United States Department of Agriculture

Forest Service

Pacific Northwest Research Station

General Technical Report PNW-GTR-363

November 1995

Definitions and Codes for Seral Status and Structure of Vegetation

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Abstract

Hall, Frederick C.; Bryant, Larry; Clausnitzer, Rod; Geier-Hayes, Kathy; Keane, Robert; Kertis, Jane; Shlisky, Ayn; Steele, Robert. 1995. Definitions and codes for seral status and structure of vegetation. Gen. Tech. Rep. PNW-GTR-363. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 39 p.

Definitions and codes for identifying vegetation seral status and structure are desired for land management planning, appraising wildlife habitat, and prescribing vegetation treatment. Codes are only presented; they are not a system for determining seral status or stand structure. Terms defined are climax, potential natural community (PNC), succession, seral status, thresholds, altered PNCs, life-form layer, dominant species, successional indicator species, structure classes, cover, and strata. Plant communities may be divided into three life-form layers where appropriate: tree, shrub, and herb/cryptogam. Each layer may be appraised and coded separately for seral status, or a single code may be used. Coding is provided for plant community structure class according to size, cover, and strata in a life-form layer. Seral status and structure may be coded together.

Keywords: Seral status, succession, threshold, structure, life-form.

Contents

Introduction

The USDA Forest Service has developed coding systems for plant communities that have been classified into potential natural communities (PNC), plant associations, habitat types, or stable community types (Hall 1995). These codes are assigned to vegetation units that are considered climax, environmentally stable, at their PNC status, or otherwise at an estimated endpoint in secondary succession. Codes do not address seral (successional) status or structural class. Methods for assigning codes to seral status and structural classes are described here.

We see a need for consistent use of seral and vegetation structure terms, definitions of these terms, and some criteria by which the terms can be characterized and identified. Identification of sera] vegetation and vegetation structure is desirable for several reasons:

1. Inventories require that a label be placed on items being inventoried; vegetation inventory useful for making land management decisions requires a characterization or descriptive identification of current vegetation status. Sera] and structure codes accomplish this (Helliwell and Rawlings 1994; Simpson and others 1994; USDA Forest Service 1993, 1994).

2. Seral status and structure class of vegetation are key factors for appraising wildlife habitat. These factors need definitions and labels (Brown 1985, Thomas 1979, Thomas and Maser 1986).

3. Silvicultural treatment of forest stands requires knowledge of successional processes (Means 1982, Murphy 1991) as does management of livestock grazing on natural rangelands (Busby and others 1994). Seral and structure codes identify conditions resulting from these processes.

We also think that successional and structural concepts and codes should be equally applicable to simple, nonforest potential natural communities (PNCs) as to complex, multilayered, and multispecies forest PNCs. For example, codes should encompass the variability from single-layer scablands on 4 to 6 inches of soil composed of Sandberg's bluegrass, one-spike oatgrass, and moss (POSA3-DAUN-TORTULA) producing only 150 pounds of biomass per acre per year, to Douglas-fir overstory and tanoak understory trees with salal shrub layer and dogbane herb layer (PSME/LIDE3/GASH/APAN)-a four-layer PNC producing 5,500 pounds of biomass per acre per year (see appendix A for acronyms).

This coding is designed to be flexible and to accommodate a variety of precision levels. Seral status may be coded by life-form layer (tree, shrub, herb) based on sophisticated research results as well as a single estimate of successional status based on an observer's experience. Structure of a plant community can be coded for a single, tallest life-form, or it can be noted for all life-forms. Both seral status and structure may be combined to depict current stand conditions. And finally, either or both may be assigned to an appropriately classified PNC.

Brief definitions are presented first, followed by a discussion and codes for sera] status where up to three life-form layers may be evaluated separately. Next, vegetation structure and codes are presented, ending with a combination of seral status, structure, and PNC.

Definitions

These are brief, working definitions. Detailed discussion and rationale for selected terms are in appendix B, as noted.

Canopy cover--The downward vertical projection from the outside profile of the canopy (crown) of a plant measured in percentage of land area covered. A 50 percent canopy cover means that 50 percent of the land area is covered by plant crowns.

Climax--The plant community that appears to be self-perpetuating in the absence of disturbance and that is not followed by a different subsequent community (see appendix B).

Cryptogams--Nonvascular plants such as mosses, liverworts, and lichens.

Dominant species--Those species with greatest canopy cover on a site. They may or may not be important as indicators of succession or PNC.

Life-form layers--Three life-form layers are defined as follows (Driscoll and others 1984):

> **Tree:** Woody species taller than 16.5 ft at maturity; a species defined as a tree in a plant community or successional classification.
>
> **Shrub:** Woody species shorter than 16.5 ft at maturity; a species defined as a shrub in a plant community or successional classification.
>
> **Herb:** Grasses, forbs, ferns, mosses, lichens, and other cryptogams; woody vegetation (half-shrubs) shorter than 6 in at maturity; a species defined as an herb in a plant community or successional classification.

Plant association--A specific kind of PNC that has been classified according to prescribed methodology. Associations have also been called habitat types, range sites, and ecological types (Hall 1995).

Potential natural community (PNC)--The biotic community that one presumes would be established and maintained over time under present environmental conditions if all secondary successional sequences were completed without additional human-caused disturbance. Present environmental conditions include site characteristics, eroded or damaged soils, and existing climate. Grazing by native fauna and natural disturbances, such as drought, floods, wildfires, wind, insects, and disease, are inherent in the **development** of communities. However, PNCs are described **without** disturbance by natural elements, including fire. PNCs may include naturalized nonnative species. PNCs also have been called plant associations, habitat types, and range sites (see appendix B). They are used as a reference point and as an **achievable** end-point in secondary succession.

> **Altered PNC--**Conditions where a threshold has been crossed such that succession back to the historical PNC is no longer feasible. Invasion by alien species, such as cheatgrass (BRTE), also may create an altered PNC. In many cases, this new PNC cannot be effectively evaluated for seral status. A code denotes this condition.

Primary succession--The slow, geological process of plant community change as soil and topography are altered by geological weathering; not dealt with in this paper.

Secondary succession--An ecological process of progressive change in a plant community after disturbance leading to a relatively stable PNC under existing environmental conditions. Secondary succession also may be retrogressive after disturbance, regressing from the PNC to a less stable plant community (see appendix B). When "succession" is used in this publication, it refers to secondary succession (see "primary succession," above).

Seral status--A stage of secondary successional development; also called seral stage. The following four seral stages are recognized (USDA Forest Service 1991):

Potential Natural Community (PNC): The potential natural community under - existing environment; seral species scarce to absent.

Late seral: PNC species are dominant, but seral species still persist.

Mid seral: PNC species are increasing and colonizing the site; they are approaching equal proportions with seral species.

Early seral: Clear dominance of seral species; PNC species absent or in very low numbers. Absence of a "life-form layer" (see definition) also means early seral, such as absence of any trees in a forest PNC.

Depauperate: Low canopy cover in a life-form due to dense woody cover by trees or shrubs. Both shrub and herb layers are generally depauperate in the stem exclusion stage of forest stand development (fig. 1).

Figure 1-(Left) Depauperate shrub and herb layers due to dense sapling regeneration in a ponderosa pine/bitterbrush/Idaho fescue PNC (PIPO/PUTR/FEID). (Right) Five years after precommercial thinning, Idaho fescue has responded but the bitterbrush layer has not.

Site--The soil and topography currently existing on a specific tract of ground. Soil may be the undisturbed, historical solum or it may have been altered or damaged, which constitutes a new soil and implies a new PNC. Aspect, elevation, steepness, and position on a slope contribute to topographic site qualities.

Stand condition--The combination of structure and seral status.

Strata--Even or uneven heights of individuals within a life-form; for example, three heights of trees in a forest PNC would constitute three tree strata, which is called uneven height.

Structure--The tree diameter class, canopy cover, and strata in forested PNCs; shrub height, canopy cover, and strata in shrubland PNCs; and herb canopy cover and strata in herbland PNCs. All may be combined for coding structure: tree, shrub, and herb structure in forested PNCs and shrub plus herb structure for shrubland PNCs.

Successional indicator species--Those species that reflect characteristics of a successional stage or PNC. In successional investigations, dominant and indicator species frequently are used together to identify seral status (Steele and Geier-Hayes 1989). Successional indicator species are determined by scientists through field investigations as described by Arno and others (1986).

Threshold--An ecological condition where disturbance has so altered a plant community or site that succession back to the historical PNC is no longer feasible. Before crossing a threshold, a disturbed plant community can usually go through succession back to the historical PNC. After the threshold is crossed, successional processes are altered and a new PNC has been created (Busby and others 1994). This condition is called an altered PNC.

Disturbance may selectively affect various life-form layers. These effects can cause different rates of successional change within life-forms. And most probably, various life-forms will respond at different rates of change.

Concept of Seral Status

Therefore, each life-form layer may be considered separately as to seral status. A tree/shrub/herb community would have three ratings of succession, one for each layer. The concept will be illustrated by using life-forms as they apply to five different kinds of potential natural plant communities: single life-form-bluebunch wheatgrass-Sandberg's bluegrass (AGSP-POSA3); double life-forms-big sagebrush/bluebunch wheatgrass (ARTR/AGSP); and three kinds of triple life-forms-juniper/big sagebrush/bluebunch wheatgrass (JUOC/ARTR/AGSP), ponderosa pine/bitterbrush/elk sedge (PIPO/PUTR/CAGE), and Doug las-fir/ninebark/meadowrue (PSME/PHMA/THOC). Examples of influences affecting seral status are livestock grazing, low-severity fire, logging, and invasion by nonnative species.

Influences Affecting Life-Form Seral Status

Livestock grazing-Livestock grazing tends to have a very selective influence on plant communities. Heavy grazing results in physiological damage to palatable species, causing them to lose competitive status and decline (decreasers), a condition called retrogressive succession. Bluebunch wheatgrass (AGSP) is one of these. In bluebunch wheatgrass/Sandberg's bluegrass, a major decline in wheatgrass, increase in cheatgrass (BRTE), and colonization by tarweed (MAGL) might indicate **early** seral status. In big sagebrush/bluebunch wheatgrass, this reaction to grazing would also indicate **early** seral in the herbaceous life-form, while the shrub life-form remained at

PNC status. In juniper/big sagebrush/bluebunch wheatgrass, the reaction would indicate **early** seral in the herbaceous life-form while both the shrub and tree life-forms remained at PNC status. Clearly, all three of these plant communities are not at "**early** seral" status.

