine plot membership in a type and are used for comparison of individual plots to other plots in a type. They may include information on environmental characteristics (e.g., slope, aspect, or elevation). See also **synthesis table**.

attribute. One of a set of descriptive terms; a characteristic (adapted from Lincoln et al. 1998).

business needs. Ongoing tasks related to a particular business or project and the information and other support contributing to the completion of these tasks.

canopy closure. The proportion of ground, usually expressed as a percentage, that is occupied by the perpendicular projection downward of the aerial parts of the vegetation of one or more species. It usually refers to the tree life form of the uppermost canopy, as seen from above, and cannot exceed 100 percent. Canopy closure is similar in concept to absolute canopy.

canopy cover. (1) The proportion of ground, usually expressed as a percentage, that is occupied by the perpendicular projection down on to it of the aerial parts of the vegetation or the species under consideration. The additive cover of multiple strata or species may exceed 100 percent (FGDC 1997). (2) The percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings in the canopy are included (SRM 1989, USDA NRCS 1997). Canopy cover is synonymous with canopy closure (Helms 1998). For woody plants, canopy cover is synonymous with crown cover (USDA NRCS 1997, Helms 1998).

character species. A species that shows a distinct maximum concentration, quantitatively and by presence, in a well-definable vegetation type (Mueller-Dombois and Ellenberg 1974).

class. (1) The first (highest) level in the National Vegetation Classification Standard (NVCS) hierarchy based on the structure of the vegetation and determined by the relative percentage of cover and the height of the dominant, uppermost life forms (Ecological Society of America 1999). (2) A group of individuals or other units similar in selected properties and distinguished from all other classes of the same population by differences in these properties (Buol et al. 1973).

classification. (1) The process of grouping similar entities into named types or classes based on shared characteristics. (2) The grouping of similar types (in this case, vegetation) according to criteria (in this case, physiognomic and floristic) that are considered significant for this specific purpose. The rules for classification must be clarified before the types are identified in the classification standard. The classification methods should be clear, precise, quantitative where possible, and based on objective criteria so that the outcome will be the same no matter who developed the definition (or description). Classification by definition involves definition of class boundaries (FGDC 1997, citing UN-EP/FAO 1995).

classification methodology standards. Procedures to follow to implement a data classification standard. Procedures describe how data are analyzed to produce a classification (FGDC 1996).

classification scheme or system. A set of target classes or a legend that serves as the basis of a classification or map (Lachowski et al. 1996).

clearinghouse. See **National Geospatial Data Clearinghouse** (FGDC 1998).

climax. A self-replacing plant community or species with no evidence of replacement by other plants.

climax plant community. Stable community in an ecological succession that is able to reproduce itself indefinitely under existing environmental conditions in the absence of disturbance. Viewed as the final stage or endpoint in plant succession for a site. The climax community develops and maintains itself in steady state conditions.

community. (1) A general term for an assemblage of plants living together and interacting among themselves in a specific location; no particular ecological status is implied. (2) Any group of organisms interacting among themselves (Daubenmire 1978).

community composition. The kinds, absolute amounts, or relative proportions of plant species present in a given area or stand. It can be described qualitatively or quantitatively. The latter may use absolute amounts or relative proportions of the plant taxa present. Express the amount of each plant taxon as percent cover (FGDC 1997, Jennings et al. 2004).

community type. An aggregation of all plant communities with similar structure and floristic composition. A unit of vegetation in a classification with no particular successional status implied.

composition. (1) The amount or proportion of the plant species on a given area (adapted from SRM 1989). (2) A list of the species that comprise a community or any other ecological unit (Lincoln et al. 1998).

compositional group. A map unit that comprises a grouping of alliances or dominance types with similar taxonomic composition and physiognomy (Brackney and Jennings 1998).

compound element. A group of data elements and other compound elements. Compound elements represent higher level concepts that cannot be represented by individual data elements (FGDC 1998).

constancy. The number of occurrences of a species in a group of plots, all the same size divided by the total number of plots. Expressed as a percentage; i.e., if a particular community has 10 plots and a species is found in 8 of the 10, the constancy of that species is 80 percent.

coordinates. In mapping, pairs of numbers that express horizontal distances along orthogonal axes; or, triplets of numbers measuring horizontal and vertical distances (FGDC 1998).

compositional groups. Map units that comprise a grouping of alliances or dominance types with similar taxonomic composition and physiognomy (Brackney and Jennings 1998).

cover. Usually meant as canopy cover that is the gross outline of the foliage of an individual plant or group of plants in a stand or plot. Expressed as a percent of the total area of the plot and may exceed 100 percent if more than one layer is considered. See also **canopy cover** and **vegetation cover**.

cover type. A designation based on the plant species forming a plurality of composition in a given area, e.g., oak-hickory (FGDC 1997). The Society of American Foresters (SAF) forest cover types (Eyre 1980) and the Society for Range Management (SRM) rangeland cover types (Shiflet 1994) are examples of cover types.

crown closure (percent). Percentage of area covered by the vegetation canopy (USDA Forest Service 1999).

data classification standard. Provides groups or categories of data that serve an application, e.g., wetland and soil classifications (FGDC 1996). In other words, a data classification standard specifies and defines a set of categories that must be used or crosswalked to by Federal agencies. The physiognomic levels of the National Vegetation Classification Standard (NVCS) are a data classification standard.

data element. A logically primitive item of data (FGDC 1998).

data standards. Describe objects, features, or items that are collected, automated, or affected by activities or functions of agencies. Data standards are semantic definitions that are structured in a model (FGDC 1996).

data steward. A person designated to manage large datasets and ensure their updating and quality.

dataset. Collection of related data. See also **geospatial data** (USDA Forest Service 2004c).

diagnostic species. Any species or group of species whose relative constancy or abundance clearly differentiates one type from another (Jennings et al. 2004). This definition implies that diagnostic species must be determined empirically through analysis of plot data (Mueller-Dombois and Ellenberg 1974).

differential species. A plant species that, because of its greater fidelity in one kind of community than in others, can be used to distinguish vegetation units (Gabriel and Talbot 1984, as cited in Jennings et al. 2004).

differentiating characteristics. Properties selected as the basis for grouping individuals into classes (Buol et al. 1973).

digital elevation model (DEM). Digital data file containing an array of elevation information over a portion of the Earth's surface (USDA Forest Service 1999).

digital image. A two-dimensional array of regularly spaced picture elements (pixels) constituting a picture (FGDC 1998).

digital number (DN). The numerical value of a specific pixel. The DN corresponds to the average radiance measured in each pixel (Lachowski et al. 1996).

digital orthophoto quad (DOQ). Digital representation of an aerial photo with ground features located in their "true" positions (USDA Forest Service 1999).

division. The level in the FGDC physiognomic hierarchy separating earth cover into either vegetated or nonvegetated categories (ESA et al. 1999).

dominance. The extent to which a given species has a strong influence in a community because of its size, abundance, or coverage. Strong dominance affects the fitness of associated species (adapted from Lincoln et al. 1998).

dominance type. A recurring plant community defined by the dominance of one or more species that are usually the most important ones in the uppermost or dominant layer of the community, but sometimes of a lower layer of higher coverage (adapted from Gabriel and Talbot 1984, as cited in Jennings et al. 2004).

dominant. An organism exerting considerable influence on a community by its size, abundance, or coverage (Lincoln et al. 1998).

dominant species. The species with the highest percentage of cover, usually in the uppermost layer (Kimmins 1997, as cited in Jennings et al. 2004).

dynamic sampling. The collection and analysis of resource data to measure changes in the amounts, spatial distribution, or condition of resource types or parameters over time (adapted from Helms 1998).

earth cover. The observed physical cover as seen on the ground or through remote sensing. Examples of earth cover classes include vegetated, unvegetated, water, and artificial cover (human construction). A given piece of land can fit in one earth cover class only, which makes earth cover mutually exclusive at the same scale of mapping (FGDC 1997).

ecosystem. A complete interacting system of organisms and their environment (USDA Forest Service 1991).

ecotone. The boundary or transitional zone between adjacent communities or biomes; tension zone (Lincoln et al. 1998).

electromagnetic spectrum. The range of energy transmitted through space in the form of electric or magnetic waves, extending from cosmic waves to radio waves. Included in this spectrum are visible and infrared regions that are particularly important for land remote sensing applications (Lachowski et al. 1996).

element. Parts of the sections or chapters in the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata (http://www.fs.fed.us/gac/metadata/glossary.html). Elements are numbered starting with the section number. A set of elements with subparts is called a compound element, for example, 2.1.1 (Data Quality Information, Attribute Accuracy, Attribute Accuracy Report). The FGDC standard contains 334 different elements, 119 of which exist only to contain other elements (USDA Forest Service 2004c).

error matrix. A table used as a starting point for a series of descriptive and analytical statistical techniques used for accuracy assessment of maps or other products. Error matrices score each observation (sample) according to the class it has been assigned to in the classified map and the "true" class, as determined by reference data. Error matrixes are sometimes referred to as confusion or difference matrixes because reference data is not always absolutely accurate (Lachowski et al. 1996).

evaluation. The comparison of dynamic sampling results to management objectives consisting of predetermined standards, expected norms, threshold values, and/or trigger points.

existing vegetation. (1) The plant cover or floristic composition and vegetation structure occurring at a given location at the current time. (2) The plant species existing at a location at the present time. Contrast with **potential natural vegetation**.

feature selection. A preprocessing technique that aims to reduce the amount of data in an image by isolating individual raw bands for further image processing (Lachowski et al. 1996).

Federal Geographic Data Committee (FGDC). An interagency committee, organized in 1990 under the Office of Management and Budget (OMB) Circular A-16 that promotes the coordinated use, sharing, and dissemination of geospatial data on a national basis. The FGDC is composed of representatives from 17 Cabinet-level and independent Federal agencies (USDA Forest Service 2004c).

FGDC compliant metadata. To be compliant with the Federal Geographic Data Committee (FGDC) metadata standard, a metadata record must successfully pass through the FGDC metaparser. The metaparser is often run directly from the metadata creation tool, such as MetaLite, but can also be run separately. If the record is incomplete or improperly formatted, the metaparser flags the errors. In general terms, FGDC-compliant metadata can be relatively simple or complex depending on the number of elements that are required. If the metadata exists for a required element, it should be entered (USDA Forest Service 2004c).

fidelity. The degree of restriction of a plant species to a particular situation, community, or association (Lincoln et al. 1998).

flora (adj. floral, floristic). (1) All the plant species that make up the vegetation of a given area (Allaby 1994). (2) The plant life of a given region, habitat, or geological stratum (Lincoln et al. 1998).

floristic classification. Classification of plant communities, emphasizing species composition. It may include considerations of species abundance, dominance, growth form, and so on. Emphasize the plant species comprising the vegetation instead of life forms or structure. Floristic classifications are based on community composition and/or diagnostic species.

floristic composition. A list of plant species of a given area, habitat, or association (Lincoln et al. 1998).

foliar cover. The percentage of ground covered by the vertical projection of the aerial portion of plants. Small openings in the canopy and intraspecific overlap are excluded (SRM 1989).

forb. Broad-leaved herbaceous plant (adapted from FGDC 1997).

fuzzy logic. A type of reasoning designed to accommodate ambiguity. Using fuzzy sets in accuracy assessment permits explicit recognition of the possibility of ambiguity regarding appropriate map labels for some locations on a map/classification. This recognition can help the user determine the relative (not absolute) accuracy of a particular classification, and thus the usefulness of that classification for applications requiring varying levels of accuracy (Lachowski et al. 1996).

geographic information system (GIS). The term frequently applied to geographically oriented computer technology. In its broadest sense, GIS is a system for capturing, storing, checking, manipulating, analyzing, and displaying data that are spatially referenced to the Earth (Lachowski et al. 1996).

geometric correction. An image processing technique that reorients the image data to compensate for the Earth's rotation and variations in satellite position and attitude (USDA Forest Service 1999).

geospatial data. Information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. This information may be derived from remote sensing, mapping, and surveying technologies (FGDC 1998).

global positioning system (GPS). An array of space satellites and ground receivers that use geometry to provide information about the precise latitude, longitude, and elevation of a particular point (Lachowski et al. 1996).

gradsect technique. The gradsect technique is a form of stratified random sampling that may be cost effective for sampling vegetation patterns along environmental gradients (Gillison and Brewer 1985). See also **representative sampling**.

grid. (1) A set of grid cells forming a regular, or nearly regular, tessellation of a surface. (2) Set of points arrayed in a pattern that forms a regular, or nearly regular, tessellation of a surface. The tessellation is regular if formed by repeating the pattern of a regular polygon, such as a square, equilateral triangle, or regular hexagon. The tessellation is nearly regular if formed by repeating the pattern of an "almost" regular polygon such as a rectangle, nonsquare-parallelogram, or non-equilateral triangle (FGDC 1998).

group. The level in the National Vegetation Classification Standard (NCVS) hierarchy below subclass based on leaf characters and identified and named in conjunction with broadly defined macroclimatic types to provide a structural-geographic orientation (ESA et al. 1999).

habit. The general growth form and appearance of a species. See also **growth form** and **physiognomy.**

habitat. (1) The combination of environmental or site conditions and ecological processes influencing a plant community (Jennings et al. 2004). (2) Area or type of environment in which an organism or population normally lives or occurs.

herb. Nonwoody vascular plants, such as grasses, grass-like plants, and forbs (adapted from FGDC 1997).

high resolution visible (HRV). The type of sensor mounted on SPOT satellites. The HRV "push broom" scanning system is different than the Landsat mirror-sweep scanning systems, and has the advantage of eliminating geometric errors introduced in the sensing process by variations in scan mirror velocity (Lachowski et al. 1996).

homogeneous types. Map units composed of a homogeneous condition of vegetation or uniform type; map unit that comprises a single alliance or dominance type, with at least 85 percent of the area in a polygon.

horizontal. Tangent to the geoid or parallel to a plane that is tangent to the geoid (FGDC 1998).

image classification. The process of assigning the pixels of an image to discrete categories or classes (Lachowski et al. 1996).

image interpretation. (1) The systematic examination of image data; frequently involves other supporting materials, such as maps and field observations (Lillesand and Kiefer 2000). (2) Basis for delineation of map units is normally discontinuities in texture reflecting life form composition, stocking, tree crown size differences, and/or apparent tree height (Stage and Alley 1973).

image processing. A general term referring to manipulation of digital image data; includes image enhancement, image classification, and image preprocessing (or rectification) operations (Lachowski et al. 1996).

image segmentation. The process of dividing digital images into spatially cohesive units or regions. These regions represent discrete objects or areas in the image (Ryerd and Woodcock 1996).

indicator species. (1) A species whose presence, abundance, or vigor is considered to indicate certain environmental conditions (Gabriel and Talbot 1984, as cited in Jennings et al. 2004). (2) Species that are sensitive to important environmental feature of a site such that its constancy or abundance reflect significant changes in environmental factors. (3) Plant whose presence indicates specific site conditions or a type.

inventory. The systematic acquisition, analysis, and organization of resource information needed for planning and implementing land management (adapted from USDA NRCS 1997).

land cover. (1) The ecological state and physical appearance of the land surface, e.g., forest and grassland. Note that land may be changed by human intervention, natural disturbances, or plant succession (Helms 1998). (2) The observed physical categories of an area as seen on the ground or through remote sensing. Examples include vegetated, nonvegetated, surface water, urban and developed. Land cover classes are mutually exclusive at the same scale of mapping (adapted from FGDC 1997).

Landsat. Name for the series of Earth-observing satellites first launched in 1972 by NASA; originally named Earth Resource Technology Satellite (ERTS). Landsat satellites serve as platforms for several sensors including the return beam vidicon, Landsat Multispectral Scanner (MSS), and Landsat Thematic Mapper (TM) (Lachowski et al. 1996).

Layer (GIS). A digital information storage unit, also known as theme. Different kinds of information (e.g., roads, boundaries, lakes, and vegetation) can be grouped and stored as separate digital layers or themes in a GIS (Lachowski et al. 1996).

layer or stratum. (1) A structural component of a community consisting of plants of approximately the same height structure (e.g., tree, shrub, and herbaceous layers). (2) The definition and measurement of these structural components in their vertical and height relationships to each other (e.g., tree subcanopy layer, shrub understory layer) (adapted from Ecological Society of America 1999).

life form. (1) The characteristic structural features and method of perennation of a plant species; the result of the interaction of all life processes, both genetic and environmental (Lincoln et al. 1998). Life form is related to growth form, physiognomy, and habit but also includes consideration of the type and position of renewal (perennating) buds that the other terms typically do not include. (2) Includes gross morphology (size, woodiness, etc.), leaf morphology, life span, and phonological (or life cycle) phenomena (Barbour et al. 1980).

map. (1) A spatial representation, usually graphic on a flat surface, of spatial phenomena (FGDC 1998). (2) A representation, usually on a plane surface, of a region of the Earth or heavens (Robinson et al. 1978).

map feature. An individual area or delineation on a map is a map feature. Specific map features are nonoverlapping and geographically unique, but will contain one or more thematic components (i.e., map unit) that may be repeated across multiple map features. Map feature is synonymous with the commonly used terms of polygon and region.

map levels. Define different intensities of field study, different degrees of detail in mapping, different levels of abstraction in defining and naming map units, and different map unit designs. Adjustment in these elements forms the basis for differentiating four levels of vegetation mapping: national, broad, scale, and base. The levels are intended to aid in the identification of the operational procedures used to conduct vegetation mapping activities and also indicate general levels of the quality control applied during mapping. These levels affect the kind and precision of subsequent interpretations and predictions (adapted from USDA Soil Survey Division Staff 1993).

map scale. The extent of reduction required to display a portion of the Earth's surface on a map; defined as a ratio of distances between corresponding points on the map and on the ground (Robinson et al. 1978). Scale indirectly determines the information content and size of the area being represented. The mapping scale is determined by the agency's business needs and the characteristics of the data obtained for the project area. Maps generated from digital imagery can appropriately be displayed at a range of scales.

map unit. A collection of features defined and named the same in terms of their vegetation characteristics (USDA Soil Survey Division Staff 1993). Each map unit differs in some respect from all others in a geographic extent. Map units are differentiated in map unit design and defined in a map unit description. Design of map units generalizes the taxonomic units present to the smallest set that (1) meets the objectives of the map, and (2) is feasible to delineate with available resources and technology.

map unit aggregation type. A map unit attribute that describes the arrangement of vegetated condition found in a map feature or polygon. An aggregation type consists of a homogenous dominance type, plant association, compositional group, or vegetation complex arrangements of dominance types or plant associations.

map unit design. The process establishing the relationship between vegetation classifications and map products depicting them.

metadata. Refers to "data about data"; describes the content, quality, condition, and other characteristics of a given set of data. Its purpose is to provide information about a dataset or some larger data holdings to data catalogues, clearinghouses, and users. Metadata is intended to provide a capability for organizing and maintaining an institution's investment in data to provide information for the application and interpretation of data received through a transfer from an external source (Jennings et al. 2004, as modified from FGDC 1997).

minimum map unit (MMU). Smallest map feature delineated; requirements vary for different map levels.

modeling. In reference to geospatial data, the process of creating a new GIS layer by combining or operating on existing layers. Modeling creates images) that contain several types of information comprising several GIS variables; e.g., a scene may be considered in terms of its vegetation, elevation, water, and climate at the same time (Lachowski et al. 1996).

monitoring. (1) The systematic collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives (adapted from SRM 1989). (2) The collection and analysis of resource data to measure changes in the amounts, spatial distribution, or condition of resource types or parameters over time.

multispectral. Sensors or images that record or display data from two or more bands of the electromagnetic spectrum (USDA Forest Service 1999).

natural classification. Classification in which the differentiating criteria are selected to "bring out relationships of the most important properties of the population being classified, without reference to any single specified and applied objective." (Buol et al. 1973). Also called scientific classification.

natural/seminatural. (1) Areas dominated by native or established vegetation that has not been cultivated or treated with any annual management or manipulation regime. (2) Areas that cannot be assessed as to whether the vegetation was planted or cultivated by humans (adapted from FGDC 1997).

noise. Nonmeaningful variation in species abundances that obscure patterns and relationships in the dataset. Sources of noise include chance distribution and establishment of seeds, local disturbances, microsite variation, outliers, and misidentification of species.

nonvegetated (mapping). In mapping, this category includes the FGDC sparsely Vegetated class combined with the Nonvegetated class. Vegetation comprises less than 10-percent cover at the peak of the growing season. In the land cover classification system (Anderson Level I), water, barren land, perennial snow/ice, and urban/built-up land are examples of nonvegetated landscapes (Anderson et al. 1976).

nonvegetated (soil). Landscape usually associated with open water or human-modified land, such as heavy industrial commercial transportation facilities (adapted from USDA Soil Survey Division Staff 1993).

object. A digital representation of all or part of an entity instance (FGDC 1998).

omission error. In remote sensing, a mistake of exclusion occurring in an image classification. Omission errors are displayed in an error matrix during the accuracy assessment process and serve to alert the analyst to mislabeling of reference sites (Lachowski et al. 1996).

order. In the National Vegetation Classification Standard hierarchy, order is the lower level immediately following division. The orders in the Vegetated division are generally defined by dominant life form (tree, shrub, dwarf shrub, herbaceous, or nonvascular) (FGDC 1997).

outlier. Refers to data or a sample that has low similarity to all other samples in the dataset.

overall accuracy. A common measure of a classification's accuracy. Overall accuracy is calculated by dividing the total number of correct samples by the total number of assessment sites (Lachowski et al. 1996).

overstory tree diameter. The mean diameter at breast height (4.5 feet or 1.37 meters above the ground) for the trees forming the upper or uppermost canopy layer (Helms 1998).

panchromatic. Refers to single band imagery (USDA Forest Service 1999).

patch. A relatively homogenous nonlinear area that differs from its surroundings (Forman 1995); can specifically describe forested patches, nonforest vegetation patches, rock/barren patches, or water patches.

pattern. Repeating coordinated species abundance and groups of samples with similar species composition.

physiognomic classification. A level in the classification hierarchy defined by the relative percent canopy cover of the tree, shrub, dwarf shrub, herb, and nonvascular life form in the uppermost strata during the peak of the growing season (FGDC 1997).

physiognomy. (1) The characteristic feature or appearance of a plant community or vegetation (Lincoln et al. 1998). (2) The overall appearance of a kind of vegetation (Daubenmire 1968, Barbour et al. 1980). (3) The expression of the life forms of the dominant plants and vegetation structure (Mueller-Dombois and Ellenberg 1974, Barbour et al. 1980).

pixel. Two-dimensional picture element that is the smallest nondivisible element of a digital image (FGDC 1998).

platform. In remote sensing, the physical object (e.g., balloon, rocket, or satellite) that carries the remote sensor. In computing use, may also refer to a type of technical system that is used for processing, displaying, querying, and storing information, e.g., a "technology platform" (Lachowski et al. 1996).

plot. (1) "A circumscribed sampling area for vegetation" (Lincoln et al. 1998). (2) "any two-dimensional sample area of any size. This includes quadrates, rectangular plots, circular plots and belt transects (very long rectangular plots). Belt transects are often called strips or transects" (Mueller-Dombois and Ellenburg 1974).

point. In reference to geospatial data, a dimensional-dimensional object that specifies geometric location. One coordinate pair or triplet specifies the location. Area point, entity point, and label point are special implementations of the general case (USDA Forest Service 2004c).

polar. A classification of climate based on the Koppen System for regions where the warmest month is colder than 50 °F (10 °C) (Bailey 1980).

pocosin wetlands. An upland swamp or bog of the coastal plain of the southeastern United States (Helms 1998).

potential natural vegetation (PNV). The vegetation that would become established, if all successional sequences were completed without interference by man under the present climatic and edaphic conditions (Tüxen 1956, as cited in Mueller-Dombois and Ellenberg 1974). Concepts such as succession, site, and environmental factors are all part of PNV. Existing vegetation is simply what is there at the time of sampling. PNV classifications are based on existing vegetation**.** succession and environmental factors (e.g., climate, geology, soil) considered together.

preferential sampling. Locating plots subjectively without preconceived bias (Mueller-Dombois and Ellenberg 1974).

preprocessing. In mapping and remote sensing use, the group of processes typically completed on an image before analysis or classification with the goal of improving the quality of the data. Preprocessing operations may include geometric and radiometric corrections (Lachowski et al. 1996).

producer's accuracy. An accuracy measure based on omission error as shown in the error matrix. The producer's accuracy is calculated by dividing the total number of correctly classified sites of a certain category by the total number of sites surveyed in the same category (Lachowski et al. 1996).

quantitative inventory. The objective quantification of the amount, composition, condition, and/or productivity of resource types or parameters within specified levels of statistical precision. (adapted from Helms 1998).

radiometric correction. In remote sensing, an image preprocessing technique that adjusts for influence from scene illumination, atmospheric conditions, viewing geometry, and instrument response characteristics (USDA Forest Service 1999).

raster data. Data organized in a grid of columns and rows. Raster data usually represent a planar graph or geographical area (Lachowski et al. 1996).

reference data. (1) "Ground truth" data used in the image classification and accuracy assessment processes and/or for direct image interpretation. Ground truth data are assumed to be "true" information regarding surface features. In remote sensing projects, reference data serve two main purposes: (a) reference data establish a link between variation on the ground and in the image that is necessary for assigning image-modeling units (pixels or regions) to discrete land cover classes in the image classification process; and (b) reference data help assess the accuracy of a map. (2) Any secondary data that support the primary remote sensing data and thus may include the ancillary data used to classify the image (adapted from Lachowski et al. 1996).

reflectance. The total solar energy incident on a given feature minus the energy that is either absorbed or transmitted by the feature. Reflectance is dependent on the material type and condition, and allows different features in a visual image to be distinguished (Lachowski et al. 1996).

relative composition. List of the proportions of each plant species relative to the total amount of all species present in a given area or stand (FGDC 1997, Jennings et al. 2004).

remote sensing. (1) The gathering of data regarding an object or phenomenon by a recording device (sensor) that is not in physical contact with the object or phenomenon under observation (Lachowski et al. 1996). (2) The science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer 1987).

representative sampling. Systematic or random location of plots within strata; rejection criteria may be necessary, however, to avoid sampling obvious ecotones, which are of limited use for classifying vegetation. The gradsect technique or gradient directed sampling is one example of this approach (Austin and Heylingers 1991, as cited in Jennings et al. 2004). The gradsect technique is a form of stratified random sampling that may be cost effective for sampling vegetation patterns along environmental gradients (Gillison and Brewer 1985). See also **gradsect technique**.

resolution. The minimum difference between two independently measured or computed values that can be distinguished by the measurement or analytical method being considered or used (USDA Forest Service 2004c).

resource mapping. The delineation of the geographic distribution, extent, and landscape patterns of resource types or attributes.

scale. (1) The relationship between a distance on a map and the corresponding distance on the Earth. For example, a scale of 1:24,000 means that 1 unit of measure on the map equals 24,000 of the same units on the Earth's surface (Helms 1998). (2) Ecology, the level of spatial resolution perceived or considered (Helms 1998). (3) In general, the degree of resolution at which ecological processes, structures, and changes across space and time are observed and measured (USDA Forest Service 1993).

scientific classification. See natural classification.

sensor. A device that records electromagnetic radiation or other data about an object and presents it in a form suitable for obtaining information about the environment (Lachowski et al. 1996).

series. In vegetation classification, an aggregation of taxonomically related plant associations that takes the name of climax species that dominate the principle layer; a group of associations or habitat types with the same dominant climax species. Conceptually a series is analogous to an alliance; the series is a PNV concept (adapted from Driscoll et al. 1984).

shrubs. Woody plants that generally exhibit several erect, spreading, or prostrate stems and have a bushy appearance. In instances where life form cannot be determined, woody plants less than 5 meters in height are considered shrubs (FGDC 1997).

site. An area delimited by fairly uniform climatic and soil conditions (similar to habitat).

spatial data. Data that record the geographic location and shape of geographic features and their spatial relationships to other features (USDA Forest Service 2004c).

spatial resolution. The measure of sharpness or fineness in spatial detail.; determines the smallest object that can be resolved by a given sensor, or the area on the ground represented by each pixel. For digital imagery, spatial resolution corresponds to pixel size and may be understood as roughly analogous to "grain" in photographic images (Helms 1998).

species. In biological classification, the category below genus and above the level of subspecies and variety; the basic unit of biological classification (adapted from Lincoln et al. 1998).

spectral resolution. The dimension and number of specific bands (wavelength intervals) in the electromagnetic spectrum that a sensor can detect (Lachowski et al. 1996).

stand. (1) The basic unit of mapping and inventory (Graves 1913). (2) A community, particularly of trees, possessing sufficient uniformity regarding composition, age, spatial arrangement, or condition, to be distinguishable from adjacent communities, so forming a silvicultural or management entity (Ford-Robertson 1971). In the context of the protocol supported by this technical guide, the terms "patch" and "stand" may be synonymous depending on the degree that management considerations are incorporated into stand delineations along with compositional and structural characteristics.

stratum. In general, one of a series of layers, levels, or gradations in an ordered system. In the natural environment, the term is used in the sense of (1) a region of sea, atmosphere, or geology that is distinguished by natural or arbitrary limits, or (2) a layer of vegetation, usually of the same or similar height (adapted from FGDC 1998).

structure. (1) The spatial arrangement of the components of vegetation (Lincoln et al. 1998). (2) A function of plant size and height, vertical stratification into layers, and horizontal spacing of plants. Physiognomy refers to the general appearance of the vegetation; structure describes the spatial arrangement of plants in more detail. Do not confuse physiognomy and structure (Mueller-Dombois and Ellenberg 1974).

succession. Partial or complete replacement of one community by another (Daubenmire 1978).

successive refinement. The basic working approach of community ecologists; involves repeated cycles of knowledge, questions, and observations (Pfister and Arno 1980, Gauch 1982).

supervised classification. A method of image classification that depends on the direct involvement of the analyst in the pattern recognition process. See also **unsupervised classification** (USDA Forest Service 1999).

synthesis tables. Summaries of mean and constancy by species and by types in a table with types across the top and species down the side. These are essential to compare between types. The data are summed by type in a synthesis table; association tables present data by plots or sample units.

tabular data. Data that describe things using characters and numbers formatted in columns and rows (USDA Forest Service 2004c).

taxonomic unit (taxon [s.], taxa [pl.]). The basic set of classes or types that comprise a classification. Taxonomic units can be developed for physiognomic classifications (e.g., tree dominated classes or shrub dominated classes), floristic classifications (e.g., dominance type classes or plant association classes), and they can be developed for structural classifications (e.g., canopy cover classes and/or tree size classes). Taxonomic units represent a conceptual description of ranges and/or modal conditions in vegetation characteristics. A taxonomic unit (or taxon) is a class developed through the scientific classification process, or a class that is part of a taxonomy (USDA Soil Survey Division 1999).

technical classification (or technical grouping). A classification in which the differentiating characteristics are selected "for a specific, applied, practical purpose" (Buol et al. 1973, Pfister and Arno 1980).

temporal resolution. A measure of how often a given sensor obtains imagery of a particular area, also called coverage. For satellite data, temporal resolution depends on the satellite's orbit schedule and off-nadir pointing capability. Temporal resolution is important for projects requiring multitemporal imagery, such as change detection projects (Lachowski et al. 1996).

thematic aggregation. The process of combining spatially distinct map features based on their categorical similarity and spatial arrangement.

Thematic Mapper (TM). A sensor carried aboard Landsat 4 and 5. Data are collected in seven electromagnetic spectral bands that were selected for vegetation analysis. Landsat 7also has a panchromatic band with 15-meter spatial resolution; an onboard, full aperture, 5-percent absolute radiometric calibration; and a thermal infrared channel with 60-meter spatial resolution (USDA Forest Service 1999).

thematic resolution. The level of categorical detail present within a given map unit. In a general sense, increased thematic resolution is represented by an increase in the number of map units and conversely fewer map units for coarser thematic resolution. While thematic resolution is often implied by geographic or spatial resolution, a direct relationship is not inherent (Helms 1998).

theme. Group of data that represent a place or thing such as soils, vegetation, or roads. A theme may be less concrete, such as population density, school districts, or administrative boundaries (USDA Forest Service 2004c).

theme (GIS). See **layer**.

training site. In mapping, the geographical area represented by the pixels in a training sample. Usually, training sites have been previously identified through ground truth data or aerial photography. Also called training fields (Lachowski et al. 1996).

trees. Woody plants that generally have a single main stem and have more or less definite crowns. In instances where life form cannot be determined, woody plants at least 5 meters in height are considered trees (FGDC 1997).

unsupervised classification. In mapping, a computer-automated method of spectral pattern recognition in which some parameters are specified by the user and used to uncover statistical patterns inherent in the image data. See also **supervised classification** (USDA Forest Service 1999).

user's accuracy. In reference to accuracy assessment, an accuracy measure based on a commission error in the error matrix. Also known as reliability, user's accuracy is the probability that pixels classified on the map actually represent the category on the ground. User's accuracy is calculated by dividing the total number of correctly classified sites of a certain category by the total number of the certain category classified by the map (Lachowski et al. 1996).

vascular plant. Plant with water and fluid conductive tissue (xylem and phloem); includes seed plants, ferns, and fern allies (FGDC 1997).

vector data. Data that represents physical forms (elements) such as points, lines, and polygons. In terms of GIS, vectors typically represent a boundary between spatial objects (Lachowski et al. 1996).

vegetated. Areas having at least 1 percent or more of the land or water surface with live vegetation cover at the peak of the growing season (FGDC 1997).

vegetation complexes. Map units that comprise a grouping of dissimilar alliances that are spatially and ecologically related on the landscape (called ecological complex in GAP Bulletin 7, Brackney and Jennings 1998).

vegetation cover. Vegetation that covers or is visible at or above the land or water surface; a subcategory of earth cover. The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants (FGDC 1997).

vegetation data. The attributes of the vegetation that are used to classify and characterize the vegetation type and to map vegetation stand. These data come from the interpretation of remotely sensed imagery, fieldwork, and other thematic data sources (FGDC 1997).

vegetation mapping. The process of delineating the geographic distribution, extent, and landscape patterns of vegetation types based on composition, physiognomy, and structure.

vegetation type. A named class of plant community or vegetation defined on the basis of selected shared floristic, physiognomic, and/or structural characteristics that distinguish it from other classes of plant communities or vegetation.

vertical. At right angles to the horizontal; includes altitude and depth (FGDC 1998).

