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) Vegetation Classification Standard (1997) 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 2.25). 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 1.23.

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 (1997) Vegetation Classification Standard 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."

2.21 Vegetation Classification Process

The process of classifying vegetation types consists of a preliminary stage (ideally) done 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.

5. **Develop a sampling strategy** consistent with the classification criteria that will encompass the full range of environmental factors within 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.

    If the classification is inadequate go back to step 6 or 7 and repeat the cycle.
    If it does work well and meets documentation standards go to 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.

2.211 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 2.24 and 2.25).

1. Literature Review. 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. 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.

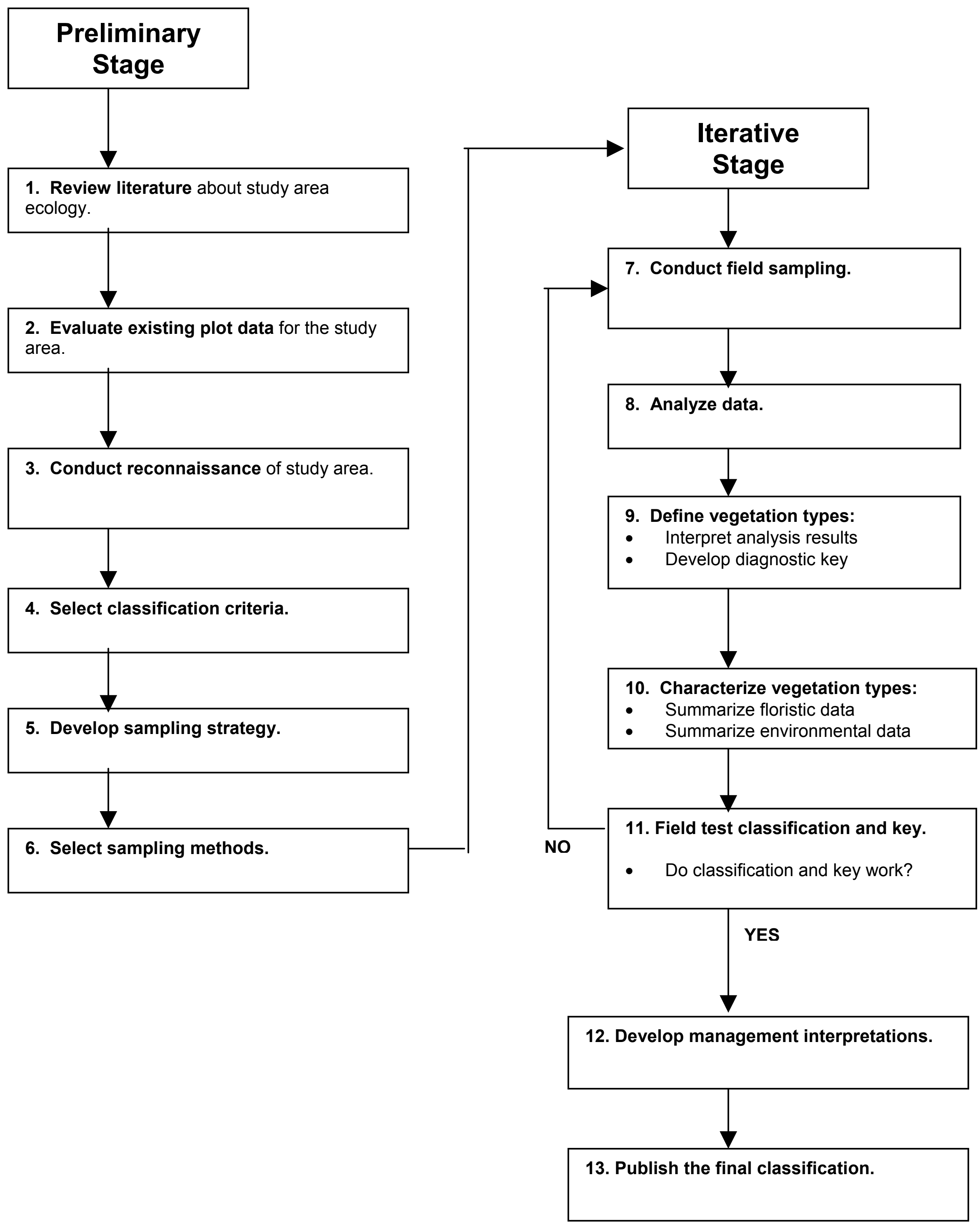

Figure 2.1. Flow diagram of vegetation classification process.