Reaction of forested communities to grazing is similar. Overgrazing in the ponderosa pine/bitterbrush/elk sedge (PIPO/PUTR/CAGE) association can result in virtual elimination of elk sedge (CAGE), resulting in **early** seral status of the herb life-form layer and no damage to the shrub and tree life-forms (fig. 2). Should bitterbrush be seriously depleted, the shrub life-form might become **mid** seral while trees remain at **PNC** status and herbs at **early** seral. Livestock forage rating guides deal with these conditions (USDA Forest Service 1967).

Low-severity fire-Low-severity fire selectively influences plant communities in a degree similar to livestock grazing but in quite a different way. Burning bluebunch wheatgrass/ Sandberg's bluegrass will reduce plant vigor for the first few years but probably will not change either species composition or dominance and, therefore, may not affect seral status.

Effects of low-severity fire on big sagebrush/bluebunch wheatgrass are quite different. Big sagebrush (ARTR) is killed by fire but seral indicator shrubs such as rabbit-brush (CHNA) tend to be stimulated, particularly due to reduced competition from sagebrush. Now the shrub life-form is set back to **early** seral while the herb life-form is still at **PNC** status.

Similarly, low-severity fire in juniper/big sagebrush/bluebunch wheatgrass kills both the tree and shrub life-forms, thereby setting both back to **early** seral (fig. 3). A fire that has little effect on the herbaceous life-form causes major differences in seral status when herbaceous, shrub, or tree PNCs are compared.

Another influence of low-severity fire is its differential effect on ponderosa pine/ bitterbrush/elk sedge compared to Doug las-fir/ninebark/meadowrue. An underburn in ponderosa pine/bitterbrush/elk sedge kills bitterbrush (PUTR) but does not significantly affect the herbaceous or tree life-forms, which results in **PNC**-status tree, **early** seral shrub, and **PNC**-status herbaceous life-forms. In Doug las-fir/ninebark/meadowrue, the same fire does little to affect seral status because ninebark (PHMA) and meadowrue (THOC) both reproduce by rhizomes and quickly resume their **PNC** status.

Logging-Logging also tends to have differential effects on tree, shrub, and herb layers. When trees are removed from the ponderosa pine/bitterbrush/elk sedge or Douglas-fir/ ninebark/meadowrue associations, the tree life-form goes to **early** seral while shrub and herb life-forms can remain in **PNC** status (fig. 4).

These selective effects of disturbance on various life-form layers is the reason that it may be desirable to rate them separately for seral status. A single, overall successional rating tends to be misleading.

Invasion by nonnative species-Nonnative species may be introduced intentionally through seeding or be unintentionally carried to the site by animals or equipment. In some cases, these exotics may compete so effectively as to constitute an altered PNC. Introduction of cheatgrass (BRTE) is an example of change in successional pathways leading to PNCs different from historical systems, a topic discussed in detail by Monsen and Kitchen (1994). An example is overgrazed big sagebrush/bluebunch wheatgrass changing to big sagebrush/cheatgrass (ARTR/BRTE) (McArthur and others 1990, Monsen and Kitchen 1994).

Figure 2-Contrast along a fenceline showing effects of heavy cattle use on the herb life-form layer in a ponderosa pine/pinegrass (PIPO/CARU) PNC. Right of the fence is early seral status herb layer, left is PNC. The tree life-form layer is PNC in both cases. Evaluating seral status by life-form layer improves description of current vegetation conditions.

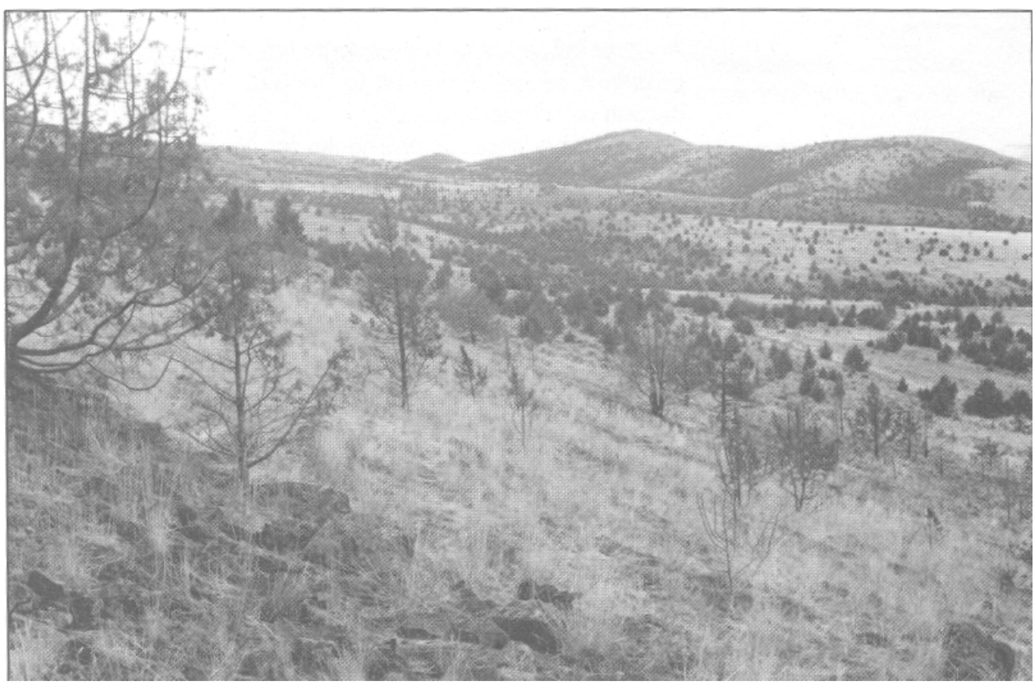

Figure 3-Effects of a low-severity fire in a juniper/big sagebrush/bluebunch wheatgrass (JUOC/AVM T R/ AGSP) PNC. Fire has set the tree and shrub life-form layers back to early seral while the herb layer is at PNC.

Figure 4-A clearcut in grand fir/pinegrass where the tree life-form layer is early seral and the herb layer is at PNC.

Coding Seral Status

The following examples introduce the concept of coding seral status. Two degrees of precision will be developed, each with a coding system: (1) seral status by life-form layer where up to three layers may be coded; and (2) a single seral status code for the tallest layer. Coding is also provided to indicate the sophistication used to determine seral status: evaluated from an investigation classifying succession or by observer estimation.

Investigations Classifying Succession

Classification of seral status by sophisticated investigation has been outlined by Arno and others (1985, 1986), Clausnitzer (1993), and Steele and Geier-Hayes (1987, 1989, 1992, 1993, 1994). The ponderosa pine (PIPO) phase of the Douglas-fir/ninebark/meadowrue (PSME/PHMA/THOC) potential natural community (PNC) will be used to illustrate all aspects of seral and structural coding. The diagrams in figures 5, 6, and 7, are a summary of Steele and Geier-Hayes's (1989) 65-page comprehensive analysis of succession in this PNC. They evaluate each life-form layer for seral status.

Stand condition for illustration is as follows: the tree life-form layer has ponderosa pine (PIPO) dominant at 21 to 32 in diameter breast height (d.b.h.) and 20 percent canopy cover with Douglas-fir (PSME) in the understory at 1 to 20 in d.b.h. and 30 percent canopy cover; the shrub layer has bittercherry (PREM) dominant at 7 ft tall and 15 percent cover with spiraea (SPBE) at 18 in tall and 25 percent cover; and the herb layer is dominated by pinegrass (CARL!) at 50 percent cover with meadowrue (THOC) at 20 percent cover.

Figures 5, 6, and 7 identify these stand conditions by a circle around the plant species described. In each case, seral status is indicated. Nomenclature is shown in table 1.

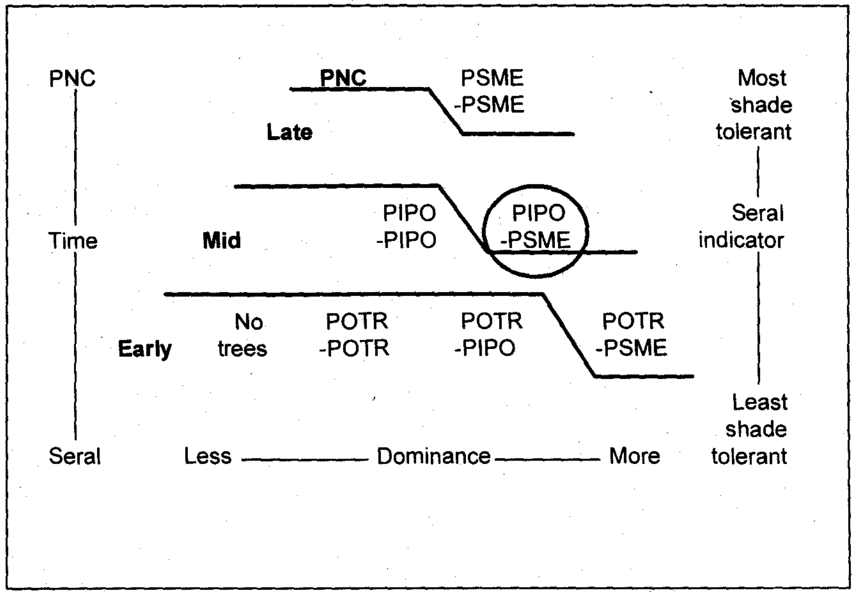

Figure 5-Tree life-form succession diagram for the PRO phase of PSME/PHMA/THOC potential natural community from Steele and Geier-Hayes (1989, fig. 3). Descriptive code for the circled PIPO-PSME is shown in table 1. Dominant and indicator trees define each seral status; the indicator is the top species and dominant the bottom species of each pair. PIPO-PSME (circled) denotes **late** seral status.