List of Abbreviations and Acronyms

AEUI	Aquatic Ecological Unit Inventory
ASPRS	American Society of Photogrammetry and Remote Sensing
CALVEG	Classification and Assessment with Landsat of Visible Ecological Groupings
CFR	Code of Federal Regulations
CISC	Continuous Inventory of Stand Conditions
CSDGM	Content Standard for Digital Geospatial Metadata
CSE	Common Stand Exam
CVU	Common Vegetation Unit
CWHR	California Wildlife Habitat Relationships
d.b.h.	diameter at breast height
DEM	digital elevation model
ESA	Ecological Society of America
FHM	Forest Health Monitoring
FIA	Forest Inventory Analysis
FSH	Forest Service Handbook
FSM	Forest Service Manual
FGDC	Federal Geographic Data Committee
GAP	Gap Analysis Project
GIS	Geographic Information System
GPS	Global Positioning System
ICEC	International Classification of Ecological Communities
lidar	Light detection and ranging
MLRA	Major Land Renewable Resource Areas
MMU	minimum map unit
MODIS	Moderate Resolution Imaging Spectroradiometer
MSS	Multispectral Scanner
NDVI	Normalized Difference Vegetation Index
NFMA	National Forest Management Act of 1976
NFS	National Forest System
NGDC	National Spatial Data Infrastructure
RCS	Natural Resources Conservation Service
NRI	National Research Institute
NRIS	Natural Resource Information System
NSDI	National Spatial Data Infrastructure
NSSDA	National Standard for Spatial Data
NVC	National Vegetation Classification

NVCS	National Vegetation Classification Standard
NWI	National Wetlands Inventory
OMB	Office of Management and Budget
PCA	Principal Component Analysis
PNV	Potential Natural Vegetation
PRISM	Parameter-elevation Regressions on Independent Slopes Model
R1	Region 1, USDA Forest Service, Northern Region
R2	Region 2, USDA Forest Service, Rocky Mountain Region
R8	Region 8, USDA Forest Service, Southern Region
RMSE	root-mean-square data
RPA	Forest and Rangeland Resources Planning Act of 1974
SAF	Society of American Foresters
SILC	Satellite Image Land Classification
SRM	Society for Range Management
TES	Threatened and Endangered Species
TEUI	Terrestrial Ecological Unit Inventory
USDA	U.S. Department of Agriculture
U.S.C.	United States Code
USGS	U.S. Geological Survey
VPF	Vector Product Format
VSS	Vegetation Stand Structure

Appendix 1A.

Federal Geographic Data Committee Guiding Principles for Vegetation Classification

This appendix was taken from Federal Geographic Data Committee (FGDC),Vegetation Subcommittee. 1997. Vegetation classification standard. FGDC-STD-005. Reston, VA: Federal Geographic Data Committee, U.S. Geological Survey. http://www.fgdc.gov/standards/documents/standards/vegetation/vegclass.pdf.

The guiding principles for the Federal Geographic Data Committee's National Vegetation Classification Standards (NVCS) (FGDC 1997) are listed below. Italics indicate goals that have not been fully achieved to date. Revision of the physiognomic classification standard and completion of the floristic classification methodology standard will address most of these goals.

1. The classification is applicable over extensive areas.

2. *The vegetation classification standard is compatible, wherever possible, with other earth cover/land cover classification standards*.

3. The classification will avoid developing conflicting concepts and methods through cooperative development with the widest possible range of individuals and institutions.

4. *Application of the classification must be repeatable and consistent*.

5. When possible, the classification standard will use common terminology (i.e., terms should be understandable and jargon should be avoided).

6. For classification and mapping purposes, the classification categories were designed to be mutual exclusive and additive to 100 percent of an area when mapped within any of the classification's hierarchical levels (Division, Order, Class, Subclass, [Group], Subgroup, Formation, Alliance, or Association). *Guidelines have been developed for those instances where placement of a floristic unit into a single physiognomic classification category is not clear. Additional guidelines will be developed as other such instances occur.*

7. The classification standard will be dynamic, allowing for refinement as additional information becomes available.

8. The NVCS is of existing, not potential, vegetation and is based upon vegetation condition *at the optimal time during the growing season*. The vegetation types are defined on the basis of inherent attributes and characteristics of the vegetation structure, growth form, and cover.

9. The NVCS is hierarchical (i.e., aggregatable) to contain a small number of generalized categories at the higher level and an increasingly large number of more detailed categories at the lower levels. The categories are intended to be useful at a range of scales.

10. The upper levels of the NVCS are based primarily on the physiognomy (life form, cover, structure, leaf type) of the vegetation (not individual species). The life forms (e.g., herb, shrub, or tree) in the dominant or uppermost stratum will predominate in the classification of the vegetation type. *Climate and other environmental variables are used to help organize the standard, but physiognomy is the driving factor*.
11. The lower levels of the NVCS are based on actual floristic (vegetation) composition. The data used to describe alliance and association types must be collected in the field using standard and documented sampling methods. The alliance and association units are derived from these field data. *These floristically based classes will be nested under the physiognomic classes of the hierarchy*.

Appendix 1B.

National Vegetation Classification Standards Physiognomic Hierarchy Overview

The quoted material contained in this appendix was taken from Federal Geographic Data Committee (FGDC),Vegetation Subcommittee. 1997. Vegetation classification standard. FGDC-STD-005. Reston, VA: Federal Geographic Data Committee, U.S. Geological Survey. http://www.fgdc.gov/standards/documents/standards/vegetation/vegclass.pdf.

Unquoted material contained in this appendix was provided by David Tart, Regional Vegetation Ecologist, USDA Forest Service, Intermountain Region.

The FGDC National Vegetation Classification Standards (NVCS) (1997) establishes a hierarchical vegetation classification with nine levels. The top seven levels are primarily based on physiognomy. The two lowest levels, alliance and association, are based on floristic attributes. The seven physiognomic levels are described below. These descriptions include the FGDC definition of the level, classification criteria, and any issues implementation that have hampered implementation of the physiognomic classification standard.

1. **Division.** "The first level in the classification standard separating Earth cover into either vegetated or non-vegetated categories" (FGDC 1997).

   Classification Criteria: The Vegetated Division is defined as "Areas having equal to or greater than 1 percent or more of the land or water surface with live vegetation cover at the peak of the growing season" (FGDC 1997). Areas with less than 1 percent live vegetation comprise the Nonvegetated Division. The Nonvegetated Division is subdivided no further. The remaining levels of the physiognomic hierarchy are all subdivisions of the Vegetated Division.
   Implementation Issues: Detection of 1 percent vegetation through remote sensing is not feasible. The Multi-Resolution Landscape Characterization (MRLC) 2000 proposed land cover classes define Barren as less than 20 percent vegetation cover.

2. **Order.** "The next level in the hierarchy under Division. The Orders within the Vegetated Division are generally defined by dominant life form (tree, shrub, dwarf shrub, herbaceous, non-vascular)" (FGDC 1997).

   Classification Criteria: Orders are classified based on the dominant life form or tallest life form with at least 25-percent canopy cover. They are based predominantly on vegetation structure.

Implementation Issues: The Nonvascular Dominated Order does not include crustose lichens, which are essentially regarded on non-living at this level of the classification. This has no ecological meaning and appears to represent a bias toward what can be detected through remote sensing.

3. **Class.** "A level in the classification hierarchy defined by the relative percent canopy cover of the tree, shrub, dwarf shrub, herb, and nonvascular life forms in the uppermost strata during the peak of the growing season" (FGDC 1997).

   Classification Criteria: Classes are based on the following structural attributes:
   - Tree canopy cover
   - Shrub height and canopy cover
   - Herbaceous vs. nonvascular canopy cover

   Implementation Issues: Only two of the five orders are subdivided at the class level, the Tree Dominated and Shrub Dominated Orders. These divisions, based on tree canopy cover and shrub height, have proved impractical in several classification and mapping projects. Thus, the Order and Class levels may be merged when the physiognomic hierarchy is revised (FGDC 2001a).

4. **Subclass.** "A level in the classification determined by the predominant leaf phenology of woody plants or the leaf type and periodicity of herbaceous plants" (FGDC 1997).

   Classification Criteria: Subclasses are based on the following life form attributes:
   - Leaf phenology (e.g., evergreen vs. deciduous)
   - Gross morphology (e.g., graminoid vs. forb)
   - Herb periodicity (e.g., annual vs. perennial)

5. **Group.** "A level of the classification defined by a combination of climate, leaf morphology, and leaf phenology" (FGDC 1997).

   Classification Criteria: Groups are based on the following life form, structural, and abiotic attributes:
   - Climatic Regime (e.g., temperate, tropical, subpolar)
   - Leaf morphology (e.g., extremely xeromorphic)
   - Leaf phenology (e.g., cold- vs. drought-deciduous)
   - Presence of a sparse woody layer in grasslands.

   Implementation Issues: Climatic regime is not a vegetation attribute, so its use violates FGDC guiding principle number 8 (see Appendix 1A). Additionally, climatic regime cannot be assessed in a one-time visit to a plot.

6. **Subgroup.** "A level of the hierarchy that splits Natural/Semi-Natural vegetation types from the Planted/Cultivated vegetation types" (FGDC 1997).

Classification Criteria: Subgroups are based on the following definitions:

Natural/Seminatural. Areas dominated by native or established vegetation that has not been cultivated or treated with any annual management or manipulation regime. In cases where it cannot be assessed whether the vegetation was planted or cultivated by humans, the vegetation is considered "Natural/Semi-Natural."

Planted/Cultivated. Areas dominated with vegetation which has been planted in its current location by humans and/or is treated with annual tillage, a modified conservation tillage, or other intensive management or manipulation. The majority of vegetation in these areas is planted and/or maintained for the production of food, feed, fiber, or seed.

Implementation Issues: These definitions have proved problematic, particularly in forest plantations of native tree species. The ESA Vegetation Classification Panel has deferred on this issue, stating, "…at this time, no standards for defining naturalness are proposed" (Jennings et al. 2002).

7. **Formation.** "A level of the hierarchy based on ecological groupings of vegetation units with broadly defined environmental and additional physiognomic factors in common. This level is subject to revision as the vegetation Alliances and Associations are organized under the upper levels of the hierarchy" (FGDC 1997).

Classification Criteria: Formations are based on the following life form, structural, and abiotic attributes:

- Elevation zone (e.g., alpine, submontane)
- Flooding regime (Cowardin 1979)
- Leaf morphology (e.g., xeromorphic)
- Tree crown shape (e.g., cylindrical)
- Presence of sparse tree layer in shrublands
- Leaf phenology and morphology of sparse tree layer in shrublands
- Leaf phenology and morphology of sparse woody layer in grasslands
- Shrub growth form (e.g., suffruticose, cushion, mat)
- Presence of succulents in shrublands
- Leaf phenology of shrubs (e.g., facultative-deciduous)
- Plant height in herbaceous vegetation
- Graminoid rooting habit (e.g., sod-forming vs. bunch)

Implementation Issues: The plethora of attributes used to define formations has produced many types that are not mutually exclusive based on their names. Since no diagnostic key has been written for formations, consistently assigning plots or associations to formations is impossible.

Elevation zones and flooding regime cannot be determined during a one-time plot visit. Recognition of elevation zones as defined by the FGDC (1997) requires a spatial analysis of vegetation patterns following completion of the classification of associations and alliances. Thus, it is impractical to use elevation zone as a top-down classification criterion. Flooding regimes reflect average or modal growing season conditions over several years, which cannot be practically evaluated in the field.

Appendix 1C.

Draft Key to Federal Geographic Data Committee Physiognomic Subclass

This appendix was developed by David Tart, Regional Vegetation Ecologist, USDA Forest Service, Intermountain Region, August 2002.

This key is not a product of, nor is it endorsed by, the FGDC Vegetation Subcommittee. It was written to improve the author's understanding of the FGDC physiognomic hierarchy and to facilitate comparison of the Society of American Foresters and Society for Range Management cover types to the FGDC Vegetation Classification Standard (FGDC-STD-005). FGDC-STD-005 indicates that a simple dichotomous key to the standard will be developed as part of testing and validating the physiognomic levels, but such a key has not yet been completed. It is hoped that this key can serve as a starting point for achieving that objective.

This key identifies the following levels of the 1997 FGDC vegetation hierarchy: Division, Order, Class, and Subclass. It is designed to be used in conjunction with the Vegetation Classification Standard (FGDC-STD-005) published by the Vegetation Subcommittee of the Federal Geographic Data Committee in June, 1997. That document should be used together with this key to identify physiognomic vegetation types. The key is followed by a list of the natural/seminatural vegetation types in the physiognomic hierarchy, by level, from Division to Subclass.

Instructions for Using the Key

The key is arranged by physiognomic hierarchy level. Divisions (Vegetated and Nonvegetated) are identified first. The rest of the key pertains only to the Vegetated Division. Orders within the Vegetated Division are keyed out first, followed by Classes within each Order and Subclasses within each Class.

The key is dichotomous, with couplets of two leads each (for example, 1a and 1b). Choose the couplet that best fits the plot or stand you are trying to assign to a physiognomic type. Each choice will lead you to either the name of a vegetation type or to another couplet. Names of Orders and Classes are followed by a number in parentheses. This number indicates the couplet where the key to the next level of the hierarchy begins. For example, Shrub Dominated Order is followed by (12) in lead 5a, indicating that the key to Classes within the Shrub Dominated Order begins at couplet 12. The code for each vegetation type is listed at the right-hand margin of the key. However, no codes have been established for the Division and Order levels of the hierarchy.

Terminology in the key follows the FGDC Vegetation Classification Standard (FGDC 1997) cited above. The glossary in that document should be consulted when using the key.

List of FGDC Vegetation Types

The List of FGDC Vegetation Types (p. 10) uses the following conventions:

- The list is arranged by hierarchy level and code. All Divisions are listed first, followed by all the orders, etc.
- Italicized codes and names indicated types that have not yet been identified in the United States. (e.g., *IVC Mixed evergreen-deciduous dwarf-shrubland* Subclass on p. 10)

Caveats and Disclaimers

As noted above, this key has not been produced or approved by the FGDC Vegetation Subcommittee. The author accepts sole responsibility for any errors in this key.

Key to FGDC Existing Vegetation Hierarchy

Code

1a. Vegetation cover <1% ....Non-Vegetated Division

1b. Vegetation cover >1%..Vegetated Division (2)

Key to Orders (Within the Vegetated Division)

2a. Vegetation cover excluding crustose
lichens ≤ 10%...No Dominant Life Form Order VII
= Sparse Vegetation Class (27)

2b. Vegetation cover excluding crustose lichens >10% 3

3a. Total tree (woody plants ≥ 5m tall)
canopy cover ≥ 25% ....Tree Dominated Order (11)

3b. Total tree canopy cover < 25% 4

4a. Shrub (woody plants ≥ 0.5m tall),
dwarf-shrub (woody plants < 0.5m tall),
herb, and nonvascular plant cover each
less than tree cover..Tree Dominated Order (11)

4b. Shrub, dwarf-shrub, herb, and/or nonvascular
plant cover greater than tree cover...5

5a. Total shrub (woody plants ≥ 0.5m tall)
canopy cover ≥ 25%...........................Shrub Dominated Order (12)

5b. Total shrub canopy cover <25% 6

6a. Dwarf-shrub (woody plants<0.5m tall),
herb, and nonvascular plant cover each
less than shrub cover ....Shrub Dominated Order (12)

	Code
6b. Dwarf-shrub, herb, and/or nonvascular plant cover greater than shrub cover...7	
7a. Total dwarf-shrub (woody plants<0.5m tall) canopy cover $\geq$ 25%............................Shrub Dominated Order (12)	
7b. Total dwarf-shrub cover < 25% 8	
8a. Herb and nonvascular plant cover each less than dwarf-shrub cover..........................Shrub Dominated Order (12)	
8b. Herb and/or nonvascular plant cover greater than dwarf-shrub cover...9	
9a. Total herb cover $\geq$ 25%.................................Herb Dominated Order = Herbaceous Vegetation Class (22)	V
9b. Total herb cover < 25%...10	
10a. Herb cover greater than total cover of bryophytes, noncrustose lichens, and alga ....Herb Dominated Order = Herbaceous Vegetation Class (22)	V
10b. Herb cover less than total cover of bryophytes, noncrustose lichens, and alga ....Nonvascular Dominated Order = Nonvascular Vegetation Class (25)	VI

Keys to Classes

Key to Classes Within the Tree Dominated Order

11a. Total tree canopy cover $\geq$ 61% ....Closed Tree Canopy Class (14)	I
11b. Total tree canopy cover < 61% ....Open Tree Canopy Class (16)	II

Key to Classes Within the Shrub Dominated Order

12a. Total shrub (woody plants $\geq$ 0.5m tall) canopy cover $\geq$ 25%...Shrubland Class (18)	III
12b. Total shrub canopy cover < 25% 13	
13a. Shrub canopy cover > dwarf-shrub (woody plants < 0.5m tall) canopy cover.........Shrubland Class (18)	III
13b. Shrub canopy cover < dwarf-shrub canopy cover..Dwarf-shrubland Class (20)	IV

Keys to Subclasses

Code

Key to Subclasses Within the Closed Tree Canopy Class

14a. Evergreen species contribute > 75%
of the total tree cover ....Evergreen Closed Tree Canopy IA

14b. Evergreen species contribute ≤ 75%
of the total tree cover 15

15a. Deciduous species contribute > 75%
of the total tree cover ....Deciduous Closed Tree Canopy IB

15b. Deciduous species contribute ≤ 75%
of the total tree cover...............Mixed Evergreen-Deciduous Closed Tree Canopy IC

Key to Subclasses Within the Open Tree Canopy Class

16a. Evergreen species contribute > 75%
of the total tree cover ....Evergreen Open Tree Canopy IIA

16b. Evergreen species contribute ≤ 75%
of the total tree cover 17

17a. Deciduous species contribute > 75%
of the total tree cover.........................Deciduous Open Tree Canopy IIB

17b. Deciduous species contribute ≤ 75%
of the total tree cover ....Mixed Evergreen-Deciduous Open Tree Canopy IIC

Key to Subclasses Within the Shrubland Class

18a. Evergreen species contribute > 75%
of the total shrub cover ....Evergreen Shrubland IIIA

18b. Evergreen species contribute ≤ 75%
of the total shrub cover 19

19a. Deciduous species contribute > 75%
of the total shrub cover...................................Deciduous Shrubland IIIB

19b. Deciduous species contribute ≤ 75%
of the total shrub cover.......Mixed Evergreen-Deciduous Shrubland IIIC

Key to Subclasses Within the Dwarf-Shrubland Class

20a. Evergreen species contribute > 75%
of the total dwarf-shrub cover ....Evergreen Dwarf-Shrubland IVA

		Code
20b. Evergreen species contribute ≤ 75% of the total shrub cover	21	
21a. Deciduous species contribute > 75% of the total dwarf-shrub cover	Deciduous Dwarf-Shrubland	IVB
21b. Deciduous species contribute ≤ 75% of the total dwarf-shrub cover	Mixed Evergreen-Deciduous Dwarf-Shrubland	IVC

Key to Subclasses Within the Herbaceous Vegetation Class (Herb Dominated Order)

22a. Non-emergent herbs structurally supported by water and rooted in substrate contribute > 50% of total herbaceous canopy	Hydromorphic Rooted Vegetation	VC
22a. Non-emergent herbs structurally supported by water and rooted in substrate contribute ≤ 50% of total herbaceous canopy	23	
23a. Perennial graminoids contribute > 50% of total herbaceous canopy	Perennial Graminoid Vegetation	VA
23b. Perennial graminoids contribute ≤ 50% of total herbaceous canopy	24	
24a. Perennial forbs, including ferns and biennials, contribute > 50% of total herbaceous canopy	Perennial Forb Vegetation	VB
24b. Perennial forbs, including ferns and biennials, contribute ≤ 50% of total herbaceous canopy	Annual Graminoid or Forb Vegetation	VD

Key to Subclasses Within the Nonvascular Vegetation Class (Nonvascular Dominated Order)

25a. Bryophytes generally dominate the nonvascular plant cover	Bryophyte Vegetation	VIA
25b. Bryophytes do not dominate the nonvascular plant cover	26	
26a. Foliose or fruticose lichens generally dominate the nonvascular plant cover	Lichen Vegetation	VIB
26b. Foliose or fruticose lichens do not dominate the nonvascular plant cover	Alga Vegetation	VIC

Key to Subclasses Within the Sparse Vegetation Class (Vegetation Not Dominant Order)

27a. Vegetation characterized by plants growing in fissures of, or growing adnate on cliffs, level to gently sloping bedrock, or pahoehoe lava flows ....Consolidated Rock Sparse Vegetation VIIA

27b. Vegetation not characterized by plant growing on consolidated rock substrates 28

28a. Vegetation characterized by plants growing in or on boulder to gravel-sized substrates ....Boulder, Gravel, Cobble, or Talus Sparse Vegetation VIIB

28b. Vegetation not characterized by plants growing on gravel-sized or larger substrates ....Unconsolidated Material Sparse Vegetation VIIC

List of FGDC Vegetation Types by Hierarchical Level

Italics indicate a type that has not yet been identified in the United States.

Level	Code	Name
Division	—	Nonvegetated
	—	Vegetated
Order	—	Tree Dominated
	—	Shrub Dominated
	—	Herbaceous Dominated
	—	Nonvascular Dominated
	—	No dominant life form
Class	I	Closed Tree Canopy
	II	Open Tree Canopy
	III	Shrubland
	IV	Dwarf Shrubland
	V	Herbaceous Vegetation
	VI	Nonvascular Vegetation
	VII	Sparse Vegetation
Subclass	IA	Evergreen closed tree canopy
	IB	Deciduous closed tree canopy
	IC	Mixed evergreen—deciduous closed tree canopy
	IIA	Evergreen open tree canopy
	IIB	Deciduous open tree canopy
	IIC	Mixed evergreen—deciduous open tree canopy
	IIIA	Evergreen shrubland
	IIIB	Deciduous shrubland
	IIIC	Mixed evergreen—deciduous shrubland
	IVA	Evergreen dwarf-shrubland
	IVB	Deciduous dwarf-shrubland

Level	Code	Name
Subclass (continued)	*IVC*	*Mixed evergreen—deciduous dwarf-shrubland*
	VA	Perennial graminoid vegetation
	VB	Perennial forb vegetation
	VC	Hydromorphic rooted vegetation
	VD	Annual graminoid or forb vegetation
	VIA	Bryophyte vegetation
	VIB	Lichen vegetation
	VIC	Alga vegetation
	VIIA	Consolidated rock sparse vegetation
	VIIB	Boulder, gravel, cobble, or talus sparse vegetation
	VIIC	Unconsolidated material sparse vegetation

Appendix 2A.

Example Field Forms and Instructions

This appendix includes examples of forms for recording plot metadata, environmental attributes, and vegetation data for ocular macroplots (see section 2.4).

2A.1 Instructions for General Site Data Form

Collect the following data elements at all sample sites. **R** = required; **O** = optional.

Field Name	Instructions
Site ID	**R** Record a plot number or site identifier unique within the project.
Project Name	**R** Record the name of the project.
Date	**R** Record the month, day, and year in the format MMDDYYYY.
Sample Type(s)	**R** Record the type(s) of data collected on the plot using the following codes: **OCMA** = Ocular Macroplot; **FLLI** = Flora Line Intercept **FLCO** = Flora Cover/Frequency; **FLPO** = Flora Point Cover **FLTR** = Flora Tree Data; **SOPE** = Soil Pedon (Individual tree measurements)
Examiner(s)	**R** Record the last name, first name, and middle initial of all crewmembers. Record the name of the principal investigator first.
Plot Location Type	**R** Record the approach used to locate the plot using the following codes: **P** = Preferential **R** = Random **S** = Stratified Random (or systematic) See section 2.3 of the technical guide for a discussion of sampling strategies.
Species List Type	**R** Record the completeness of the plant species list for the plot using the following codes: **C** = **Complete**—All plant species present at time of sampling are recorded. **R** = **Reduced**—Not all plant species are recorded. The list may be limited by a cover threshold (e.g., > 5% cover) or relative abundance (e.g., five most abundant species). **S** = **Selected**—Not all plant species recorded. A protocol- or project-specific list of species are recorded whenever they are present on a plot. **L** = **Lifeform Only**—No species are recorded. Cover is only recorded for life forms, and usually by layer or size class within life form. A complete species list is required for developing and describing new associations and alliances. See section 2.43 of the technical guide for more information.
Plot Area	**R** Record the area of the macroplot or belt transect in either acres or square meters, and the unit of measure (UOM) used. See section 2.41 of the technical guide for guidelines for determining plot size.
Plot Size	**R** Record actual plot dimensions. Radius for circular plots; width and length for rectangular plots. Also record the UOM used.
Vegetation Classification	**R** Record as much classification information as known at the time of sampling including the potential natural vegetation (PNV) series, association, and reference; existing vegetation alliance, association and reference; ecological type; and FGDC Subclass. Subclass is determined in the field using the key in Appendix 1C.

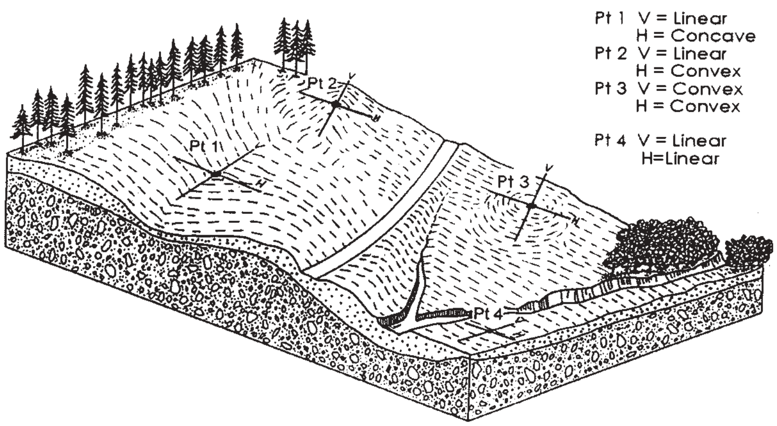
Field Name	Instructions
GPS Location	**R** Record the location of the sample site using latitude-longitude or UTM with zone.
Aerial Photo ID	**O** Record the photo identification number.
Flight Line	**O** Record the three-digit photo flight line.
Roll #	**O** Record the three-digit roll number and contract fiscal year. For example, “189” identifies roll 1 taken in fiscal year 1989.
Plot Photo Label	**O** Record a descriptive alpha/numeric label to track photos. Example is roll number followed by exposure # “2-14” to help label and track photos after processing.
Photo Description	**O** Record a description of the photo subject.
Film Type	**O** Record the type of film when a film camera is used.
Digital Photo File Name	**O** When a digital camera is used, record the filename of the photo.
Elevation	**R** Record the sample site elevation in feet, to the nearest 10 feet.
Slope	**R** Record the sample site average slope, in percent.
Aspect	**R** Record the sample site aspect in degrees. For slopes that have no aspect, record a zero. For due north, record 360.
Horizontal Slope Shape	**O** Record the horizontal shape of the plot. See appendix section 2A.11 and figure 2A.1 for values and codes.
Vertical Slope Shape	**O** Record the vertical shape of the plot. See appendix section 2A.11 and figure 2A.1 for values and codes.
Slope Complexity	**O** Record the slope complexity of the plot using the following codes: **S** = Simple = Linear, convex, or concave in shape. **C** = Complex = Broken, undulating, or patterned in shape.
Slope Position	**R** Record the two-dimensional position of the plot on the landform using the following codes: **SU** = Summit; **SH** = Shoulder; **BS** = Backslope **FS** = Footslope; **TS** = Toeslope
Slope Position Modifier	**R** Record the modifier which best describes the primary slope position using the following codes: **LR** = Lower; **MD** = Mid; **UP** = Upper
Ground Surface Cover Type	**R** Record each ground surface cover type present in the plot. See appendix sections 2A.12 and 2A.13 for types, descriptions, and codes.
Ground Surface Cover Percent	**R** Record an ocular estimate of the percentage of the plot covered by each ground surface cover type.
Disturbance Type	**O** Record major disturbance events. See section 2A.14 in this appendix for a list of disturbance types and codes.
Disturbance Extent Affected	**O** Record the vegetation affected and/or the ground cover affected in percent.
Disturbance Date	**O** Record the disturbance date in years, to the nearest year.

2A.1.1 Vertical and Horizontal Shape Code

The following codes should be used for vertical and horizontal slope shape. Some of the slope shapes are illustrated in figure 2A.1.

Code	Description
BR	**Broken**—cliffs, knobs, and/or benches interspersed with steeper slopes; generally characterized by sharp, irregular breaks.
CV	**Convex**—raised, arched up, curved out.
LI	**Linear/Planar**—straight, even, or smooth.
CC	**Concave**—depressional, curved in.
UN	**Undulating** (also rolling)—pattern of one or more low relief ridges or knolls and draws.
PA	**Patterned**—relief of hummocks and swales with several feet.
FL	**Flat**—straight and level.
XX	**Unable to assess**

Figure 2A.1. *Vertical and horizontal slopes.*

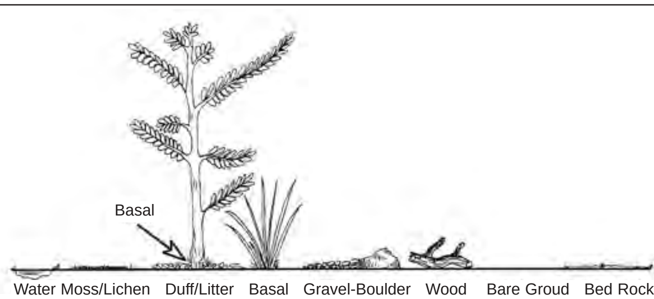


2A.1.2 Ground Surface Cover

Ground surface cover estimates are ocular. Absolute percent cover of the fixed area plot is the standard and is required. Ground surface cover is defined as the percent of plot surface area occupied by the ground cover type. Estimate to the nearest 1 percent in the 1–10 percentage range, to the nearest 5 percent for amounts exceeding 10 percent. Figure 2A.2 illustrates some ground cover types. The table on page 2A-4 is a reduced set of ground cover categories used in existing vegetation classification to describe and develop interpretations for ground cover and document disturbance effects.

Code	Description
BARE	**Bare soil:** Soil particles < 2 mm not covered by rock, cryptogams, or organic material. Does not include any part of a road, but does include foot trails.
Live vegetation categories:	
BAVE	**Basal vegetation:** Basal vegetation is the soil surface occupied by live basal or root crown portion of vascular plants, including live trees. Typically ranges between 3–7%; 15 % is very high and rarely encountered.
NONV	**Nonvascular:** Plants or plant-like organisms without specialized water or fluid conductive tissue (xylem and phloem). Includes mosses, liverworts, hornworts, lichens, algae, and bacterial soil crusts.
Organic debris categories:	
LITT	**Litter:** Plant litter and duff not yet incorporated into the decomposed top humus layer. Includes twigs < _ inch in diameter, ash from burned plants, dead nonvascular plants, and dung.
WOOD	**Wood:** Any dead woody material > _ inch in diameter, small and large woody debris, regardless of depth. Includes bases of standing dead trees and shrubs.
Rock categories:	
BEDR	**Bedrock:** A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
BOUL	**Boulders:** Rock > 600 mm (24 inches) in diameter or length.
COBB	**Cobbles:** Rock fragments between 75 and 250 mm (3 and 10 inches) in diameter.
GRAV	**Gravel:** Rock fragments between 2 and 75 mm in diameter.
PAVE	**Pavement:** A natural concentration of closely packed and polished stones at the soil surface in a desert (may or may not be an erosional lag). **Or** rock fragments < 19.1 mm in diameter.
ROCK	**Total Rock:** Relatively hard, naturally formed mineral or petrified matter > 2 mm in diameter.
RROC	**Range Rock:** Rock fragments > _ inch (19.1 mm) in diameter.
STON	**Stones:** Rock fragments between 250 and 600 mm (10 and 24 inches) in diameter.
Miscellaneous categories:	
PEIS	**Permanent Ice and Snow:** Surface area covered by apparently permanent ice and/or snow at the time of plot measurement.
ROAD	**Road:** Any road or vehicle trail that is regularly maintained or in long-term continuous use. Includes cutbanks and fills.
TRIS	**Transient Ice and Snow:** Surface area covered by apparently transient ice and/or snow at the time of plot measurement.
WATE	**Water:** Includes transient water that obscures other cover types and permanent water where the water table is above the ground bogs, swamps, marshes, and ponds.

Figure 2A.2. *Ground surface cover types.*



The following ground cover types should be recorded whenever they are present and are included on the example General Site Data form: bare soil, basal vegetation, nonvascular, litter, and wood. More detailed subdivisions of these categories are available in the Natural Resource Information System (NRIS), but are not recommended for vegetation classification. The miscellaneous categories should also be recorded whenever present. Rock cover must be recorded using one of the three sets of categories described below.

2A.1.3 Rock Ground Cover Types

Rock cover on the ground surface should be described using one of the following sets of ground cover types. Set 1 is the minimum requirement. Set 3 is recommended for vegetation classification and description performed in conjunction with Terrestrial Ecological Unit Inventory (TEUI). Set 2 is used primarily for specific rangeland monitoring methods.

Rock Set 1		Rock Set 2		Rock Set 3	
ROCK	All rock from gravel to bedrock.	PAVE	Pavement (2–19.1 mm diam.)	GRAV	Gravel (2–75 mm diam.)
		RROC	Rock (> 19.1 mm diam.)	COBB	Cobbles (75–250 mm diam.)
				STON	Stones (250–600 mm diam.)
				BOUL	Boulders (> 600 mm diam.)
				BEDR	Bedrock

2A.1.4 Disturbance Event Code Categories

The following codes should be used for disturbance and treatment types:

Code	Disturbance or Treatment	Code	Disturbance or Treatment
10000	Insects (General)	50003	Drought
10011	Ant (Formicidae)	50004	Flooding/High Water
11000	Bark Beetles	50011	Snow/Ice
12000	Defoliators	50013	Wind/Tornado
13000	Chewing Insects	50015	Avalanche
14000	Sucking Insects	50016	Mud/Landslide
15000	Boring Insects	51001	Channel Erosion
16000	Seed/Cone/Flower/Fruit Insects	51002	Soil Creep
17000	Gallmaker Insects	51010	Slump
18000	Insect Predators	70005	Land Clearing
19000	General Diseases	70006	Land Use Conversion
20000	Biotic Damage	70008	Mechanical
21000	Root/Butt Diseases	71000	Timber Harvest
22000	Stem Decay/Cankers	71002	Firewood Harvest
23000	Parasitic/Epiphytic Plants	71027	Natural Changes (No Cut)
23001	Mistletoe	73000	Regeneration Activities (General)
24000	Decline Complexes/Dieback/Wilts	73004	Seeding (Trees-Natural)

Code	Disturbance or Treatment	Code	Disturbance or Treatment
25000	Foliage Diseases	73005	Seeding (Trees-Artificial)
26000	Stem Rusts	73008	Grass Seeding
27000	Broom Rusts	73015	Site Preparation
30000	Fire	73016	Brush Control
41002	Beaver	74000	Timber Stand Improvement (General—Noncommercial)
41003	Big Game (e.g., Deer)	75000	Prescribe Burning (General)
41016	Browsing	75004	Planned Ignition—Prescribed Burn—Natural Fuels
41021	Rodents	75005	Unplanned Ignition—Prescribed Burn—Natural Fuels
41022	Elk	78007	Miscellaneous Upland Recreation Activities
42001	Cattle	78008	Miscellaneous Riparian Recreation Activities
42004	Sheep	80000	Multidamage (Insects/Diseases)
		90000	Unknown

2A.2 Instructions for Vegetation Composition Form

The Vegetation Composition Form can be used to record or summarize data for a number of sampling methods. The following describes its use for the ocular macroplot method.

2A.2.1 Vegetation Sampling Metadata

The first part of the Vegetation Composition Form records metadata about the vegetation sampling methods and who collected the data. The plot location should be recorded on the General Site Data Form.

General Site Data Form

USDA Forest Service

SITE ID NO.	PROJECT NAME		
DATE (MM-DD-YYYY)	SAMPLE TYPE(S)		
EXAMINER: LAST NAME	First Name	Middle Initial	
PLOT LOCATION TYPE:	SPECIES LIST TYPE:	PLOT AREA: UOM	
PLOT SIZE: RADIUS WIDTH LENGTH UOM		STATE:	

VEGETATION CLASSIFICATION

PNV SERIES:	PNV ASSOC:	PNV REFERENCE:
EV ALLIANCE:	EV ASSOC:	EV REFERENCE:
ECOLOGICAL TYPE:		FGDC SUBCLASS:

GPS LOCATION

LAT.	UTM	NORTH
LONG.	ZONE	EAST

AERIAL PHOTO INFORMATION

DATE	SOURCE	SCALE	PROJ/CODE	FLIGHT LINE	ROLL NO.	EXP. NO.