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 within 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.*, ugulates), keystone species (*e.g.,* beavers), and other species that may influence vegetation.

2. Evaluate Existing Plot Data. In addition to relevant literature, all plot data available for the study area should be reviewed and its usefulness to the vegetation classification project evaluated. Some plot data may be used directly to help develop the classification; while some 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. Reconnaissance. Reconnaissance is a matter 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). It is 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 can validly be used (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, then timber productivity data must be collected on at least a subset of the plots. Classification criteria for associations and alliances are described in sections 2.24 and 2.25, 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. The major environmental gradients identified through literature review and reconnaissance should be used to stratify the survey area for sampling. At a minimum, the study area can be stratified by elevation, landform, slope, aspect, geology, parent material, and vegetation patterns noted during reconnaissance (See Section 2.3.). Individual sample plots should be located within areas of uniform vegetation and environment (FGDC 1997, Jennings *et al*. 2003).

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, the sampling methods used in those studies should be given serious consideration. As noted in step 4 above, other uses of the plot data may require collection of additional attributes. Such additional attributes should be kept to 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.

2.212 Iterative Stage

The iterative stage implements the project plan developed in the preliminary stage. Gauch (1982) recommends a pilot study be done to refine the sampling and data analysis methods. The first year of a classification project usually serves as a pilot study whether intended or not. Refining your criteria and methods amounts to revisiting steps 4, 5, and 6 of the classification process and revising your project plan. Any changes should be carefully documented. Iterative refinement of a classification can continue, or be re-initiated, during vegetation mapping.

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

8. Data Analysis. The analysis procedures used by community ecologists are designed to detect patterns and relationships within 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 non-interpretable 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. Vegetation Type Definition. 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. The attributes that distinguish each group are used to develop a diagnostic key for field identification of the preliminary associations. The key is tested on the entire dataset and revised as needed. See section 2.7 for vegetation type description requirements.

10. Vegetation Type Characterization. Characterization entails describing the properties and components of a category or class. Once the vegetation types are defined, species composition and environmental data are summarized to characterize the types. A vegetation type description should describe 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 involves using the key and descriptions in the field to identify vegetation types. This is often done 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 documented as well. 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 land management decisions. Some interpretations depend solely on attributes of the existing vegetation and others are a function of successional relationships to other vegetation types. Once 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 gain 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. Once the classification is complete, a report should be published that includes vegetation type descriptions, diagnostic keys, and documentation of the sampling and analysis methods used to develop the classification. See section 2.7 for more details on the contents of the report. Peer review of the final manuscript is required and publication in a refereed forum is preferred in order to provide scientific credibility. The regional ecologist should oversee the peer review process and see that new vegetation types are added to the corporate database.

2.22 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; but hierarchical classifications also group those classes based on shared attributes. A hierarchy allows 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 within 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; 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*.

2.23 Vegetation Classification Criteria

Developing a classification system involves selecting criteria for defining and differentiating categories. The criteria used will 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, while bottom-up classifications typically incorporate many attributes. Vegetation classification systems have generally used two types of criteria – physiognomic and floristic.

2.231 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 are typically few-factored 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, *etc*.), 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, while structure describes the spatial arrangement of plants in more detail. "Physiognomy should not be confused with structure…" (Mueller-Dombois and Ellenberg 1974).

2.232 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. The amount of each plant taxon should be expressed as percent cover (FGDC 1997, Jennings *et al*. 2003). These three approaches should be distinguished 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*. The amount of each plant taxon should be expressed 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*. The proportion of each plant taxon should be expressed 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, but species amounts or proportions 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*. 2003). 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. These are defined as follows:

> **Dominant species** – "*the species with the highest percent of cover, usually in the uppermost … layer"* (Kimmins 1997 as cited in Jennings *et al*. 2003). 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*. 2003). 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*. 2003). 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*. 2003). Indicator species may represent either 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 is usually done 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*. 2003). The distributions of diagnostic species along environmental gradients may be used to evaluate the utility of a classification.