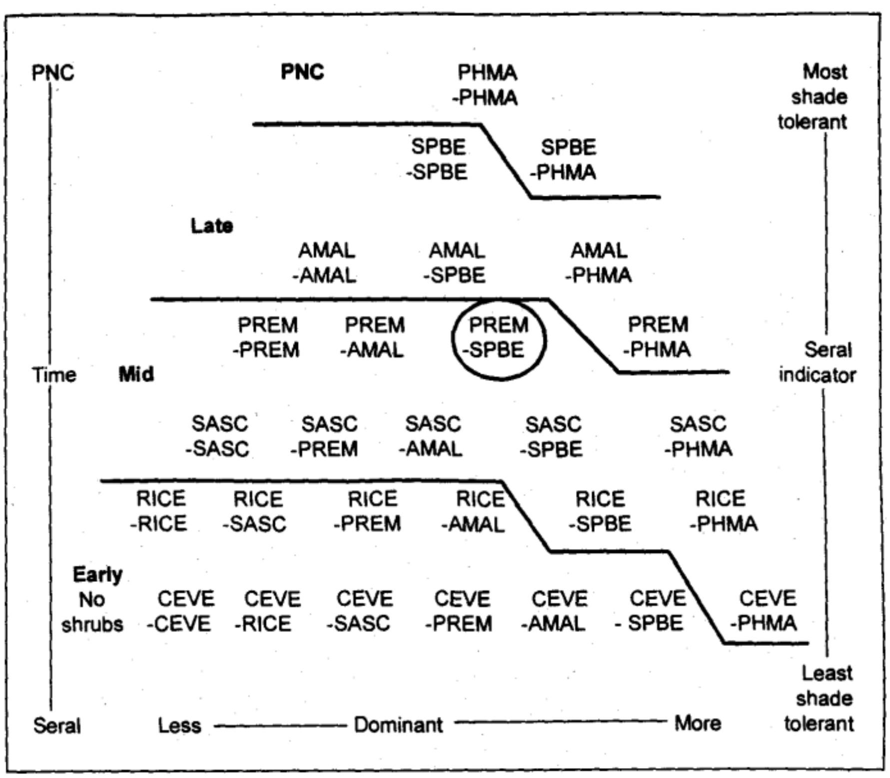

Figure 6-Shrub life-form succession diagram for the PIPO phase of PSME/PHMA/THOC potential natural community from Steele and Geier-Hayes (1989, fig. 9). Descriptive code for the circled PREM-SPBE is shown in table 1. Combinations of dominant and indicator shrubs define the characteristics of each seral status; the indicator is the top species and dominant the bottom species of each pair. PREM-SPBE (circled) denotes mid seral status.

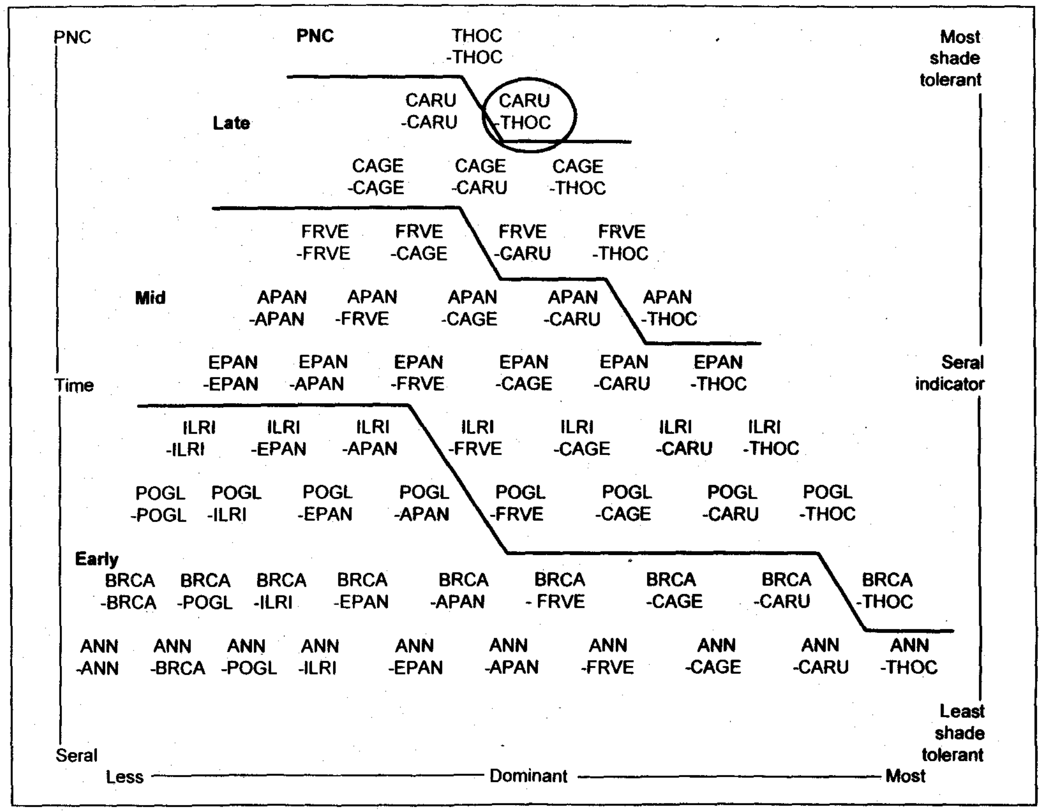

Figure 7-Herbaceous life-form succession diagram for the PRO phase of PSME/PHMA/THOC potential natural community from Steele and Geier-Hayes (1989, fig. 15). The descriptive code for the circled CARU-THOC is shown in table 1. Combinations of dominant the indicator herbs define the characteristics of each seral status; the indicator is the top species and dominant the bottom species of each pair. CARU-THOC (circled) denotes PNC status.

Table 1-Life-form indicator and dominant species shown in figures 5, 6, and 7 for the Douglas-fir/ninebark/meadowrue PNC by seral status

	Seral status[a]			
Species	PNC[b]	Late	Mid	Early
Tree:				
Indicator		PIPO		
Dominant		PSME		
Shrub:				
Indicator			PREM	
Dominant			SPBE	
Herb:				
Indicator	THOC			
Dominant	CARU			

[a] Seral status is defined in table 4.

[b] PNC is Potential Natural Community (see definitions).

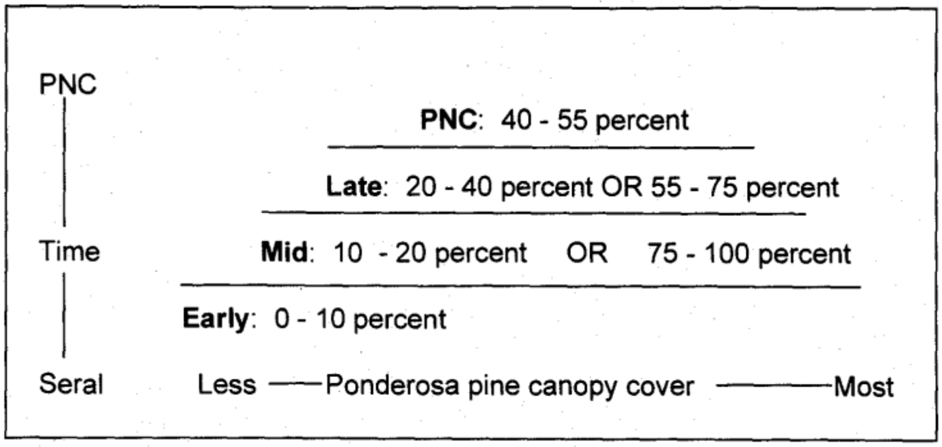

Figure 8-Single tree species life-form successional diagram for the ponderosa pine/bitterbrush/elk sedge (PIPO/PUTR/CAGE) potential natural community (PNC). Only PIPO occurs in the tree life-form so its seral status is indicated by percentage of canopy cover. Cover of PNC mature stands averages 40 to 55 percent, whereas cover in saplings and poles may exceed 55 percent as they become stagnated (fig. 1). This high cover also tends to reduce shrub and herb cover and may occasionally eliminate some PNC species capable of regenerating under 40 to 55 percent tree cover (fig. 1).

Table 2-Potential natural community (PNC) codes[a]

Code	PNC	Code	PNC
Coniferous tree species:		Forb lands:	
CA	Alpine, open, forest park	FM	Moist (mesic) forb land
CC	Western redcedar	FS	Subalpine or alpine forb land
CD	Douglas-fir	FW	Wet forb land
CE	Subalpine fir, Engelmann spruce		
CF	Silver or noble fir	Grasslands:	
CH	Western hemlock		
CJ	Western Juniper	GA	Annual grasslands
CL	Lodgepole pine	GB	Bunchgrasses
CM	Mountain hemlock	GM	Mesic (forest zone) grasslands
CP	Ponderosa, Jeffery pine	GR	Rhizomastous grass-sedge
CR	Red fir	GS	Subalpine, alpine grasslands
CS	Sitka spruce		
CW	Grand or white fir	Meadows (wet) grass-sedge:	
Hardwood tree species:		MD	Dry meadow
		MM	Moist meadow
HA	Alder	MS	Subalpine or alpine
HB	Bigleaf maple	MT	Tule, standing water
HC	Cottonwood-ash bottoms	MW	Wet meadow
HL	Canyon live-oak tree size		
HO	Oak, Oregon or black	Shrublands:	
HQ	Quaking aspen		
HT	Tanoak tree size	SC	Chaparral
		SD	Dry shrubland (sagebrush)
		SM	Mesic (forest zone) shrubland
		SS	Subalpine, alpine shrubland
		SW	Wet shrubland

[a] Codes are from Hall 1995.

Single Species Life-Form Seral Status

Typical successional diagrams are not possible for life-forms containing only one important species such as ponderosa pine (PIPO) or juniper (JUOC) PNCs. Ponderosa pine/bitterbrush/elk sedge is an example (fig. 8). Simple presence or absence of ponderosa pine or juniper does not help much in defining the three seral status levels below PNC.

Two choices are available in such an instance: (1) code as either **PNC** or **early** seral based on the presence or absence of trees, or (2) use canopy cover as the criteria for assigning seral status to one of the four categories.

Use of canopy cover is shown in figure 8. Pine canopy cover of mature trees at PNC averages 40 to 55 percent. Assign a percentage of canopy cover to each seral status: **PNC** is 75 to 100 percent of potential so pine canopy cover is 40 to 55 percent, **late** is 50 to 75 percent of PNC so pine canopy cover would be 20 to 40 percent, **mid** is 25 to 50 percent of PNC so pine cover is only 10 to 20 percent, and **early** is 0 to 10 percent of PNC and where trees are absent so pine canopy cover is 0 to 10 percent (USDA Forest Service 1991).

Forest stands sometimes have sapling and pole canopy cover that greatly exceeds cover in mature stands (PNC cover; see fig. 1). This condition is commonly associated with stagnation (stem exclusion stage) (Oliver and Larson 1990, Waring and Schlesinger 1985). Here, excessive cover may be assigned to a seral status: **late** is 100 to 135 percent of PNC, and **mid** is over 135 percent of PNC cover. In figure 8, ponderosa pine canopy cover of 55 to 75 percent is **Late** seral and 75 to 100 percent cover is **mid** seral (fig. 1). High cover by trees reduces dominance and density of shrub and herb layers (Oliver and Larson 1990, USDA Forest Service 1967) and causes the plant community to be depauperate of PNC species (fig. 1). Lower seral status ratings reflect this condition.