PLOT PHOTO INFORMATION

LABEL	PHOTO DESCRIPTION	FILM TYPE	DIGITAL PHOTO FILE NAME

MORPHOMETRY

ELEVATION	SLOPE	ASPECT	SHAPE HOR.	SHAPE VERT.	COMPLEXITY	POSITION
						______________ MOD______________

GROUND SURFACE COVER

TYPE	PERCENT	TYPE	PERCENT	TYPE	PERCENT	TYPE	PERCENT
BAVE		BARE					
NONV							
LITT							
WOOD							

MAJOR DISTURBANCE EVENTS

DISTURBANCE TYPE	EXTENT AFFECTED		DISTURBANCE DATE	NOTES:
	VEGETATION	GROUND COVER		

Remarks:

Field Name	Instructions
Site ID	**R** Record a plot number or site identifier that is unique within the project. This must match the Site ID on the General Site Data Form.
Date	**R** Record the month, day, and year in the format MMDDYYYY.
Examiner(s)	**R** Record the last name, first name, and middle initial of all crewmembers. Record the name of the principal investigator first.
Sample Type	**R** Record the type of data collected on the plot using one of the following codes: **OCMA** = Ocular Macroplot; **FLLI** = Flora Line Intercept **FLCO** = Flora Cover/Frequency; **FLPO** = Flora Point Cover **FLTR** = Flora Tree Data
Species List Type	**R** Record the completeness of the plant species list for the plot using the following codes: **C = Complete**—All plant species present at time of sampling are recorded. **R = Reduced**—Not all plant species are recorded. The list may be limited by a cover threshold (e.g., > 5% cover) or relative abundance (e.g., five most abundant species). **S = Selected**—Not all plant species recorded. A protocol- or project-specific list of species are recorded when ever they are present on a plot. **L = Lifeform Only**—No species are recorded. Cover is only recorded for life forms, and usually by layer or size class within life form. A complete species list is required for developing and describing new associations and alliances. See section 2.43 of the technical guide for more information.
Plot Area	**R** Record the area of the macroplot or belt transect in either acres or square meters, and the unit of measure **(UOM)** used. See section 2.41 of the technical guide for guidelines for determining plot size.
Area UOM	**R** Record the unit of measure for the plot area, either acres or square meters.
Plot Size	**R** Record actual plot dimensions. Radius for circular plots; width and length for rectangular plots. Also record the UOM used.
Size UOM	**R** Record the unit of measure for the plot dimensions, either feet or meters.
Height UOM	**R** Record the unit of measure for plant heights, either feet or meters.
Diameter UOM	**R** Record the unit of measure for tree diameters.

2A.2.2 Canopy Cover by Life Form

Record the canopy cover for each item in this part of the form. Canopy cover is "the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included" (SRM 1989, USDA NRCS 1997). See technical guide sections 2.233 and 2.45 for more information about canopy cover and ocular estimation techniques.

Complete the fields in this part of the form as described below.

All Veg	**Total Vegetation Cover.** Record the percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of all vascular plants within the sample unit (plot or transect).
Trees	**Tree Cover.** Record the total cover of trees—woody plants that generally have a single main stem, have more or less definite crowns, and are usually equal to or greater than 5 meters in height at maturity (see technical guide section 2.421).
Shrubs	**Shrub Cover.** Record the total cover of shrubs—woody plants that generally have several erect, spreading, or prostrate stems which give it a bushy appearance, and are usually less than 5 meters in height at maturity (see technical guide section 2.421). Shrub cover includes the cover of dwarf shrubs.
Dwarf Shrubs	**Dwarf Shrub Cover.** Record the total cover of dwarf shrubs—caespitose, suffrutescent, matted, or cushion-forming shrubs which are typically less than 50 cm tall at maturity due to genetic and/or environmental constraints (see technical guide section 2.421).
Herbs	**Herb cover.** Record the total cover of herbs—vascular plants without significant woody tissue above the ground, with perennating buds borne at or below the ground surface (see technical guide section 2.421). Includes forbs, graminoids, ferns, and fern allies. Herb cover must be equal to or less than the sum of graminoid cover and forb cover.
Graminoids	**Graminoid Cover.** Record the total cover of graminoids—flowering herbs with relatively long narrow leaves and inconspicuous flowers with parts reduced to bracts. Includes grasses, sedges, rushes, and arrowgrasses (see technical guide section 2.421).
Forbs	**Forb Cover:** Record the total cover of forbs—spore-bearing herbs or flowering herbs with relatively broad leaves and/or showy flowers (see technical guide section 2.421). Include ferns or fern allies.

Dwarf shrubs are a subcategory of shrubs. Forbs, graminoids, and fern-likes are subcategories of herbs. Total canopy cover of additional life forms can be recorded in part 3 of the Vegetation Composition Form as needed.

2A.2.3 Canopy Cover by Species

The third part of the Vegetation Composition Form is used to record data about vegetation layers and individual plant species. This portion of the form is divided into two sections: one for trees and shrubs and another for herbs and nonvascular organisms.

Record a complete list of all plant species within the sampling unit. Record only those species present in the plot. Do not record species that are present in the stand but do not occur within the plot. Record the canopy cover for each species. Do not use cover classes. Estimate percent canopy cover of each species, life form, layer, or size class within the plot as follows:

- Use 0.1 as “trace” for items present but clearly less than 1 percent cover.
- Estimate to the nearest 1 percent between 1 and 10 percent cover.
- Estimate to at least the nearest 5 percent between 10 percent and 30 percent cover.
- Estimate to at least the nearest 10 percent for values exceeding 30 percent cover.

Record a life form and life form modifier for each species using the codes in tables 2.5 and 2.6 of the technical guide, respectively (see technical guide section 2.49). These are used for crosswalking to the FGDC physiognomic hierarchy and describing physiognomy of associations and alliances (Jennings et al. 2004).

2A.2.4 Canopy Cover and Structural Data by Layer

Species data may also be recorded by layer if desired. The following instructions describe how to record data for tree and shrub layers, and for tree and shrub species by layer.

2A.2.4.1 Tree Layer Definitions

Trees vary widely in mature height, from 5 meters to over 50 meters (FGDC 1997). This variation must be taken into account when defining layers or height classes for trees. For this purpose, a **dwarf tree** is defined as a tree that is typically less than 12 meters tall at maturity due to genetic and/or environmental constraints. A stand of dwarf trees typically has a site-specific potential height growth of less than 12 meters. The layers described below are defined separately for dwarf trees where necessary.

The following tree layers must be described whenever they are present in the sampling unit (e.g., macroplot or transect):

- **Overstory—**The overstory layer includes all trees greater than or equal to 5 meters in height that make up the forest canopy. In dwarf tree stands, the overstory consists of trees that have attained at least half of their site-specific potential height growth and make up the forest canopy.
- **Regeneration—**The regeneration layer includes all trees less than 5 meters in height. In dwarf tree stands the regeneration layer includes trees that have attained less than half of their site-specific potential height growth and are clearly overtopped by the overstory trees.

The overstory may optionally be subdivided into the following sublayers, if they occur, to describe stand structure in more detail:

- **Main Canopy—**The dominant and codominant overstory trees that receive direct sunlight from above and make up the majority of the forest canopy.
- **Supercanopy—**Scattered overstory trees that clearly rise above the main canopy.
- **Subcanopy—**Overstory trees that are clearly overtopped by and separate from the main canopy, but are larger and taller than the regeneration layer.

The regeneration layer may optionally be subdivided into the following sublayers:

- **Saplings—**Regenerating trees greater than 1.4 meters (4.5 feet) in height or regenerating dwarf trees greater than 1 meter in height.
- **Seedlings—**Regenerating trees less than 1.4 meters (4.5 feet) in height or regenerating dwarf trees less than 1 meter in height.

2A.2.4.2 Tree Layer Data Requirements and Instructions

Canopy cover, predominant plant height, and predominant crown height must be recorded for the tree overstory and regeneration layers. Predominant diameter must also be recorded for the overstory. Record these attributes using the following procedures:

- **Canopy Cover—**Record percent canopy cover for each layer and optional sublayer occurring within the sampling unit. Canopy cover of a layer cannot be greater than the sum of the canopy cover values of its sublayers. Layer cover, however, can be and typically is less than the sum of the sublayer covers due to overlapping of the sublayers.
- **Predominant Plant Height—**Record the predominant, or prevailing, tree height for the overstory and regeneration layers to the nearest meter and nearest foot, respectively. To determine this height, select a representative tree for the layer and estimate its height using a clinometer and measuring tape. The representative tree for the overstory layer must be in the main canopy. The representative tree for the regeneration layer must be from the sublayer (sapling or seedling) with the most canopy cover. Predominant plant height may also be recorded for each optional sublayer.
- **Predominant Crown Height**—Record the predominant, or prevailing, crown height for the overstory and regeneration layers to the nearest meter. Crown height is the vertical distance from ground level to the lowest whorl with live branches in at least three of four quadrants around the stem. To determine crown height, select a representative tree for the layer and estimate its crown height using a clinometer and measuring tape. The representative tree for the overstory layer must be in the main canopy. The representative tree for the regeneration layer must be from the sublayer

(sapling or seedling) with the most canopy cover. Predominant crown height may also be recorded for each optional sublayer.

- **Predominant Diameter—**Record the predominant, or prevailing, tree diameter for the overstory layer to the nearest inch. Predominant diameter is the prevailing diameter of the most abundant tree species in a layer or sublayer. To determine this diameter, select a representative tree and measure it with a diameter tape, using procedures described in *Common Stand Exam Field Guide*. The representative tree for the overstory layer must be in the main canopy. Measure the diameter at breast height (DBH) whenever possible; otherwise, measure diameter at root crown (DRC), and record the diameter in the appropriate column (DBH or DRC) of the Vegetation Composition Form.

Table 2A.1 shows an example of the required and optional data for tree layers.

Table 2A.1. *Example of completed data for tree layers and sublayers.*

Life Form	LF Mod.	Layer	Species	Canopy Cover	Pred. Plant Height (m)	Pred. Crown Height (m)	Pred. DBH (in)	Pred. DRC
T	—	**TO**	—	***45***	***10***	***6***	***12***	—
T	—	TOSP	—	*5*	*12*	*8*	*15*	—
T	—	TOMC	—	*40*	*10*	*6*	*12*	—
T	—	TOSB	—	*10*	*7*	*2.5*	*8*	—
T	—	**TR**	—	***10***	***4***	***0.3***	***t***	
T	—	TRSA	—	*5*	*4*	*0.3*	*t*	
T	—	TRSE	—	*5*	*0.3*	*0*		

2A.2.4.3 Data for Shrub Layers

The following shrub layers may optionally be described when present in the sampling unit (e.g., macroplot or transect):

- **Tall Shrubs—**Shrubs greater than 2 meters in height. (May occasionally include shrubs over 5 meters tall but clearly multistemmed.)
- **Medium Shrubs—**Shrubs 0.5 to 2 meters in height.
- **Low Shrubs—**Shrubs less than 0.5 meter in height.

When shrub layers are described, canopy cover and predominant plant height should be recorded for each layer. Predominant crown height may also be recorded. Record these attributes using the following procedures:

- **Canopy Cover—**Record percent canopy cover for each shrub layer occurring within the sampling unit. Total shrub cover cannot be greater than the sum of the individual layer cover values, but may be less.

- **Predominant Plant Height**—Record the predominant, or prevailing, height of each shrub layer to at least the nearest foot. Predominant plant height is the prevailing upper height of the shrubs within a layer. To determine this height, select a representative individual shrub andmeasure its height with an appropriate method (e.g., tape measure for low to medium shrubs or clinometer for tall shrubs).
- **Predominant Crown Height**—Record the predominant crown height for each shrub layer to at least the nearest foot. Crown height for shrubs is the vertical distance from ground level to the lowest live foliage or branches. To determine crown height, select a representative shrub for the layer and measure or estimate its crown height.

Table 2A.2 shows an example of completed shrub layer data.

Table 2A.2. *Example of completed data for shrub layers.*

Life Form	LF Mod.	Layer	Species	Canopy Cover	Pred. Plant Height (m)	Pred. Crown Height (m)
S	—	ST	—	*1*	*3*	*1*
S	—	SM	—	*9*	*1*	*0.3*
S	—	SL	—	*Tr*	*0.3*	*0*
T	—	TRSE	—	*5*	*0.3*	*0*

2A.2.5 Optional Canopy Cover and Structural Data by Species by Layer

Canopy cover and structural data may optionally be recorded separately for each species for each layer or sublayer in which it occurs.

2A.2.5.1 Data for Tree Species by Layer

Canopy Cover

Record the total canopy cover of each tree species and the canopy cover of each species within each layer in which it occurs. Cover by sublayer may also be recorded. This may require up to eight rows of data, depending on the number of sublayers in which a species occurs. An example is shown in Table 2A.3 below with required data in bold text. In this example, the canopy cover of Ponderosa pine (*Pinus ponderosa*) is 45 percent. Within the overstory and regeneration layers its canopy cover is 35 and 10 percent, respectively, indicating there is no overlap between the two layers. No sapling or seedling occurs

Table 2A.3. *Example of completed data for shrub layers.*

Life Form	LF Mod.	Layer	Species	Canopy Cover
T	*TN*	—	*PIPO*	*45*
T	*TN*	*TO*	*PIPO*	*35*
T	*TN*	*TOMC*	*PIPO*	*30*
T	*TN*	*TOSB*	*PIPO*	*10*
TR	*PIPO*	*10*		
T	*TN*	*TRSA*	*PIPO*	*6*
T	*TN*	*TRSE*	*PIPO*	*4*

directly under an overstory tree. However, there is overlap between main canopy and subcanopy trees. Ponderosa pine cover is 30 percent in the main canopy and 10 percent in the subcanopy, while overstory cover is only 35 percent. This indicates 5-percent overlap between main canopy and subcanopy Ponderosa pine.

The possibility of overlap between sublayers requires that overstory and regeneration cover for each tree species is estimated or measured directly, not calculated by summing the sublayer values. When recording species cover by sublayer using the ocular macroplot method, it is most efficient to first estimate canopy cover by sublayer, and then estimate the overlap (if any) between sublayers to derive canopy cover for the overstory and regeneration layers.

Predominant Plant Height

Record predominant height of each tree species for each layer in which it occurs. To determine this height, select a representative tree and estimate its height with a clinometer and measuring tape, using procedures described in Common Stand Exam Field Guide.

Predominant Crown Height

Record predominant crown height of each tree species for each layer in which it occurs. To determine this height, select a representative tree and estimate or measure the vertical distance from the ground to the canopy base.

Predominant Age

Record the predominant age of each tree species in the overstory layer. Refer to the *Common Stand Exam Field Guide* for methods of determining tree age.

Predominant Diameter

Record predominant diameter (DBH or DRC as appropriate) for the overstory layer. To determine this diameter, select a representative tree and measure it with a diameter tape, using procedures described in *Common Stand Exam Field Guide*.

Stem Count

Record stem counts for each tree species occurring in the regeneration layer. Stems may optionally be recorded by sublayer (sapling and seedling). Counts can be made on the entire plot or a portion of the plot depending on the density of each species. When stems are counted on a portion of the plot, the fraction of the plot and the raw count are recorded in the Remarks section of the form. These values are then used to calculate a count for the entire plot, which is recorded in the stem count column of the form.

An example of a completed data set for one tree species in shown below in Table 2A.4. Predominant plant height, crown height, diameter, age, and stem count have been added to the canopy cover data in Table 2A.1.

Table 2A.4. *Example of completed data for tree layers and sublayers.*

Life Form	LF Mod.	Layer	Species	Canopy Cover	Pred. Plant Ht	Pred. Crown Ht	Pred. DBH (in)	Pred. DRC	Pred. Age	Stem Count
T	*TN*	—	*PIPO*	*45*						
T	*TN*	*TO*	*PIPO*	*35*	*40*	*15*	*30*	—	*150*	
T	*TN*	*TOMC*	*PIPO*	*30*	*40*	*15*	*30*	—	*150*	
T	*TN*	*TOSB*	*PIPO*	*10*	*20*	*5*	*12*	—	*80*	
T	*TN*	*TR*	*PIPO*	*10*	*4*	*0.5*				*13*
T	*TN*	*TRSA*	*PIPO*	*6*	*4*	*0.5*				*4*
T	*TN*	*TRSE*	*PIPO*	*4*	*0.3*	*0*				*9*

2A.2.5.2 Data for Shrub Species by Layer

Canopy Cover

Record the total canopy cover of each shrub species. The canopy cover of each species within each layer in which it occurs may optionally be recorded, but is not required. This may require up to four rows of data, depending on the number of layers in which a shrub species occurs. The possibility of overlap between layers requires that total canopy cover for each shrub species be estimated or measured directly, not calculated by summing the species by layer cover values.

Predominant Crown Height

Record predominant crown height of each shrub species for each layer in which it occurs. To determine this height, select a representative shrub and estimate or measure the vertical distance from the ground to the lowest live foliage.

Predominant Height

Record predominant height of each shrub species or optionally for each layer in which the species occurs. Predominant height is the prevailing upper height of the shrub species within a layer. To determine this height, select a representative individual shrub and measure its height with an appropriate method (e.g., tape measure for low to medium shrubs or clinometer for tall shrubs).

Table 2A.5 shows an example of completed shrub species and species by layer data.

Table 2A.5. *Example of completed data for shrub species by layers.*

Life Form	LF Mod.	Layer	Species	Canopy Cover	Pred. Plant Height (m)	Pred. Crown Height (m)
S	*SBD*	—	*QUGA*	*9*	*1*	*0.2*
S	*SBD*	*ST*	*QUGA*	*1*	*3*	*1*
S	*SBD*	*SM*	*QUGA*	*8*	*1*	*0.2*
S	*SM*	—	*ARTRP4*	*1*	*0.7*	*0.2*
S	*SM*	*SM*	*ARTRP4*	*1*	*0.7*	*0.2*

2A.2.6 Basal Area Data

Basal area may optionally be collected using a single prism point at the center of a macroplot or midpoint of a transect. Follow the procedures in the Common Stand Exam Field Guide. Record the basal area, in square feet per acre, and the expansion factor (BAF) of the prism used.

2A.2.7 Blank Vegetation Composition Form and Completed Examples

A blank Vegetation Composition Form is provided on the following page. It is followed by examples of a completed General Site Data Form and Vegetation Composition Form.

Vegetation Composition Form

Site ID No.:	Date: __ __ / __ __ / __ __ __ __	Examiner(s): ____________________
Sample Type:	Species List: C or R or S or L	

Plot Area:	Area UOM:	Height UOM:
Plot Size - Radius: Length: Width:	Size UOM:	Diameter UOM:

Percent Canopy Cover by Life Form

Life Form:	All Veg	Trees	Shrubs	Dwarf Shrubs	Herbs	Grasses	Forbs
% Cover:							

Percent Canopy Cover and Structure Data by Layer and Species

Trees and Shrubs

Life Form	LF Mod	Layer	Plant Code	Can. Cover	Pred Plant Ht	Pred Crown Ht	Pred DBH	Pred DRC	Pred Age	Stem Count
T	**---**	**TO**	**---**							
T	---	TOSP	---							
T	---	TOMC	---							
T	---	TOSB	---							
T	**---**	**TR**	**---**							
T	---	TRSA	---							
T	---	TRSE	---							
S	---	ST	---							
S	---	SM	---							
S	---	SL	---							

Herbaceous and Nonvascular

Life Form	LF Mod	Layer	Plant Code	Can. Cover	Pred Ht.

Basal Area:	BAF Used:

Remarks:

General Site Data Form

USDA Forest Service

Site ID # *FSR4BT92DT127*	Project Name *B-T East TEUI*			
Date (mm-dd-yyyy) *08-23-1995*		Sample Type(s) *OCMA, SOPE*		
Examiner: Last Name *Tart Ferwerda*		First Name *David Martin*		Middle Initial *L*
Plot Location Type: *P*	Species List Type: *C*		Plot Area: *1/10* UOM *ACRE*	
Plot Size: Radius *37.2* Width Length UOM *FEET*			State: *WY*	

Vegetation Classification		
PNV Series: *ABLA*	PNV Assoc: *VASC, PIAL*	PNV Reference: *Steele&1983*
EV Alliance: *PIAL*	EV Assoc: *VASC*	EV Reference: *NONE*
Ecological Type:		FGDC Subclass: *IIA*

GPS Location		
Lat. *43° 18' 44"*	UTM	North
Long. *110° 12' 33"*	Zone	East

Aerial Photo Information

Date	Source	Scale	Proj/Code	Flight Line	Roll No.	Exp. No.
09-01-1989					*1715*	*87*

Plot Photo Information

Label	Photo Description	Film Type	Digital Photo File Name

Morphometry

Elevation	Slope	Aspect	Shape Hor.	Shape Vert.	Complexity	Position Mod
9900'	*9%*	*19°*	*UN*	*UN*	*C*	*BS UP*

Ground Surface Cover

Type	Percent	Type	Percent	Type	Percent	Type	Percent
BAVE	*8*	BARE	*2*	*STON*	*7*		
NONV	*4*	*BEDR*	*5*	*BOUL*	*5*		
LITT	*50*	*GRAV*	*1*				
WOOD	*15*	*COBB*	*3*				

Major Disturbance Events

Disturbance Type	Extent Affected		Disturbance Date	Notes:
	Vegetation	Ground Cover		

Remarks: *Stop# B0606B. Location from pin-pricked photo, not GPS.*

Vegetation Composition Form

Site ID #: FSR4BT92DT127	Date: 08-23-1995	Examiner(s): David L. Tart
Sample Type: OCMA	Species List: (C) or R or S or L	Martin Ferwerda

Plot Area: 1/10	Area UOM: acre	Height UOM: feet
Plot Size - Radius: 37.2 Length: Width:	Size UOM: feet	Diameter UOM:

Percent Canopy Cover by Life Form

Life Form:	All Veg	Trees	Shrubs	Dwarf Shrubs	Herbs	Grasses	Forbs
% Cover:	(80)	45	35	35	12	7	5

Percent Canopy Cover and Structure Data by Layer and Species

Trees and Shrubs

Life Form	LF Mod	Layer	Plant Code	Can. Cover	Pred Plant Ht	Pred Crown Ht	Pred DBH	Pred DRC	Pred Age	Stem Count
T	---	TO	---	37	50	17				
T	---	TOSP	---	---	---	---				
T	---	TOMC	---	29	50	17				
T	---	TOSB	---	12	30	12				
T	---	TR	---	17	---	---				
T	---	TRSA	---	8	---	---				
T	---	TRSE	---	9	---	---				
S	---	ST	---	---	---	---				
S	---	SM	---	---	---	---				
S	---	SL	---	35	1	---				
T	TN	---	ABLA	20	---	---				
T	TN	TO	ABLA	7	30	12				
T	TN	TR	ABLA	16	---	---				
T	TN	---	PIAL	20	---	---				
T	TN	TO	PIAL	20	45	15				
T	TN	TR	PIAL	0.1	---	---				
T	TN	---	PIEN	13	---	---				
T	TN	TO	PIEN	12	60	20				
T	TN	TR	PIEN	1	---	---				
S	SD	SL	VASC	35	1	0				

Herbaceous and Nonvascular

Life Form	LF Mod	Layer	Plant Code	Can. Cover	Pred Ht.
H	HF		ASTER	0.1	1
H	HF		EPAN2	0.1	1
H	HF		ERIGE2	0.1	0
H	HF		HIGR	0.1	1
H	HG		CARO5	2	0
H	HG		JUDR	0.1	1
H	HG		POCU	0.1	2
H	HG		PONEW	5	3
H	HG		POPA3	0.1	1

Basal Area:	BAF Used:
Remarks:	

Appendix 3A.

Example of Mapping Keys to Life Form and Dominance Types

This appendix was taken from USDA Forest Service, Pacific Southwest Region, *Forest Inventory and Analysis User's Guide*, May 2002, Chapter 700—Appendices, CALVEG Types.

Example Mapping Keys To Life Form and Dominance Types in the Pacific Southwest Region

Field Key to CALVEG Dominance Types in Zone 1 – North Coast and Montane

CALVEG Key for North Coast and Montane Ecological Province (CALVEG Zone 1) Used in Type Identification, Mapping, and Accuracy Assessment of Map Products

I. Key to Lifeforms

1A. If total vegetation plot cover > 10% in conifers ... 2
1B. If total vegetation plot cover < 10% in conifers ... 3

2A. If total vegetation plot cover > 15% in hardwoods ... **mixed lifeform** and go to **II Key to Conifers** for the conifer component and **III Key to Hardwoods** for the hardwood component.
2B. If total vegetation plot cover < 15% in hardwoods **conifer lifeform** and go to **II Key to Conifers**

3A If total vegetation plot cover >10% in hardwoods **hardwood lifeform** and go to **III Key to Hardwoods**
3B. If total vegetation plot cover <10% in hardwoods ... 4

4A. If total vegetation plot cover > 10% in shrubs ... **shrub lifeform** and go to **IV Key to Chaparrals, Shrubs and Subshrubs**
4B. If total vegetation plot cover < 10% in shrubs ... 5

5A. If total vegetation plot cover > 10% in other vegetation ... **herbaceous lifeform** and go to **V Key to Grasses and Forbs**
5B. If total plot cover < 10% in other vegetation ... **non-vegetated** and go to **VI Key to Non-Vegetated Types**

II. Key to Conifers

cc = conifer canopy cover

1A. A single species of conifer species has > 50% cc ... 2

1B. No single conifer species has > 50% cc ... 40

2A. One **Cypress** species has > 50% cc ... 3

2B. Another single conifer species has > 50% cc ...8

3A. **Sargent Cypress** has > 50% cc ... **MS (Sargent Cypress)**

3B. Not as above ... 4

4A. **McNab Cypress** has > 50% cc ... **MN (McNab Cypress)**

4B. Not as above ... 5

5A. **Pygmy Cpress** has > 50% cc ... **MY (Pygmy Cypress)**

5B. Not as above ... 6

6A. **Baker Cypress** has > 50% cc ... **MO (Baker Cypress)**

6B. Not as above ... 7

7A. **Monterey Cypress** has > 50% cc ... **MM (Monterey Cypress)**

7B. Not as above ... 47

8A. **Coastal Redwood** has > 50% cc ... **RW (Redwood)**

8B. Not as above ... 9

9A. **Port Orford Cedar** has > 50% cc ... **PO (Port Orford Cedar)**

9B. Not as above ... 10

10A. **Red Fir** has > 50% cc and **White Fir** present, the combination > 75% cc ... **RF (Red Fir)**

10B. Not as above ... 11

11A. **White Fir** has > 50% cc and **Red Fir** present, the combination > 75% cc ... **WF (White Fir)**

11B. Not as above ... 12

12A. **Ponderosa Pine** has > 75% cc (or **Ponderosa Pine** and **Jeffrey Pine** in combination has > 75% and **Ponderosa Pine** > **Jeffrey Pine**) and Great Basin species (**Bitterbrush, Curlleaf Mountain Mahogany, Basin Sagebrush, Western Juniper, or California Juniper**) do not occur in understory ... **PP (Ponderosa Pine)**
12B. Not as above ... 13

13A. **Ponderosa Pine** has > 75% cc (or **Ponderosa Pine** and **Jeffrey Pine** in combination has > 75% cc) and Great Basin species (**Bitterbrush, Curlleaf Mountain Mahogany, Basin Sagebrush, Western Juniper, or California Juniper**) occur in understory ... **EP (Eastside Pine)**
13B. Not as above ... 14

14A. **Jeffrey Pine** has > 75% cc (or **Ponderosa Pine** and **Jeffrey Pine** in combination has > 75% and Jeffrey Pine > Ponderosa Pine) and Great Basin species (**Bitterbrush, Curlleaf Mountain Mahogany, Basin Sagebrush, Western Juniper, or California Juniper**) do not occur in understory ... **JP (Jeffrey Pine)**
14B. Not as above ... 15

15A. **Jeffrey Pine** has > 75% cc and Great Basin species (**Bitterbrush, Curlleaf Mountain Mahogany, Basin Sagebrush, Western Juniper, or California Juniper)** occur in understory ... **EP (Eastside Pine)**
15B. Not as above ... 16

16A. **Pacific Douglas-Fir** has > 75% cc ... **DF (Pacific Douglas-Fir)**
16B. Not as above ... 17

17A. **Whitebark Pine** has > 75% cc ... **WB (Whitebark Pine)**
17B. Not as above ... 18

18A. **Western White Pine** has > 75% cc ... **WW (Western White Pine)**
18B. Not as above ... 19

19A. **Foxtail Pine** has > 75% cc ... **FP (Foxtail Pine)**
19B. Not as above ... 20

20A. **Mountain Hemlock** has > 75% cc ... **MH (Mountain Hemlock)**
20B. Not as above ... 21

21A. **Knobcone Pine** has > 75% cc ... **KP (Knobcone Pine)**
21B. Not as above ... 22

22A. **Western Juniper** has > 75% cc ... **WJ (Western Juniper)**
22B. Not as above ... 23

23A. **Gray Pine** has > 75% ... **PD (Gray Pine)**
23B. Not as above ... 24

24A. **Lodgepole Pine** has > 75% cc ... **LP (Lodgepole Pine)**
24B. Not as above ... 25

25A. **Engelmann Spruce** has > 75% cc ... **EA (Engelmann Spruce)**
25B. Not as above ... 26

26A. **Brewer Spruce** has > 75% cc ... **PB (Brewer Spruce)**
26B. Not as above ... 27

27A. **Grand Fir** has > 75% cc ...**GF (Grand Fir)**
27B. Not as above ... 28

28A. **Bishop Pine** has > 75% cc ... **PM (Bishop Pine)**
28B. Not as above ... 29

29A. **Monterey Pine** has > 75% cc ... **PR (Monterey Pine)**
29B. Not as above ... 30

30A. **Beach Pine** has > 75% cc ... **PS (Beach Pine)**
30B. Not as above ... 31

31A. **Sitka Spruce** has > 75% cc ... **SK (Sitka Spruce)**
31B. Not as above ... 32

REM: This starts the > 50 and < 75% two-conifer species groups
32A. **Douglas-Fir** has > 50% cc; **Redwood** is present ... **RD (Redwood - Douglas-Fir)**
32B. Not as above ... 33

33A. **Douglas-Fir** has > 50% cc; **Ponderosa Pine** has > 20% cc ... **DP (Douglas-Fir - Ponderosa Pine)**
33B. Not as above ... 34

34A. **Douglas-Fir** has > 50% cc; **White Fir** has > 20% cc ... **DW (Douglas-Fir - White Fir)**
34B. Not as above ... 35

35A. **Douglas-Fir** has > 50% cc; **Grand Fir** has > 20% cc ... **DG (Douglas-fir - Grand Fir)**
35B. Not as above ... 36

37A. **Ponderosa Pine** has > 50% cc; **White Fir** has > 20% cc ... **PW (Ponderosa Pine - White Fir)**
37B. Not as above ... 38

38A. **Sitka Spruce** has > 50% cc; **Redwood** has > 20% cc ... **SR (Sitka Spruce - Redwood)**
38B. Not as above ... 39

39A. **Sitka Spruce** has > 50% cc; **Grand Fir** has > 20% cc ... **SG Sitka Spruce - Grand Fir)**
39B. Not as above ... 40

REM: this starts condition in which no single conifer species > 50% sc
40A. **Red Fir** in combination with **White Fir** > 75% cc and **Red** Fir > **White Fir** ... **RF (Red Fir)**
40B. Not as above ... 41

41A**. White Fir** in combination with **Red Fir** > 75% cc and **White Fir** > **Red Fir** ... **WF (White Fir)**
41B. Not as above ... 42

42A. Any of these species in combination are present but do not dominate the cc: **Mountain Hemlock, Foxtail Pine, Western White Pine, Whitebark Pine** ... **SA (Subalpine Conifers)**
42B. Not as above ... 43

43A. Any of these species in combination are present but do not dominate the cc: **Noble Fir, Alaska Cedar, Engelmann Spruce, Brewer Spruce, Port Orford Cedar, Pacific Yew** ... **MK (Klamath Mixed Conifer)**
43B. Not as above ... 44

44A. **Ponderosa Pine** and/or **Sugar Pine** in combination > 10% cc ... **MP (Mixed Conifer - Pine)**
44B. Not as above ... 45

45A. **White Fir** and **Red Fir** combined have > 20% cc ... **MF (Mixed Conifer - Fir)**
45B. Not as above .. 46

46A. Any of these species in combination are present but do not dominate the cc: **Jeffrey Pine, Lodgepole pine, McNab Cypress, Sargent Cypress, Gray Pine, or Western White Pine** and elevation is less than 5000 ft (1525 m) ... **MU (Ultramafic Mixed Conifer)**
46B. Not as above … 47

47. Conifer type not determined ... **UC**

III. Key to Hardwoods
hc = hardwood canopy cover

1A. One hardwood species (or genus) has > 50% hc ... 2
1B. No single hardwood species (or genus) has > 50% hc ... 23

2A. **Tanoak** has > 50% hc ... **QT (Tanoak [Madrone])**
2B. Otherwise ... 3

3A. **Madrone** has > 50% hc ... **QH (Madrone)**
3B. Otherwise ... 4

4A. **Willow** has > 50% hc ... **QO (Willow)**
4B. Otherwise ... 5

5A. **Red Alder** has > 50% hc ... **QR (Red Alder)**
5B. Otherwise ... 6

6A. **White Alder** has > 50% hc ... **QE (White Alder)**
6B. Otherwise ... 7

7A. **Mountain Alder** has > 50% hc ... **TA (Mountain Alder)**
7B. Otherwise ... 8

8A. **Black Cottonwood** has > 50% hc ... **QX (Black Cottonwood)**
8B. Otherwise ... 9

9A. **Fremont Cottonwood** has > 50% hc ... **QF (Fremont Cottonwood)**
9B. Otherwise ... 10

10A. **Quaking Aspen** has > 50% hc ... **QQ (Aspen)**
10B. Otherwise ... 11

11A. **Bigleaf Maple** has > 50% hc ... **QM (Bigleaf Maple)**
11B. Otherwise ... 12

12A. **Tree Chinquapin** has > 50% hc ... **TC (Tree Chinquapin)**
12B. Not as above ... 13

13A. **Black Oak** has > 50% hc ... **QK (Black Oak)**
13B. Not as above ... 14

14A. **Oregon White Oak** has > 50% hc ... **QG (Oregon White Oak)**
14B. Not as above ... 15

15A. **Blue Oak** has the greatest hardwood cover ... **QD (Blue Oak)**
15B. Not as above ... 16

16A. **Coast Live Oak** has > 50% hc ... **QA (Coast Live Oak)**
16B. Not as above ... 17

17A. **Canyon Live Oak** has > 50% hc ... **QC (Canyon Live Oak)**
17B. Not as above ... 18

18A. **Interior Live Oak** has > 50% hc ... **QW (Interior Live Oak)**
18B. Not as above ... 19

19A. **Valley Oak** has > 50% hc ... **QL (Valley Oak)**
19B. Not as above ... 20

20A. **California Bay** has > 50% hc ... **QB (California Bay)**
20B. Not as above ... 21

21A. **Eucalyptus** of any species has > 50% hc ... **QZ (Eucalyptus)**
21B. Not as above ... 22

22A. **California Buckeye** has > 50% hc ... **QI (California Buckeye)**
22B. Not as above ... **Unknown Hardwood Type** ... **HD**