2.233 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 allows 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 as follows:

> **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, 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 (Daubemire 1968, SRM 1989). Neither can exceed 100% for a single species, but both can total over 100% 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%. For example, tree canopy closure and total vegetation canopy cover as described in section 3.222 cannot exceed 100%.

Foliar cover and canopy cover are "not necessarily correlated" (Daubenmire 1968) for either a species or a plant community. Consequently, one or the other should be used to develop a national vegetation classification. All Forest Service vegetation sampling for classification purposes must use canopy cover, not foliar cover, for the following reasons:

1. Canopy cover better estimates the "area that is directly influenced by the individuals of each species" (Daubenmire 1968).

2. Canopy cover, or canopy closure, is easier than foliar cover to estimate from aerial photos 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.

3. The majority of Forest Service legacy data for vegetation classification uses canopy cover instead of foliar cover.

2.24 Association Criteria

An **association** is *"a vegetation classification unit defined on the bases of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy"* (Jennings *et al*. 2003). 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. Habitat is not a classification criterion for existing vegetation, but 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 in order 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 associations can later be grouped into alliances and related to the physiognomic levels of the National Vegetation Classification Standard (NVCS) (FGDC 1997, Jennings *et al*. 2003). The minimum amount of plot data needed for classifying associations is described in section 2.261.

2.25 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*. 2003). 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 prior to completing classification of associations, an interim top-down approach to classifying "alliances" may be needed. The FGDC Vegetation Classification Standard (FGDC 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*. 2003)

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*. 2003).

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 requires 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 Forest Inventory and Analysis (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:

1. 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 (2002).

2. Society of American Foresters (SAF) Forest Cover Types based on plurality of basal area (Eyre 1980). SAF types apply only to stands with 25% or more canopy cover of trees.

3. 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 non-forested vegetation.

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

2.26 Classification Standards

Establishment of a new association, alliance, or dominance type requires that the vegetation type be adequately sampled, 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.

2.261 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 is needed 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) less 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 2.32.

2.262 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 the user has only to select one or the other. Following is a simple example of a dichotomous key:

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 MOUNTIAN-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**

It should be noted that diagnostic keys generally do not exist for the published dominance types described in Section 2.25 (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. See the key to sagebrush alliances developed by Reid *et al*. (2002) for an example.

2.263 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:

1. Synthesis tables (summaries of constancy and mean cover by species for each type).
2. Association tables (individual plot data for each type).
3. 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.

2.31 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 (PRISM at http://www.ocs.orst.edu/prism/prism_new.html, Daymet at 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 in order to minimize bias. Stratification into finer vegetation units requires detailed knowledge of the study area based on intensive reconnaissance (Mueller-Dombois and Ellenberg 1974).

2.32 Plot Location

Plots may be located within sampling strata either preferentially (Gauch 1982, Jennings *et al*. 2003) or objectively (Mueller-Dombois and Ellenberg 1974). Preferential sampling locates plots within areas with relatively uniform physiognomy, floristic composition, and environmental conditions. Objective sampling locates plots systematically or randomly within strata. The objective approach is also called representative sampling (Jennings *et al*. 2003).

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 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). There is no completely objective way to evaluate homogeneity, but the following guidelines have been successfully used by ecologists for many years (Mueller-Dombois and Ellenberg 1974, Gauch 1982):

1. The plot should not include any obvious change in physiognomy.

2. The predominant taxa in each vegetation layer should be consistently distributed across the plot.

3. 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 then samples cannot be located in stands that lack suitable site trees. An otherwise acceptable stand might be rejected for sampling because the trees are infected with mistletoe.

Representative sampling employs systematic or random location of plots within 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*. 2003). It is a form of stratified random sampling which 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*. 2003), 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 GPS) and metadata.
4. List all the plant species present within 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 2002a) and line intercept (USDA Forest Service 2002b) 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 compared to macroplot sampling (Jennings *et al*. 2003). The cover-frequency and line intercept methods are not compliant with the FGDC (1997) Vegetation Classification Standard (VCS) because they do not accommodate all the physiognomic attributes required to crosswalk data to the NVCS physiognomic hierarchy.

2.41 Plot Size and Shape

Plots should be small enough to be efficient, yet large enough to include most of the species present within the community. Pre-sampling tests should be conducted by listing the species present in a set of nested plots of increasing area. The required minimum plot size 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 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). Several common plot sizes and the temperate vegetation types in which they are commonly used are shown in Table 2.2. 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.