Coding Life-Form Seral Status

Coding seral status-Seral status codes have a six-digit field. The first two characters are taken from table 2 and indicate kind of PNC, the third denotes how the seral status was determined (table 3), and the fourth, fifth, and sixth denote seral status of tree, shrub, and herb life-forms, respectively, as shown in table 4. If a life-form is not present, the letter "X" must be entered. The Doug las-fir/ninebark/meadowrue example is described as follows:

CD (PNC: Douglas-fir) **C** (classified study) **L** (tree) **M** (shrub) **P** (herb)

The code would be: **CDCLMP**

This code, CDCLMP, is read as indicating a **coniferous forest** (C) with PNC potential for **Douglas-fir** (D) that was **classified** (C) by using a research study, as **late** seral (L) tree status, **mid** seral (M) shrub status, and **PNC** (P) herb status. It also could be combined with a PNC plant association code.

Seral status plus PNC association--Seral status coding may be attached to a code identifying a special kind of PNC: either a subseries four-character code or a plant association six-character code. The code CDS721 (Hall 1995) is Doug las-fir/ninebark/meadowrue as classified by Steele and others (1981). When combined with seral status, **omit** the PNC code preceding seral status to avoid duplication. Then separate the codes with a virgule (/).

CDS721/CLMP This code is read as: PRO phase of the PSME/PHMA/THOC potential natural community (PNC) (Steele and others 1981) as classified by Steele and Geier-Hayes (1989) as to **late** seral tree layer, **mid** seral shrub layer, and **PNC** herb layer.

Table 3-Seral classification code, source, and criteria

Code	Source	Criteria
C	Classified	Seral status is classified from an investigation or research study that has characterized seral status in the PNC being evaluated.
E	Estimated	Seral status has been estimated based on the observer's best analysis of the vegetation.
A	Altered	Disturbance has changed the historic PNC resulting in a soil or vegetation threshold being crossed; an estimation of seral status may not be possible.

Table 4-Seral status code, source, and criteria

Code	Source	Criteria
P	PNC	The potential natural community under existing environment; seral species scarce to absent.
L	Late seral	PNC species are dominant, but sera[species still persist.
M	Mid seral	PNC species are approaching equal proportions with seral species.
E	Early seral	Clear dominance of seral species; PNC species absent or very low in cover; absence of a life-form layer such as absence of trees in a forest PNC.
X	None	A life-form is not present or status is not deter mined.
D	Depauperate	Low canopy cover in a life-form due to dense woody cover (that is, stem exclusion stage)(fig. 1).

Use of "C" when attached to a PNC association code indicates that seral status is based on a successional study of the PNC represented by the code**. Use of "E"** means seral status has been estimated for the PNC.

A four-character subseries code also may be used (Hall 1995). For example, SD20 is dry shrub life-form dominated by big sagebrush (ARTR). When it is estimated to be in PNC status for the shrub layer and mid seral status for the herb layer, the code would be: **SD201EXPM** ("X" indicates no tree layer).

Coding an Estimated Seral Status

Sophisticated research studies are not always available, yet one may still have need to document seral status. Tentative status of species in relation to PNC may be estimated based on observation and the autecological characteristics. Minore (1979), for example, has an excellent discussion on shade tolerance of trees and some reaction to disturbance. Many forage species have been discussed in regard to their reaction to grazing (USDA Forest Service 1937).

Investigators familiar with an area have observed reactions of plant communities and species to various kinds of disturbance. Thus, a reasonable estimate of seral status by life-form layer can be made if the kind of PNC is known. Estimation of seral status is noted with an "E" after the code for PNC. It would be shown as follows:

CDELMP Douglas-fir PNC **estimated** to be in late tree, mid shrub and PNC herb seral status.

Coding a Single Seral Status

A single seral status may be coded based on the tallest potential life-form layer in a PNC. It follows the same format as life-form status: two-character PNC code, one-character classification source, and a one-character seral status code. The Douglas-fir/ninebark/ meadowrue example would be:

CDCL Douglas-fir PNC in late seral status determined by use of an investigation classifying succession. "L" denotes the seral status of the tree layer, which is the tallest life-form.

Coding an Altered PNC

When a soil or vegetation threshold has been crossed and the historic.PNC can no longer be restored, use the letter "A" after the PNC code to denote an altered PNC. Many times, seral status cannot be estimated because successional pathways of the new PNC are not known. When this occurs, use an "X" after the "A" to indicate unknown seral status:

CDAX Douglas-fir PNC that has been altered and seral status is unknown.

A single seral status rating tends to be misleading because it does not accommodate a variety of disturbances. Recall the discussion in the section, "Concept of Seral Status," where grazing, fire, and logging were shown to affect ponderosa pine/bitterbrush/elk sedge in very different ways. Two of these influences would code to PNC (heavy grazing and underburning) and one would code to early seral (logging).

Examples from the discussion in the section, "Concept of Seral Status," are shown in table 5.

Plant Community Structure

All plant communities have structure, ranging from open-canopy, single-layer Sandberg's bluegrass-onespike oatgrass-moss (POSA3-DAUN-TORTULA) scablands to closed-canopy multiple-layer forests such as Doug las-fir/tanoak/salal/dog bane (PSME/LIDE3/ GASH/ APAN). Elements of structure used in coding are diameter, height, canopy cover, and evenness of strata within a life-form layer.

Forest Land Structure

Structural development of forest stands has been extensively discussed by Oliver and Larson (1990). They focus on changes in stand structure and tree species dominance and call the process stand development rather than succession. They discuss four structural stages with both single- and multiple-species stands that may be either single cohort (even aged) or multicohort (similar to but broader than the concept of "uneven aged"). The structural stages are:

1. Stand initiation
2. Stem exclusion
3. Understory reinitiation
4. Old growth

Table 5--Coding seral status for the examples discussed in the section, "Concept of Seral Status"

PNC	Influence	Life-form codes	Single code
PSME/PHMAITHOC	Figs. 5, 6, 7	CDCLMP	CDCL
PIPO/PUTR/CAGE	Overgrazed	CPEPPE	CPEP
	Underburned	CPEPEP	CPEP
	Clearcut	CPEEPP	CPEE
JUOC/ARTR/AGSP	Overgrazed	CJEPPE	CJEP
	Burned	CJEEEP	WEE
ARTR/AGSP	Overgrazed	SDEXPE	SDEP
	Burned	SDEXEP	SDEE
AGSP/POSA3	Overgrazed	GBEXXE	GBEE

A structural stage does not indicate seral status, as illustrated with a western hemlock (TSHE) PNC community. Species dominance in the **stem exclusion stage** could occur within each of the following seral stages:

• Red alder (ALRU) dominant (**early** seral)
• Douglas-fir dominant (**mid** seral)
• Western hemlock and Douglas-fir codominant (**late** seral)
• Western hemlock dominant (**PNC** status)

East of the Cascade Range, a grand fir PNC could have any seral status in the **stem exclusion stage** as follows:

• Western larch (LAOC) dominant (**early** seral)
• Douglas-fir and western larch codominant (**mid** seral)
• Douglas-fir and grand fir codominant (**late** seral)
• Grand fir dominant (**PNC** status)

Alternatively, seral status of a forest stand does not indicate structure. Examples are as follows for **mid** seral status in western hemlock:

• Stand initiation where sapling-diameter Douglas-fir is dominant.
• Stem exclusion where pole-diameter Douglas-fir is, dominant.
• Understory reinitiation where medium-diameter Douglas-fir is dominant.
• Old growth where large- and giant-diameter Douglas-fir are dominant.

Clearly, stand structure is not synonymous with seral status, a point discussed by Oliver and Larson (1990). Structural stage can affect evaluation of life-form seral status, however. This can be illustrated by the **stem exclusion stage:** shrub and herb layers have, by definition, become depauperate due to dense tree cover. They do not have the composition or dominance of species characteristic of PNC conditions (USDA Forest Service 1967). As a result, shrub and herb life-form layers in **stem exclusion** may rate **depauperate** in seral status (fig. 1). This is coded "D" (table 4).

We propose that a set of structural size classes be used to quantify Oliver and Larson's (1990) stages. They are classes of tree diameter, shrub height, canopy cover, and strata within a life-form layer, as shown in tables 6, ?, and 8. Appendix C has criteria and citations for these data.

Coding structure-Structural codes for trees are shown in table 6. They are preceded by a PNC code as listed in table 2. Commonly, the PNC code indicates the coded structure (that is, forest, shrub, or herb); exceptions are noted below. Combining tree diameter class with cover and strata provides a means by which stand structure can be generally described. For example, pole-diameter trees may be coded as none, open, moderate, or dense (stem exclusion) and even strata; medium-diameter trees may be coded as none, open (understory reinitiation), moderate, or dense (stem exclusion) and may be even strata or uneven strata. Some examples previously discussed would be:

CDLTMU Douglas-fir PNC of large-diameter trees, moderate cover, and uneven tree strata; tree structure of the PSME/PHMA/THOC example.

CPMTMU Ponderosa pine of medium-diameter trees, moderate cover, and uneven tree strata; the PIPO/PUTR/CAGE overgrazed example.

CJPTOU Western juniper of pole-diameter trees, open cover, and uneven tree strata; the JUOC/ARTR/AGSP overgrazed example.

Tree cover less than 10 percent-When "N" is appropriate for total tree cover, several options and interpretations are available. In the **shrub-herb** diameter class, "N" indicates less than 10 percent tree cover or no trees and "O" indicates 10 to 40 percent cover, both qualifying as an opening for wildlife habitat. If "M" or "D" are used, tree canopy cover is too dense to qualify as a wildlife opening (Hall and others 1985).

Other options when tree cover is less than 10 percent, where "N" might be used, are to code structure of the shrub or the herb life-form instead of tree life-form. Note that all tree diameter classes end in "T" except shrub-herb "SH" (table 6), all shrub height classes end in "S" (table 7), and that herblands are identified by "HE" (table 8). Thus, a forest PNC **without** trees can be coded for shrub or herb structure rather than forest structure. Some coding and interpretations are as follows:

CDLTMU Douglas-fir PNC of large-diameter trees, moderate cover, uneven strata; the PSME/PHMA/THOC example.

CDSHNN Douglas-fir PNC in shrub-herb class, no trees (less than 10 percent cover), and no tree strata; the PSME/PHMA/THOC example clearcut.

CDTSMU The same Douglas-fir PNC described above but using the shrub life-form structure of tall shrubs, moderate shrub cover, uneven shrub strata; the PSME/PHMA/THOC example clearcut.[1]

CDHEDU A different Douglas-fir PNC stand with no tree or shrub layers but rated as dense cover and uneven strata of herbs (see footnote 1).

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[1] A forest PNC followed by a shrub or herb structure means **less than 10 percent tree cover**; if the herb layer is shown, **both tree and shrub cover** are less than 10 percent each.