REM: this begins the mixed hardwoods groups; no single species > 50% hc
23A. Combination of **Tanoak** and **Madrone** has > 50% hc ... **QT (Tanoak [Madrone])**
23B. Otherwise ... 24

24A. **Black** or **Fremont Cottonwood** and any species of **Alder (Red, White, Sitka, or Mountain)** in combination have > 50% hc ... **QJ (Cottonwood - Alder)**
24B. Otherwise ... 25

25A. **Willow** of any species and **Aspen** in combination have > 50% hc ... **QS (Willow - Aspen)**
25B. Otherwise ... 26

26A. **Willow** of any species and **Alder (Red, White, Sitka, or Mountain)** in combination have > 50% hc ... **QY (Willow - Alder)**
26B. Otherwise ... 27

27A. Otherwise a mixture of hardwoods, including **Valley Oak, California Bay, Canyon, Coast and Interior Live Oaks, California Black and Oregon White Oak, Blue Oak, Madrone**, and **California Buckeye** ... **NX (Mixed Hardwoods)**
27B. Otherwise ... **Unknown Hardwood Type** ... **HD**

IV. Key to Shrubs
sc = shrub canopy cover

1A. **Pygmy (Ft. Bragg) Manzanita** has > 10% sc ... **AN (Pygmy [Ft. Bragg] Manzanita)**
1B. Not as above ... 2

2A. Either **Salal** or **California Huckleberry** have > 50% sc ... **CB (Salal - California Huckleberry)**
2B. Not as above ... 3

3A. **Curlleaf Mountain Mahogany** has > 50% sc ... **BM (Curlleaf Mountain Mahogany)**
3B. Otherwise ... 4

4A. **Basin Sagebrush** as > 50% sc ... **BS (Basin Sagebrush)**
4B. Not as above ... 5

5A. **Bitterbrush** has > 50% sc ... **BB (Bitterbrush)**
5B. Not as above ... 6

6A. **Low Sagebrush** as > 50% sc ... **BL (Low Sagebrush)**
6B. Not as above ... 7

7A. Any species of **Rabbitbrush** alone or in combination has > 50% sc ... **BR (Rabbitbrush)**
7B. Not as above ... 8

7A. **Chamise** has > 50% sc ... **CA** (**Chamise**)
7B. Not as above ... 8

8A. **Whiteleaf Manzanita** has > 75% sc ... **CW (Whiteleaf Manzanita)**
8B. Not as above ... 9

9A. **Greenleaf Manzanita** has > 75% sc ... **CG (Greenleaf Manzanita)**
9B. Not as above ... 10

10A. **Pinemat Manzanita** has > 75% sc ... **CN (Pinemat Manzanita)**
10B. Not as above ... 11

11A. **Manzanita** of any other species alone or in combination with or without Whiteleaf or Greenleaf Manzanita > 75% sc ... **SD (Manzanita)**
11B. Not as above ... 12

12A. **Huckleberry Oak** has > 75% sc ... **CH (Huckleberry Oak)**
12B. Not as above ... 13

13A. **Brewer Oak** has > 75% sc ... **CJ (Brewer Oak)**
13B. Not as above ... 14

14A. **Wedgeleaf Ceanothus** has > 75% sc ... **CL (Wedgeleaf Ceanothus)**
14B. Not as above ... 15

15A. **Blueblossom Ceanothus** has > 75% sc ... **SC (Blueblossom Ceanothus)**
15B. Not as above ... 16

16A. **Snowbrush** has > 75% sc ... **CV (Snowbrush)**
16B. Not as above ... 17

17A. **Coyote Brush** has > 75% sc ... **CK (Coyote Brush)**
17B. Not as above ... 18

REM: mixed species:
18A. Any other combination of **Ceanothus,** including non-dominant **Wedgeleaf, Deerbrush, Blueblossom,** or **Snowbrush** has > 75% sc ... **CC (Ceanothus Chaparral)**
18B. Not as above ... 19

19A. **Salal** and **California Huckleberry** in combination has > 75% sc ... **CB** (**Salal - California Huckleberry**)
19B. Not as above ... 20

20A. Any other species of scrubby oaks alone or in combination of the following have > 75% sc: **Scrub Oak, Shrub Interior Live Oak, Shrub Canyon Live Oak, Leather Oak, Sadler Oak, Huckleberry Oak, Oregon White or Brewer Oak, California Black Oak** ... **CS (Scrub Oak)**
20B. Not as above ... 21

21A. Any of following species present and in combination have > 10% sc: **Blueblossom Ceanothus, Coastal Whitethorn, Hairy Manzanita, Shrub California Bay, Salal, California Huckleberry, Wax Myrtle, Yellow Bush Lupine,** any species of **Rhododendron, Red Huckleberry, Thimbleberry** ... **NC (North Coastal Scrub)**
21B. Not as above ... 22

22A. Any of the following in combination have > 10% sc: **Chamise, Wedgeleaf Ceanothus, Lemmon Ceanothus, Whiteleaf Manzanita, Common Manzanita,**

Stanford Manzanita, Birchleaf Mountain Mahogany, Toyon, **Pine Mat Ceanothus, Hollyleaf Redberry** ... **CQ (Lower Montane Mixed Chaparral)**
22B. Not as above ... 23

23A. Any of the following in combination of two or more have > 10% sc: **Greenleaf Manzanita, Hoary Manzanita, Mountain Whitethorn, Deerbrush, Cascara, Shrub Canyon Live Oak, Bush Chinquapin, Fremont Silktassel,** any species of **Snowberry**, **Mahala Mat** ... **CX (Upper Montane Mixed Chaparral)**
23B. Not as above ... 24

24A. Elevation < 5000 ft (1525 m); any of the following in combination have > 10% sc: **Jepson Ceanothus, ShrubTanoak, Creeping Barberry, Dwarf Barberry, Piper's Oregongrape, Wavyleaf Ceanothus, Huckleberry Oak, Whiteleaf Manzanita, Interior Silktassel, Siskiyou Mat, Leather Oak** ... **C1 (Ultramafic Mixed Chaparral)**
24B. Not as above ... 25

25A. Elevation > 5000 ft (1525 m); any of following alone or in combination have > 10% sc: **Bush Chinquapin, Shrub Tanoak, Mountain Whitethorn, Pinemat Manzanita, Huckleberry Oak, Bitter Cherry** ... **CM (Upper Montane Mixed Shrub)**
25B. Not as above. .. 26

26. **Unknown Shrub Type ... US**

V. Key to Herbaceous
hg = herbaceous/grass canopy cover

1A. Annual grasses mixed with annual and/or perennial forbs have > 50% hg ... **HG (Annual Grass - Forb)**
1B. Not as above ... 2

2A. Hydrophytic grasses and grass-like species (sedges, rushes, bulrushes) in mixture with hydrophytic herbaceous species (false hellebore, lily, shooting star, gentian, etc.) growing mainly in organic soil have > 50% hg ...**HJ (Wet Meadows**)
2B. Not as above ... 3

3A. Pastures or semi-natural areas containing mixtures of annual and perennial grasses and annual and/or perennial forbs have > 50% hg ... **HM (Perennial Grass - Forb)**
3B. Not as above ... 4

4A. Coastal brackish or salt marshes surrounding open water containing mixtures of Common Pickleweed, Cordgrasses, or Saltgrass > 50% hg ... **HC (Pickleweed - Cordgrass)**
4B. Not as above ... 5

5A. Marshes adjacent to perennial fresh water sources containing mixtures of Tule or other Bulrushes and Cattails rooting below the water's surface have > 50% hg ... **HT (Tule - Cattail)**
5B. Unknown herbaceous or grassland type ... **Grass-GR**

VI. Key to Non-Vegetated
nvc = non-vegetated cover

1A. Agricultural uses comprise > 50% nvc ... **AG (Agriculture**)
1B. Not as above ... 2

2A. Coastal dunes comprise > 50% nvc ... **DU (Dunes**)
2B. Not as above ... 3

3A. Snow or ice fields at the highest elevations comprise > 50% nvc ... **SN (Snow/Ice)**
3B. Not as above ... 4

4A. Urban or otherwise developed landscapes (highways, etc.) > 50% nvc ... **UB (Urban or Developed)**
4B. Not as above ... 5

5A. Open water or confined water courses occupy > 50% nvc ... **WA (Water)**
5B. Not as above ... 6

6A. Otherwise naturally barren landscapes (cliffs, bedrock, etc.) occupy > 50% nvc ... **BA (Barren)**
6B. Unknown type ... **NF (Non-Forested)**

Appendix 3B.

Example of a Structured Aerial Photointerpretation Data Gathering Protocol

This appendix was taken from the *Northern Region Vegetation Mapping Project Aerial Photointerpretation Guides,* USDA Forest Service, Missoula, MT and contains schematic guides for collecting and documenting data using aerial photointerpretation methods.

Training and accuracy assessment data are generated through a structured aerial photointerpretation process that integrates a variety of field sampled inventory datasets. Our experience suggests that an aerial perspective is often useful for remote sensing training data acquisition, and that skilled interpreters can add local knowledge and experience to the classification process. Additionally, resource aerial photography remains the most available remote sensing data source; however, we integrate high-resolution, multispectral data with resource photography where available. This structured photo interpretation process provides an explicit mechanism to integrate existing field sample data from a variety of sources, both within the U.S. Department of Agriculture (USDA) Forest Service and from cooperating entities. Existing field data is screened to ensure data quality and currency using a standardized process. This provides the opportunity to benefit from the agency's substantial investment in field data while screening out data rendered unusable by management activities, disturbance agents, and/or time since collection. Through this process the image interpreter is able to "fit" field data and other ancillary data to the segmented imagery. This process accomplishes the same objective described by Robinson and Tilton (1991), but fits the training data to the segmentation rather than fitting the segmentation to the training data. Common image interpretation techniques are used to characterize elements of vegetation pattern that comprise life form, dominance type, tree size class, and tree canopy cover (Avery 1977, Campbell 1987, Lillisand and Kiefer 1987, Lachowski et al. 1995). The variables collected include life form/land use class cover percent and connectivity, dominance type cover percent and connectivity, tree size class cover percent, tree canopy cover percent and connectivity, and total vegetation canopy cover percent.

Northern Region Vegetation Mapping Project Photointerpretation Guide

Model Number/Forest Number Coverage Name. Column Name: **MNFN** 4 digits

Photointerpreter. Column Name: **PI** 3 characters
Record photo interpreter's Initials (2 or 3 characters).

Polygon_link. Column Name: **Poly_link** 6 digits
Record Polygon_link from the Model/Image Analyst Polygon Coverage.

Flag. Column Name: **Flag** 1 digit

- 0 = No flag.
- 1 = Flag—Discrepancy between photo and Thematic Mapping (TM) imagery.
  - For example, green, live trees on photo and recent burned or harvest on TM imagery.
  - Make note of condition in General Comments.
  - If a poly-link is flagged, it is not photointerpreted and therefore RPN is not needed.
- 2 = Flag—Discrepancy likely between photo and TM imagery due to anticipated insect and pathogen related mortality.
- 3–7= Reserved flags.
- 8–9= Image analyst flags that can be used at their discretion.

Reference Data Region-Polygon Number. Column Name: **RPN** 4 digits
Consecutive number (1–9,999) assigned by image analyst to those region-polygons selected for photointerpretation.

Owner. Column Name: **Own** 2 digits
Attributed by GIS routine. Record 2-digit traditional National Forest identifier or R1-VMP code for "Other Ownership."

District. Column Name: **Dist** 2 digits.
Attributed by GIS routine. Record 2-digit Ranger District identifier for National Forest lands.

Aerial Photo Identification. Column Name: **API** 17 characters
Record the photo that covers the majority of the region's polygon, leaving no spaces in code.

- First 6 digits represent Photo Symbol/Project ID.
- Next 4 digits represent the roll number.
- Next 4 digits represent the exposure number.
- Last 4 digits represent the flight line number; use at the discretion of the image analyst.

Photo Scale: Column Name: **PS** 2 characters
Record the nominal photo scale using the following convention:

- 1:16,000—code as 16.
- 1:5,000—code as 5.

DOQQ Quadrangle: Column Name: **Quad** 20 characters
Optional—note name of quad.

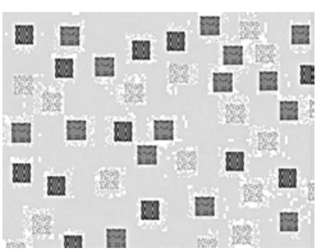
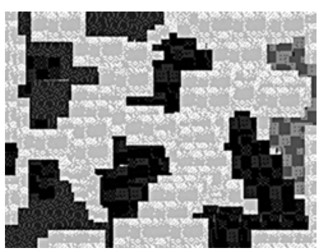
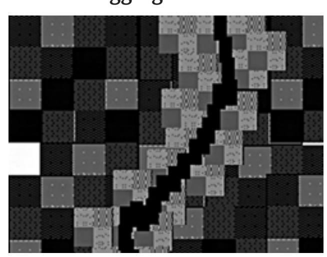
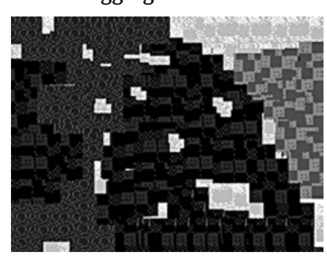
Manual Classification Code. Column Name: **MCC** 3 characters Interpretation of TM data only where region consists of nearly 100% of the following classes: Use this field and the codes below to identify poly_links that can be used to assist in manual classification of nonforested types. If these codes are used, stop data entry after this field.		
CLD	Cloud	
SCD	Shadow—cloud	
STP	Shadow—topographic	
RCK	Rock	Includes scree
BAR	Bare ground	Includes gravel pits, sandbars
WAT	Water	
SNW	Snow and ice	
RDT	Recently dead trees	With foliage attached—red, orange, yellow
BRN	Recently burned	
RDS	Gravel and native surface roads	
PAV	Paved roads	Concrete or blacktop highways
MAN	Man-made structures	Buildings

Inventory Data Type. Column Name: **IDT** 2 characters	**Inventory Data Identifier**. (Also known as Setting Identifier)
Column Name: **IDI** XX characters Record the type of data used to assist in the photointerpretation. If multiple data types are available, code the one judged to be the best. 0 No Data 1 R1 Standard Exam or Quick Plot 2 R1 PGP 3 R1 Other 4 R1VMP-CSE field data 5 ECODATA plant comp data 6 ECODATA tree data 7 FIA 8 IPNF CVS 9 IPSAC training data—ground and helicopter 10 Image analyst walk-through, drive-by 50 Flathead Indian Reservation 51 Nez Perce Indian Reservation 61 GNP Vegetation Mapping Project 62 BLM 63 FWS 64 Other Federal 71 Montana State 72 Idaho State	Record the stand or plot number associated with the reference data as follows: • 0 No Data • FSVeg 14 characters • ECODATA XX characters • FIA data XX characters • IPSAC data XX characters • IPNF CVS data XX characters • GNP VMP data XX characters • Other measured data XX characters Walk-through, drive-by image analyst's last name.

Life Form Data

Life Form. Column Name: **LF** 3 characters. Identify the life form.
A. Tree life form > 10% canopy cover ……………………....**TRE.** A. Tree life form < 10% canopy cover……………………..……….Go to B.
B. Shrub life form > 10% canopy cover …………………..…**SHR.** B. Shrub life form < 10% canopy cover……………………….….…Go to C.
C. Grass/Forb life form > 10% canopy cover ………………. **GFB.** C. Grass/Forb life form < 10% canopy cover…………………..….Go to D.
D. TRE+SHR+GFB+ nonvascular > 10% canopy cover ……**NDL** [no dominant life form]. D. TRE+SHR+GFB+ nonvascular < 10%…………………………Go to E.
E. TRE+SHR+GFB+ nonvascular < 10% and > 1% canopy cover…**SVG** [sparsely vegetated]. E. TRE+SHR+GFB+ nonvascular < 1%…………………………...**NVG** [nonvegetated].

Life Form Code. Column Name: **LFC**. 1 character. **Optional Use.** This field can be hidden during data entry, populated with an update query at a later date, then converted to a .dbf and joined to region-polygon coverage for use with eCognition.	
1	TRE—Tree
2	SHR—Shrub
3	GFB—Grass/forb
4	NDL—No dominant life form
5	SVG—Sparsely vegetated
6	NVG—Nonvegetated

Life Form Connectivity. Column Name: **LFCon** 2 characters Identify the connectivity of the life forms above.			
DA: Disaggregated	**SA: Semiaggregated**	**AL: Aggregated-Linear**	**AN: Aggregated-Nonlinear**
			
Example: Each "patch" < 1% cover. similar life forms.	Example: "Small" contiguous patches of dissimilar life forms.	Example: Contiguous linear features of of dissimlar life form. roads, powerlines, riparian features, avalanche chutes, ski runs.	Example: "Larger" contiguous patch of dissimilar life forms.

Tree Size Class Canopy Cover. Column Names: **See Below** 2 digits
Estimate canopy cover for each of the five classes below; zero-fill any classes without trees.

- Estimate canopy cover to the nearest 1% for size classes that are < 10%.
- You may estimate canopy cover to the nearest 5% for size classes with canopy cover > 10%.
- Ensure that the total of all size classes represents the total canopy coverage for the polygon.
- Ensure that for polygons identified as tree life form, the total of all size classes > 10%, and that for polygons not identified as tree life form, the total of all size classes < 10%.

TLFC	Tree life form canopy cover	All sizes
VLCC	Very large tree canopy cover	> 20.0-in d.b.h.
LTCC	Large tree canopy cover	15.0–19.9-in d.b.h.
MTCC	Medium tree canopy cover	10.0–14.9-in d.b.h.
STCC	Small tree canopy cover	5.0–9.9-in d.b.h.
SSCC	Seedlings/saplings canopy cover	< 5.0-in d.b.h.

Tree Dominance Type 1. Column Name: **Dom_1** 14 characters
Based on photointerpretation of canopy cover. Use common four-letter abbreviations for species, such as PIPO, PICO, and ABLA for single-, two- and three-species mixes.

A. Single most abundant species **> 60%** of total canopy cover……… **List single species.**
A. Single most abundant species **< 60%** of total canopy cover…..… Go to B.

B. 2 most abundant species **> 80%** of total canopy cover and each species individually is > 20% of total canopy cover ..**List 2 species**, in order of abundance.
B. 2 most abundant species **< 80%** of total canopy cover…………..… Go to C.

C. 3 most abundant species **> 80%** of total canopy cover and each species individually is > 20% of total canopy cover……………...**List 3 species**, in order of abundance.
C. 3 most abundant species **< 80%** of total canopy cover……………..… Go to D.

D. Shade intolerant species total CC **>** shade tolerant species total CC…..**IMXS.**
D. Shade intolerant species total CC **<** shade tolerant species total CC…..Go to E.

E. GF+C+WH canopy cover > AF+S+MH canopy cover ……………………..**TGCH.**
E. GF+C+WH canopy cover < AF+S+MH canopy cover ……………………..**TASH.**

Tree Dominance Type 3. Column Name: **Dom 3** 9 characters

Reassign dominance types identified as three species above to one of the three mixed-species classes, also above.

IMXS—Shade-intolerant mix
TASH—Shade-tolerant subalpine fir, spruce, and mountain hemlock
TGCH—Shade-tolerant grand fir, cedar, western hemlock

For example, a three-species label of ABLA/PSME/PICO should be assigned to either IMXS or TASH. Where ABLA is 41% and the PSME and PICO are both 21%, the remaining 17% will determine the label—TASH if it is PIEN; IMXS if it is LAOC.

The single-species, two-species, and mixed-species classes should be populated with an update query later, not by the photointerpreter.

Shrub Life Form Canopy Cover Class. Column Name: **SHR_CC** 6 characters Total canopy cover of all trees, expressed as percent of the region polygon.
0
1–9
10–24
25–40
40–59
60–100

Shrub Life Form Canopy Cover Class Code. Column Name: **SLFC** 1 character This field can be hidden during data entry, populated with an update query at a later date, then converted to a .dbf and joined to region-polygon coverage for use with eCognition.	
0	0%
1	1–9%
2	10–24%
3	25–40%
4	40–59%
5	60–100%

Shrub Dominant Class. Column Name: **SDom** 5 characters	
SRIP	Shrub—Riparian
SMES	Shrub—Mesic
SXER	Shrub—Xeric
SSUB	Shrub—Subalpine
SALP	Shrub—Alpine

Grass/Forb Life Form Canopy Cover Class. Column Name: **GFB_CC** 6 characters Total canopy cover of all trees, expressed as percent of the region polygon.
0
1–9
10–24
25–40
40–59
60–100

Grass/Forb Life Form Canopy Cover Class Code. Column Name: **GLFC** 1 character This field can be hidden during data entry, populated with an update query at a later date, then converted to a .dbf and joined to region-polygon coverage for use with eCognition.	
0	0%
1	1–9%
2	10–24%
3	25–40%
4	40–59%
5	60–100%

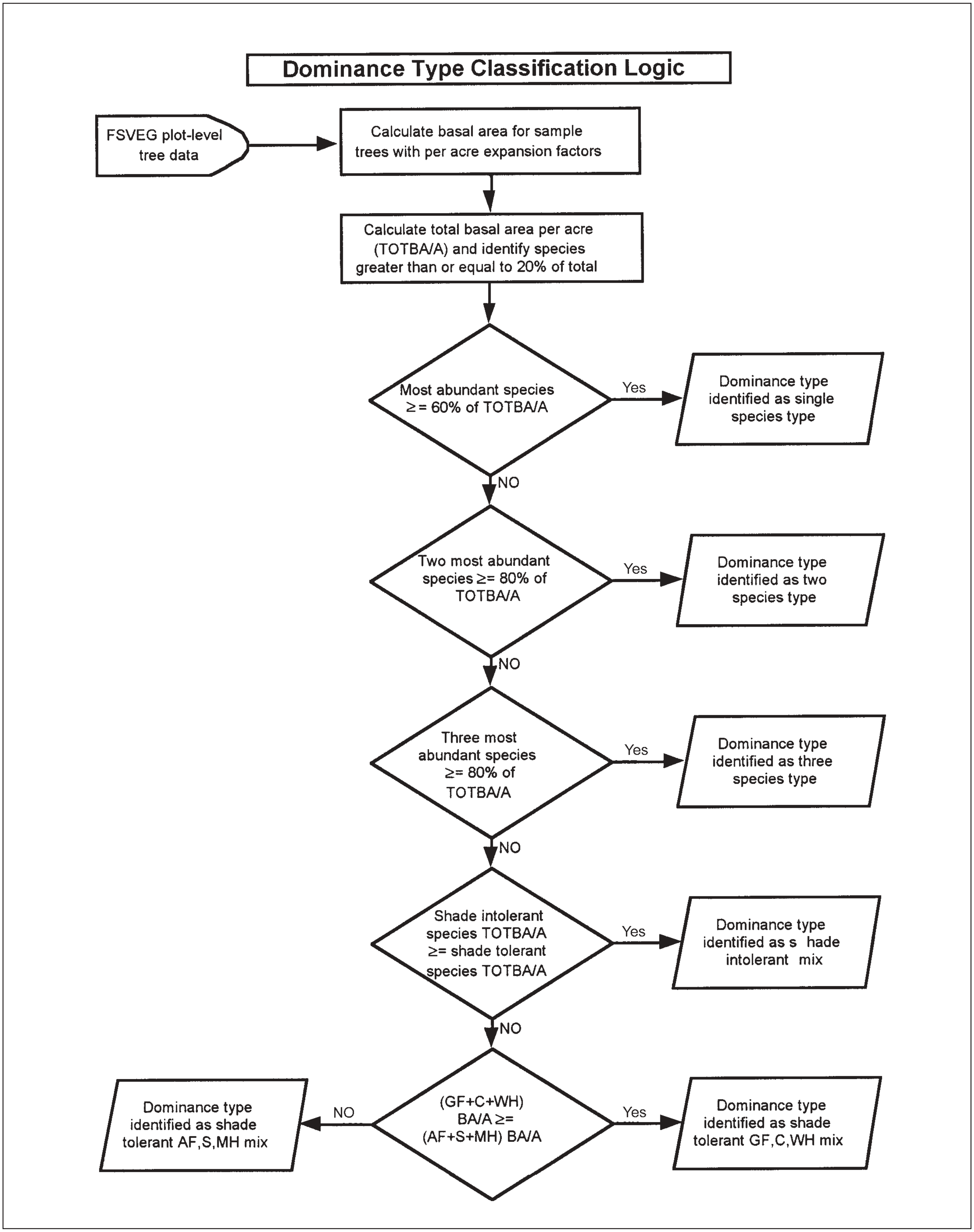
Grass/Forb Dominant Class. Column Name: **SDom** 5 characters	
GFWET	Grass/Forb—Wetland
GFRIP	Grass/Forb—Riparian
GFMES	Grass/Forb—Mesic
GFXER	Grass/Forb—Xeric
GFSUB	Grass/Forb—Subalpine
GFALP	Grass/Forb—Alpine

Nonvegetarian Life Form Canopy Cover Class. Column Name: **NVG_CC** 6 characters Total canopy cover of all trees, expressed as percent of the region polygon.
0
1–9
10–24
25-40
40–59
60–100

Nonvegetarian Life Form Canopy Cover Class Code. Column Name: **NLFC** 1 character This field can be hidden during data entry, populated with an update query at a later date, then converted to a .dbf and joined to region-polygon coverage for use with eCognition.	
0	0%
1	1–9%
2	10–24%
3	25-40%
4	40–59%
5	60–100%

NVG Dominance Classes. Column Name: **NDom** 4 characters Select the most dominant type based on photointerpretation, independent from TM imagery.		
RCK	Rock	Includes scree
BAR	Bare ground	Includes gravel pits, sandbars
WAT	Water	
SNW	Snow and ice	
RDT	Recently dead trees	With foliage attached—red, orange, yellow
ODT	Older dead trees	Without foliage but retaining branchwood
SNG	Very old dead trees	Boles only, little or no branchwood
LWD	Litter and down woody debris	Tree and shrub litter fall, logs; excludes recently cured annual or senescent perennial grass/forb)
BRN	Recently burned	
RD	Nonpaved roads	Native surface and gravel roads
PAV	Paved roads	Concrete or blacktop highways
MAN	Manmade structures	Buildings

General Comments—254 characters maximum. Record any pertinent *general* information such as region polygon delineation concerns, region polygon variability and possible effect on field sampling, and reference data.


Dominance Type Classification Logic
FSVEG plot-level tree data
Calculate basal area for sample trees with per acre expansion factors
Calculate total basal area per acre (TOTBA/A) and identify species greater than or equal to 20% of total
Most abundant species ≥= 60% of TOTBA/A
Yes
Dominance type identified as single species type
NO
Two most abundant species ≥= 80% of TOTBA/A
Yes
Dominance type identified as two species type
NO
Three most abundant species ≥= 80% of TOTBA/A
Yes
Dominance type identified as three species type
NO
Shade intolerant species TOTBA/A ≥= shade tolerant species TOTBA/A
Yes
Dominance type identified as s hade intolerant mix
NO
(GF+C+WH) BA/A ≥= (AF+S+MH) BA/A
NO
Dominance type identified as shade tolerant AF,S,MH mix
Yes
Dominance type identified as shade tolerant GF,C,WH mix

Appendix 3C.

Examples of Existing Vegetation Mapping Protocols Used To Produce Mid-Level Geodatasets

Programmatic overview of the Pacific Southwest Region process was taken from USDA Forest Service, Pacific Southwest Region, *Forest Inventory and Analysis User's Guide*, May 2002, Chapter 200, "Vegetation Classification and Mapping."

Project documentation was taken from USDA Forest Service, Northern Region, Northern Region Vegetation Mapping Project Documentation (R1-VMP), 2004.

Pacific Southwest Region Process

Contents

200—Vegetation Classification and Mapping

Assessing the condition of forests often involves maping and inventorying of vegetation. Conventional methods use manual interpretation of stereoscopic aerial photography to delineate areas of homogeneous vegetation (usually termed stands) using analysis of image tone, texture, and topography. With the availability of computers and satellite imagery, automated procedures have been developed to capture the same attributes for delineating stands.

210—Conventional Versus Automated Method

The conventional methodology for producing vegetation maps begins with the delineation and mapping of forest stands. Natural resource professionals skilled in air photointerpretation techniques use conventional resource photography, typically normal color, 9” x 9” positive prints at a scale of 1:15,840 or 1:24,000, to delineate forest stands by drawing boundaries around homogeneous areas of uniform vegetation. Typically, a minimum size of 5 acres is required for delineation. Concurrent with the delineation process, the stand boundaries are transferred manually from the air photos to 7.5-minute topographic quadrangles, and labels are affixed to each stand indicating the species composition, height, crown density, and other features of interest for forest management purposes. The stand maps thus produced are a basic information resource, widely used at the National Forest and Ranger District levels. Because this process is based on manual photointerpretation, it can be time consuming and costly, as well as inconsistent from analyst to analyst.

The boundaries on the stand maps are then scanned photomechanically and entered into an automated, computerized database through Geographic Information System (GIS) software. Once scanned and edited, the polygons are displayed by map section with a GIS system and stand labels are assigned. At the present time, the labeling process is relatively costly and labor intensive.

An automated method of mapping forest vegetation has been developed over the last 15 years using image processing and GIS technology. It was designed to overcome the problems of conventional methods by electronically extracting and processing tonal, textural, and terrain information from Major sources of information consist of registered Landsat imagery, digital terrain data, and ground-based information used in map classification, stand delineations, canopy, size class, and ecological modeling.

Comparison of samples from forest strata identified by the automated method with strata identified by conventional procedures showed that both have about the same potential to reduce the variance of timber volume estimates over simple random sampling.

The automated method bypasses manual photointerpretation by using classification of Landsat and registered digital terrain data. Labeling of the automatically defined classes is still required, but can be done much more rapidly and efficiently than in the conventional procedure. Furthermore, by utilizing image processing software systems, the classified images, which are the analog of stand maps, can be electronically transferred through software to the polygon-format files into GIS data bases.

220—Automated Classification of Forest Vegetation

In mapping existing vegetation for large area inventories, habitat analysis, fire fuels modeling, and other vegetation-based information needs, four key attributes characterize each forest stand or region: life form, species types (CalVeg), and for forest types, average visible tree crown size, and canopy closure. Each of these attributes is characterized independently and in a hierarchical fashion. A hierarchical approach that first classes the most general landscape features (life form) results in a framework onto which more detailed floristic and structural information can be added. Mapping each of these attributes independently minimizes the confusion between attributes that have only slight image tone and texture differences. Additionally, mapping vegetation attributes separately allows for the application of the most appropriate classification technique. For example, unsupervised classification has been shown to be effective for mapping life forms and tree crown size, but relatively poor as a singular technique for vegetation type.

The basis of mapping existing vegetation with remote sensing techniques is to use the same three characteristics of tone, texture, and terrain that the photo interpreter uses in delineating forest stands or region boundaries, as well as life form classification. Landsat imagery reflectance vectors provide tonal information for brightness and greenness, and Digital Elevation Model (DEM) 1:24,000 or Defense Mapping Agency (DMA) 1:250,000 digital terrain data provide the required terrain information. Texture data are derived from Landsat imagery. The computer processing is carried out using ERDAS Imagine, Image Processing Workbench (IPW), or similar image processing systems in combination with ARC-INFO or other geographic information systems that support raster- based layers. The accuracy of final vegetation maps is improved by integration of existing GIS layers of water bodies from Cartographic Feature Files (CFFs) and mapped areas of plantations and nonstocked forest land on wildfire areas. In a departure from the traditional method of stand delineation, an automated, systematic method of generating spatial, unattributed stands or regions is used. Stand delineations are independent of map attribute classification so as to avoid reducing spatial accuracy by incorporating error inherent in thematic classifications. Through the application of image segmentation algorithms, consistent delineations of landscape features and growth forms are created based on user-defined spectral and spatial parameters (see Figure 1.1). This process allows for stand delineations to be produced more quickly and efficiently than traditional photo interpretation techniques. Image-derived stands are subsequently combined with vegetation attribute maps through GIS software to produce a stand-based, multi-attribute vegetation database (see Figures 1.2,1.3).

Life form mapping is performed using unsupervised classification techniques. Tree size class is also mapped using this technique, or in combination with supervised classification. In either case, a large number of ground observations of stands with different average tree sizes is necessary to produce reliable maps for this attribute.

Typically, an automated, hierarchical vegetation mapping process identified vegetation species as the next level of map information produced following life form classification. Because forest composition varies systematically with terrain, species type can be modeled using terrain data and ancillary GIS data. To quantify the relationship between elevation, slope, aspect, and CalVeg type, field data is required. The simplest method of quantification involves systematically observing each CalVeg type at all aspects, slopes, and elevations, and plotting this on a graph. Variations in ecological relationships across a forest, geographical areas, or Natural Regions need to be identified and unique mapping rules developed for each region.

The structural attributes of overstory tree size and tree canopy closure are most typically mapped following the development of life form and vegetation type information. This allows for prestratification of tree types into groups with unique and similar physiological characteristics. The intent is to minimize confusion in mapping structural attributes across physically variable populations.

230—Modeling Ecological Relationships

Observations in western coniferous forest areas show that forest composition varies systematically with topography in many places. The distribution patterns of coniferous species have long been associated with particular elevation ranges; species are often referred to as “low-elevation” or “high-elevation” species. Red fir, for example, is usually considered a high-elevation species. Compass aspect (direction that a slope faces) also influences tree growth and species distribution. North-to-northeast exposures are typically more favorable for tree growth than drier southwestern exposures (in the northern hemisphere). As a result, species that exhibit elevational zonation tend to occur at lower elevations on northeast-facing slopes. These terrain relationships influence climate (in particular moisture and temperature), which in turn controls species distributions. Satellite remote sensing is used for mapping the life forms of conifer, hardwood, shrub, meadows, barren land, grass, and water. However, remote sensing is not particularly strong in differentiating species or groups of species that are similar, since the variation in spectral signatures (i.e., light reflectance) can be large. Therefore, the terrain variables of elevation, slope, and aspect are useful in modeling species associations (Macomber et al. 1991).

Natural Regions

Because a large national forest may exhibit extensive climatic, geologic, and ecological diversity, plant species-habitat relationships and spectral signatures that characterize particular vegetation types are unlikely to be consistent in all portions. Therefore, the project area is divided into Natural Regions in which ecological relationships remain fairly constant and signature extension should be valid throughout. This not only facilitates the accuracy of ecological type modeling within regions, but also creates serves as "processing areas" to simplify image processing work.

Natural Regions are defined as areas within which the elevation-aspect ranges of the various major vegetation types remain constant. Traditionally, Natural Regions have been designated primarily on the basis of ground reconnaissance, interviews with resource professionals familiar with a particular area, and relevant background material (i.e., geology maps, isohyetal maps, published documentation). Sections and subsections of the recently implemented National Hierarchical Framework of Ecological Units (ECOMAP) are now used to determine appropriate Natural Regions.

Digital Terrain Processing

USGS Digital Elevation Models (DEMs) use image-processing software to derive classes for elevation and slope/aspect. DEM images are first mosaiced to cover the area of the Landsat TM image, then registered to the Landsat scene and resampled to match the TM image.

Elevation and slope/aspect images are then converted to ARC/INFO grids. Slope is divided into four classes and aspect into three classes. Refer to Figure 2.1 by clicking on the button below. The resultant combination classes represent incremental levels of solar insolation with class 1 being the coolest and moistest and class 10 the hottest and driest. Slope and aspect also affects parameters such as soil development, which exerts environmental influences on plant species composition. Where significant correlations of species composition to soil type are observed, digital soil layers may also be used as a model input.