It is acceptable to adjust the plot shape to fit within the homogeneous area to be sampled. Staying within 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 within the vegetation stand. Plot size should not be adjusted on steep slopes in order to avoid over-estimating canopy cover as compared to plots on level ground (Mueller-Dombois and Ellenberg 1974). See Appendix 2A for instructions for recording plot area and dimensions.

2.42 Identification of Life Forms and Layers

Canopy cover of major life forms is required to describe vegetation structure, to crosswalk plot data and vegetation types to the FGDC physiognomic hierarchy (FGDC 1997, Jennings *et al*. 2003), 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 2.491.

Table 2.2. Commonly Used Macroplot Sizes

Standard Plot Area	Equivalent Plot Area	Plot Dimensions		Default Plot Dimensions or Shape	Temperate vegetation types where commonly used
		Radius of Circular Plot	Side of Square Plot		
50 m^2	~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 m^2	~1/40 ac	5.6 m 18.5 ft	10.0 m 32.8 ft	10 x 10 m square	
375 m^2 **(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 & Woodland Riparian Large Shrubland
400 m^2	~1/10 ac	11.3 m 37.0 ft	20.0 m 65.6 ft	20 x 20 m square	
1/10 ac	~405 m^2	11.4 m 37.2 ft	20.1 m 66.0 ft	circular	
500 m^2	~1/8 ac	12.6 m 41.4 ft	22.3 m 73.3 ft	circular	
800 m^2	~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 m^2	16.1 m 52.7 ft	28.4 m 93.3 ft	circular	
1000 m^2	~1/4 ac	17.8 m 58.5 ft	31.6 m 103.7 ft	20 x 50 m rectangular	High-diversity Forests
2500 m^2	~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

2.421 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 within the vertical projection of the outermost perimeter of the natural spread of foliage of plants of that life form (Section 2.233). 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 equal to or greater than 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 which 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 – "V*ascular 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 – *Non-aquatic 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 – *Non-aquatic, non-graminoid herbs with relatively broad leaves and/or showy flowers* (adapted from FGDC 1997). Includes both flowering and spore-bearing, non-graminoid herbs.

Section 2A.22 of Appendix 2A includes instructions for recording canopy cover by life form on the Vegetation Composition field form.

2.422 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. See Section 2A.242 of Appendix 2A for detailed instructions for recording these attributes on the Vegetation Composition form. Percent canopy cover, predominant tree height, predominant crown height, and predominant diameter (Section 2.423) must be estimated for the following 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 which 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 greater than or equal to 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 sub-layers in order to describe vegetation structure in more detail:

Supercanopy (TOSP) – Scattered overstory trees that clearly rise above the main canopy.

Main Canopy (TOMC) – The 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 sub-layers may not be present. Record percent canopy cover, the predominant or prevailing tree height, predominant crown height, and the predominant diameter of each sub-layer. 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 sub-layers:

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 1meter (3.3 feet).

Seedlings (TRSE) – Regenerating trees less than 1.4 meter (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 non-established classes. The criteria for established seedlings may vary by species and by Region. Required and optional tree and shrub layers are summarized in Table 2.3.

2.423 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 over 5 meters in height but clearly multi-stemmed.)

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 lifeform. See section 2.491 for more information.

2.43 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 within the plot area, except when sampling narrow riparian communities. In such riparian communities overhanging trees rooted outside the community (across an ecotone) should not be included in the species list.

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) Non-Established (TRSEN)
Shrubs (S)		Tall Shrubs (ST) Medium Shrubs (SM) Low Shrubs (SL)

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% when a measurement would show it to be 3%. It is vital that field employees are 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 flora(s) 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 (% cover, life form, *etc*.).

2.44 Species Canopy Cover Data

Estimate the total canopy cover of each species using the procedure in Section 2.45. For tree species, estimate its canopy cover within the overstory and regeneration layers in addition to total cover for the species. Assign each species within the macroplot an appropriate life form and life form modifier as defined in Section 2.491. Each species may belong to only one life form.