Table 6-Forest land structural classes

Code	Class	Characteristics
Tree diameter classes:[a]		
SH	Shrub-herb	Trees, if present, less than 1 inch d.b.h.; area may be dominated by grasses, herbs, shrubs or bare ground; trees may dominate but are less than 1 inch d.b.h.
ST	Sapling trees	Trees from 1 to 4.9 inches d.b.h. (20 TPA[b])
PT	Pole trees	Trees from 5 to 8.9 inches d.b.h. (15 TPA)
MT	Medium trees	Trees from 9 to 20.9 inches d.b.h. (10 TPA)
LT	Large trees	Trees from 21 to 31.9 inches d.b.h. (10 TPA)
GT	Giant trees	Trees from 32 to 47.9 inches d.b.h. (5 TPA)
RT	Remnant trees	Trees larger than 48 inches d.b.h. (5 TPA)
Tree canopy cover classes:[c]		
N	None	Less than 10 percent canopy cover
O	Open	From 10 to 40 percent canopy cover
M	Moderate	From 40 to 69 percent canopy cover
D	Dense	Over 70 percent canopy cover
Tree strata classes:		
N	None	No tree life-form
E	Even strata	A single tree strata; less than 30 percent difference in size of trees
U	Uneven strata	Two or more tree strata; more than 30 percent difference in height between trees. To qualify as a strata, canopy cover in the strata must exceed 10 percent except for regeneration less than 1 inch d.b.h. where at least 100 established trees per acre (22 feet between trees) qualifies as a strata.

[a] Applies to the largest trees or tree species. A class is determined by the average d.b.h. of the number of trees per acre (TPA) shown.
[b] TPA = trees per acre.
[c] Applies to all tree strata added together.

CPMSOE Ponderosa pine PNC without a tree layer in medium-tall shrubs of open cover and even shrub strata; the PIPO/PUTR/CAGE example clearcut (see footnote 1).

CJHEMU Western juniper without tree or shrub layers, herbaceous layer at moderate cover and uneven strata; the JUOC/ARTR/AGSP example burned (see footnote 1).

Table 7-Shrubland structural classes

Code	Class	Characteristics
Shrub height classes:[a]		
NS	No shrubs	Less than 10 percent canopy cover
LS	Low shrubs	Shrubs less than 1.7 feet tall (20 inches)
MS	Medium shrubs	Shrubs 1.7 to 6.5 feet tall
TS	Tall shrubs	Shrubs 6.5 to 16.5 feet tall
Shrub cover classes:[b]		
N	None:	Less than 10 percent canopy cover
O	Open:	From 10 to 25 percent canopy cover
M	Moderate:	From 26 to 66 percent canopy cover
D	Dense:	Over 67 percent canopy cover
Shrub strata classes:		
N	None	No shrub strata
E	Even strata	One shrub stratum; less than 30 percent difference in height
U	Uneven strata	Two or more shrub strata which may be made up of different heights; greater than 30 percent difference in height. A second shrub strata must have at least 25 percent of the total canopy cover.

[a] Height class is determined by the average height of the 20 tallest shrubs per acre (45-foot spacing).
[b] Canopy cover applies to all shrubs added together.

Shrubland Structure

Structure for shrublands is characterized by four shrub heights, four canopy covers, and two strata as shown in table 7. Appendix C has criteria and citations for these data.

Coding shrub structure-Structural codes are preceded by a two-character PNC code taken from table 2. This is followed by a two-character height code and single codes for cover and strata. If the shrub life-form is absent (less than 10 percent cover), structure of the herbaceous layer may be used.

SDMSOE Dry shrubland PNC of moderately tall shrubs with open cover and even strata; the ARTR/AGSP example before overgrazing or burning.

SDNSNN Dry shrubland PNC with no shrub layer, no shrub cover, and no shrub strata; the ARTR/AGSP example after fire.

SDHEMU Dry shrubland PNC without a shrub layer but with an herbaceous layer at moderate cover and uneven strata; the ARTR/AGSP example after fire.

CDTSMU Douglas-fir PNC without a tree layer but with tall shrubs of moderate cover and uneven strata; the PSME/PHMA/THOC example clearcut.

Table 8-Herbland structural classes

Code	Class	Characteristics
Herbland life-form:		
HE	Herbland	The only life-form present
Cover of herbs for all species, including cryptogams:		
N	None	Less than 10 percent canopy cover
O	Open	From 10 to 25 percent canopy cover
M	Moderate	From 26 to 66 percent canopy cover
D	Dense	Greater than 67 percent canopy cover
Strata of herblands, including cryptogams:		
N	None	No herb life-form (bare ground)
E	Even strata	One strata of herbs; less than 30 percent difference in height; cryptogams must be less than 10 percent cover
U	Uneven strata	Two or more herb strata, greater than 30 percent difference in height; cryptogams at 10 percent or greater cover constitute a strata; canopy cover in a strata must exceed 10 percent.

Herbland Structure

Herblands are composed of only one life-form but do have canopy cover and strata characteristics. Coding is shown in table 8.

Coding Structure Summary

A layer structure is coded as six characters: PNC as two characters from table 2, size as two characters, cover as one, and strata as one character. The Douglas-fir/ ninebark/ meadowrue example had ponderosa pine at 21 to 32 inches in diameter and 20 percent cover, Douglas-fir as an understory at 1 to 20 inches in diameter and 30 percent cover, bittercherry at 7 ft tall and 15 percent cover, spiraea at 18 in tall and 25 percent cover, pinegrass at 50 percent cover, and meadowrue at 20 percent cover. These conditions may be coded as follows:

Tree layer: **CDLTMU** = Douglas-fir PNC of large-diameter trees, moderate tree cover, and uneven tree strata.

Shrub layer: **TSMU** = Tall shrubs, moderate shrub cover, and uneven shrub strata.

Herb layer: **HEDU** = Herb layer, dense herb cover, and uneven herb strata.

If all life-forms are to be coded for structure, begin with PNC code of the tallest and proceed to the shortest: PNC, tree, shrub, herb. Use PNC only at the beginning. The codes above then would be:

CDLTMU-TSMU-HEDU

which would read as follows: Douglas-fir PNC currently in large-diameter trees of moderate cover and uneven tree strata, tall shrubs of moderate cover and uneven strata, and an herbaceous layer that is dense in cover with uneven strata.

Note the difference between the coding above and coding for a PNC where a life-form layer is missing; that is, less than 10 percent cover:

Tree layer: **CDLTMU =** Douglas-fir PNC of large-diameter trees, moderate tree cover, and uneven tree strata; the PSME/PHMA/THOC.

Shrub layer: **CDTSMU** = Douglas-fir PNC with **less than 10 percent** tree cover, tall shrub layer of moderate shrub cover, uneven shrub strata; the PSME/PHMA/THOC clearcut.

Herb layer: **CDHEDU** = Douglas-fir PNC with **less than 10 percent** tree cover and **less than 10 percent** shrub cover with an herb layer, dense herb cover, and uneven herb strata; the PSME/PHMA/THOC with no tree or shrub layers.

Codes are shown in table 9 for PNCs discussed in the section, "Concept of Seral Status," and listed in table 5 for seral status.

Table 9-Structure of plant communities discussed in the section, "Concept of Seral Status," and shown in table 5 for seral coding

PNC	Condition	Code
PSME/PHM[THOC	(example[a])	CDLTMU-TSMU-HEDU
PIPO/PUTR/CAGE	Overgrazed	CPMTMU-MSMU-HEOE
	Underburned	CPMTMU-NSNN-HEDE
	Herb structure[b]	CPMTMU-HEDE
	Clearcut	CPSHNN-MSMU-HEDE
	Shrub structure[c]	CPMSMU-HEDE
JUOC/ARTR/AGSP	Overgrazed	CJPTOU-MSOU-HEOE
	Burned	CJSHNN-NSNN-HEMU
	Herb structure[d]	CJHEMU
ARTR/AGSP	Overgrazed	SDMSOU-HEOE
	Burned	SDNSNN-HEMU
	Herb structure[e]	SDHEMU
AGSP/POSA3	Overgrazed	GBHEOE

[a] The example illustrated in figures 5, 6, and 7.
[b] Underburned with no shrub structure; omit shrub layer and use herb layer.
[c] Clearcut with no tree structure; omit tree layer and use shrub and herb layers.
[d] Burned with no tree or shrub structure; use only the herb layer.
[e] Burned with no shrub structure; use only the herb layer.

Table 10-Seral status and stand structure for forests

Tree size class	Life-form layer	Seral status: Early	Mid	Late	PNC
Inches					
Shrub-herb					
less 1 d.b.h.	Tree	1[a]			
	Shrub				1
	Herb				1
Sapling trees					
1-5 d.b.h.	Tree .				
	Shrub				
	Herb				
Pole trees					
5-9 d.b.h.	Tree				
	Shrub				
	Herb				
Medium trees					
9-21 d.b.h.	Tree				2[b]
	Shrub				2
	Herb	2			
Large trees					
21-23 d.b.h.	Tree			3[c]	
	Shrub		3		
	Herb				3
Giant trees					
32-48 d.b.h.	Tree				
	Shrub				
	Herb				
Remnant trees					
over 48 d.b.h.	Tree				
	Shrub				
	Herb				

[a] 1 Ponderosa pine/bitterbrush/elk sedge-clearcut.
[b] 2 Ponderosa pine/bitterbrush/elk sedge-overgrazed.
[c] 3 Douglas-fir/ninebark/meadowrue-the example.

Combining Seral Status and Vegetation Structure

Structural conditions may be combined with seral status by use of a matrix as proposed by Simpson and others (1994). Several of the forested stands discussed earlier have been located in the matrix of table 10.

Tree cover and strata may be added to these criteria. Recall that Douglas-fir/ninebark/meadowrue was **late** seral in the tree layer with ponderosa pine (PIPO) overstory and

Table 11-Seral status and vegetation structure for PNCs coded in tables 5 and 9

PNC	Condition	Seral status/structure
PSME/PHMA/THOC	(example[a])	CDCLMP/LTMU-TSMU-HEDU
PIPO/PUTR/CAGE	Overgrazed	CPEPPE/MTMU-MSMU-HEOE
	Underburned	CPEPEP/MTMU-NSNN-HEDE
	Herb structure[b]	CPEPEP/MTMU-HEDE
	Clearcut	CPEEPP/SHNN-MSMU-HEDE
	Shrub structure[c]	CPEEPP/MSMU-HEDE
JUOC/ARTR/AGSP	Overgrazed	CJEPPE/PTOU-MSOU-HEOE
	Burned	CJEEEP/SHNN-NSNN-HEMU
	Herb structure[d]	CJEEEP/HEMU
ARTR/AGSP	Overgrazed	SDEXPE/MSOU-HEOE
	Burned	SDEXEP/NSNN-HEMU
	Herb structure[e]	SDEXEP/HEMU
AGSPIPOSA3	Overgrazed	GBEXXE/HEOE

[a] Example from figures 5, 6, and 7.
[b] Underburned with no shrub structure; omit shrub layer and use herb layer.
[c] Clearcut with no tree structure; omit tree layer and use shrub and herb layers.
[d] Burned with no tree or shrub structure; use only the herb layer.
[e] Burned with no shrub structure; use only the herb layer.