Building an Ecological Terrain Model

Field training site data collected via quad maps and aerial photography forms the basis for the ecological terrain modeling. Observations are made throughout the project area, within each Natural Region, to sample the range of elevation/slope/aspect combinations. Data are recorded for the occurrence of each major vegetation type at different locations to determine the extent of a type within a Natural Region. Slope angle, elevation, and aspect are recorded for conifer, hardwood, and shrub types that occur within a Natural Region.

Particular attention is paid to the elevation/slope/aspect combinations where vegetation changes within a Natural Region. For example, a Mixed Conifer-Fir forest type can occur within an elevational band of up to 7,000 feet in a particular Natural Region. On north aspects above 7,000 feet, red fir becomes the major type. However, red fir may not occur on south aspects below 8,000 feet, and may not occur at all on south aspects with greater than 60% slope. In addition to recording the elevation/slope/aspect combinations of different vegetation types, field notes are also collected with more detail on species composition throughout a project area. This information facilitates the development of descriptions for vegetation types within a project area, and also supports cross-walking between classification systems. The notes are also used to address anomalies remaining in the map following model application.

After field data collection, the information is transferred to a matrix graph that assigns a type to combinations of elevation and slope/aspect classes (see Figure 2). Slope is divided into 4 classes and aspect into 3 classes (see Figure 1). These 10 classes represent increasing levels of solar insolation, with class 1 being the coolest and moistest, and class 10 the hottest and driest. In addition to field data, any ancillary data such as old vegetation maps, ecological classification data, silvicultural stand exam data, etc., that exists will be utilized to make decisions about what types occur across a Natural Region and where vegetation types change within a matrix graph. Each Natural Region will be comprised of three matrix graphs, one each for conifers, hardwoods and shrubs. Obviously, some generalization about the compositions of each type and the actual “boxes” where change takes place exists; however, this method produces better results for mapping vegetation types across large land areas than can be achieved using spectral signatures alone.

Figure 1. *Slop/Aspect Classes.*

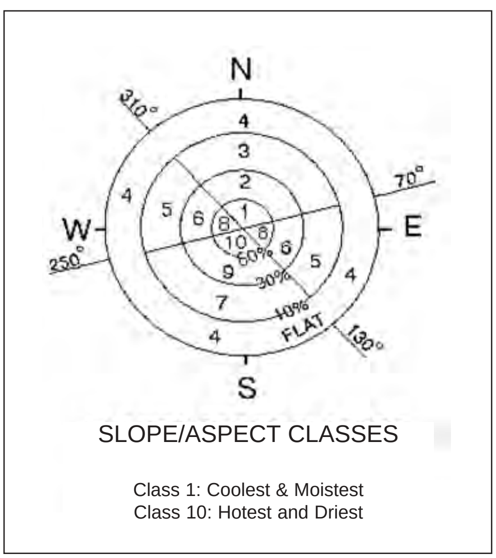
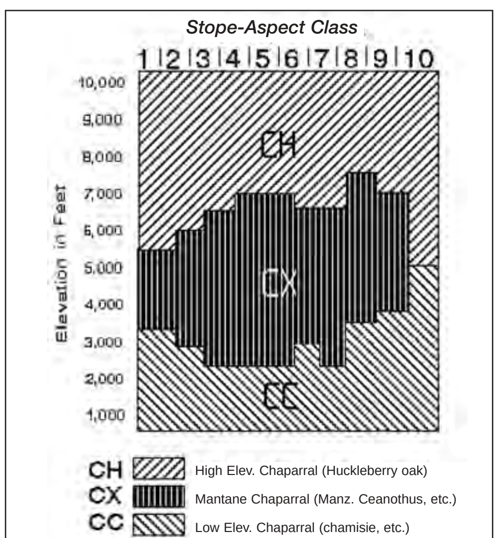


Figure 2. *Shrub CALVEG types.*



Life-Form Classification. Prior to modeling ecological relationships for vegetation type, the Landsat image is classified into several life forms: conifer, hardwoods, mixed, shrub, wet herbaceous, dry herbaceous, barren, water, snow, agricultural, and urban. Other more specific vegetation types that have unique spectral properties may be mapped at this time as well.

Cloud areas are also distinguished in this step and are subsequently classified into one of the above life forms, utilizing various techniques. Plantations are added as a separate layer, to distinguish productive forest land from shrub, meadow, grass, or barren classes. Water bodies are also added from Cartiographic Feature Files (CFFs), where available, to maintain spatial consistency in lakes.

Image classification produces a "pixel-based" land cover map utilizing an unsupervised classification technique. This technique produces spectral cluster classes known as a "per pixel classification". A large number of classes are produced, which are then processed by an analyst into simpler, smaller sets and labeled with the appropriate life form.

Image classification occurs with individual pixels, not stands. Therefore, an additional step utilizes an image segmentation procedure which delineates stand boundaries, based on spectral similarities. When combined with the per pixel classification, a "stand based" land cover map is produced. This map is then passed through a decision rule process, which utilizes analyst specified decision rules to label the stands or polygons, based on the per pixel classification. Although life forms classification is based on spectral differences, decision rules are utilized to determine conifer, hardwood and shrub polygons from each other. The decision rules are determined by the classification system and further influenced by the analyst who compensates for class variation within a specific classification product. The decision rules are to label a polygon as conifer if 10% of the tree canopy cover is conifer. If there is at least 10% conifer cover then a polygon is labeled as conifer. If there is less than 10% conifer canopy cover, but at least 10% hardwood cover, the polygon is labeled as hardwood. If less than 10% tree cover exists, and there is at least 10% cover of shrubs, the polygon is labeled as shrub. Otherwise it will be labeled as one of the other categories based on plurality. Editing is then carried out on these stands or polygons to resolve any ambiguous results for life form. This stand life form map is then used as input to the ecological terrain model.

In subsequent processes, stand polygon boundaries are drawn between non-conifer areas, and between conifer areas which are at least one size class and or density class apart. The minimum mapping unit is 5 acres for contrasting types, and 10 acres for non-contrasting types, where size or density of the inclusion area is only one class different than the surrounding area.

Building an Ecological Terrain Model

Field training site data is collected to form the basis for the ecological terrain modeling. Observations are made throughout the project area, within each Natural Region, to sample the range of elevation/slope/aspect combinations. Quad maps and aerial photography are used to collect the data. Observations are recorded for the occurrence of each major vegetation type at different locations to determine the extent of a type within a Natural Region. Slope angle, elevation and aspect are recorded for conifer, hardwood and shrub types that occur within a Natural Region.

Particular attention is paid to the elevation/slope/aspect combinations where vegetation changes. For example, a mixed conifer-fir forest type can occur within an elevational band of up to 7,000 feet in a particular Natural Region. On north aspects above 7,000 feet, red fir becomes the major type. However, red fir may not occur on south aspects until an elevation of 8000 feet and may not occur at all on south aspects with greater than 60% slope. In addition to recording the elevation/slope/aspect combinations of different vegetation types, field notes are also collected with more detail on species composition throughout a project area. This facilitates the development of descriptions for vegetation types within a project area, as well as provide additional data needed for crosswalking between classification systems. These notes are also used to address anomolous error remaining in the map following model application.

After field data collection, the data is transferred to a matrix graph which assigns a type to a combination of elevation and slope/aspect class (Figure 2.2). In addition to field data, any ancillary data such as old vegetation maps, ecological classification data, silvicultural stand exam data, etc., that exists will be utilized to make decisions about what types occur across a Natural Region and where vegetation types change within a matrix graph. Each Natural Region will have three matrix graphs completed, one each for conifers, hardwoods and shrubs. Obviously, there is some generalization about the compositions of each type and the actual “boxes” where change takes place; however, this method can improve the results for mapping vegetation types across large land areas, than with using spectral signatures alone.

CalVeg is the classification system being used for the mapping of existing vegetation. After the types are plotted on matrix graphs and separated in slope-aspect-elevation space, rules for the prediction of CalVeg types are developed. The input for the rules are the elevation maps and the slope/aspect maps that were already created in IPW and ARC. These “rules” produce a separate “map” for conifers, hardwoods and shrubs within each Natural Region. This map represents the potential for finding a particular existing vegetation type at the specified elevation and slope/aspect class, based on field training site data and ancillary ecological information.

The final step is to combine these layers with the stand based cover map which represents life form for the area. These layers become the inputs to which the modeling rules are applied. The actual model application is performed in ARC/GRID using ARC macro language (AML) scripts which can be easily modified if rule refinements are necessary. Subsequent AML outputs become the draft vegetation type or CALVEG layers that are field reviewed and, if necessary, revised before integration into the final map products. In this way, all conifers, hardwoods and shrubs, within a Natural Region, are assigned a specific type or series level label of the CALVEG classification system based on these rules. Meadows and dry grass were previously broken out during life form image classification and polygon formation, and do not undergo more specific identification. The basic process is to intersect separate layers in a geographic information system; the life form layer together with each model layer representing the potential types for conifers, hardwoods and shrubs.

Not all vegetation types can be modeled with terrain data. Examples include vegetation growing on serpentines, and those with specific moisture or soil requirements, such as lodgepole pine. In these cases, ancillary information is sought to delineate where these areas can occur. Resource professionals from the national forests very often have mapped these areas or know where they are. In such cases, these are brought in as another GIS layer that then supercedes the results of the ecological terrain model. The quality of vegetation type maps produced from remote sensing can be greatly improved with specific information derived from ancillary data, both in the use of building the terrain model, and to delineate types that are not as directly influenced by terrain variables. In some cases, ecological modeling may consider differences in soils or geology as variables to be input into type modeling, particularly in areas where terrain does not strongly influence vegetation compositions. Increasingly, environmental variables known to drive vegetation distribution are being captured and maintained as digital information. As these data are developed and become available, the predictive accuracy of ecological models.may increase.

CALVEG Classification System

The CalVeg Classification of California Vegetation system was initiated in January 1978 by the Region 5 Ecology Group of the U.S. Forest Service with headquarters in San Francisco. The acronym means **C**lassification and **A**ssessment with **L**andsat of **V**isible **E**cological **G**roupings. The CalVeg team's mission was to classify California existing, rather than potential, vegetation communities for use in statewide resource planning considerations. This was accomplished with the use of color infrared satellite imagery and field verification of types by current soil-vegetation mapping efforts as well as professional guidance through a network of contacts throughout the state. Maps were produced at a statewide scale of 1:1,000,000 in electronic format as well as regional maps at scales of 1:250,000 produced as overlays to existing baseline or "sheet" maps at that scale. It was one of the earliest statewide vegetation coverages easily available for computerized mapping efforts and was considered to be useful for landscape level, watershed level or coarser scale applications, such as forest level planning and analysis. The first maps produced under this classification using current remotely sensed imagery and methods were those of the southern Sierra national forests in the mid-1980s at an image resolution of 30 meters or greater. Some of these older maps have been updated one or more times in the interim period.

Whereas regional forest types are groupings used for forest canopy modeling, inventory and general planning, the CALVEG classification can be more suitable for multiple-use resource information needs of the National Forests. The key in Appendix B can serve as criteria for separating CALVEG types from each other. More detailed descriptions are available in the U.S. Forest Service document **CALVEG: A Classification of California Vegetation**. Some descriptions have been refined further than what is in this document, to provide more specificity of type descriptions for particular National Forest mapping projects.

Regional Forest Type

Regional forest type is a level of classification used to divide forests into broad categories based on species composition. The underlying reason for the differentiation of regional types is that forest stands of tree size and canopy density characteristics, but different regional types, will have different timber volumes. Regional types are typically defined by the dominant species in the stand; for example: red fir, Douglas fir, ponderosa pine, or simply mixed conifer. This broader grouping is useful in modeling forest canopy geometry, where average crown width and length for a regional forest type with a common mix of tree species can be estimated.

The field graphs used to define CALVEG types by Natural Regions are also used in modeling regional forest type, by grouping closely related CALVEG types into regional types.

231—Field Notes Record

Major Vegitation Type – Field Notes

Date:______________ Observer:____

Observation

Quad No.: ___________ Point No. : ____________ Photo No.: ___________ Slope: _____________

Aspect: _____________ Elevation: ____________

Overstory
Total Tree
Canopy Cover % : __________________________

Overstory
Total Conifer
Canopy Cover % : __________________________

Overstory Total
Hardwood Canopy Cover % : _________________

Total Shrub
Cover % : ________________________________

Total Herb Cover %: _______________________
(Forbs/Graminoids/Ferns)

	Species	%Cover		Species	%Cover
Overstory Conifers	______________	______________	Shrubs	______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
Hardwoods	______________	______________	Forbs Ferns/ Grasses	______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
	______________	______________		______________	______________
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CalVeg Type ______________________________ WHR Type ______________________________

240—Forest Canopy Modeling

The Canopy Model

Canopy modeling is accomplished using geometric modeling procedures. The canopy model is used to obtain estimates of "treeness" or values of "M," which are in turn inverted to give estimates of canopy closure as percent cover values for each forest stand or region. The four-component canopy model consists of sunlit tree crowns, sunlit background, shaded tree crowns, and shaded background (see Figure 2.3). This mixed model mimics the light sources contributing to reflectance values for each 30-meter pixel area of a Landsat image brightness-greenness band combination and its varience between pixels within a stand.

Compensating for Illumination

Most National Forest land being classified contains rugged terrain. Terrain effects how the sunlight is reflected or absorbed by an object or surface and the intensity of the sunlight received, causing increased variance in the spectral values of the Landsat image. The variation is produced by differential illumination of slopes (i.e., shadows) caused by high topographic variation combined with low sun angle at the time of observation of the Landsat overpass. To minimize this effect, image dates are obtained for mid-to-late summer, when the sun is the highest and the shaded slopes receive the most sunlight. Even so, the more densely stocked forest areas with normal illumination have the same spectral reflectance as more sparsely stocked stands in poorly illuminated or shaded areas. This problem rules out the separation of forest canopy attributes based solely on spectral reflectances. Thus, it is necessary to develop a means of separating the image into categories based on illumination conditions at the time of the Landsat overpass.

The registered terrain data are used to model illumination conditions for each pixel within a stand or region. The angle between a normal-to-the-land surface and the sun at the time of the Landsat overpass is calculated. For a diffuse (Lambertian) reflector, the apparent brightness of a surface under constant illumination at angle z will be proportional to cos(z). Thus, a cos(z) image displays the brightest values for pixels directly facing the sun, and the darkest values for pixels in shade. From the cos(z) image, a mask is created to divide the image into two categories based on illumination: well-illuminated, and poorly illuminated (shaded). The cutoff between these two categories is a zenith angle of 60°; areas with angles greater than 60° are considered poorly illuminated.

The mask of shaded and well-illuminated pixels is created and serves to divide the area being mapped into its shaded and unshaded components. Since only a small percent of the image will be shaded, however, many classes remain undivided. The result of this action is to reduce within-class variation effectively and remove a potentially adverse effect on the predictive process.

Canopy Model Inputs

The canopy model requires several kinds of information: Landsat imagery, time and location of the satellite when the image was taken, topography of the stands, average proportion of crown length to crown radius by regional forest type, and component signatures from known locations with known values for the model components (see Figure 3).

The Landsat image is recombined as two transformations, brightness and greenness. These are used in both the signature estimation procedure and as values for each pixel in a forest stand. The time and location of the satellite are used to calculate the local solar zenith, and also in combination with the slope and aspect information to determine the surface geometry of each stand.

Data collected from a number of individual stands are used to calibrate the component signatures of the canopy model, shaded and sunlit crowns, and background for each regional forest type. The information also supports development the tree geometry parameters of crown length to crown radius, b to r ratio (see Figure 4).

For each Regional Forest type, the crown model is calibrated using detailed information for known stands and then run across the entire map area for all pixels within stands. For all stands labeled with the same regional type, an estimate of M, or treeness, is determined for each pixel, and then inverted to obtain estimates of canopy cover for each stand (see Figure 5).

Figure 3. *Hypothetical location in feature space of four components of the model: illuminated crown (C), shadowed background (T), illuminated background (G), shadowed background (Z), and the coverage trajectory from the background (G) to X∞.*

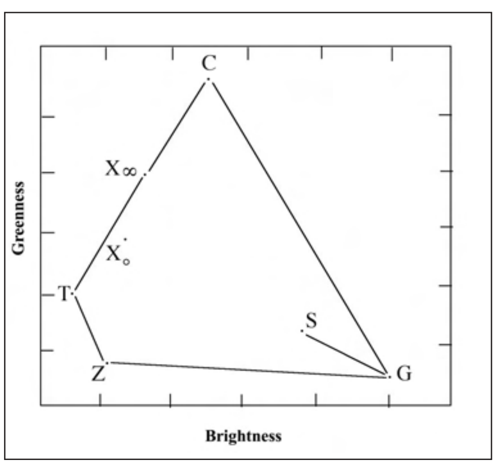


Figure 4. *Simple spheroid model of a conifer tree in the canopy reflectance model. r = radius of crown; b = half - height of crown; h = height of stem; 0 = solar zenith angle; A(0) = area of shaded background.*

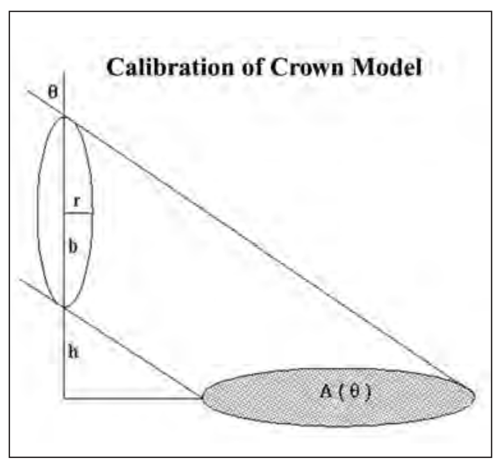
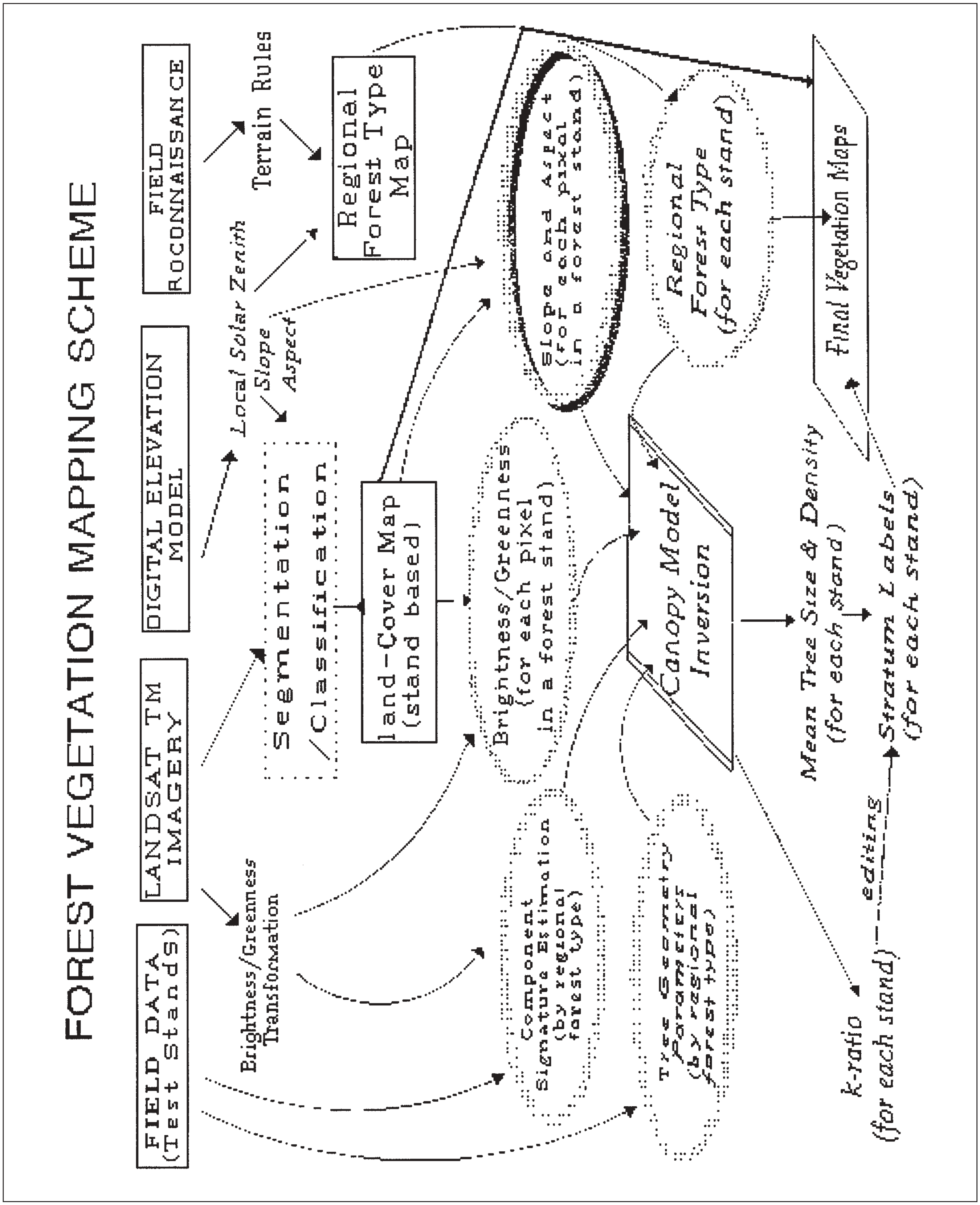


Figure 5. *Forest Vegetation Mapping Scheme.*



250—Tree Size Class Estimations

Estimating average tree size class is the hardest stand attribute to obtain from image-processing techniques, or directly from aerial photos. Several factors, none of which are totally independent, tribute to the difficulty. Aerial photos capture visible crowns from a “birds eye view”; from this angle, portions of the tree crowns are hidden from view by the shadowing and overlapping of trees in the upper canopy; thus, only part of what is actually in a forest stand—the visible crown diameter of the top story trees—can be measured directly on aerial photos. Because crown diameter and tree diameter at breast height (DBH) are highly correlated, estimates of tree size can be made by measuring their crowns. However, the relationship of crown width to DBH relationships do vary by species, especially for hardwoods compared to conifers. The other key factor causing estimation errors in average tree size occurs when in mixed stands, when trees vary from large to small. This is the case for many stands found in California due to fire, pests, and harvesting history.

When estimating tree size using Landsat imagery, a large number of training stands are required to overcome this problem. Most of the reflected light received from the ground to the satellite is a function of tree canopy cover, not tree size. Although tree size does affect the texture of the image, it also affects the measure of variance of neighboring pixel values where the larger the variance value, the larger the trees; this same effect can occur from clumped small trees with bright background areas between the clumps. This problem causes confusion of large trees with small trees.

The most reliable procedure for mapping average tree size is unsupervised classification. All pixels classified as trees are now reclassified for tree size using the information from known stands that are homogenous. The focus of the classification is to separate the small pole-size trees from the large timber-size trees, and default the remaining into the medium-size class. Although this procedure is not as exacting as doing detailed measurements on aerial photos or in-place stand exams, it does produce a useable map when combined with the plantation layer for the smaller seedling, sapling, and pole stand sizes.

260—Collecting Training–Site Information

Field Data Collection—Canopy/Size

It is important to have accurate field data in each of the major forest types in order to model canopy cover and conduct unsupervised classification for classes. Our approach is to model canopy cover based on the geometry of forest canopies and the position of the sun. This approach allows for variation in the bidirectional reflectance of forest canopies and the effects of sun angles, surface topography, background vegetation, and shadowing. Field data must, therefore, reflect the range of conditions that are encountered within a project area.

Major forest types (conifers and hardwoods) for the project area are identified ased on field reconnaissance, published material, and discussion with knowledgeable local experts. Major forest types correspond to CALVEG Series Level types; for example, red fir, eastside pine, blue oak, etc. Training stands are chosen as representative samples of each major forest type, on illuminated, shaded, and flat slopes. Illuminated slopes are those at a south-southeast aspect with a greater than 30% slope; shaded are on north-northwest aspects and greater than 30% slope; and flat are those with less than 20% slope. This describes the mid-range of possible illumination conditions (flat) and the two extremes (shaded and illuminated) for calibrating the canopy model.

Training stands are further stratified by canopy cover class: 10-30%, 31-69%, and greater than 70% canopy closure. Training stands are chosen with aerial photography interpretation to determine if they meet the sets of condition described above. In addition, they should be at least 10 acres in size and homogenous in canopy cover. Further verification of training stands that meet the above set of conditions occurs in the field before data collection.

For each canopy model training site, a 16-point grid is installed, with points located at equal distances from each other (Quick Plot Stand Exam, see Section 374 for plot configuration). The distance between points varies with the size of the stand, to sample all portions of the area. At each point, information on elevation, slope and aspect is recorded. A variable-radius plot is used, and for all trees that fall into the plot, species, crown position, crown ratio and diameter at breast height (DBH) are recorded. At each point, one tree first tree from north will also have height and crown diameters measured. Two site trees are located within each training site, to core for age and determine the site index for the stand. Information is also collected on "background" found beneath the canopy, including percent cover of seedlings, saplings, shrubs, forbs and grasses, and any ground material (rock, duff, etc.) that may be present.

Size canopy training sites must also include a range of all major forest types in the project area on illuminated, shaded, and flat conditions across 4 size class groups. These classes are for poles (6-12" DBH), small trees (12-24" DBH), medium trees (25-36" DBH), and large trees (greater than 40" DBH). Again, each training site must be at least 10 acres in size, and fairly homogenous with regards to size class. Stands should also be single-storied, even-aged stands, with moderate crown density. No field data are collected, since they are used for an unsupervised classification, not a modeling technique. The stand is delineated on aerial photographs and topographic quadrangles, and information on type (species composition), tree size class, and illumination angle are recorded.

Training site data are processed and summarized using the USFS Region 5 Forest Inventory and Analysis System software for input into the canopy model and size classification.

270—Integrating Remote Sensing Products In GIS

Unlike the conventional method of vegetation mapping where the stand maps must be photo-to-map transferred, scanned, or digitized and labeled, the automated classification data file is converted from pixel format (raster) to polygon format (vector). Most GIS software can accommodate this as a standard routine. The resulting vegetation map is now a layer in the GIS data base that may be overlaid with administrative, compartment, and/or watershed boundaries. If plantations, nonstocked forest areas from fires, and/or water bodies have not been incorporated during the mapping phase, they can now override these areas by using the GIS software to update the vegetation maps. Once the map update and overlay process is complete, net National Forest acre values can be calculated for each unique vegetation label or attribute of interest, broad life form, or CALVEG type. Maps can be easily produced for use in forest inventory, land management planning, watershed analysis, or landscape analysis projects.

280—Accuracy Assessment

All vegetation type maps contain errors. It is impossible to create absolutely accurate delineations between vegetation types, largely because vegetation does not grow in homogenous patches or stands. By nature, vegetation boundaries are likely to be diffuse, or fuzzy, rather than sharp and contrasting. Errors can be of several types. Errors of omission occur when “conifers are mapped as something other than conifers.” Conversely, an error of commission occurs when “shrubs are mapped as conifers.” Registration errors can affect large areas of a map, causing the boundary lines to be shifted in one direction.

Accuracy assessment of maps improves their utility by providing the user with information about the nature, magnitude, frequency, and source of errors. If the user knows that some of the conifers are mapped as something other than conifer, it will help explain why the total acreage of conifer falls short of expected values. On the other hand, if the acreage of conifer seems excessive, it could well be because many of the shrubs were mapped as conifer. An accuracy assessment can be conducted in a variety of ways, but the two primary methods are the Error Matrix and the Fuzzy Set.

An error matrix involves comparing mapped labels with on-the-ground conditions at the site. The observer has only to determine if the mapped label is right or wrong. If the mapped unit is “conifer” and the observer finds shrubs, it counts as an error. A matrix table is constructed using mapped labels on one axis, and observed conditions on the other axis. The higher the proportion of “matches” there are, the more accurate the map. The error matrix is sometimes referred to as a “Confusion Table” because it can highlight the types that are often confused. If 25% of the sites labeled conifer actually contain shrubs, then it can be inferred that a high level of confusion exists between conifer and shrubs.

Fuzzy Set theory goes a step beyond looking at right vs. wrong and confusion. It requires that the observer, without knowledge of the map label, make an unbiased evaluation of the site and rate all possible labels on a relative scale from "absolutely right" to "absolutely wrong." For example, if the observer was evaluating a pure red fir stand, he/she would rate a label of "hardwoods" as absolutely wrong, but might rate "mixed conifer-fir" as wrong, but close. Or a shrub/hardwood site might get an OK rating for either the "shrub" or "hardwood" label, but would receive "absolutely wrong" for a conifer label.

The benefit of using Fuzzy Set accuracy assessment is that it provides more information about the nature, magnitude, and location of errors. Below is an example from the accuracy assessment recently completed on a forest mapping project:

> Polygons labeled conifer can reliably be expected to be conifers except on steep, northwest-facing slopes where confusion with hardwoods may occur.

Regardless of how carefully a vegetation map is prepared, errors will always occur. An accuracy assessment is essential to provide the user with the necessary information to interpret the map wisely. Forest inventory information can be used in the preparation of accuracy assessments, as long as all unique vegetation types and conditions are sampled in a nonbiased fashion.

Northern Region Vegetation Mapping Project Documentation

Contents

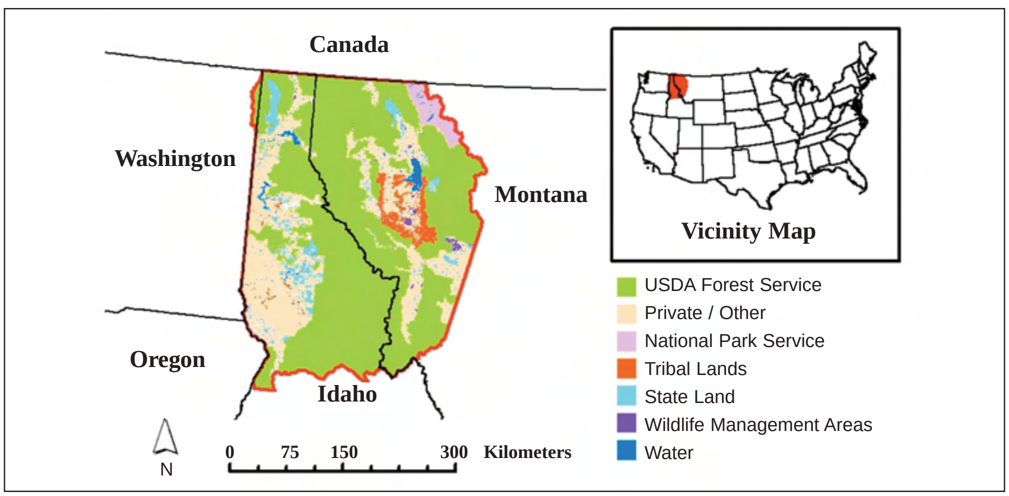
Executive Summary

Existing vegetation is the primary natural resource managed by the USDA Forest Service and by most forest landowners and land management agencies. The agency is charged with managing vegetation for a variety of human uses while maintaining the integrity of ecosystem components and processes at national, regional, and local scales. Development of consistent and continuous current vegetation data of sufficient accuracy and precision to address the principal resource concerns supports ecosystem assessment and land management planning. Many of the analyses needed to address multiple resource issues are essentially analyses of vegetation pattern and process relationships. These vegetation analyses support a variety of Forest Service business needs, including:

- Forest planning, including revision and amendment of existing plans
- Forest-level and regional fuels assessments for implementation of the National Fire Plan
- Ecosystem assessment at the watershed scale of all lands within a watershed (4th/5th HUC EAWS), independent of ownership
- Resource Planning Act reporting requirements
- Forest and rangeland assessments
- Postfire assessments
- Project-level cumulative effects analyses

Responding to these business needs, the Regional Forester's Team tasked the Northern Region, Resource Information Management (RIM) Board to develop a plan to map current vegetation west of the Continental Divide. The Northern Region Vegetation Mapping Project, hereafter referred to as R1-VMP, was designed to meet this identified need (see Figure 1).

Figure 1.— *Northern Region Vegetation Mapping Project area.*



The Regional Forester's Team had two programmatic objectives for R1-VMP:

1. Produce a consistent and continuous geospatial database for existing vegetation and associated attributes covering the northern Idaho and western Montana portions of the Northern Region. These data will be continuous across all ownerships and be produced following a consistent methodology; they will also be compatible with the recently completed SILC3 vegetation-mapping project for the eastside of the Northern Region, as well as recent national standards for vegetation classification and mapping.
2. Develop remote sensing and spatial analysis skills on each forest to facilitate long-term use and maintenance of these datasets. The skills and experience gained by forest-level employees will provide the basis for forest-specific refinements of the regional data and specialized analysis support.

Based on an remote-sensing applications, R1-VMP was developed with the following design elements:

- Utilization of ECOMAP section-level delineations to limit the variance associated with vegetation types within the study area.
- Extensive use of ancillary data and ecological modeling to improve classification results.
- Extensive use of summer and fall Landsat TM data to exploit seasonal variation in vegetation and other land cover classes.
- Utilization of TM image segmentation and merge procedures to create base classification units.
- Utilization of hierarchical classification to provide a consistent linkage between the lower levels commonly used by the agency and the upper levels required by the Federal Geographic Data Committee (FGDC) Vegetation Classification Standards (VCS).
- Generation of training and accuracy assessment data through a structured aerial photo interpretation process.

The result of R1-VMP is a geospatial database used to produce four primary map products for life form, tree canopy cover class, tree diameter, and dominance type. Map products have a variable minimum map unit (MMU) size varying from 1 acre for water features, 2.5 acres for grass-forb and shrub, to 5 acres for tree land cover. The geospatial database can be used as needed to construct user-specified map themes at varying MMU to aid in the analysis of management questions related to forest vegetation. The details of database and map product development and accuracy assessment are included in the project report.

A maintenance and update strategy annually identifies areas of changed conditions for systematic updates of the R1-VMP data.

1.0 Introduction

Existing vegetation is the primary natural resource managed by the USDA Forest Service and most forest landowners and land management agencies. The agency is charged with managing vegetation for a variety of human uses while maintaining the integrity of ecosystem components and processes at national, regional, and local scales. One of the most fundamental information needs to support ecosystem assessment and land- management planning is consistent and continuous current vegetation data of sufficient accuracy and precision to address the principal resource concerns. The primary ecosystem component managed is vegetation. Other ecosystem components, such as water, soil, fuels, and air quality, as well as terrestrial and aquatic fauna, are managed indirectly by way of vegetation management and/or access management. Much of the data needed to address multiple resource issues are derived from vegetation pattern and process analyses. These vegetation analyses are used to support a variety of Forest Service business needs including:

- Forest planning, including revision and amendment of existing plans
- Forest-level and regional fuels assessments for implementation of the National Fire Plan
- Ecosystem Assessment at the Watershed Scale (EAWS) that assess all lands within a watershed (4th/5th HUC EAWS), independent of ownership
- Resource Planning Act reporting requirements
- Forest and rangeland assessments
- Postfire assessments
- Project-level cumulative effects analyses.

Maps are the most convenient and universally understood means of graphically representing the spatial arrangement and relationships among features on the earth's surface (Mosby 1980). A map is indispensable for recording, communicating, and facilitating analysis of such information relating to a specific area. Accurate and up-to-date maps of existing vegetation are commonly used for inventorying, monitoring, and managing numerous resources on National Forests (e.g., wildlife habitat), including the business requirements listed above. Recognition of the importance of map products to support this wide variety of business needs was a primary consideration in identifying existing vegetation as a national Geographic Information System (GIS) layer for the Forest Service. This same recognition resulted in the development of the *Existing Vegetation Classification and Mapping Technical Guide* (Brohman and Bryant 2005) to establish Forest Service standards and procedures for classification and mapping of existing vegetation. This technical guide is authorized by Forest Service Manual (FSM) 1940 and has been developed according to direction in Forest Service Handbook (FSH) 1909. These standards were developed to guide the development of future classification and mapping products following the Federal Geographic Data Committee (FGDC) vegetation classification standards and provide a hierarchical approach to map unit design.