It is recommended (but not required) that canopy cover be estimated for each tree species within each of optional sub-layers. Doing so provides approximate relative age distributions for tree species (Daubenmire 1968, Mueller-Dombois and Ellenberg 1974), which can be used to roughly describe past succession within the stand. Since size-age relationships are not constant, such data should be interpreted with caution and supplemented with actual age data (Harper 1977).

2.45 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 within the plot as follows:

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

Do not record species that do not occur in the plot, but are present in the stand, in the species list. 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, then a larger plot size should be used.

Table 2.4 lists commonly used plot sizes and the dimensions of squares representing 1% and 5% of the plot area. Canopy cover can be consistently estimated by walking through a macroplot and counting the number of 1% or 5% units of a species present within the plot. Canopy cover for life forms, layers, or size classes can be similarly estimated. Estimates should be crosschecked with one another for consistency and help account for overlap between layers within a life form or species, species within a layer, *etc*. 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 2.491.

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 ocular estimates by periodically sampling with cover-frequency transects or line intercept methods (USDA Forest Service 2002a and 2002b). When using the

Table 2.4. Plot Sizes and Dimensions of Squares Equaling 1% and 5% of the Plot

Plot Size (area)	Side of a 1% Square	Side of a 5% 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
1/10-acre	2.0 m 6.6 ft	4.5 m 14.7 ft
1/5-acre	2.8 m 9.3 ft	6.4 m 20.9 ft
1000 m^2	3.2 m 10.4 ft	7.1 m 23.2 ft

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.

2.46 Plant Height and Diameter Data

Record the predominant plant height and crown height including unit of measure, for any tree or shrub layer present within 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 2.421. Predominant height for each species within each layer is also useful information, but is optional. See Sections 2A.242 and 2A.243 of Appendix 2A for instructions for determining predominant plant height and crown for trees and shrubs.

The predominant diameter at breast height (dbh) or root collar (drc), must be recorded for each tree layer. Record diameter to the nearest inch rather than using diameter classes. Classes can be assigned later. See Section 2A.242 of Appendix 2A for instructions for measuring predominant diameter and recording it on the Vegetation Composition form.

2.47 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 in order 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. Guidelines for describing elevation, slope gradient and aspect, ground cover, slope position, and slope shape can be found in Appendix 2A. Guidelines for describing landform and geologic parent material can be found in the Terrestrial Ecological Unit Inventories (TEUI) Technical Guide (Winthers *et al*. 2004).

While not collected in the field, climatic data should also be attached to plot records for data analysis and description of vegetation types. This may be done using national climate coverages such as DayMet and PRISM, or based on local weather station data.

2.48 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 hard 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 assures that basic metadata will always be stored with the dataset and is accessible to all users.

2.481 Project Metadata

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

Project Name: Provide 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, photography or imagery sets, *etc*.

Protocol: Documents the protocol followed (*i.e.,* 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; whereas, 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 (*i.e.,* variable radius plot sampling)

Sample Design: Documents the sample design used for the plots within 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.

2.482 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, *etc.*) the appropriate unit of measure (feet, meter, *etc.*) must accompany the value and be stored with the data.

2.49 FGDC Physiognomic Crosswalk Attributes

The FGDC (1997) Vegetation Classification Standard 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." However, the FGDC physiognomic hierarchy is being revised 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 allows plot data to be quickly cross-walked 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 upon 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 equal to or greater than 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 which 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 Modifer 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 millimeters (1 sq in) in area and seasonally loses all of 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 millimeters(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 over 5 meters in height at maturity.
S	**SD**	**Dwarf-shrub** - *A caespitose, suffrutescent, creeping, matted, or cushion-forming shrub which 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 which is typically more than 50 cm tall at maturity with leaves that have well-defined leaf blades that are typically greater than 645 square millimeters(1 sq in) in area and seasonally loses all of its leaves and becomes temporarily bare-stemmed.* (FGDC 1997)
	SBE	**Broad-leaved evergreen shrub** - *A shrub with a branching crown which is typically more than 50 cm tall at maturity with leaves that have well-defined leaf blades that are typically greater than 645 square millimeters(1 sq in) in area and has green leaves all year round.* (FGDC 1997)
	SM	**Small-leaved shrub** - *A shrub which is typically more than 50 cm tall at maturity with leaves that have well-defined leaf blades that are typically less than 645 square millimeters(1 sq in) in area.* (FGDC 1997) Includes both evergreen and deciduous shrubs with small leaves.
	SN	**Needle-leaved shrub** - *A shrub which 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 non-flowering 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 non-aquatic, non-graminoid herb with relatively broad leaves and/or showy flowers*. Includes both flowering and spore-bearing, non-graminoid 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 non-flowering, spore-bearing forb.* Includes non-aquatic, non-woody ferns, clubmosses, horsetails, and quillworts.
	HG	**Graminoid** - *A non-aquatic, 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, non-flowering, 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 filamentous 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.***