Douglas-fir (PSME) understory and a combined cover of 50 percent. This would be **uneven strata** and **moderate** cover. Methods for combining the codes are presented below.

Coding by Seral Status and Structure

Combining seral status with structure means combining most of the coding. Suggested order would be PNC, seral classification source, seral status of tree, shrub, and herb lifeforms/size, cover, strata. The PNC code preceding structure is dropped when combining with seral status to avoid duplication. Using the Douglas-fir/ninebark/meadowrue example, stand condition would be Douglas-fir PNC, classification study source, late seral tree, mid seral shrub, PNC herb status/large-diameter trees, moderate cover, and uneven strata. Coding would be:

CDCLMP/LTMU

A complete stand condition description would add shrub and herb structure as follows:

CDCLMP/LTMU-TSMU-HEDU

This would read as: Douglas-fir PNC evaluated by a classification study indicating late seral tree, mid seral shrub, and PNC herb layers; currently in large-diameter trees of moderate cover with uneven tree strata; tall shrubs of moderate cover in uneven shrub strata; and an herbaceous layer that is dense in cover and of uneven strata.

Codes for the PNCs previously illustrated in tables 5 and 9 are shown combined in table 11.

Combining PNC Association, Seral Status, and Vegatation Structure

List the PNC association code first and separate it from seral status by a virgule (/), separate seral status from vegetation structure by another virgule, then list the structure codes by tree-shrub-herb layers. The Doug las-fir/ninebark/meadowrue example would be:

CDS721/CLMPILTMU-TSME-HEDU

which is read as Douglas-fir/ninebark/meadowrue plant association as described by Steele and others (1981), which has been classified according to Steele and Geier-Hayes (1989) as late seral tree, mid seral shrub and PNC herb layers with large-diameter trees of moderate canopy cover and uneven strata, tall shrubs of moderate canopy cover and uneven strata, and an herbaceous layer that is dense in cover and of uneven strata.

Conclusion

Seral status of plant communities can be based on separate evaluations of each lifeform layer: tree, shrub, and herb-cryptogam. Thus, a one- to three-part estimate of successional status is produced, depending on how many life-forms are present in PNC. Assessment by life-form provides refined documentation of plant community successional characteristics and provides opportunities to relate disturbance factors to the seral status. Structure of stands may be added to seral status to complete a documentation of stand condition. Coding systems are proposed to index seral status and structure of existing vegetation.

Metric Equivalents

1 inch (in) = 2.54 centimeters
1 foot (ft) = 0.31 meter

Literature Citations (Annotated)

Allen, Barbara H. 1987. Ecological type classification for California: the Forest Service approach. Gen. Tech. Rep. PSW-98. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 8 p.

Discusses plant community classification and the relation between habitat type, plant association, range site, and PNC plant community type, all of which are based on the "climax" or PNC concept. A table summarizes similarities and differences among 11 approaches.

Archer, Steve; Scifres, Charles; Bassham, C.R. 1988. Autogenic succession in a subtropical savanna: conversion of grassland to thorn woodland. Ecological Monographs. 58(2): 111-127.

Discusses vegetational change on the Rio Grande Plains of Texas to test the hypothesis that former grasslands have been converted to dense thorn woodlands since settlement. The conclusions were that mesquite invades grassland and forms nuclei of shrub clusters that expand; woody plant community development has been highly punctuated by variations in precipitation; and livestock grazing and fire suppression are only two of several factors causing a change from grassland to shrubland.

Arno, Stephen F.; Simmerman, Dennis G.; Keane, Robert F. 1985. Forest succession on four habitat types in western Montana. Gen. Tech. Rep. INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 74 p. .

Describes species characterizing succession and provides means to record their reaction; provides concepts and methods for characterizing succession.

Arno, Steven F.; Simmerman, Dennis G.; Keane, Robert F.1986. Characterizing succession within a forest habitat type-an approach designed for resource managers. Res. Note INT-357. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 8 p.

Presents in detail how to determine and characterize succession in forested plant communities.

Brown, E. Reade, tech. ed. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1: Chapter narratives. R6 F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 332 p.

Demonstrates that successional vegetation is a key component in wildlife habitat; treatment to attain desired wildlife habitat must consider both potential and successional vegetation.

Busby, Frank E. "Fee"; Buckhouse, John C.; Clanton, Donald C. [and others].

1994. Rangeland health: new methods to classify, inventory, and monitor rangelands. Washington, DC: National Academy Press. 182 p.

Seral status of rangelands applies to both vegetation and soils. Rangeland health deals with the nature of successional conditions and defines thresholds beyond which a plant community cannot, through secondary succession, return to the original potential natural community.

Cain, Stanley A. 1939. The climax and its complexities. American Midland Naturalist. 21: 147-158.

Discusses problems associated with single species dominance and plant community stability in relation to environmental changes (mostly climate). Emphasizes instability of "climax" as environment changes and how we perceive stable environment. Was it the same when the community evolved as it is today or will be tomorrow? Also implies that structural complexity is thought to be related to climax, but it may not be.

Clausnitzer, Roderick 8.1993. The grand fir series of northeastern Oregon and southeastern Washington: successional stages and management guide. R6 ECO-TP-05093. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 202 p.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs. 22: 301-329.

The plant community is at the climax stage if it appears to be self-regenerating and there is no concrete evidence that it is followed by a different subsequent community. It is in the seral stage if interrupted age-gradients in species populations show that the sociologic status of at least some of the species is temporary.

Daubenmire, 8.1976. The use of vegetation in assessing the productivity of forest lands. Botanical Review. 42: 115-143.

Climax is any association that appears to be self-perpetuating in the absence of disturbance. There is no demonstrable evidence that it is susceptible to natural replacement by another community under the existing conditions of climate, soil, and flora. Seral is any community that through existing population structure, or observation through time, has demonstrated progressive (unidirectional) change in its composition or structure; any species unsuccessful in competing for habitat resources. Forest undergrowth approximates climax status soon after the first seral trees form an essentially closed canopy, especially where the seral and climax overstories are of the same physiognomic type; for example, evergreen conifers.

Daubenmire, Rexford. 1968. Plant communities: a textbook of plant synecolgy. New York: Harper and Row. 300 p.

Climax is a multiconditioned product of succession, its character reflecting the influences of all edaphic, aerial, and biotic factors that compose the environmental complex. Describes climatic, edaphic, topographic, fire, zootic, and combinations of climaxes; see p. 229-237 (basically after Tansley).

Driscoll, Richard S.; Merkel, Daniel L.; Radloff, David L. [and others]. 1984. An ecological land classification framework for the United States. Misc. Publ. 1439. Washington, DC: U.S. Department of Agriculture, Forest Service. 56 p.

Discusses the concept of climax, pristine vegetation, current vegetation resulting from human influences on environment, and the concept of potential natural communities under **existing** environmental conditions, which may include altered soil (eroded) and altered environment (fire suppression). The authors discuss the lowest level in the plant community classification hierarchy, the association, and its relation to habitat type, range site, and other bottom-level classifications. They propose a three-way classification framework combining vegetation, topography and geology, and soil. Provides UNESCO worldwide criteria for defining trees, shrubs, and kinds of PNCs.

Foster, D.R.; Zebryk, T.M. 1993. Long-term vegetation dynamics and disturbance of a Tsuga-dominated forest in New England. Ecology. 74(4): 982-998.

Evaluates long-term vegetation dynamics of two forest stands by use of pollen analysis in swamp sediments. Nonstability due to various disturbances over the last 12,000 years was found; Tsuga tend to recover from disturbance in 300 to 1200 years.

Glenn-Lewin, David C.; Peet, Robert K.; Veblen, Thomas T. 1992. Plant succession: theory and prediction. New York: Chapman & Hall. 352 p.

Discusses and rejects the Clementsian paradigm of ultimate stable state, then covers various concepts and generalities of succession and final stability (climax) or lack of stability. Chapters by various authors present current concepts of succession leading to a constantly changing "climax": "In many landscapes successional change rarely proceeds all the way to a climax endpoint ...."

Greig-Smith, P. 1964. Quantitative plant ecology. London: Butterworths. 256 p.

Defines climax as relative stability of the composition and structure (life-form) of a plant community after reasonably directional change due to disturbance (see p. 213-215).

Halt, Frederick C. 1995. Pacific Northwest ecoclass codes for seral and potential natural vegetation. R6 ECOL-TP-12-95. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Discusses the relation among plant association, habitat type, range site, and the suggested approach used by the USDA Forest Service for adding productivity, reaction to disturbance, and critical management requirements to classification by association. Develops an open-ended system to identify plant associations that uses a six-digit alpha-numeric code; provides six appendixes listing various groupings of associations in different hierarchial systems. Seral and structure codes are given.

Hall, Frederick C.; Brewer, Larry W.; Franklin, Jerry F.; Werner, Richard L. 1985.
Plant communities and stand conditions. In: Brown, E. Reade, tech. ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1: Chapter narratives. R6 F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region: 17-31.

Defines stand conditions used in this current report. We (the authors, GTR-363) chose not to use seral status.

Helliwell, R.; Rawlings, R. 1994. Plants, plant communities, and plant succession of the Big Summit Ranger District, Ochoco National Forest, Oregon. Prineville, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Ochoco National Forest.

Provides matrix tables from which table 9 in our report (this paper, GTR-363) was developed; provides indicator values by species and plant association groups for modification of the Ochoco Forest plan.

Kormandy, Edmund J.1969. Concepts of ecology: concepts of modern biology series. Englewood Cliffs, NJ: Prentice-Hall Biological Series. 209 p.

Climax is a complex functioning plant community with increasing niches, diversity in flora and fauna, and variety in structure. Thus there is less likelihood that a shift in one component will adversely affect the system as a whole (p. 158-159).

McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., comps. 1990. Proceedings: Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 351 p.

Contains 11 papers on cheatgrass invasion, competition, fire effects, and shrub die-off. Annuals such as cheatgrass are mentioned in several other articles dealing with shrub health.

Means, Joseph E., ed. 1982. Forest succession and stand development research in the Northwest. Proceedings of a symposium; 1981 March 26; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, Oregon State University. 171 p.

Comprehensive document on forest succession, seral status, and past, existing, and proposed research.

Meeker, Donald O., Jr.; Merkel, Daniel L. 1984. Climax theories and a recommendation for vegetation classification-a viewpoint. Journal of Range Management. 37(5): 427-430.