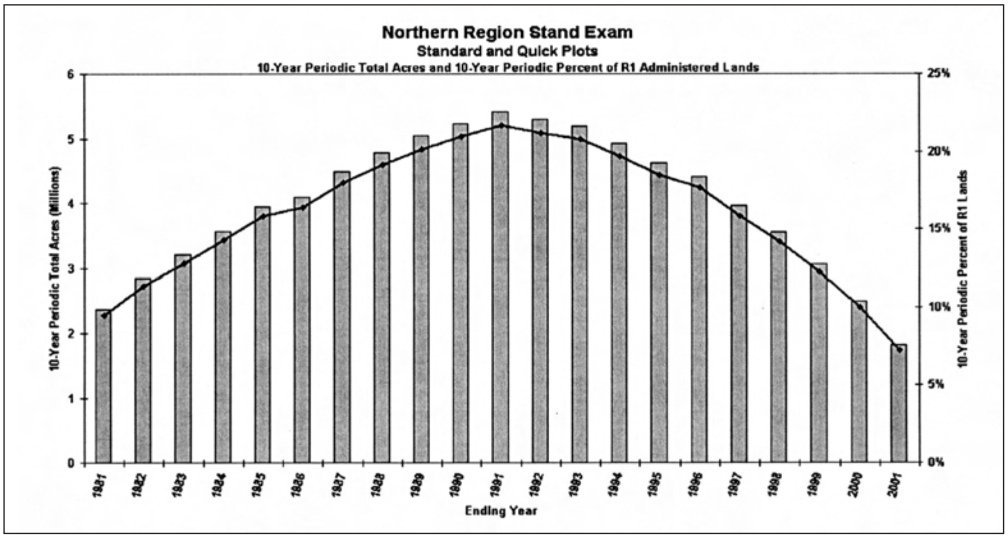
Ecosystem assessment and land management planning at national and regional scales require consistent standards for classification and mapping of existing vegetation. Such standards have never been developed because, until recently, most Forest Service planning and management standards have focused on issues at the local scale. The breadth of the Forest Service mission necessitates that classification and mapping protocols be designed to deal with a wide range of issues. The agency cannot develop a separate classification and/or map for every question land managers face. The agency must, therefore, describe and map fundamental units of vegetation that can be interpreted to address numerous questions. This requires hierarchical classification and multiscale mapping so existing vegetation can be described and mapped at the appropriate level of detail for each issue.

Historically, vegetation inventory and mapping have been conducted through some form of two-stage sampling of forest stands. The term ***stand*** has long been used to refer to the basic unit of forest management (Toumey 1937); therefore, it has been used as the basic unit of mapping and inventory (Graves 1913). A *stand* is defined as "a community, particularly of trees, possessing sufficient uniformity as regards composition, age, spatial arrangement, or condition, to be distinguishable from adjacent communities, so forming a silvicultural or management entity" (Ford-Robertson 1971). This process normally consisted of the delineation of "timber stands" with stereo, vertical aerial photography. The basis for delineation of stands was discontinuities in texture (reflecting stocking and crown size differences) or apparent tree height (Stage and Alley 1972).

The second stage was normally field sampling of the delineated stands or a stratified random sample with subsequent inference of field-sampled strata characteristics to unsampled stands within the strata. This process also involved transferring the photo delineations to a base map. These stand delineations reflected management considerations, as well as vegetative composition and structure. They often included several vegetation types that were different in terms of composition and structure, but were similar in terms of management implications and/or history. The term "stand" was also extended to describe nonforest vegetation, rock or barren areas, or water bodies. Although extending the stand-mapping concept made these maps more comprehensive, it did not map fundamental units of vegetation that could be interpreted to address numerous questions. Additionally, these maps represent a dynamic ecosystem component and have a finite period of currency. The intent with this inventory and mapping strategy was to regularly update the data, normally every decade.

Figure 1 illustrates the status of stand exam based inventory data for the Northern Region and the "decay curve" associated with trends in inventory data by displaying a 10-year periodic total that filters out "stale" inventory data from the total. These data apply almost exclusively to the suitable timber base, as defined by the National Forest

Figure 1. *USDA Forest Service, Northern Region, stand exam program status summary for 1980-2001.*



Management Act of 1976 (US Public Law 94-588 1976). The remaining areas outside the suitable base have few stand exam-inventory data, even though many of the questions and issues apply to all lands. In addition, there are no specific design considerations for the collection and storage of these data to facilitate their use by other land management agencies or private landowners.

Responding to this information need, the Northern Region Resource Information Management (RIM) Board developed a plan to provide for a regional resource information capability, commiting the region to a prioritized set of projects for the next 3 years. The Regional Forester's Team approved the RIM Board's recommended plan, and the board identified a number of corporate datasets and information systems as priorities, including resource mapping and development of a GIS core layer for current vegetation. The Northern Region Vegetation Mapping Project, hereafter referred to as R1-VMP, was designed to meet this need. The project design was accepted by the RIM Board to be completed as a 3-year project beginning in March of 2001.

The Regional Forester's Team had two programmatic objectives for R1-VMP:

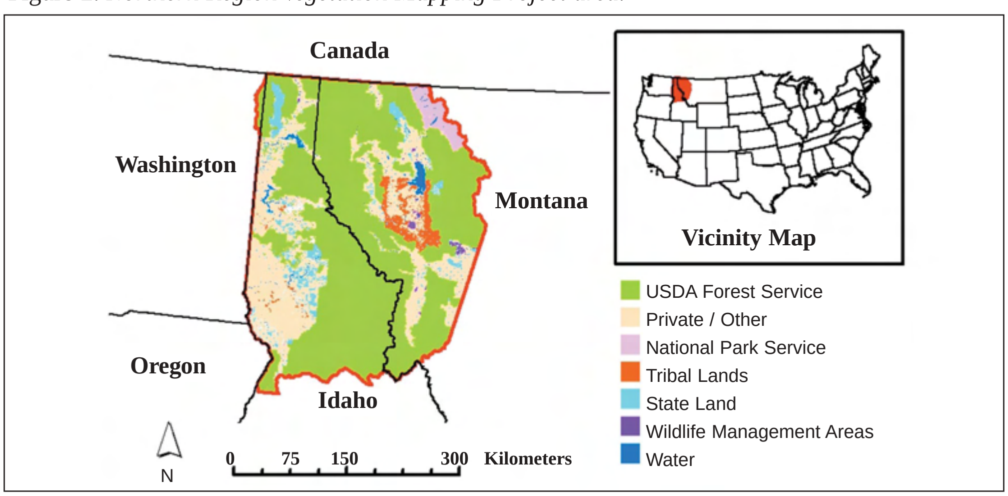
1. Produce a consistent and continuous geospatial database for existing vegetation and associated attributes covering the northern Idaho and western Montana portions of the Northern Region. These data will be continuous across all ownerships and be produced following a consistent methodology. They will also be compatible with the recently completed SILC3 vegetation-mapping project for the eastside of the Northern Region, as well as recent national standards for vegetation classification and mapping.
2. Develop remote sensing and spatial analysis skills on each forest to facilitate long-term use and maintenance of these datasets. The skills and experience gained by forest-level employees will provide the basis for Forest-specific refinements of the Regional data and specialized analysis support.

The first objective of R1-VMP was to provide the Northern Region and cooperating agencies with a geospatial database of vegetation and land cover based on consistent analytical logic and methods, and mapped continuously across all ownerships. This geospatial database with its associated inventory data supports land management planning and sustainable forest management at regional, subregional, and landscape assessment scales. These data also provide the analytical basis for vegetation pattern and process analyses associated with forest management planning. It is also explicitly designed to provide for project-level analyses using the same analytical logic and scale-appropriate methods. This design element facilitates establishing the relations among individual projects and Forest-wide or Regional management direction. These data should also facilitate cumulative effects analyses for many projects. The project area for R1-VMP covers all ownerships and encompasses approximately 27,000,000 acres (11,000,000 hectares) of the USDA Forest Service, Northern Region (Figure 2). The area extends from the Continental Divide to the Washington and Oregon borders, and from the Salmon River to the Canadian border.

The second objective was accomplished through a team concept that draws on multiple organizational levels within the region. Within this structure, regional office personnel provide overall project coordination and oversight, as well as technical assistance, training, and specialized skills. Forest personnel provide the local field experience and specialized skills needed to produce a quality product and develop the knowledge and experience needed to effectively utilize and improve these data for forest- and project-level analysis objectives.

In the early stages of the project it became increasingly obvious that R1-VMP was not a mapping project but, in fact, a classification, mapping, and inventory project. The R1-VMP team needed to facilitate the discussion with the Northern Region Vegetation Council regarding the evaluation and adjustment of the existing regional classification

Figure 2. *Northern Region Vegetation Mapping Project area.*



logic. Numerous problems had been identified with the classification logic and associated algorithms used in the SILC projects and concerns had been expressed that the classes were not exhaustive and/or mutually exclusive. Additional concerns regarding the eventual integration of the map products with some form of inventory data were also raised. Coordination with the Northern Region Vegetation Council and the Regional Forest and Rangeland staff resulted in the modification of this project to accomplish these longer-term objectives. Accordingly, this project documentation describes the general relationship of vegetation classification, mapping, and inventory followed by sections describing each of these processes relative to R1-VMP. The following project documentation tiers to and expands on the *Existing Vegetation Classification and Mapping Technical Guide* (Brohman and Bryant 2005). Particularly relevant sections of the technical guide are included here directly, rather than incorporating by reference.

2.0 General Relationship of Classification, Mapping, and Inventory

As discussed in the introduction, one of the most fundamental information needs for implementing any sustainable forest management strategy is consistent and continuous current vegetation data of sufficient accuracy and precision to address the principal issues and resource concerns. Many of the analyses needed to address multiple resource issues are essentially analyses of vegetation pattern and process relationships. All of these analyses rely on the data models produced from vegetation classification, mapping, and/or inventory. R1-VMP is designed to utilize these three types of data models to provide robust existing vegetation information for a wide variety of analysis applications. It is important, however, to remember the caution of the distinguished statistician George Box who observed “All models are wrong—but some models are useful.” Useful is therefore defined by the ability of these data models to address an intended analysis application. The following sections describe the classification, mapping, and inventory logic/methods of the R1-VMP data. Users of these data should evaluate R1-VMP in the context of the intended use.

A number of significant terms are commonly associated with vegetation classification, mapping, and inventory. These terms are defined in order to ensure a clear and consistent discussion of the concepts and relationships presented in this project documentation.

Existing vegetation is the plant cover, or floristic composition and vegetation structure, occurring at a given location at the current time.

Classification is the process of grouping of similar entities into named types or classes based on shared characteristics. A **vegetation type** is a named category of plant community or vegetation defined on the basis of shared floristic and/or physiognomic characteristics that distinguish it from other kinds of plant communities or vegetation.

Taxonomic units are the basic set of classes or types that comprise a natural or scientific classification. Taxonomic units can be developed for physiognomic classifications (e.g., tree-dominated classes or shrub-dominated classes) or floristic classifications (e.g., dominance-type classes or plant association and alliance classes). Taxonomic units represent a conceptual description of ranges and/or modal conditions in vegetation characteristics. **Technical groups** are the basic set of classes or types that comprise a technical classification. Technical groups can be developed for structural classifications (e.g., canopy cover classes and/or tree size classes). Technical groups represent a conceptual description of ranges and/or modal conditions in vegetation characteristics.

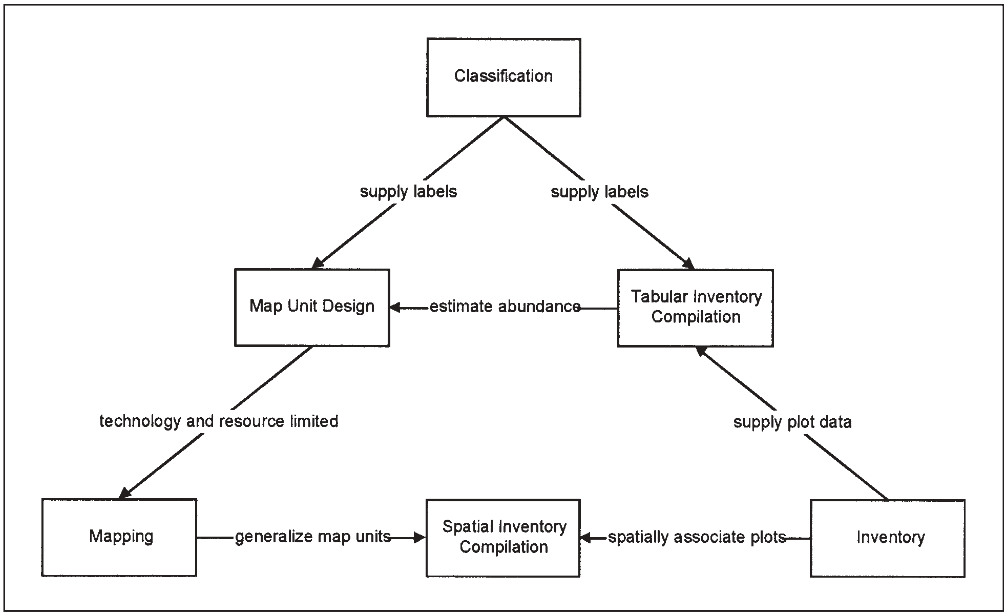
Vegetation mapping is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. A **vegetation map unit** is a collection of areas with a common definition and name reflecting their component taxonomic units and/or technical groups. Units depicted on maps within individual areas or delineations that are non-overlapping and geographically unique are referred to as **map features** (e.g., polygon delineations or region delineations). **Thematic resolution** is the level of categorical detail present within a given set of map units. In a general sense, increased thematic resolution is represented by an increase in the number of map units and fewer map units conversely represent coarser thematic resolution. While thematic resolution is often implied by geographic or spatial resolution, a direct relationship is not inherent.

Vegetation inventory is the process of applying an objective set of sampling methods to quantify the amount, composition, and condition of vegetation within specified limits of statistical precision.

These three processes and the resulting data models are integrally related, but they are separate. Vegetation classification defines and describes vegetation types and/or structural characteristics (i.e., what is it?). Vegetation mapping spatially depicts the distribution and pattern of vegetation types and/or structural characteristics (i.e., where is it?). Vegetation inventory quantifies the amount, composition, and condition of vegetation (i.e., how much is there?). The conceptual relationships between classification, mapping, and inventory are schematically depicted in Figure 3.

A one-to-one relationship between vegetation types (from a classification) and vegetation map units is uncommon given the limitations of mapping technology and the level of floristic detail in most classifications. Mapping, therefore, usually entails trade-offs among thematic and spatial resolution and accuracy, as well as cost. The goal is constrained optimization, not perfection. This problem is reduced somewhat when vegetation types (such as dominance types), and structural classifications are designed to be applied to mapping projects. Similarly, there is rarely a sufficient sample size to quantify all vegetation types. Inventory compilation usually involves tradeoffs to generalize and aggregate vegetation types and/or structural classes to achieve the sample size needed to provide estimates consistent with the intended analysis applications.

Figure 3. *Relationships of vegetation classification, mapping, and inventory.*



Because these ecosystems are dynamic, evolutionary, and have limited predictability, many of the analyses needed for ecosystem management strategies require a variety of simulation models. The majority of these simulation models rely heavily on accurate and relatively detailed vegetation data (e.g., SIMPPLE, WATSED, and FARSITE). These models vary in the specificity and detail of vegetation data needed, but most require continuous spatial data with consistently classified attribute data. Classification, mapping, and inventory each contribute data elements used in these simulation models.

The concepts of vegetation classification and mapping, as well as the general relationships between them, are well described in *Existing Vegetation Classification and Mapping Technical Guide* (Brohman and Bryant 2005). This project documentation describes the Northern Region's procedures used in R1-VMP for classification and mapping of existing vegetation, and identifies the mechanism for integrating these classifications and maps with inventory data collected through the Forest Inventory and Analysis (FIA) program. This document also specifically describes the classification logic, mapping methods, and inventory compilation strategies used in R1-VMP.

3.0 Vegetation Classification

A comprehensive discussion of the nature, purposes, and principles of the classification of natural phenomena was included in John Stuart Mill's *System of Logic* (1st ed., 1846), a treatise on inductive logic as the basis of the scientific method. Classification is a fundamental activity of science and an integral part of assimilating and organizing information to produce knowledge (Mill 1846; Buol et.al. 1980; Gauch 1982).

Classification is the process of grouping of similar entities into named types or classes based on selected shared characteristics. Classification is a form of inductive reasoning that "establishes general truths from a myriad of individual instances" (Trewartha 1968). Classification is a fundamental activity of science and an integral part of human thought and communication (Gauch 1982). It is how we assimilate and organize information to produce knowledge. "When we have a definition for anything, when we really have studied its nature to the point where we can say that it is "this" and not "that," we have achieved knowledge" (Gerstner 1980 as cited in Boice 1998). Even if classification categories are conceptual or abstract rather than absolute facts, they still serve to formulate general truths based on numerous observations.

A **class** is "a group of individuals or other units similar in selected properties and distinguished from all other classes of the same population by differences in these properties" (Buol et al. 1980). The properties selected as the basis for grouping individuals into classes are called **differentiating characteristics** (Buol et al. 1980). There are two fundamental approaches to selecting differentiating characteristics; they produce two different kinds of classes (Mill 1846) and two different kinds of classifications (Buol et al. 1980; Pfister and Arno 1980; USDA 1993).

A **natural or scientific classification** is *a* classification in which the differentiating criteria are selected in order to "bring out relationships of the most important properties of the population being classified, without reference to any single specified and applied objective" (Buol et al. 1980). In developing a scientific classification, "all the attributes of a population are considered and those which have the greatest number of covariant or associated characteristics are selected as the ones to define and separate the various classes" (Buol et al. 1980). A set of classes developed through scientific classification is referred to as **taxonomy** (USDA 1993). A **taxonomic unit** (or **taxon**) is a class developed through the scientific classification process, or a class that is part of taxonomy.

A **technical classification** (or **technical grouping**) is a classification in which the differentiating characteristics are selected "for a specific, applied, practical purpose" (Buol et al. 1980, Pfister and Arno 1980). The resulting classes are called **technical groups**. In contrast to natural classifications, technical classifications are based on one or a few properties to meet a specific interpretive need, instead of considering all the properties of the population.

Vegetation classification consists of grouping a potentially infinite number of stands or plots into relatively few vegetation types. A **vegetation type** is a named class of plant community or vegetation defined on the basis of selected shared floristic and/or physiognomic characteristics, which distinguish it from other classes of plant communities or vegetation. Vegetation types are taxonomic units developed through the scientific classification process as described above. Scientific classification makes meaningful generalizations about each vegetation type possible, thus reducing complexity and furthering communication while maintaining meaningful differences among types (Pfister and Arno

1980). Members of a vegetation type (e.g., plots or stands) should be more similar to each other than they are to members of other vegetation types. Structural classifications, such as those based on canopy cover, are technical groups developed through a technical classification process. Technical groups also generalize all possible conditions into classes that are more similar to members of the same class than to members of other classes and provide the basis for analysis applications and interpretations related to the "applied, practical purpose" of the classification.

Following the classification principles described above as well as the mid-level classification standards included in the *Existing Vegetation Classification and Mapping Technical Guide* (Brohman and Bryant 2005), the Northern Region Vegetation Council developed and adopted the following vegetation and landcover classifications.

3.1 Physiognomic and Floristic Classification

Physiognomic and floristic composition are the most fundamental components of a vegetation map. The National Vegetation Classification (NVC) (FGDC 1997) has defined a hierarchical system for arranging these components into taxonomic units, which is the foundation for the map hierarchy described in the technical guide. When the NVC was adopted as an FGDC standard in 1997 the document provided the description of both the physiognomic and floristic composition components. Two floristic levels, alliances and associations, were defined. Standards were provided for only the physiognomic portion of the hierarchy. To further develop standards for the NVC, the Ecological Society of America (ESA), through a memorandum of understanding with the FGDC, established a vegetation classification panel. In May 2002 the ESA vegetation panel submitted Standards for Associations and Alliances of the U.S. National Vegetation Classification (Jennings et al. 2004). The ESA document states as follows: "Consistent with FGDC principles, the standards here for floristic units relate to vegetation classification and are not standards for the identification of mapping units. Nevertheless, types defined using these standards can be mapped and can be used to design useful map units subject to the limitations of scale and mapping technology." The ESA proposed standards for associations and alliances along with the physiognomic standards in the 1997 U.S. National Vegetation Classification form the basis for the mapping standards identified in the technical guide. It is assumed that all map units will fit somewhere within this hierarchy, whether or not they are included in the FGDC classification**.**

Landscape features dominated by land uses (e.g., urban areas) and water bodies are to be mapped as non-vegetative if they are less than the minimum standard for vegetative cover. Mapping continuous areas requires using land use and cover as well as vegetation classification systems. While many areas of the National Forests could be mapped using map units defined by vegetation physiognomic classification only, sparsely vegetated

Life Form (order level of the NVCS physiognomic hierarchy)		
Code	**Label**	**Description**
3100	GFB	Grass/Forb dominated life form
3300	SHR	Shrub dominated life form
4000	TRE	Tree dominated life form
5000	WTR	Water landcover
7000	SVG	Sparsely vegetated landcover

Life Form Key		
A.	Tree dominated life form > 10% canopy cover	**TRE**
B.	Tree dominated life form < 10% canopy cover	Go to B
A.	Shrub dominated life form > 10% canopy cover	**SHR**
B.	Shrub dominated life form < 10% canopy cover	Go to C
C.	Grass/Forb dominated life form > 10% canopy cover	**GFB**
C.	Grass/Forb dominated life form < 10% canopy cover	Go to D
D.	TRE+SHR+GFB+non-vascular >10% canopy cover	**NDL** [no dominant life form]
D.	TRE+SHR+GFB+non-vascular <10%	Go to E
E.	TRE+SHR+GFB+non-vascular <10% and >1% canopy cover	**SVG** [sparsely vegetated]
E.	TRE+SHR+GFB+non-vascular <1%	**NVG** [non-vegetated]

and non-vegetated areas mapped solely as such, give little information to the map user. Water was explicitly included as a life form-level land cover class and classes such as snow, clouds, and shadows were replaced using adjacent life forms.

Floristic map units based on vegetation types from a fully documented and adopted existing vegetation classification system are required by the national standard; however, few vegetation classifications that meet the FGDC exist in the Northern Region. The near term availability of adopted FGDC vegetation classifications prompted the Vegetation Council to develop and adopt a consistent approach to the classification and mapping of dominance types. Dominance types have been widely used in the development of map units where remote sensing imagery is the primary basis for map feature delineation. “Under the dominance approach, vegetation types are classified on the basis of dominant plant species found in the uppermost stratum. Determining dominance is relatively easy, requiring only a modest floristic knowledge. However, because dominant species often have a geographically and ecologically broad range, there can be substantial floristic and ecologic variation within any one dominance type.”…“ ‘Dominance types’ provide a simple method of classification based on the floristic dominant (or group of closely related dominants) as assessed by some measure of importance such as biomass, density, height, or leaf-area cover” (Kimmins 1997). They represent one of the lowest levels in several published classification hierarchies (e.g., Cowardin et al. 1979; Brown et al.1980).

The dominant classification adopted for R1-VMP is based on relative canopy cover and is exhaustive and mutually exclusive. The basic classification logic is illustrated in the following tree dominance-type key:

Tree Dominance-Type Key

A. Single most abundant species ≥ **60%** of total canopy cover .... **List single species**
A. Single most abundant species ≤ **60%** of total canopy cover .... Go to B

B. 2 most abundant species ≥ **80%** of total canopy cover and each species individually is ≥ 20% of total canopy cover .... **List 2 species**, in order of abundance
B. 2 most abundant species ≤ **80%** of total canopy cover .... Go to C

C. 3 most abundant species ≥ **80%** of total canopy cover and each species individually is ≥ 20% of total canopy cover .... **List 3 species**, in order of abundance
C. 3 most abundant species ≤ **80%** of total canopy cover .... Go to D

D. Shade intolerant species total CC ≥ shade tolerant species total CC .... **IMXS**
D. Shade intolerant species total CC ≤ shade tolerant species total CC .... Go to E

E. GF+C+WH canopy cover ≥ AF+S+MH canopy cover .... **TGCH**
E. GF+C+WH canopy cover ≤ AF+S+MH canopy cover .... **TASH**

3.2 Tree Diameter Classification

Tree diameter class (also called overstory tree diameter class) is defined here as any of the intervals into which a range of tree diameters may be divided for classification (Helms 1998). In this project the mean diameter at breast height (4.5 ft /1.37 m. above the ground) is calculated for the trees forming the upper or uppermost canopy layer (Helms 1998). Note: this mean is calculated as the basal area weighted mean diameter.

Tree diameter class

Code	DBH	Description
1	0-4.9	Seedling/Sapling
2	5-9.9	Small tree
3	10-14.9	Medium tree
4	15-19.9	Large tree
5	20 +	Very Large tree

3.3 Tree Canopy Cover Classification

Tree canopy cover (also called tree canopy closure) is defined here as the total non-overlapping tree canopy in a delineated area as seen from above. (Tree canopy cover **is not** defined by a hemispherical projection as seen from below.) Tree canopy cover below 10% is considered a nontree polygon. The tree canopy cover breaks are consistent with the physiognomic class breaks for vegetation.

Tree canopy cover class

Code	Cover %	Description
1	10-24.9%	Low
2	25-59.9%	Moderate
3	60-100%	High

4.0 Map Design

Map design involves two fundamental processes. The first, map unit design, identifies the vegetation characteristics to be mapped and assembles or develops classification keys for each of the map attributes used to describe those characteristics. This process establishes the relationship between vegetation classification and mapping. The second process, map feature design, identifies the spatial characteristics and structure of the map.

A **vegetation map unit** is a collection of areas identically defined and named in terms of their component taxonomic units and/or technical groups (adapted from USDA, Soil Survey Division 1993). These vegetation map units can be based on the taxonomic units and technical groups of physiognomic, floristic, or structural classifications, or on combinations of these. Map units are designed to provide information and interpretations to support resource management decisions and activities. The map unit design process establishes the criteria for aggregating or differentiating vegetation taxonomic units and technical groups to create corresponding map units. Therefore, a mapping unit is comprised of one or more taxonomic units and/or technical groups from one or more specific classifications. The criteria used to aggregate or differentiate within physiognomic types, vegetation types, or structural classes to form mapping units will depend on the purpose of, and the resources devoted to, any particular mapping project (Jennings et al. 2004). For example, map units designed to provide information on existing forest structure to characterize wildlife habitat or fuel condition would be based on a combination of tree canopy cover technical groups and tree diameter technical groups. The map unit design process is more complex for floristic classifications than for relatively simple structural classifications. The mapping standards for vegetation cover, tree canopy closure, and tree diameter described in this section represent general-purpose map unit designs for each structural classification at all map levels, although local information needs may occasionally require exceeding the standards.

Map units depicted on maps within individual areas or delineations that are non-overlapping and geographically unique are referred to as **map features** (e.g., polygon delineations or region delineations). The map feature delineation process should be based on the map units identified in the map unit design process. Typically, one map unit is repeated across the landscape in many individual map feature delineations.

The design process for the primary R1-VMP map products is described in the following sections.

4.1 Physiognomic and Floristic Map Design

The dominance type classification described in section 3.1 was aggregated and generalized using the following logic to identify the map units used in R1-VMP. The variable minimum map feature standard used for life form applied to dominance types.

DOMINANCE TYPE 1—ELEMENTAL CLASSIFICATION [DOM1]
Classification Rule Set: 1-species > 60% tot BA that species 2-species > 80% tot BA those 2-species—listed in order of abundance 3-species > 80% tot BA those 3-species—listed in order of abundance Shade intol. > Shade tol. IMXS [intolerant mixed spp] Shade tol. > shade intol. G, WRC, WH > AF, ES, MH TGCH G, WRC, WH < AF, ES, MH TASH **Results in over 850 different types**
DOMINANCE TYPE 4—SPECIES GROUPS [DOM4]
Classification Rule Set: 1-Species: Same as DOM1 2-Species: All 2-species DOM1 types with the same most abundant species are grouped into SPPP-1MIX (e.g., ABGR-PSME, ABGR-PICO, etc = ABGR-1MIX) 3-Species: All 3-species types with the same most abundant species (from DOM1) are grouped into SPPP-2MIX e.g., ABGR-PSME-PICO, ABGR-PICO-LAOC, etc = (ABGR-2MIX) IMXS, TASH, TGCH: Same as DOM1 **Results in over 42 different types**
DOMINANCE TYPE 4—SPECIES GROUPS [DOM4]
Map Unit Design A frequency distribution of DOM4 types is made from FIA PSU data. If either the single-species or the single-species-1MIX are less than 1% of the total number of forested FIA PSUs, they are collapsed into a single species.

The dominance type map unit design process described in this section produced slightly different sets of map units for each model, reflecting the ecological differences in these models (see Appendix A). Combining the map units for each model resulted in 36 unique dominance types. An objective evaluation of the map accuracy of R1-VMP dominance types illustrated the nature and magnitude of map error associated with this large set of map units and suggested logical aggregations of map units to achieve reasonable accuracy for the regional product. It is important to recognize that the structure of the error varied by dominance type and between models. Therefore, forest or planning zones may aggregate dominance types differently depending on the intended analysis application and the geographic extent of the analysis area (see ssection 5.10).

4.2 Tree Diameter Map Design

To reduce error to acceptable levels, the tree diameter classification described in Section 3.2 was aggregated and generalized to the following three classes for R1-VMP. The variable minimum map feature standard used for life form applied to tree diameter classes.

Tree diameter map units		
Code	**DBH**	**Description**
1	0–4.9	Seedling/sapling
23	5–14.9	Small/medium tree
45	15–20 +	Large/very large tree

4.3 Tree Canopy Cover Map Design

The tree canopy cover classes described in section 3.3 were adopted and mapped as classified. The variable minimum map feature standard used for life form applied to tree canopy cover classes.

4.4 Minimum Map Feature

Minimum map feature is the term used to describe the smallest size polygon required in a map. A homogeneous area must be delineated in a map if it is equal to or greater in areal extent than the minimum map feature standard for each map level. Stated another way, no differing condition, greater in area than the minimum map feature as defined by the map unit design can be left as an unmapped inclusion in a larger polygon.

The life form and landcover classes described in section 3.1 were adopted and mapped as classified. A variable minimum map feature standard was implemented as follows:

The dominance type map units, tree canopy cover map units, and tree diameter map units, described in sections 4.1 through 4.3 respectively, nest hierarchically under life form and follow the same minimum map feature standard.

Life form minimum map feature		
Code	**Label**	**Minimum Map Feature**
3100	GFB	2.5 Acres
3300	SHR	2.5 Acres
4000	TRE	5.0 Acres
5000	WTR	1.0 Acre
7000	SVG	5.0 Acres

5.0 Vegetation Mapping

Vegetation mapping is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characterisitcs. Satellite-based remote sensing classifications (mainly using LANDSAT-TM data) with their associated GIS coverages or grids and attribute databases have increasingly been used for large area, low-cost vegetation and landcover mapping (Lachowski et al. 1996; Redmond et al. 1996; Johnston et al. 1997; Cohen et al. 1998; Mickelson et al. 1998; Stoms et al. 1998). These satellite-based classifications are gradually replacing aerial photography as the primary image data for vegetation mapping. Wynne and Carter (1997) compare characteristics of satellite remote sensing data and aerial photography relative to these mapping applications:

- Satellite images are digital; they provide direct and cost effective GIS coverages and databases. The spatially accurate conversion of aerial photo delineations to digital coverage is expensive and time consuming.
- Digital images are easy to send over computer networks; they can be delivered within hours of acquisition.
- Given a specified resolution, satellite images typically provide greater coverage than aerial photography.
- Satellite images often have better geometric fidelity than aerial photos because of their altitude and stability of orbits.
- Some space-borne sensors include wavelengths band, such as mid-infrared, and thermal infrared, that cannot be detected by film.
- Repeat coverage is easily obtained; it is easily coregistered and used for applications such as change detection and monitoring.

The USDA Forest Service national direction contained in the "Existing Vegetation Mapping Protocol" (Brewer et al. 2003) in the *Existing Vegetation Classification and Mapping Technical Guide* (Brohman and Bryant 2003) reflects the trend toward the use of satellite remote sensing classification for vegetation mapping. R1-VMP represents the current implementation of this national direction in the Northern Region. The following sections, exerted and expanded from Brewer and others (2003), describe the analytical logic and general methodology utilized in the mapping process.

5.1 Acquisition and Preprocessing of Image and Ancillary Data

Landsat TM imagery was chosen for this work because the near-infrared and mid-infrared reflectance of vegetation is strongly related to important vegetation canopy characteristics. Additionally, the high spectral resolution of Landsat TM imagery was preferred above the high spatial resolution of other sensors, such as SPOT and Landsat TM data are acquired continuously and archived data could, therefore, be purchased to meet the time and area needs. Landsat TM data can also be purchased as "floating scene" or "path-level" formats providing of up to three TM scenes as a single field of view, thereby reducing the image handling and preprocessing requirements, as well as costs.

A good seasonal image data acquisition window for forest vegetation opens slightly after the date at which the vegetation is fully mature and closes just prior to its senescence. Similarly, a good data acquisition window for exploiting meaningful phenological differences in forest vegetation opens slightly after senescence and ends with snowfall. The consideration of an acquisition window instead of an acquisition date provides greater operational flexibility (to minimize cloud cover or other atmospheric interference), because it permits the date to be chosen based on a satellite overpass. In this case, the “peak green” and “fall” image data were obtained from the EROS Data Center with the following acquisition dates and according to the following parameters:

Cell Sizes: 30m reflective, 15m panchromatic, 60m thermal (both high and low)
Orientation: Path
Datum: WGS 84
Projection: Space Oblique Mercator
File Format: FSTL7
Path 41 Image Acquisition Dates: 10 July 2002; 14 October 2002
Path 42 Image Acquisition Dates: 18 August 2002; 6 November 2002
Path 43 Image Acquisition Dates: 6 August 2002; 12 October 2002

All images were ortho-rectified to previously terrain-corrected images for the respective paths using the Geometric Correction Module and the Landsat orbit model in ERDAS IMAGINE (ERDAS 1997) as well as 7.5-minute digital elevation models. Between 200 and 300 ground-control points (GCP) throughout each of the unrectified images were used in the ortho-rectification process. The rectification involved the Cubic Convolution algorithm with a resulting Root Mean Square (RMS) error was less than one-half of a pixel, or 7.5m, 15 m, or 30m depending on the cell size. The R1-VMP image handling steps, ortho-rectification process, and resulting datasets are documented in appendix B. Ancillary topographic data derived from 7.5-minute digital elevation models downloaded from the U.S. Geological Survey were assembled, co-registered, and clipped to the same study area boundary.