Project data, plot data, and vegetation type data that are collected or derived as part of this existing vegetation classification protocol should be stored in the Forest Service Natural Resource Information System (NRIS). Formats and procedures for data storage will follow those 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 are 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. This means there will be data entry screens and database fields and standard codes 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 document may not necessarily be accommodated in NRIS and might not follow a national standard. Coordinate with regional and national stewards on such matters.

Archival materials associated with the classification project such as maps, photos, reports, and plot data sheets should be labeled with name of project and plot identification and stored together in an accessible and protected location.

2.51 Data Cleaning

Data should be reviewed for completeness and obvious errors before entry into 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 entry of data and error checking. Once data are entered into the NRIS database, there are several common methods 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 non-existent 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 errors in entry that would not be disallowed by lookup table restrictions. For example, one could enter a plot slope of 180%, but the reviewer may know that no plot in the study could possibly have a plot slope of 180%.

Query the data table containing all of 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 within 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 within 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 non-meaningful 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. An **outlier** is a sample with low similarity to all other samples in a dataset.

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 abiotic and biotic factors influencing plant species distributions within the study area. Integrating all of this information is the job of the ecologist and cannot be automated.

Jennings et al. (2003) 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, Podani 2000)." It is also critical that ecologists understand the concepts and mathematics of each methods in order to appropriately interpret the analysis results (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, both 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*. 2003). 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 prior 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, proposed associations should be documented using both synthesis and association tables to facilitate peer review and correlation of vegetation types (see Section 2.263). 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 development and review of diagnostic keys.

Examples of synthesis and association tables are shown in Tables 2.7 and 2.8 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 over 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 NRCS Plants database.

Table 2.7. Example of a Synthesis Table for Vegetation Classification

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)	
	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% 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% constancy
Black text	25 - 59% constancy
Gray Text	≤ 24% constancy

Table 2.8. Example of an Association Table for Vegetation Classification

Grp	Plot #	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*

2.7 Reporting

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

2.71 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.

A descriptive approach to naming that uses a combination of dominant and diagnostic species to name the type should be used. "The names of dominant and diagnostic taxa are the foundation of the association and alliance names" (Jennings et al. 2003). Names of associations and alliances should include at least one or more species names from the uppermost layer of the type. For alliances, taxa from lower layers should be used sparingly. Among the taxa that are chosen to name the type, those of the same life form (tree, shrub, herb, or nonvascular) are separated by a hyphen (-), and 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. Nomenclature and plant codes (i.e. plant symbols) for vascular plant taxa used in type names should follow the USDA-NRCS PLANTS database. Examples of naming conventions follow in Table 2.9.

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

2.72 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 should include 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 geographic data on the type, such as where it has been identified in the state or forest and its geographic distribution, if known from other sources.

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. A table of plant taxa should be included, including 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. Diagnostic species should be clearly indicated in the constancy/cover table. The main life forms in each type should be specified, including height and percent cover of each life form or layer, as applicable. The sample size for the type must be included.

Environmental Data: Information should be provided on site conditions, such as climate, elevation, slope aspects, slope steepness, topographic slope position, landforms, geologic parent materials, and soils. Describe the range as well as the central tendency of these attributes.

Vegetation Dynamics: A description should include the successional and disturbance factors that influence the type. Its successional relationship to other types should be mentioned, 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: The placement of the association, alliance, or dominance type within the FGDC physiognomic hierarchy is to be stated from division through group.

Supporting Data: Plot data used in the analysis of the type is to be specified, 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.

2.73 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 within the NRIS database:

- All levels of the FGDC physiognomic classification (FGDC 1997)
- Society of American Foresters Cover Types (SAF 1980)
- Society of Rangeland Management Cover Types (Shiftlet 1994)