Discusses four concepts of climax: monoclimax, polyclimax, climax pattern, and site climax. They propose site climax because it uses polyclimax concepts and adds soil erosion as a criterion for causing a new kind of climax. Primarily oriented toward range management and concepts of condition and trend.

Minore, Don. 1979. Comparative autecological characteristics of northwestern tree species-a literature review. Gen. Tech. Rep. PNW-87. Portland, OR: U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station.

Provides information on an extensive species list for shade tolerance and other autecological characteristics.

Monsen, Stephen B.; Kitchen, Stanley G. 1994. Proceedings: Ecology and management of annual rangelands; 1992 May 18-22; Boise, ID. Gen. Tech. Rep. I NT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 416 p.

Lists 19 papers specifically dealing with cheatgrass and 10 more where cheatgrass is part of the discussion. Topics cover fire, grazing, chemical and mechanical treatment, competition, sagebrush succession, soil characteristics, autecology, and competition with other noxious plants such as Russian star thistle and medusahead.

Mueller-Dombois, D.; Ellenberg, H. 1974. Aims and methods of vegetation ecology. New York: John Wiley & Sons.

Prefers "community stability" to the term "climax." Stability is characterized by species composition and structure of the community. Discusses in detail interpretation of structure to demonstrate replacement of species by multiaged structure as a criterion for stability. Authors do not quantify how much change in structure and species composition is tolerated for a stable community, but they do illustrate it and discuss three scales of stability: local or habitat, watershed or landscape, and regional. "In each case the stability relations would be expected to be quite different" (see p. 96-99, 397-410).

Murphy, Dennis, comp. 1991. Getting to the future through silviculture: Workshop proceedings; 1991 May 6-9; Cedar City, UT. Gen. Tech. Rep. INT-291. Ogden, UT: U.S. Department or Agriculture, Forest Service, Intermountain Research Station. 97 p.

Papers deal with existing and potential vegetation, silvicultural treatment, management objectives, wildlife habitat, and interpretation of seral status. Covers the United States.

Oliver, Chadwick D.; Larson, Bruce L. 1990. Forest stand dynamics. Biological Resource Management Series. New York: McGraw-Hill. 467 p.

Has chapters on the following: plant interactions and limitations of growth; tree architecture and growth; disturbances and stand development; overview of stand development patterns; temporal and spacial patterns of tree invasion; stand initiation stage; stem exclusion stage for single-species stands; stem exclusion stage for mixed species stands; understory reinitiation stage; old-growth stage; behavior of component cohorts in multicohort stands; development of multicohort stands; stand edges, gaps, and clumps; quantification of stand development; and forest patterns over long times and large areas.

Oosting, Henry J. 1958. The study of plant communities. San Francisco: W.H. Freeman and Co. 440 p.

Eventually, succession terminates in communities whose complex of species is so adjusted to each other, in the environment that has developed, that they are capable of reproducing within the community and of excluding new species, especially potential dominants, from becoming established (see p. 249-252).

Pielou, E.C. 1991. After the Ice Age: the return of life to glaciated North America. Chicago: The University of Chicago Press. 366 p.

Discusses the last 20,000 years and the vegetation and animal changes following the Ice Age. Part Five deals with the present epoch, succession following ice withdrawal, shifting range of trees, refugia, and lack of stability due to climate changes of communities supposedly at "climax."

Simpson, M.; Zalunardo, D.; Eglitis, A. [and others]. 1994. Viable ecosystem management guide, Ochoco National Forest. Prineville, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Ochoco National Forest. 131 p.

Provides descriptions and diagrams of stand structure and seral status; shows the combination of seral status and stand structure in matrix tables; applies the seral status-structure concept to five groups of plant associations from juniper to moist grand fir; correlates wildlife species to each seral status-structure component; lists plant association group reaction to fire and insects and disease; and provides a map and illustration of use in the Trout Creek watershed.

Steele, Robert; Geier-Hayes, Kathleen. 1987. The grand fir/blue huckleberry habitat type in central Idaho: succession and management. Gen. Tech. Rep. INT-228. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 66 p.

Steele, Robert; Geier-Hayes, Kathleen. 1989. The Douglas-fir/ninebark habitat type in central Idaho: succession and management. Gen. Tech. Rep. INT-252. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 65 p.

This study was used to illustrate seral status and stand structure. Their figures 3, 9, and 15 were reproduced as figures 5, 6, and 7, respectively, in this current paper.

Steele, Robert; Geier-Hayes, Kathleen. 1992. The grand fir/mountain maple habitat type in central Idaho: succession and management. Gen. Tech. Rep. INT-284. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research **Station. 90 p.**

Steele, Robert; Geier-Hayes, Kathleen. 1993. The Douglas-fir/pinegrass habitat type in central Idaho: succession and management. Gen. Tech. Rep. INT-298. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 83 p.

Steele, Robert; Geier-Hayes, Kathleen. 1994. The Douglas-fir/white spirea habitat type is central Idaho: succession and management. Gen. Tech. Rep. INT-305. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 81 p.

Steele, Robert; Phister, Robert D.; Ryker, Russel A.; Kittams, Jay A. 1981. Forest habitat types of central Idaho. Gen. Tech. Rep. INT-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 139 p.

Classifies habitat types (plant associations) as follows: limber pine (4), ponderosa pine (7), Douglas-fir (17), Engelmann spruce (4), grand fir (9), subalpine fir (21), lodgepole pine (4), and five other vegetation types. The ponderosa pine phase of the Douglas-fir/ ninebark habitat type was chosen to illustrate seral status and stand structure (see Steele and Geier-Hayes 1989).

Thomas, Jack Ward, tech. ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture, Forest Service. 512 p.

Deals with successional vegetation and use of seral status and stand structure to manage for wildlife habitat and diversity.

Thomas, Jack Ward; Maser, Chris, tech. eds. 1986. Wildlife habitats in managed rangelands-the Great Basin of southeastern Oregon. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. [A series].

The following separate general technical reports use seral status and vegetation structure in dealing with wildlife habitat: Plant Communities and Their Importance to Wildlife (GTR PNW-120), The Relationship of Terrestrial Vertebrates to Plant Communities and Structural Conditions (Part 1, text, GTR PNW-172), Sage Grouse (GTR PNW-187), Pronghorns (GTR PNW-145), Mule Deer (GTR PNW-139), Bighorn Sheep (GTR PNW-159), Edges (GTR PNW-85), Manmade Habitats (GTR PNW-86), and Management Practices and Options (GTR PNW-189).

U.S. Department of Agriculture, Forest Service. 1937. Range plant handbook. Washington, DC: U.S. Department of Commerce, Clearing House for Federal Scientific and Technical Information. 535 p.

Defines the autecological characteristics of range herbs, shrubs, and a few trees; includes species' reaction to grazing and palatability to various domestic livestock.

U.S. Department of Agriculture, Forest Service. 1967. Range condition standard: mixed conifer-Calamagrostis-Carex, Blue Mountains. R6 2210-53. Portland, OR: Pacific Northwest Region. 10 p.

Applies regression analysis of tree cover effects on the herbaceous life-form layer by using the three-step sampling system. As tree cover increases from 20 to 80 percent, herbaceous density as measured by use of perennial species decreases 3.3-fold, and composition of pinegrass and elk sedge decreases by 2.3-fold.

U.S. Department of Agriculture, Forest Service. 1991. Ecological classification and inventory handbook, FSH 2090.11, effective 4/26/1991. Washington, DC: U.S. Department of Agriculture, Forest Service.

Defines potential natural community (PNC) and late, mid, and early seral status. These definitions have been used for this current report.

U.S. Department of Agriculture, Forest Service. 1993. Excerpts from forest ecosystem management: an ecological, economic, and social assessment (FEMAT report). Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 139 p.

Discusses ecological assessments for terrestrial and aquatic ecosystems where seral status is a key element for inventories and management.

U.S. Department of Agriculture, Forest Service. 1994. A Federal agency guide for pilot watershed analysis. Portland, C1R: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 150 p.

Describes inventory and stratification of watersheds based on potential and existing vegetation (seral status-structure), disturbances, and aquatic characteristics and how to integrate these into a land management plan.

Waring, Richard H.; Schlesinger, William H. 1985. Forest ecosystems: concepts and management. Orlando, FL: Academic Press. 340 p.

Contains chapters on carbon balance of trees, productivity and succession, tree-water relations, hydrology, nutrient cyling, nutrient uptake and internal distribution, decomposition and soil development, susceptibility and response to natural agents, linkages of terrestrial and aquatic ecosystems, and global ecology. Productivity and succession deal with leaf area index, photosynthetic efficiency, growth, and succession. A site has a limited capacity to produce leaf area, thus leading to transpirational and photosynthetic stress. Most efficient species generally tend to displace less efficient species in succession. Excellent discussion on cause-effect systems in stand development.

Whitlock, Cathy. 1993. Postglacial vegetation and climate of Grand Teton and southern Yellowstone National Parks. Ecological Monographs. 63(2): 173-198.

Uses pollen analysis over the last 14,000 years and data for modern pollen rain to evaluate climate change and plant community change. Shows that climate change, substrate, and migration history shaped the vegetation variability.

Whittaker, R.H. 1953. A consideration of climax theory: the climax as a population and pattern. Ecological Monographs. 23(1): 41-78.

Cites about 760 references on climax and succession. Climax is defined as (1) slow change (trend) in the plant community (as opposed to directional change in seral communities); (2) reproduction of existing species; (3) regularity (homogeneity) within stands; and (4) similarity between stands on similar sites. Author does not use stand structure as a major criteria.