5.2 Ecogeographic Stratification

Lillesand and Kiefer (2000) discuss the commonality of using ancillary data to perform geographic stratification of an image dataset prior to classification. They further describe the aim of this process as to “subdivide an image into a series of relatively homogeneous geographic areas (strata) that are then classified separately.” The homogeneity of these geographic areas is largely determined by the composition of biophysical environments included in the stratification. These environment settings are important for the stratification of this type of project because they facilitate the delineation and description of ecosystems that behave in a similar manner and influence the natural disturbance processes that create finer-scale patterns such as existing vegetation (Jensen et al. 1997). The USDA Forest Service National Hierarchical Framework of Ecological Units (Bailey et al. 1994) provided the delineations used for geographic stratification of the R1-VMP project area.

As described by ECOMAP the framework is:

> a regionalization, classification, and mapping system for stratifying the Earth into progressively smaller areas of increasingly uniform ecological potentials. Ecological types are classified and ecological units are mapped based on associations of those biotic factors and environmental factors that directly affect or indirectly express energy, moisture, and nutrient gradients that regulate the structure and function of ecosystems. These factors include climate, physiography, water, soils, air, hydrology, and potential natural communities.

The appropriate level of this hierarchy for ecogeographic stratification in this project is the section-level delineation described by McNab and Avers (1994) and illustrated in figure 4. These delineations were used to stratify Landsat ETM floating scene sets in ERDAS Imagine software (ERDAS 1997). This geographic stratification results in 12 sub-path data models (Figure 5) rather than eight Landsat TM scene models. This stratification improves model performance by limiting the variance associated with vegetation types, and increases the utility of reference data.

Figure 4. *Section- and subsection-level delineations in the ECOMAP hierarchy.*

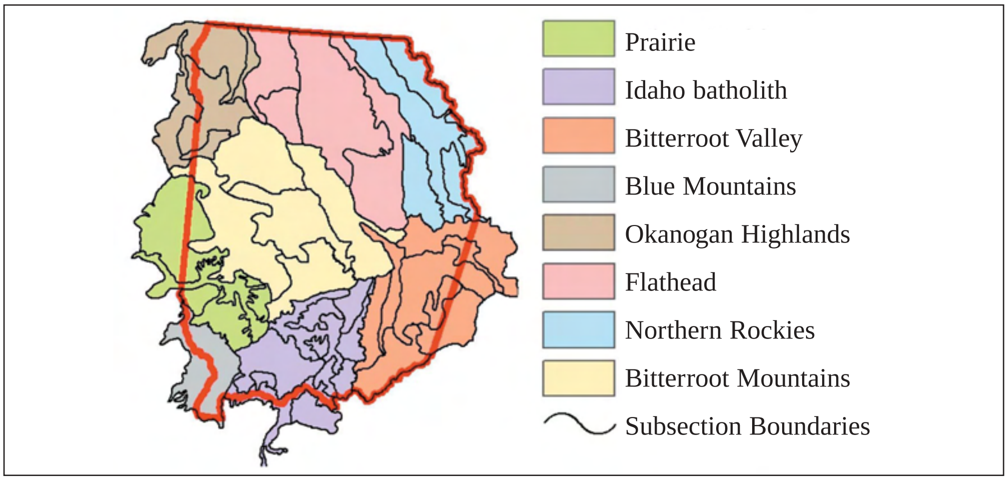


Figure 5. *Subpath data models used for ecogeographic stratification of Landsat ETM floating scenes.*

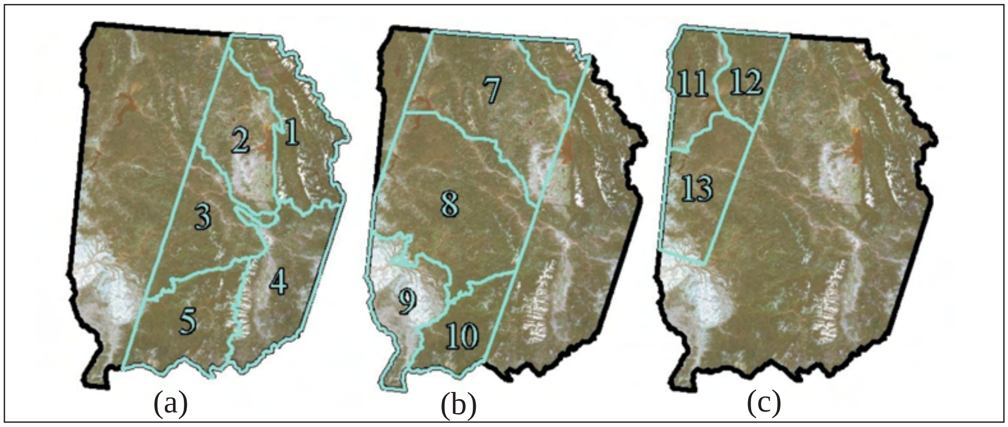
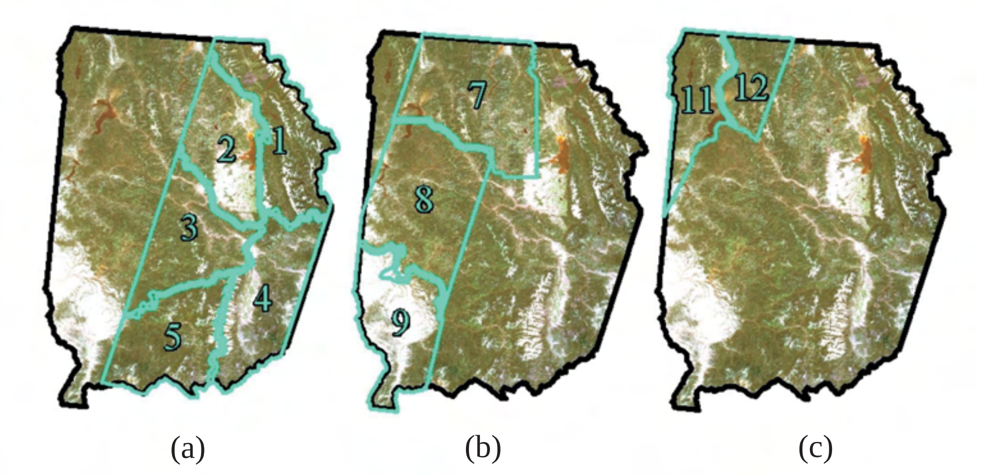


Figure 6. *Modified subpath data models used for ecogeographic stratification of Landsat ETM floating scenes.*

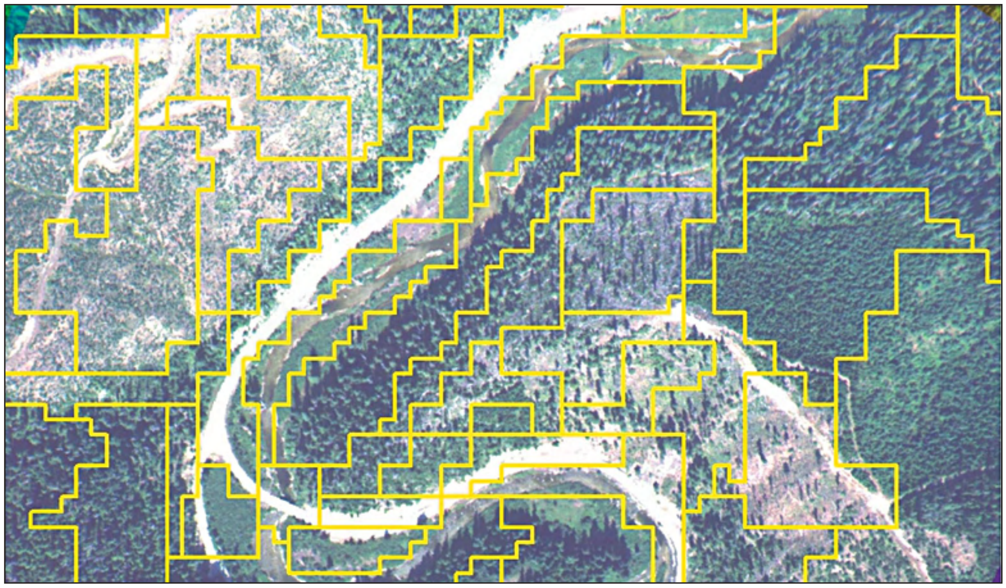


The 12 subpath data models were subsequently modified (Figure 6) to reduce file size and eliminate redundancy. The portion of model 13 not included in model 8 was appended to model 11. Similarly, the portion of model 10 not included in model 5 was appended to model 9. Models 7 and 12 were both carried through the classification process to provide flexibility in eliminating smoke and haze problems present in the image data.

5.3 Image Segmentation

As stated in Ryerd and Woodcock (1996), "image segmentation is the process of dividing digital images into spatially cohesive units, or regions. These regions represent discrete objects or areas in the image." This segmentation and merging process is influenced by the variance structure of the image data and provides the modeling units that reflect life-form composition, stocking, tree crown size differences, and other vegetation and/or landcover characteristics (Haralick and Shapiro 1985; Ryerd and Woodcock 1996). Segmentation and merging of Landsat ETM satellite imagery in R1-VMP utilized the segmentation functionality within the software eCognition (Baatz et al. 2001). The segmentation process in eCognition is based on both the local variance structure within the imagery and shape indices. This segmentation process produces image objects that serve as the base classification units within the object-oriented classification programs. These image objects effectively depict the elements of vegetation and landcover pattern on the landscape (McDonald et al. 2002). Figure 7 illustrates the image segmentation-based depiction of landscape pattern displayed over aerial digital imagery. Given the R1-VMP project objective of mapping vegetation and landcover pattern, the criteria for spatially differentiating map features was based on structural, floristic, and physiognomic characteristics of the vegetation to be mapped, as well as nonvegetated landscape elements. Within the context of R1-VMP, the delineation of map features depicting the vegetation

Figure 7. *Image segmentation of Landsat ETM data.*



configuration across the landscape representing elements of vegetation pattern is synonymous with landscape patch delineation. The term "**patch**," as defined in a glossary of common terms included in *Land Mosaics: The Ecology of Landscapes and Regions* (Forman 1995), is "a relatively homogenous nonlinear area that differs from its surroundings." This definition is consistent with other common reference texts including Picket and White (1985) and Forman and Godron (1986). It is also consistent with the common use of the term in the landscape ecology literature (Hartgerink and Buzzaz 1984; Scheiner 1992). The term patch can be refer areas of forest, nonforest vegetation, rock/barren environment, or water. In contrast, the term "stand" has long been used to refer to the basic unit of forest management (Toumey 1937). It also has been used as the basic unit of mapping and inventory (Graves 1913). A "**stand**" is defined as "a community, particularly of trees, possessing sufficient uniformity as regards composition, age, spatial arrangement, or condition, to be distinguishable from adjacent communities, so forming a silvicultural or management entity." This definition of a stand from the Society of American Forester's *Terminology of Forest Science, Technology, Practice, and Products* (Ford-Robertson 1971) is consistent with definitions from a variety of reference texts, including Toumey (1937), Smith (1986), and Oliver and Larson (1990), as well as A *Dictionary of Ecology, Evolution, and Systematics* (Lincoln et al. 1982) and the definition provided in the USDA Forest Service *Timber Management Handbook* (FSH 2709). Historically, most vegetation mapping completed by the agency has been conducted through delineation of forest stands. The terms "patch" and "stand" may be synonymous depending on the degree to which management considerations are incorporated into stand delineations along with compositional and structural characteristics. It is important to recognize, however, that many past stand delineations contain multiple vegetation conditions and map units, and are multiple map features in the R1-VMP mapping effort. The image objects delineated through the R1-VMP image segmentation process and modeled in eCognition readily aggregate thematically and comprise vegetation and landcover patches that represent the various map units in the hierarchy.

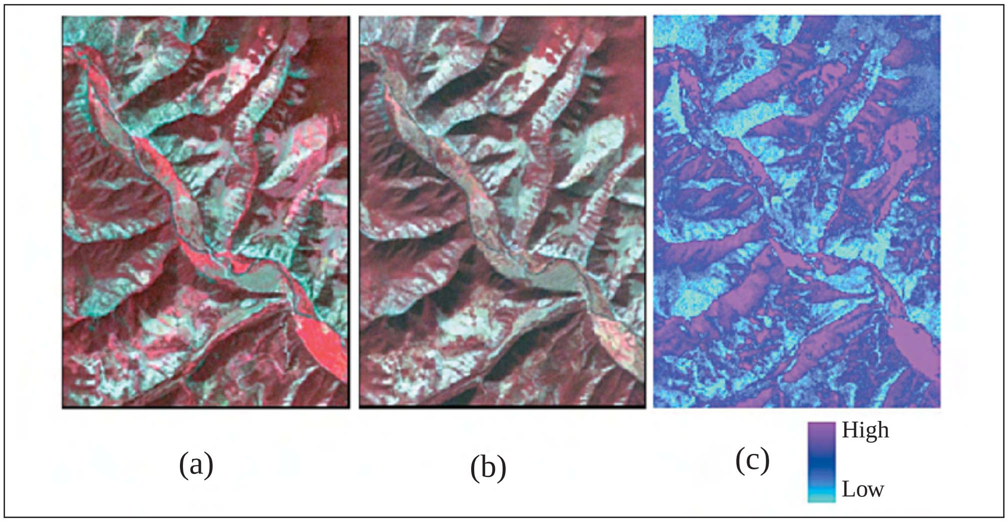
5.4 Change Detection

Change detection methodologies using digital data have been used extensively for a wide variety of analysis applications including: fire impact studies (Parra et al. 1996), land cover change in wetland areas (Hashem et al. 1996; Mahlke 1996), air pollution damage detection (Hogda et al. 1995; Solheim et al. 1995), and forest-canopy change (Coppin and Bauer 1994, 1995). Within the context of the vegetation mapping objectives R1-VMP, the change detection method is designed to exploit phenological differences in vegetation types (i.e., deciduous tree or shrub species dominance types or senescent grasses and forb species dominance types).

The R1-VMP change detection procedure, like most digital change detection procedures, must assess differences between multitemporal datasets and also separate changes of interest from those that are irrelevant to the mapping objectives. The maximization of the signal-to-noise ratio and the extraction of relevant multispectral features related to the biophysical characteristics of vegetation canopies are essential to identification of meaningful phenological differences (Ngai and Curlander 1994). Coppin and others (2001) note that preprocessing of satellite images prior to actual change detection is a critical step. They identify the goals of preprocessing as "the establishment of a more direct linkage between the data and biophysical phenomena (calibration), the removal of data acquisition errors and image noise, and the masking of contaminated and/or irrelevant scene fragments." The synopsis of procedures and their requirements for digital change detection presented by Coppin and Bauer (1996) comprise the basis of R1-VMP preprocessing.

Following preprocessing, single-band radiometric responses are often transformed to strengthen the relationship between spectral data and biophysical characteristics of vegetation canopy. Coppin and others (2001) demonstrated that a solid biophysical link is found between forest canopy features and the Kauth-Thomas transform, a particular case of a principal components analysis. The three main components of Kauth-Thomas variability are termed brightness, greenness, and wetness and are the result of a Gram-Schmidt orthogonalization process (Kauth and Thomas 1976). Changes in these three components constitute the basis of the R1-VMP analytical logic to exploit phonological differences in vegetation types (Figure 8).

Figure 8. *Changes in K-T greenness from multidate imagery. (a) July date; (b) October date; (c) degree of change between dates.*



5.5 Ecological Modeling and Other Ancillary Data

Ecological modeling and other ancillary data are used extensively by R1-VMP to improve classification results. These ecological modeling approaches are incorporated into the multisource system through knowledge-based classification and reference data stratification within the object-oriented image analysis software, eCognition (Baatz et al. 2001). This process facilitates the use of additional data such as potential vegetation settings, sub-section-level ecological units, topography, and image illumination strata for grouping or splitting classes to improve classification accuracy (Cibula and Nyquist 1987; Bolstad and Lillesand 1992; Cohen and Spies 1992; Brown et al. 1993; Coppin and Bauer 1994; Goodchild 1994).

One of the primary ecological modeling approaches used in R1-VMP incorporates data on potential natural vegetation (PNV). PNV is “the vegetation…that would become established if all successional sequences were completed without interference by man under the present climatic and edaphic conditions….” (adapted from Tuxen 1956 as cited in Mueller-Dombois and Ellenberg 1974). PNV classifications are based on existing vegetation, successional relationships, and environmental factors (e.g., climate, geology, soil, etc.) considered together. The PNV classifications within the R1-VMP project area include *Forest Habitat Types of Montana* (Pfister et al. 1977); *Forest Habitat Types of Northern Idaho: A Second Approximation* (Cooper et al. 1991); and *Grassland and Shrubland Habitat Types of Western Montana* (Mueggler and Stewart 1980). The PNV types and their associated biophysical settings have strong relationships with existing vegetation and therefore provide useful information in the image-classification process. The habitat types from these classifications were aggregated to 38 types and mapped by Jones and others (1998, 2002). R1-VMP further aggregated the 38 types to 10 types to facilitate the classification process.

In addition to PNV, R1-VMP incorporated two other biophysical variables: (1) two indices of insolation derived from combinations of slope and aspect generated from 30 meter DEM data, and (2) subsection-level delineations further subdividing the ecogeographic stratification described above and illustrated in figure 4 (McNab and Avers 1994).

R1-VMP also stratified the image data by the illumination at the time of image acquisition. This process results in three strata: (1) illuminated in both the "summer" and "fall" images; (2) nonilluminated in both the "summer" and "fall" images; and (3) illuminated in "summer" but nonilluminated in "fall." These strata improve the spectral relationships between vegetation types and reflectance values (Figure 9).

Additional ancillary information is provided by fire-severity data classifying recently burned areas (Figure 10). These data were operationally produced by the USDA Forest Service (Gmelin and Brewer 2002) following major fire events in 2000 and 2001, and are used to characterize first-order fire effects on vegetation. They are generated from a Normalized Difference Burn Ratio (NBR) analytical approach, following Key and Benson (1999) as adapted by Brewer and others (2003).

Figure 9. *Illumination strata. (a) Hillshade created from digital elevation model; (b) Illumination classes of surface for both dates of imagery.*

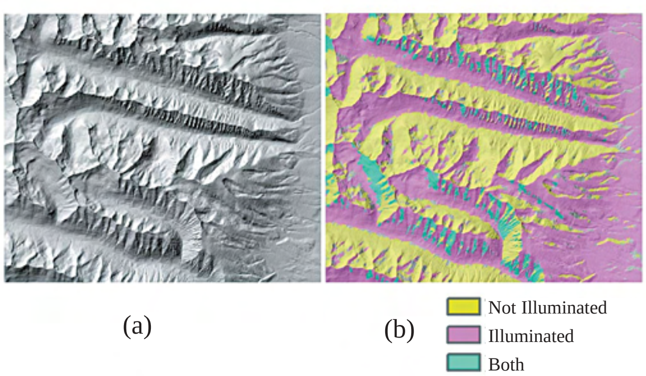
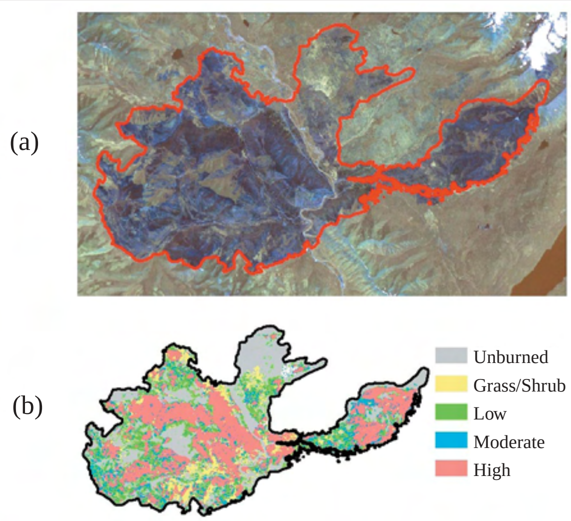


Figure 10. *Fire-severity data. (a) Post-fire image with fire scar and burn perimeter; (b) Fire-severity classes generated through a change detection process.*



5.6 Reference Data

In remote sensing projects, reference data serve two main purposes. First, reference data establish a link between variation on the ground and in the image. This link is necessary for assigning image-modeling units (pixels or regions) to discrete land-cover classes in the image classification process. Second, reference data help assess the accuracy of a map.

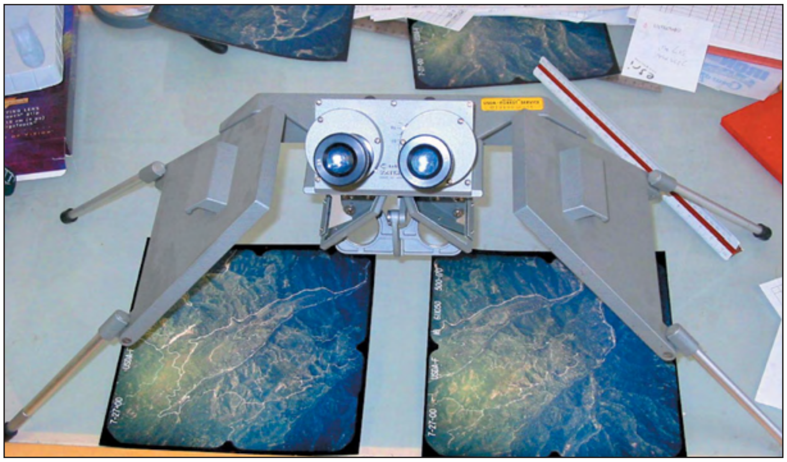
The most common sources of reference data for remote sensing projects are aerial photo interpretation and field data collection. It is quite common for remote sensing projects to use photo interpretation as a primary source of reference data or to combine these two sources. Numerous works illustrate the development and use of reference data (Strahler 1980; Shasby and Carneggie 1986; Cibula and Nyquist 1987; Fung and LeDrew 1987; Chuvieco and Congalton 1988; Leprieur and Durand 1988; Franklin and Peddle 1990; Janssen et al. 1990; Marceau et al. 1990; Cetin and Levandowski 1991; Loveland et al. 1991; Peddle and Franklin 1991; Bolstad and Lillesand 1992; Foody et al. 1992; Gong and Howarth 1992; Gong et al. 1992; Bauer et al. 1994; Coppin and Bauer 1994; Green et al. 1994; Woodcock et al. 1994; Cohen et al. 1995' Dikshit and Roy 1996; Shandley et al. 1996; Jakubauskas 1997; Johnston et al. 1997; Cross et al. 1988; Deppe 1998; and Lo and Watson 1998). Many of these studies used photo interpretation in conjunction with field sampling, while others relied exclusively on the photo interpretation to provide these reference data. Independent of the source of reference data, it is important to promote consistency between training and accuracy-assessment data. These sets should be of similar type and follow the taxonomic logic and data standards. For most projects, the same type of data is collected for training and accuracy-assessment applications.

In R1-VMP, training and accuracy-assessment data are generated through a structured aerial photo interpretation process (Appendix C) that integrates a variety of field sampled inventory datasets (Appendix D). Our experience suggests that an aerial perspective is often useful for remote sensing training data acquisition and that skilled interpreters can add local knowledge and experience to the classification process. Additionally, resource aerial photography remains the most commonly available remote sensing data source; however, we integrate high-resolution, multispectral data with resource photography where available.

This structured photo interpretation process provides an explicit mechanism for integrating existing field sample data from a variety of sources, both within the USDA Forest Service and from cooperating entities. Existing field data is screened to ensure data quality and currency using a standardized process. This provides the opportunity to benefit from the agency's substantial investment in field data while screening out data rendered unusable by management activities, disturbance agents, and/or time since collection. Through this process the image interpreter is able to "fit" field data and other ancillary data to the segmented imagery. This process accomplishes the same objective described by Robinson and Tilton (1991), but fits the training data to the segmentation rather than fitting the segmentation to the training data.

Common image interpretation techniques are used to characterize elements of vegetation pattern that comprise life form, dominance type, tree size class, and tree canopy cover (Avery 1977, Campbell 1987, Lillesand and Kiefer 1987, Lachowski et al. 1996). The variables collected include: life form/land-use class cover percent and connectivity; dominance type cover percent and connectivity; tree size class cover percent; tree canopy cover percent and connectivity, and total vegetation canopy cover percent (Figure 11).

Figure 11. *Stereoscope used in the reference data collection process.*



Field-sampled tree, vegetation composition, and ground-cover composition data were collected on a subset of a randomly selected set of region-polygons as a means to validate the photo interpretation reference data collection. Data were collected following Forest Service common stand exam (CSE) protocols and data was loaded into Field Sampled Vegetation (FSVeg) database. A comparison of the field-sampled data and the photo-interpreted data for tree dominance type, tree sizeclass and tree canopy cover is found in appendix E.

5.7 Hierarchical Classification

The Federal Geographic Data Committee (FGDC) Vegetation Classification Standards (1997) establishes a hierarchical existing vegetation classification with nine levels. The top seven levels are primarily based on physiognomy. The two lowest levels, alliance and association, are based on floristic attributes. The USDA Forest Service recently released the national direction for classification and mapping of existing vegetation to implement the FGDC standards and to provide direction for classifying and mapping structural characteristics (Brohman and Bryant 2005). This direction applies to a variety of geographic extents and thematic resolutions characterized as map levels. The Northern Region Vegetation Mapping Project is specifically designed to meet this national program direction at the mid-level.

Through the classification functionality of eCognition, a nested hierarchical classification scheme is applied that uses membership functions derived from knowledge bases for the physiognomic and structural classifications and fuzzy-set classifiers based on reference data and nearest neighbor algorithms for the floristic (dominance type) classification. This design provides a consistent linkage between the floristic and structural classifications commonly used by the agency at the mid-level and the physiognomic classifications used at the broad-level and national-level and required by the FGDC vegetation classification standards (Brohman and Bryant 2005).

Figure 12. *Hypothetical classification attributes (map units) and image objects.*

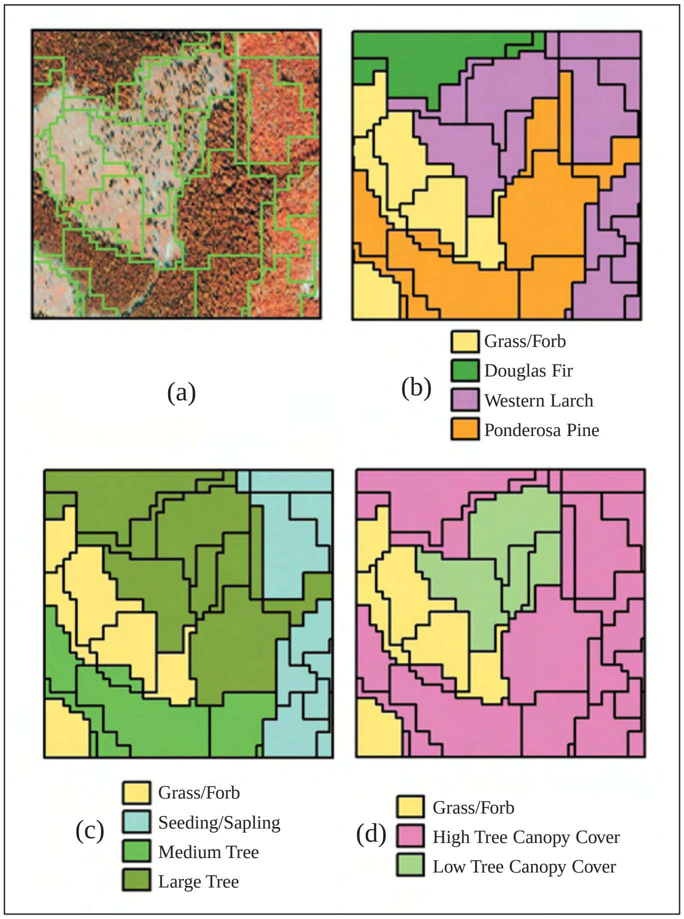
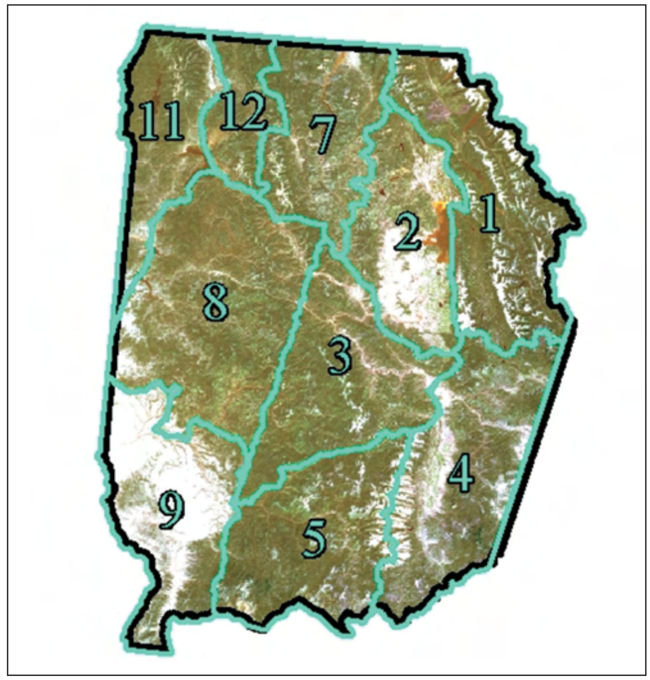


Figure 13. *Sub-path data model mosaic used for primary map products.*



Implementation of this classification hierarchy produces separate GIS coverages, grids and associated geospatial databases for four primary attributes. These attributes include: life form, dominance type, tree canopy cover, and tree size class. The hypothetical dominance type, tree size class, and tree canopy cover map products included in figure 12 illustrate the relationships of these attributes to the original image objects. These original image objects were merged following the minimum map feature standards from section 4.4. The merged image objects were then used to produce the GIS coverages and grids for the four primary map products. The original image objects with the four primary attributes could be obtained for analysis applications requiring different minimum map feature standards and/or different attribute combinations than those available from the R1-VMP deliverable map products. For information and assistance contact Northern Region, Engineering Staff; Geospatial Group. No coverage and grid combining the four attributes was produced through R1-VMP. The analytical logic used to combine these attributes should be based on intended analysis objectives. Any combination of these four primary map products could be produced to meet specific analysis objectives, with the logic of the combination defined by the end user. It is expected that a combined coverage and grid will be required to meet a variety of general analysis objectives and business needs. The specific process and logic used to produce this combined product will be defined by the Northern Region Vegetation Council and released as a map product following its completion.

5.8 Mosaic Subpath Data Models

The sub-path data models described in section 5.2 and processed as described in sections 5.3 through 5.7 were clipped and merged to create continuous GIS coverages and grids for the four primary map products. The clip and merge process created non-overlapping model boundaries (Figure 13) within the overlap zones form the original sub-path data models.

5.9 Accuracy Assessment

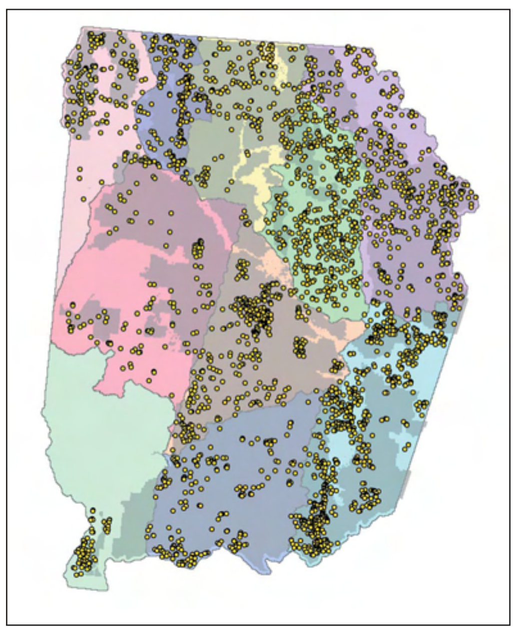
Accuracy assessments are essential parts of all remote sensing projects. First, they provide the basis to compare different methods and/or sensors. Secondly, they provide information regarding the reliability and usefulness of remote sensing techniques for a particular application. Finally, and most importantly, accuracy assessments support the spatial data used in decision-making processes. Too often vegetation and other maps are used without a clear understanding of their reliability. A false sense of security about the accuracy of the map may result in an inappropriate use of the map and important management decisions may be made on data with unknown and/or unreliable accuracy. Although quantitative accuracy assessment can be time-consuming and expensive, it must be an integral part of any vegetation-mapping project.

Accuracy, however, is not a state variable. It is very important to evaluate the results of any accuracy assessment in the context of the intended analysis application and the management decision the data and analyses are intended to support. This evaluation needs to balance the desired level of precision (i.e., the level of thematic detail) with the desired level of accuracy. For many analyses, detailed thematic classes are aggregated to produce fewer, less detailed and more accurate classes. It is appropriate in these instances to assess the accuracy of the aggregated classes rather than characterize the aggregations with the detailed assessment. It may even be appropriate to aggregate some classes based on the structure of the error, provided that the aggregations meet the analysis objectives. It is also important to determine the level of uncertainty that is acceptable to support a particular management decision. Many management decisions are based on the relative ranking of alternatives rather than the absolute differences. Conversely, some simulation modeling applications are better served by more precise (thematically detailed) data than by more accurate generalized data. These modeling applications are often used to establish long-term vegetation pattern and process relationships. These models generally perform better with a more detailed representation of vegetation patterns.

The dominance type map unit design process described in section 4.1 produced slightly different sets of map units for each model reflecting the ecological differences in these models. Combining the map units for each model resulted in 36 unique dominance types. An objective evaluation of the map accuracy of R1-VMP dominance types illustrated the nature and magnitude of map error associated with this large set of map units and suggested logical aggregations of map units to achieve reasonable accuracy for the regional product. The R1-VMP dominance type map product represents a general-purpose aggregation from 36 to 16 types that are suitable for most analysis applications. It is important to recognize, however, that the structure of the error varied by dominance type and between models. Therefore, forests and/or planning zones may aggregate dominance types differently depending on the intended analysis application and the geographic extent of the analysis area. The hierarchical classification logic used in R1-VMP allows for a relatively simple aggregation of types and recalculation of accuracy for analysis objectives that are not well served by the general-purpose product provided. The accuracy assessment documentation for the R1-VMP dominance type map product is included in appendix E.

Quantitative accuracy assessment depends on the collection of reference data. Reference data is known information of high accuracy (theoretically 100% accuracy) about a specific area on the ground (the accuracy assessment site). The assumed-true reference data can be obtained from ground visits, photo interpretations, video interpretations, or some combination of these methods. R1-VMP used the reference data process described in section 5.6 with a random sample design following Czaplewski (1999). R1-VMP training and accuracy assessment data are generated through a structured aerial photo interpretation process that integrates a variety of field sampled inventory datasets. Our experience suggests that an aerial perspective is often useful for remote sensing training data acquisition and that skilled interpreters can add local knowledge and experience to the accuracy assessment process. Additionally, collecting enough field observations is so prohibitively expensive that valid map evaluation cannot be conducted. R1-VMP followed a random selection process for accuracy assessment regions. However, the photo interpretation process was limited to areas with resource aerial photography coverage. The accuracy assessment locations are illustrated in figure 14.

Figure 14. *Accuracy assessment region locations used for primary map products.*



In a map accuracy assessment sites are generally the same type of modeling unit used to create the map (image objects as well as image objects merged to a specified minimum map feature in R1-VMP map products). Accuracy assessment involves the comparison of the categorized data for these sites (*i.e.*, image objects and merged objects) to the reference data for the same sites. The error matrix is the standard way of presenting results of an accuracy assessment (Story and Congalton 1986). It is a square array in which accuracy assessment sites are tallied by both their classified category in the image and their actual category according to the reference data. The following table provides a hypothetical example error matrix to illustrate accuracy assessment concepts and relationships (actual R1-VMP error matrices are provided in Appendix E). Typically, the rows in the matrix represent the classified image data, while the columns represent the reference data. The major diagonal, highlighted in the following table, contains those sites where the classified data agree with the reference data.

The nature of errors in the classified map can also be derived from the error matrix. In the matrix, errors (the off-diagonal elements) are shown to be either errors of inclusion (commission errors) or errors of exclusion (omission errors). Commission errors are shown in the off-diagonal matrix cells that form the horizontal row for a particular class. Omission error is represented in the off-diagonal vertical row cells. High errors of omission/commission between two or more classes indicate confusion between these classes (Story and Congalton 1986).

Useful measures of accuracy are easily derived from the error matrix.

- Overall accuracy, a common measure of accuracy, is computed by dividing the total correct samples (the diagonal elements) by the total number of assessment sites found in the bottom right cell of the matrix.
- Producer's accuracy, which is based on omission error, is the probability of a reference site being correctly classified. It is calculated by dividing the total number of correct accuracy sites for a class (diagonal elements) by the total number of reference sites for that class found in the bottom cell in each column.
- User's accuracy, which is based on commission error, is the probability that a map feature on the map actually represents that category on the ground. User's accuracy

		Reference data				
		Tree dominated	**Shrub dominated**	**Herbaceous/ nonvascular dominated**	**Sparsely vegetated**	**Row total**
Classified data	**Tree dominated**	**65**	4	22	24	115
	Shrub dominated	6	**81**	5	8	100
	Herbaceous/ nonvascular dominated	0	11	**85**	19	115
	Sparsely vegetated	4	7	3	**90**	104
	Column total	75	103	115	141	**434**

Overall Accuracy = 321/434 = 74 percent

Producer's Accuracy
Tree Dominated = 65/75 = 87 percent
Shrub Dominated = 81/103 = 79 percent
Herb/Non-vasc. Dominated = 85/115 = 74 percent
Sparsely Vegetated = 90/141 = 64 percent

User's Accuracy
Tree Dominated = 65/115 = 57 percent
Shrub Dominated = 81/100 = 81 percent
Herb/Non-vasc. Dominated = 85/115 = 74 percent
Sparsely Vegetated = 90/115 = 87 percent

is calculated by dividing the number of correct accuracy sites for a category by the total number of accuracy assessment sites, found in the right-hand cell of each row, that were classified in that category.

Confidence intervals are a commonly reported component of statistical estimates. They provide the user additional information regarding the reliability of the map product. Confidence intervals are included for each of the R1-VMP accuracy assessments.

It is often useful to evaluate these measures of accuracy relative to the aerial extent of each class. For example, when a particularly common class (e.g., 50-75% of the map area) has either a very high or a very low accuracy it has a disproportionate effect on the utility of the map for general analysis applications without a corresponding effect on the accuracy assessment. Conversely, a relatively rare type (e.g., 1-2% of the map area) regardless of its accuracy has relatively little effect on the utility of the map for general analysis applications but has the same effect on the accuracy assessment as the common type. For this reason, the R1-VMP accuracy assessment error matrices include proportions of area represented by each class.

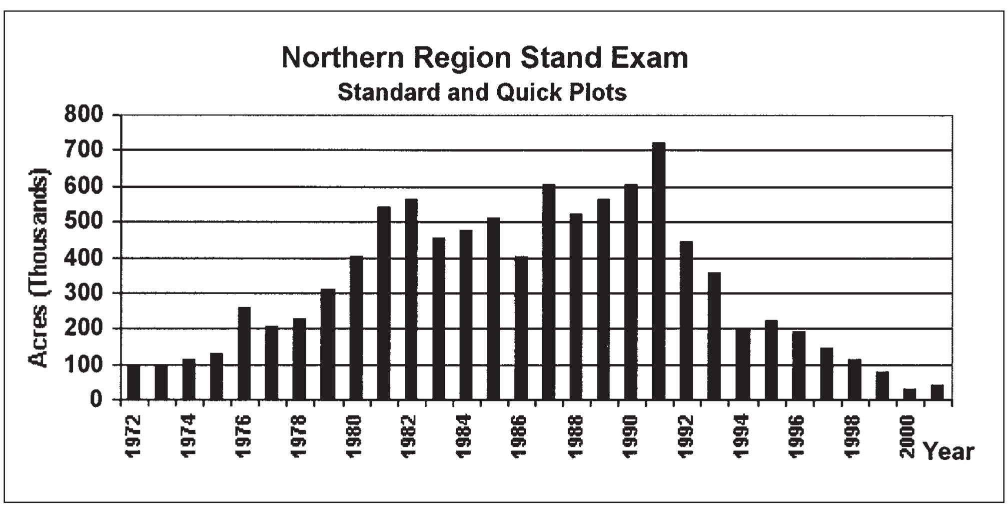
A relatively recent innovation in accuracy assessment is the use of fuzzy sets for accuracy assessments. Traditional accuracy assessment, as described above, suffers from certain limitations. First, it assumes that each accuracy site can be unambiguously assigned to a single map category (Gopal and Woodcock 1994); when in truth it may be part of a continuum between map categories. Secondly, the traditional error matrix makes no distinction between magnitudes of error. For example, in a traditional error matrix, misclassifying "Ponderosa pine dominance type" as "Intolerant mixed conifer dominance type" carries the same weight as the error of misclassifying it as "water." Fuzzy logic is designed to handle ambiguity and, therefore, constitutes the basis for part of the R1-VMP accuracy assessment. Instead of assessing a site as correct/incorrect as in a traditional assessment, an assessment using fuzzy sets can rate a site as absolutely wrong, understandable but wrong, reasonable or acceptable match, good match, or absolutely right (Gopal and Woodcock 1994). The resulting accuracy assessment can then rate the seriousness of errors as well as absolute correctness/incorrectness. For these reasons, the R1-VMP accuracy assessments for life form and dominance type include fuzzy set-based error matrices as well as the "fuzzy weights" used to convert the "straight up" error matrix.

6.0 Vegetation Inventory

The vegetation inventory data for most land management agencies and private companies only partially covers their ownership, are often out of date, and are rarely compatible with adjacent landowners. This is particularly true for federal land management agencies such as the USDA Forest Service, Northern Region, that manage large geographic areas for a variety of management objectives. Historically, most ground-based inventory data have been collected using standard plot and quick plot stand exams, as defined by the Timber Management Control Handbook (USDA Forest Service, FSH 2709). Using the USDA Forest Service, Northern Region, as an example, Brewer and others (2002) observed that most of these data apply almost exclusively to the suitable timber base, as defined by the National Forest Management Act of 1976 (US Public Law 94-588 1976). The remaining areas outside the suitable base have few stand exam data even though many of the resource questions and issues apply to all lands. The collection of stand-based data on part of the land base introduces an unknown bias when these data are used to represent the whole land base. In addition, there are no specific design considerations for the collection and storage of these data to facilitate their use by other land management agencies or private landowners.

Declining budgets for public land management agencies have resulted in dramatic reductions in the amount and geographic extent of current, detailed inventory data. The precipitous decline in standard plot and quick plot stand exams reflects budget trends for inventory programs throughout the USDA Forest Service. Brewer and others (2002) describe the effects of these reductions on current data and graphically depict the status of stand exam based inventory data for the USDA Forest Service, Northern Region (Figure 15). This graph illustrates the decline in acreage of stand exams, by year, from 1980 to 2001.

Figure 15. *USDA Forest Service, Northern Region, stand exam program status summary for 1980-2001.*



Reductions in timber sale programs on public lands, particularly National Forests, have had effects on the management (*i.e.*, harvest schedules) of both industrial and non-industrial private forests (Flowers *et al.* 1993). This change in harvest schedules has affected the currency and completeness of inventory data from private forests; proprietary data private forest landowners are reluctant to share.

Given the discontinuous and incomplete nature of most forest inventory data, as well as the difficulty in maintaining currency and sharing with other landowners, data generated by the Forest Inventory and Analysis (FIA) program of the USDA Forest Service provides a viable alternative. FIA utilizes a systematic random grid of plot clusters, remeasured periodically, to monitor the extent, condition, uses, impacts of management, and health of forest ecosystems across all ownerships in the United States. These data provide an unbiased sample for many inventory related questions. The Society of American Foresters (2000) state that "FIA is the only program that monitors the extent, condition, uses, impacts of management, and health of forest ecosystems across the United States." They further state… "FIA data serve as the foundation of large-scale policy studies and perform a pivotal role in public and private forest planning." They cite examples of regional and sub-regional analyses that influence major economic and ecological management decisions including:

- Strategic planning efforts by wood-using industries routinely incorporate FIA data into timber supply and timber product outputs.
- Development of criteria and indicators of forest sustainability depend on the growth removals, and inventory data compiled by FIA (Reams *et al*. 1999).
- National forest carbon budgets for reporting under international agreements are dependent on FIA data (Heath and Birdsey 1997).
- Assessment of ecological change and economic damage resulting from disasters such as hurricanes or widespread wildfires.

Van Deusen and others (1999) suggest a current and accurate forest ecosystem inventory is prerequisite to substantive discussion of issues like sustainability, national forest policy, carbon sequestration, changes in growth and productivity, changes in landuse and demographics, ecosystem health, and economic opportunities in the forest sector.

Over the past decade concerns have been raised regarding the currency of FIA data, historically remeasured every 6 to 18 years (Gillespie 1999). These concerns prompted the American Forest and Paper Association (AF&PA) to convene two Blue Ribbon Panels on FIA (AF&PA 1992, 1998). The high level of user community support and concerns regarding currency of FIA data surfaced by these panels and subsequent Congressional hearings resulted in legislation to implement an annualized forest inventory and monitoring program to reduce the remeasurement interval (Czaplewski 1999). It is expected that the annualized inventory design will result in substantial improvements in the currency of FIA data.

Historically, the FIA program produced area estimates of forest types in two phases following a double sampling design (Reams and VanDeusen 1999). Phase one placed a systematic random grid on aerial photography (normally 1:40,000 scale National Aerial Photography Program NAPP). These points (with a minimum area of at least 1 acre or a strip at least 250 feet wide) were then classified as forest or non-forest based on the FIA definition of at least 10% tree canopy cover. The second phase subsampled the first phase points in the field to confirm the classification. This process provided the forest area estimation for the application of the field sampling of the permanent plot clusters in the third phase. Reams and VanDeusen (1999) suggest the following three problems associated with this historical method:

- No forest non-forest map is produced
- The photo interpretation process is time-consuming and labor intensive
- Current aerial photography is not always available

These issues become increasingly problematic with the shift to an annualized inventory program. R1-VMP utilizes FIA data for two important processes. In the map unit design process FIA data are classified and utilized to estimate abundance of dominance types. These estimates are used to define the dominance types with sufficient aerial extent to include as a map unit and to identify logical aggregation strategies for dominance types with insufficient extents. The FIA data are also used for the development of sample-based Map Unit Descriptions (MUDs). In this process the FIA data are spatially associated to the R1-VMP map products and are then compiled to quantify various vegetation characteristics for each of the thematic classes in the map product (*e.g.*, dominance types or tree diameter classes). The map unit descriptions for the primary map products from R1-VMP are included in appendix F. Similar MUDs could be developed for any map products derived from R1-VMP data.

7.0 Maintaining Existing Vegetation Maps and Associated FIA Data

One key element to planning, inventory and monitoring success is the establishment of consistent vegetation baseline information. Once established, changes to vegetation can be determined along with cause of change. This information provides monitoring data to analyze the effects of change in condition of wildlife habitats, late successional old growth, forest health, mortality, growth, and standing forest volumes. Vegetation maps, when combined with ground-based inventories information, are fundamental to meet the needs of Forest and Rangeland Resources Planning Act (RPA), Forest Land and Resource Management Plans, bioregional assessments, and more localized watershed and project planning efforts. To understand vegetation changes on the landscape and its affect on related natural resources, it is necessary to track changes as well as cause of change for comparing to baseline inventories. Tracking imagery source and dates of baseline maps as well as update imagery source and date are necessary metadata. Cause of change is also important to know and aids in analysis of affected resources, such as wildlife habitat or cumulative watershed impacts.

The goal for vegetation resource information, stated in the Existing Vegetation Classification and Mapping Technical Guide (Brohman and Bryant 2005), is to have vegetation maps no older than 5 years. Map areas require updates where changes to vegetation have occurred from various causes, such as wildfire, harvest, insect and disease damage, vegetation treatments, re-growth, agriculture or other type conversions. Activity databases, aerial detection surveys, and fire severity mapping, along with digital change detection methods are useful in identifying where updates need to occur, as well as determining causes of changes in vegetation cover.

This maintenance and update strategy is designed to work with the forests and other cooperating entities to annually identify areas of changed conditions for systematic updates of the R1-VMP data. The coordination work will occur near the end of each field season (late-September/early-October) to facilitate both a field and office review. These reviews, along with other feedback throughout the year, will identify the priority areas for the next fiscal year program of work. Once the identified areas of changed condition are updated (within the limits of budget and resources), the R1-VMP data will be re-released annually on April 1st of each year.

It is expected that the Remote Sensing Applications Center (RSAC) will continue its support of the Burned Area Emergency Recovery (BAER) teams with the production of Burned Area Reflectance Classifications (BARC). The BARC data, with local interpretation and correction, will provide part of the basis for large fire activity updates. It is also expected that the Cooperative Forestry and Forest Health Protection staff will continue to provide Aerial Detection Survey (ADS) data for areas included in the current year's program of work. The ADS data, with local interpretation and correction, will provide part of the basis for insect, pathogen, and climate disturbance activity updates. Systematic digital change detection (following Coppin *et al*. 2001) coupled with activity records for National Forest System lands can provide part of the basis for silvicultural activity updates. Areas identified through theses processes can be spatially associated with the FIA plot locations and provide information for the following year's annualized inventory program of work.

By design, R1-VMP had extensive local involvement and review by the Forests as well as other cooperators. However, there will be systematic and non-systematic errors identified once these data are used operationally. This maintenance strategy also includes a "correction" component for addressing errors that were not identified during production and reviews. Additionally, this process could provide a mechanism for adding data elements to R1-VMP that were not in the original design or deliverable products. These additional data elements could result in adaptations of base products for specific analysis objectives or new specifically designed map products.

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Appendix 3D

Metadata Development Questions

This appendix was taken from the following U.S. Geological Survey Web site: http://geology.usgs.gov/tools/metadata/tools/doc/ctc/.

Metadata in Plain Language

Introduction

This document provides a general interview approach for creating metadata. It is not necessarily exhaustive but is intended to convey in plain language the basic information that will be contained in the metadata and link to pages specifying the steps required to write that information into the metadata document itself. Questions in *italics* indicate the topics and are not to be answered explicitly; those that are in plain text, indented beneath them are the questions that need to be answered.

The Questions

1. What does the data set describe?

- a. What is the title of the data set?
- b. What geographic area does the data set cover?
- c. Does the data set describe conditions during a particular time period?
- d. Is this a digital map or remote-sensing image, or something different like tabular data?
- e. *How does the data set **represent** geographic features?*
    1. How are geographic features stored in the data set?
    2. What coordinate system is used to represent geographic features?
- f. *How does the data set **describe** geographic features?*
    1. What are the types of features present?
    2. For each feature, what attributes of these features are described?
    3. What sort of values does each attribute hold?
    4. For measured attributes, what are the units of measure, resolution of the measurements, frequency of the measurements in time, and estimated accuracy of the measurements?

2. Who produced the data set?

- a. Who created the data set?
    1. Formal authors of the published work.
    2. Compilers and editors who converted the work to digital form.

3. Technical specialists who did some of the processing but aren't listed as formal authors.
4. Cooperators, collaborators, funding agencies, and other contributors who deserve mention.

b. To whom should users address questions about the data?

3. Why was the data set created?

a. What were the objectives of the research that resulted in this data set?
b. What objectives are served by presenting the data in digital form?
c. How do you recommend that the data be used?
d. Are you concerned that nonspecialists might misinterpret the data? If so, of what aspects of the data set should they be especially wary?

4. How was the data set created?

a. *From what previous works were the data drawn?*
    1. Are the source data original observations made by the authors and their cooperators?
    2. Were parts of the data previously packaged in a publication or distributed informally?
    3. Were the source data published?
    4. Were the source data compiled at a particular scale?
    5. What time period do the source data represent?
    6. What information was obtained from each data source?
b. *How were the data generated, processed, and modified?*
    1. How were the data collected, handled, or processed?
    2. For this activity did you use data from some other source?
    3. Did this activity generate an intermediate data product that stands on its own?
    4. When did this processing occur?
    5. Did someone other than the formal authors do the data processing?
c. *What similar or related data should the user be aware of?*

5. How reliable are the data; what problems remain in the data set?

a. What can you say about the accuracy of the observations?
b. How accurately are the geographic locations known?
c. If data vary in depth or height, how accurately is vertical position known?
d. Where are the gaps in the data? What is missing there?
e. Do the observations mean the same thing throughout the data set?

6. How can someone get a copy of the data set?

a. Are there legal restrictions on access or use of the data?

b. Who distributes the data?

c. What is the distributor's name or number for this data set?

d. As a distributor, what legal disclaimers do you want users to read?

e. *How can people download or order the data?*

    1. In what formats are the data available?
    2. Can users download the data from the network?
    3. Can users get the data on disk or tape?
    4. Is there a fee to get the data?
    5. How long will it take to get the data?

f. What hardware or software do people need in order to use the data set?

g. Will these data be available for only a limited time?

7. Who wrote the metadata?

a. When were the metadata last modified?

b. Has this metadata record been reviewed or will it be reviewed in the future?

c. Who wrote the metadata?

d. To what standard are the metadata intended to conform?

e. If you specified any clock times in the metadata, did you use local time, GMT, or something else?

f. Are there legal restrictions on who can get or use the metadata?

Appendix 3E.

Standard Metadata Template

This appendix was taken from the U. S. Geological Survey Web site at http://geology.usgs.gov/tools/metadata/tools/doc/template.

FGDC Metadata Template

Metadata:

Identification_Information:
    Citation:
        Citation_Information:
            Originator:
            Publication_Date:
            Publication_Time:
            Title:
            Edition:
            Geospatial_Data_Presentation_Form:
            Series_Information:
                Series_Name:
                Issue_Identification:
            Publication_Information:
                Publication_Place:
                Publisher:
            Other_Citation_Details:
            Online_Linkage:
            Larger_Work_Citation:
                Citation_Information:
    Description:
        Abstract:
        Purpose:
        Supplemental_Information:
    Time_Period_of_Content:
        Time_Period_Information:

Single_Date/Time:
Calendar_Date:
Time_of_Day:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:
Time_of_Day:
Range_of_Dates/Times:
Beginning_Date:
Beginning_Time:
Ending_Date:
Ending_Time:
Currentness_Reference:
Status:
Progress:
Maintenance_and_Update_Frequency:
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate:
East_Bounding_Coordinate:
North_Bounding_Coordinate:
South_Bounding_Coordinate:
Data_Set_G-Polygon:
Data_Set_G-Polygon_Outer_G-Ring:
G-Ring_Point:
G-Ring_Latitude:
G-Ring_Longitude:
G-Ring:
Data_Set_G-Polygon_Exclusion_G-Ring:
G-Ring_Point:
G-Ring_Latitude:
G-Ring_Longitude:
G-Ring:
Keywords:
Theme:
Theme_Keyword_Thesaurus:
Theme_Keyword:
Place:
Place_Keyword_Thesaurus:
Place_Keyword:

Stratum:
Stratum_Keyword_Thesaurus:
Stratum_Keyword:
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword:
Access_Constraints:
Use_Constraints:
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:
Address:
City:
State_or_Province:
Postal_Code:
Country:
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Browse_Graphic:
Browse_Graphic_File_Name:
Browse_Graphic_File_Description:
Browse_Graphic_File_Type:
Data_Set_Credit:
Security_Information:
Security_Classification_System:
Security_Classification:
Security_Handling_Description:

Native_Data_Set_Environment:
Cross_Reference:
Citation_Information:
Originator:
Publication_Date:
Publication_Time:
Title:
Edition:
Geospatial_Data_Presentation_Form:
Series_Information:
Series_Name:
Issue_Identification:
Publication_Information:
Publication_Place:
Publisher:
Other_Citation_Details:
Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value:
Attribute_Accuracy_Explanation:
Logical_Consistency_Report:
Completeness_Report:
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value:
Horizontal_Positional_Accuracy_Explanation:
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report:
Quantitative_Vertical_Positional_Accuracy_Assessment:
Vertical_Positional_Accuracy_Value:
Vertical_Positional_Accuracy_Explanation:
Lineage:
Source_Information:

Source_Citation:
Citation_Information:
Originator:
Publication_Date:
Publication_Time:
Title:
Edition:
Geospatial_Data_Presentation_Form:
Series_Information:
Series_Name:
Issue_Identification:
Publication_Information:
Publication_Place:
Publisher:
Other_Citation_Details:
Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Source_Scale_Denominator:
Type_of_Source_Media:
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date:
Time_of_Day:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:
Time_of_Day:
Range_of_Dates/Times:
Beginning_Date:
Beginning_Time:
Ending_Date:
Ending_Time:
Source_Currentness_Reference:
Source_Citation_Abbreviation:
Source_Contribution:
Process_Step:
Process_Description:

Source_Used_Citation_Abbreviation:
Process_Date:
Process_Time:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:
Address:
City:
State_or_Province:
Postal_Code:
Country:
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Cloud_Cover:
Spatial_Data_Organization_Information:
Indirect_Spatial_Reference:
Direct_Spatial_Reference_Method:
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type:
Point_and_Vector_Object_Count:
VPF_Terms_Description:
VPF_Topology_Level:
VPF_Point_and_Vector_Object_Information:
VPF_Point_and_Vector_Object_Type:
Point_and_Vector_Object_Count:

Raster_Object_Information:
Raster_Object_Type:
Row_Count:
Column_Count:
Vertical_Count:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
Standard_Parallel:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Azimuthal_Equidistant:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Equidistant_Conic:
Standard_Parallel:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Equirectangular:
Standard_Parallel:
Longitude_of_Central_Meridian:
False_Easting:
False_Northing:
General_Vertical_Near-sided_Perspective:
Height_of_Perspective_Point_Above_Surface:
Longitude_of_Projection_Center:

Latitude_of_Projection_Center:
False_Easting:
False_Northing:
Gnomonic:
Longitude_of_Projection_Center:
Latitude_of_Projection_Center:
False_Easting:
False_Northing:
Lambert_Azimuthal_Equal_Area:
Longitude_of_Projection_Center:
Latitude_of_Projection_Center:
False_Easting:
False_Northing:
Lambert_Conformal_Conic:
Standard_Parallel:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Mercator:
Standard_Parallel:
Scale_Factor_at_Equator:
Longitude_of_Central_Meridian:
False_Easting:
False_Northing:
Modified_Stereographic_for_Alaska:
False_Easting:
False_Northing:
Miller_Cylindrical:
Longitude_of_Central_Meridian:
False_Easting:
False_Northing:
Oblique_Mercator:
Scale_Factor_at_Center_Line:
Oblique_Line_Azimuth:
Azimuthal_Angle:
Azimuth_Measure_Point_Longitude:
Oblique_Line_Point:
Oblique_Line_Latitude:

Oblique_Line_Longitude:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Orthographic:
Longitude_of_Projection_Center:
Latitude_of_Projection_Center:
False_Easting:
False_Northing:
Polar_Stereographic:
Straight-Vertical_Longitude_from_Pole:
Standard_Parallel:
Scale_Factor_at_Projection_Origin:
False_Easting:
False_Northing:
Polyconic:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Robinson:
Longitude_of_Projection_Center:
False_Easting:
False_Northing:
Sinusoidal:
Longitude_of_Central_Meridian:
False_Easting:
False_Northing:
Space_Oblique_Mercator_(Landsat):
Landsat_Number:
Path_Number:
False_Easting:
False_Northing:
Stereographic:
Longitude_of_Projection_Center:
Latitude_of_Projection_Center:
False_Easting:
False_Northing:
Transverse_Mercator:

Scale_Factor_at_Central_Meridian:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
van_der_Grinten:
Longitude_of_Central_Meridian:
False_Easting:
False_Northing:
Map_Projection_Parameters:
Grid_Coordinate_System:
Grid_Coordinate_System_Name:
Universal_Transverse_Mercator:
UTM_Zone_Number:
Transverse_Mercator:
Scale_Factor_at_Central_Meridian:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Universal_Polar_Stereographic:
UPS_Zone_Identifier:
Polar_Stereographic:
Straight-Vertical_Longitude_from_Pole:
Standard_Parallel:
Scale_Factor_at_Projection_Origin:
False_Easting:
False_Northing:
State_Plane_Coordinate_System:
SPCS_Zone_Identifier:
Lambert_Conformal_Conic:
Standard_Parallel:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Transverse_Mercator:
Scale_Factor_at_Central_Meridian:
Longitude_of_Central_Meridian:

Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Oblique_Mercator:
Scale_Factor_at_Center_Line:
Oblique_Line_Azimuth:
Azimuthal_Angle:
Azimuth_Measure_Point_Longitude:
Oblique_Line_Point:
Oblique_Line_Latitude:
Oblique_Line_Longitude:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Polyconic:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
ARC_Coordinate_System:
ARC_System_Zone_Identifier:
Equirectangular:
Standard_Parallel:
Longitude_of_Central_Meridian:
False_Easting:
False_Northing:
Azimuthal_Equidistant:
Longitude_of_Central_Meridian:
Latitude_of_Projection_Origin:
False_Easting:
False_Northing:
Other_Grid_System's_Definition:
Local_Planar:
Local_Planar_Description:
Local_Planar_Georeference_Information:
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:
Coordinate_Representation:
Abscissa_Resolution:

Ordinate_Resolution:
Distance_and_Bearing_Representation:
Distance_Resolution:
Bearing_Resolution:
Bearing_Units:
Bearing_Reference_Direction:
Bearing_Reference_Meridian:
Planar_Distance_Units:
Local:
Local_Description:
Local_Georeference_Information:
Geodetic_Model:
Horizontal_Datum_Name:
Ellipsoid_Name:
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name:
Altitude_Resolution:
Altitude_Distance_Units:
Altitude_Encoding_Method:
Depth_System_Definition:
Depth_Datum_Name:
Depth_Resolution:
Depth_Distance_Units:
Depth_Encoding_Method:
Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label:
Entity_Type_Definition:
Entity_Type_Definition_Source:
Attribute:
Attribute_Label:
Attribute_Definition:
Attribute_Definition_Source:
Attribute_Domain_Values:
Enumerated_Domain:

- Enumerated_Domain_Value:
- Enumerated_Domain_Value_Definition:
- Enumerated_Domain_Value_Definition_Source:
- Attribute:

Range_Domain:

- Range_Domain_Minimum:
- Range_Domain_Maximum:
- Attribute_Units_of_Measure:
- Attribute_Measurement_Resolution:
- Attribute:

Codeset_Domain:

- Codeset_Name:
- Codeset_Source:

Unrepresentable_Domain:

Beginning_Date_of_Attribute_Values:

Ending_Date_of_Attribute_Values:

Attribute_Value_Accuracy_Information:

- Attribute_Value_Accuracy:
- Attribute_Value_Accuracy_Explanation:

Attribute_Measurement_Frequency:

Overview_Description:

- Entity_and_Attribute_Overview:
- Entity_and_Attribute_Detail_Citation:

Distribution_Information:

- Distributor:
  - Contact_Information:
    - Contact_Person_Primary:
      - Contact_Person:
      - Contact_Organization:
    - Contact_Organization_Primary:
      - Contact_Organization:
      - Contact_Person:
    - Contact_Position:
    - Contact_Address:
      - Address_Type:
      - Address:
      - City:
      - State_or_Province:
      - Postal_Code:

Country:
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Resource_Description:
Distribution_Liability:
Standard_Order_Process:
Non-digital_Form:
Digital_Form:
Digital_Transfer_Information:
Format_Name:
Format_Version_Number:
Format_Version_Date:
Format_Specification:
Format_Information_Content:
File_Decompression_Technique:
Transfer_Size:
Digital_Transfer_Option:
Online_Option:
Computer_Contact_Information:
Network_Address:
Network_Resource_Name:
Dialup_Instructions:
Lowest_BPS:
Highest_BPS:
Number_DataBits:
Number_StopBits:
Parity:
Compression_Support:
Dialup_Telephone:
Dialup_File_Name:
Access_Instructions:
Online_Computer_and_Operating_System:
Offline_Option:
Offline_Media:
Recording_Capacity:

Recording_Density:
Recording_Density_Units:
Recording_Format:
Compatibility_Information:
Fees:
Ordering_Instructions:
Turnaround:
Custom_Order_Process:
Technical_Prerequisites:
Available_Time_Period:
Time_Period_Information:
Single_Date/Time:
Calendar_Date:
Time_of_Day:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:
Time_of_Day:
Range_of_Dates/Times:
Beginning_Date:
Beginning_Time:
Ending_Date:
Ending_Time:
Metadata_Reference_Information:
Metadata_Date:
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:
Address:

City:
State_or_Province:
Postal_Code:
Country:
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:

Appendix 3F.

Existing Vegetation Database Structure

The Existing Vegetation National GIS Standards by Map Level table was developed by Ralph Warbington, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, and can be used to identify where vegetation physiognomic class and subclasses are likely to intersect land use land cover classes, as indicated by an "x" in the intersecting cell. Cells remaining blank are those where the two classifications do not overlap; definitions are mutually exclusive for both classification systems. For example, consider water. Water is defined as open water and will not overlap with any vegetated class. However, a wetland is defined as having both water and vegetation, and overlaps with many vegetation physiognomic classes.

For *Existing Vegetation GIS Layer Descriptions for National, Broad, Mid and Base Levels*, visit http://www.fs.fed.us/emc/rig/index3.htm.

For *Reference Tables and Definitions*, visit http://www.fs.fed.us/emc/rig/index2.htm.

Existing Vegetation National GIS Standards by Map Level

Item	Base Level	Mid Level	Broad Level	National Level
Ecoregion Levels				
Domain	R	R	R	R
Division	R	R	R	R
Province	R	R	R	O
Section	R	R	O	O
Sub-section	R	R	O	O
Land Use and Cover Categories				
USGS Anderson 1	R	R	R	R
USGS Anderson 2 (optional core)	O	O	O	O
NVC Physiognomic Levels				
Division	R	R	R	R
Order	R	R	R	R
Class	R	R	R	R
Subclass	R	R[1]	O	O

R = required.
O = optional.
[1] Required if NVC Order is Tree or Shrub Dominated; optional for other Vegetated Orders.

Existing Vegetation National GIS Standards by Map Level *(continued)*

Item	Base Level	Mid Level	Broad Level	National Level
Floristic Levels and Attributes				
Broad and National Level Cover Types				
Total Vegetative CFA Class	O	O	O	O
SAF Cover Type	R[2]	R[2]	R[2]	O
SRM Cover Type	R[3]	R[3]	R[3]	O
Mid and Base Levels				
Vegetation Map Unit Description				
Aggregation Type (homogeneous, group, or complex)	R	R	N/A	N/A
Most Abundant Type	[4]	[4]		
Regional Dominance Type 1	R	R	O	N/A
Dominance Type Reference 1	R	R	O	N/A
NVC Alliance 1	R	O	N/A	N/A
NVC Association 1 (optional core)	O	N/A	N/A	N/A
Tree CFA Class 1	R[2]	R[2]	O	O
Tree Diameter Class 1	R[2]	R	O	N/A
Shrub CFA Class 1 (optional core)	0[5]	O	O	N/A
Second Most Abundant Type	[6]	[6]		
Regional Dominance Type 2	R	R	N/A	N/A
NVC Alliance 2	R	O	N/A	N/A
NVC Association 2 (optional core)	O	N/A	N/A	N/A
Tree CFA Class 2	O	O	N/A	N/A
Tree Diameter Class 2	O	O	N/A	N/A
Shrub CFA Class 2 (optional core)	O	O	N/A	N/A
Third Most Abundant Type	[7]	[7]		
Regional Dominance Type 3	O	O	N/A	N/A
NVC Alliance 3	O	O	N/A	N/A
NVC Association 3 (optional core)	O	O	N/A	N/A
Tree CFA Class 3	O	O	N/A	N/A
Tree Diameter Class 3	O	O	N/A	N/A
Shrub CFA Class 3 (optional core)	O	O	N/A	N/A
Metadata				
Data Source	R	R	R	R
Source Date	R	R	R	R
Map Update Cause	R	R	O	O
Created By	R	R	R	R
Created Date	R	R	R	R
Created In Instance	R	R	R	R
Modified By	R	R	O	O
Modified Date	R	R	O	O
Modified In Instance	R	R	O	O

R = required.
O = optional.
N/A = not applicable.
[2] If NVC order is Tree Dominated.
[3] If NVC order is Shrub or Herbaceous Dominated.
[4] Required regardless of aggregation type; used to assign all upper levels of NVC Physiognomic and National Cover Types.
[5] If NVC order is Shrub Dominated.
[6] Required only if the Aggregation Type is a group or complex.
[7] Optional; use if the Aggregation Type is a group or complex and is needed to describe vegetation within any particular map unit.

Appendix 3G.

Comparison of Anderson Land Use Classes with Physiognomic Class and Subclass

Use the following table (developed by Ralph Warbington, USDA Forest Service, Pacific Southwest Region) to identify where vegetation physiognomic class and subclasses are likely to intersect land use land cover classes indicated by an x in the intersecting cell. Blank cells are those where the two classifications do not overlap; definitions are mutually exclusive for both classification systems.

For example, consider water. Water is defined as open water and will not overlap with any vegetated class. A wetland, however, defined as having water and vegetation, overlaps with many vegetation physiognomic classes.

Relationship between Anderson 1 Land Cover Land Use Classification and FGDC Physiognomic Class and Subclass			Urban or built-up land	Agricultural land	Range land	Forest land	Water	Wetland	Barren land	Tundra	Perennial snow or ice
	Class code	Subclass code	1	2	3	4	5	6	7	8	9
Closed tree canopy											
Evergreen	TC	EV	x	x		x		x			
Deciduous	TC	DE	x	x		x		x			
Mixed	TC	MX	x	x		x		x			
Open tree canopy											
Evergreen	TO	EV	x	x		x		x			
Deciduous	TO	DE	x	x		x		x			
Mixed	TO	MX	x	x		x		x			
Sparse tree canopy											
Evergreen	TS	EV	x	x		x		x			
Deciduous	TS	DE	x	x		x		x			
Mixed	TS	MX	x	x		x		x			
Shrubland											
Evergreen	ST	EV	x	x	x			x		x	
Deciduous	ST	DE	x	x	x			x		x	
Mixed	ST	MX	x	x	x			x		x	
Dwarf shrubland											
Evergreen	SD	EV	x	x	x			x		x	
Deciduous	SD	DE	x	x	x			x		x	
Mixed	SD	MX	x	x	x			x		x	
Herbaceous—shrub steppe											
Perennial grass	HS	PG	x	x	x					x	
Perennial forb	HS	PF	x	x	x					x	
Annuals	HS	AN	x	x	x					x	
Hydromorphic	HS	HV	x	x				x		x	
Herbaceous grassland											
Perennial grass	HE	PG	x	x	x					x	
Perennial forb	HE	PF	x	x	x					x	
Annuals	HE	AN	x	x	x					x	
HydromorphicHE	HV		x				x		x		
Nonvascular											
Bryophyte	NV	BR							x	x	
Lichen	NV	LI							x	x	
Alga	NV	AL						x			
Sparsely vegetated											
Rock	SV	RC							x		
Boulders	SV	BG							x		
Unconsolidated material	SV	UM		x					x		
Urban and built-up	SV	UB	x								
Nonvegetated	XX	XX	x				x		x		x