Appendix A
Species Acronyms

Acronym.	Scientific name	Common name
ABGR	*Abies grandis* (Dougl. ex D. Don) Lindl.	Grand fir
AGSP	*Agropyron spicatum* (Pursh) Scribn. & Smith	Bluebunch wheatgrass
ALRU	*Alnus rubra* Bong.	Red alder
ANN		Annuals
AMAL	*Amelanchier alnifolia* Nutt.	Serviceberry
APAN	*Apocynum androsaemifolium* L.	Dogbane
ARTR	*Artemisia tridentata* Nutt.	Big sagebrush
BRCA	*Bromus carinatus* Hook. & Arn.	Mountain bromegrass
BRODIAEA	*Brodiaea* species	Brodiaea
BRTR	*Bromus tectorum* L.	Cheatgrass brome
CAGE	*Carex geyeri* Boott	Elk sedge
CARU	*Calamagrostis rubescens* Buckl.	Pinegrass
CEVE	*Ceanothus velutinus* Dougl.	Shinyleaf ceanothus
CHNA	*Chrysothamnus nauseosus* (Pall.) Britt.	Gray rabbit-brush
DAUN	*Danthonia unispicata* (Thurb.) Munro	Onespike oatgrass
EPAN	*Epilobium angustifolium* L.	Fireweed
FRVE	*Fragaria vesca* L.	Strawberry
GASH	*Gaultheria shallon* Pursh	Salal
ILRI	*Lliamna rivularis* (Dougl.) Greene	Globemallow
JUOC	*Juniperus occidentalis* Hook.	Western juniper
LAOC	*Larix occidentalis* Nutt.	Western larch
LIDE3	*Lithocarpus densiflorus* (Hook. & Am.) Rehd.	Tanoak
MAGL	*Madia glomerata* Hook.	Tarweed
PHMA	*Physocarpus malvaceus* (Greene) Kuntze	Ninebark
PIPO	*Pinus ponderosa* Doug[. ex Laws	Ponderosa pine
POGL	*Potentilla glandulosa* Lindl.	Gland cinquefoil
POTR	*Populus tremuloides* Michx.	Quaking aspen
POSA3	*Poa sandbergii* Vasey	Sandberg’s bluegrass
PREM	*Prunus emarginata* (Dougl.) Walp.	Bittercherry
PSME	*Pseudotsuga menziesii* (Mirbel) Franco	Douglas-fir
PUTR	*Purshia tridentata* (Pursh) DC	Bitter-brush
RICE	*Ribes cereum* Dougl.	Squaw current
SASC	*Salix scoulerana* Barratt ex Hook.	Scouler willow
SPBE	*Spirea betulifolia* Pallas	Shiny-leaf spirea
THOC	*Thalictrum occidentale* Gray	Western meadowrue
TORTULA	*Tortula* spp.	Scabland moss
TSHE	*Tsuga heterophylla* (Raf.) Sarg.	Western hemlock

Species Common Names

Common name	Acronym	Scientific name
Annuals	ANN	
Big sagebrush	ARTR	*Artemisia tridentata*
Bitter-brush	PUTR	*Purshia tridentata*
Bittercherry	PREM	*Prunus emarginata*
Bluebunch wheatgrass	AGSP	*Agropyron spicatum*
Brodiaea	BRODIAEA	*Brodiaea* species
Cheatgrass brome	BRTR	*Bromus tectorum*
Dogbane	APAN	*Apocynum androsaemifolium*
Douglas-fir	PSME	*Pseudotsuga menziesii*
Elk sedge	CAGE	*Carex geyeri*
Fireweed	EPAN	*Epilobium angustifolium*
Gland cinquefoil	POGL	*Potentilla glandulosa*
Globemallow	ILRI	*Iliamna rivularis*
Grand fir	ABGR	*Abies grandis*
Gray rabbit-brush	CHNA	*Chrysothamnus nauseosus*
Mountain bromegrass	BRCA	*Bromus carinatus*
Ninebark	PHMA	*Physocarpus malvaceus*
Onespike oatgrass	DAUN	*Danthonia u*nispicata
Pinegrass	CARU	*Calamagrostis rubescens*
Ponderosa pine	PIPO	*Pinus ponderosa*
Quaking aspen	POTR	*Populus tremuloides*
Red alder	ALRU	*Alnus rubra*
Sandberg's bluegrass	POSA3	*Poa sandbergii*
Salal	GASH	*Gaultheria shallon*
Scabland moss	TORTULA	*Tortula*
Scouler's willow	SASC	*Salix scoulerana*
Serviceberry	AMAL	*Amelanchier alnifolia*
Shinyleaf ceanothus	CEVE -	*Ceanothus velutinus*
Shiny-leaf spirea	SPBE	*Spirea betulifolia*
Squaw current	RICE	*Ribes* cereum
Strawberry	FRVE	*Fragaria vesca*
Tanoak	LIDE3	*Lithocarpus densiflorus*
Tarweed	MAGL	*Madia glomeratus*
Western hemlock	TSHE	*Tsuga heterophylla*
Western juniper	JUOC	*Juniperus occidentalis*
Western larch	LAOC	*Larix occidentalis*
Western meadowrue	THOC	*Thalictrum occidentale*

Appendix B
Definitions and Discussion of Selected Terms

Climax-The plant community that appears to be self-perpetuating in the absence of disturbance and that is not followed by a different subsequent community (Daubenmire 1952, 1968, 1976; Driscoll and others 1984; Greig-Smith 1964; Kormandy 1969; Mueller-Dombois and Ellenberg 1974; Oosting 1958; Whittaker 1953). It is usually not completely stable but fluctuates around a modal composition and dominance of species (Cain 1939; Daubenmire 1968, 1976; Mueller-Dombois and Ellenberg 1974; Oosting 1958; Whittaker 1953). Whittaker (1953) devotes 37 pages to climax and cites about 760 references on the topic.

Some authors **imply** that vegetation structure, particularly in forest stands, is an important feature of climax conditions (Cain 1939; Daubenmire 1952, 1976; Kormandy 1969; Mueller-Dombois and Ellenberg 1974; Oosting 1958; Whittaker 1953). They emphasize that all species must be reproducing successfully, suggesting both a seed source and regeneration on the site. In woody plant communities, this presumes at least a two-storied stand. Only Mueller-Dombois and Ellenberg (1974) deal with structure in detail (p. 96-99, 397-410). They state that a naturally imposed change in structure and cover by species, even though no species is either lost or gained; constitutes instability (p. 407) and, therefore, nonclimax. Their reliance on structure and cover by species led them to use the term "stability" rather than "climax" for the end point in succession.

The concept of climax seems to be controversial with little common agreement on what it constitutes (Cain 1939, Meeker and Merkel 1984, Mueller-Dombois and Ellenberg 1974, Whittaker 1953). Recently, the concept of a "stable climax" has been challenged and replaced with the idea of a plant community that is in a constant state of flux (Archer and others 1988, Busby and others 1994, Foster and Zebryk 1993, Glenn-Lewin and others 1992, Meeker and Merkle 1984, Pielou 1991, Whitlock 1993). Therefore, the term "climax" is not used in this paper. Instead, potential natural community (PNC) is be used.

Potential natural community (PNC)-The biotic community that one presumes would be established and maintained over time under present environmental conditions if all successional sequences were completed without additional human-caused disturbance. Present environmental conditions include current climate and eroded or damaged soils. A damaged soil would produce a PNC different from that for an undamaged soil (Busby and others 1994, Meeker and Merkel 1984). Current climate may produce a PNC different from historical climate (Cain 1939, Foster and Zebryk 1993, Pielou 1991, Whitlock 1993). Grazing by native fauna and natural disturbances, such as drought, floods, wildfires, wind, insects, and disease, are inherent in the **development** of communities. However, PNCs are described **without** disturbance by natural elements, including fire. PNCs may include naturalized nonnative species. Thus, a PNC is composed of those species the **investigator presumes** will be most competitive over time (climax) and will prevent establishment by less competitive (seral) species under existing site conditions and climate, and without disturbance. PNCs also are called plant associations, habitat types, and range sites (Allen 1987, Daubenmire 1952, Driscoll and others 1984, Hall 1995).

Note the criteria for "present environmental conditions." Damaged or eroded sites have lost their ability to produce the original PNC. This is a major difference between PNC and the classical concept of climax. "Disclimax," "postclimax," and similar terms are not used. A changed soil is considered to have crossed a "threshold" whereby secondary succession back to the historical PNC is no longer possible (Busby and others 1994, Meeker and Merkel 1984). This is termed an **"altered PNC."**

At times, vegetation thresholds are crossed whereby the historical PNC is changed to a new kind of PNC (Busby and others 1994, McArthur and others 1990, Monsen and

Kitchen 1994). Severe damage to vegetation without soil degradation can destroy a historical PNC and result in succession to a different PNC. Or change in successional processes, such as invasion by highly competitive nonnative species such as cheatgrass (BRTE), may alter the historical PNC (McArthur and others 1990, Monsen and Kitchen 1994). This is also called an **"altered PNC."**

A widely held concept for characterizing PNCs is evidence of regeneration of all species in the PNC community, either regularly or periodically (gap-phase regeneration) to the eventual exclusion of seral species. The PNC is primarily indicated by presence of all PNC species with no potential for further species replacement unless the site is disturbed or the environment changes. Structure, size, canopy cover,- growth, and age distribution are not usually considered criteria for PNC. An example is a grand fir/pinegrass (ABGR/CARU) potential natural community (see appendix B for acronyms). In **mid** seral status, grand fir occurs as regeneration and saplings under dominant ponderosa pine (PIPO). The pine can be removed, leaving sapling grand fir/pinegrass, which is then considered to be in **PNC** status, even though grand fir is less than half the potential crown cover, no grand fir are mature enough to produce cones, only one strata of fir exists, and pinegrass cover is greater than it would be under full grand fir crown cover. All PNC species are present and they are reproducing, or can replace themselves sometime in the future. In this case, structure can help define stand conditions; however, structure is not a criterion for seral status (see section, "Vegetation Structure").

Variations in cover, productivity by species, and structure or age combined with size are generally not used as criteria for PNC although they are considered valuable for management purposes and may be added to seral status. PNC is used here to denote a community composed of those species whose dominance in the community is relatively stable after succession. It is a state of vegetation that can **be attained** rather than a distant vision of a nonachievable status. For example, less than 10 percent cover by a seral species is permissible, such as one old ponderosa pine per acre in a grand fir PNC community or 5 percent composition of squirreltail grass in a wheatgrass PNC.

The PNCs are used as a **reference point** to which seral status is related. Using PNC as a presumed **attainable** endpoint simplifies description and use of seral status.

Succession-The series of changes in plant communities leading to a relatively stable PNC under existing environmental conditions without further disturbance. Succession is indicated by interrupted or unbalanced age gradients in species populations, which shows that at least some of the species are temporary, or by progressive (unidirectional) change in species composition or structure (Daubenmire 1952, 1968, 1976; Greig-Smith 1964; Mueller-Dombois and Ellenberg 1974; Whittaker 1953).

Size of woody vegetation, crown cover, and productivity usually are not criteria. Directional, rather than random, change in species is the criterion for recognizing succession.

Retrogressive succession is discussed in detail by Busby and others (1994) and Meeker and Merkle (1984). They describe how livestock grazing can damage soil, or vegetation, or both, causing a downward trend (retrogressive) in the historical PNC community. Methods for rating this situation have been called range condition guides (USDA Forest Service 1967). At times, retrogressive succession proceeds to the point where a threshold is crossed and secondary succession back to the historical PNC is no longer feasible, a condition we term an **"altered PNC."**

Appendix C

This appendix may be copied and used as a field reference.

Seral and Structural Codes

Summary of seral and structural codes repeating tables 2 through 4 and 6 through 8 with references on the criteria selected.

Table 12-Potential natural community (PNC) codes[a] (table 2)

Code	PNC	Code	PNC
Coniferous tree species:		Forb lands:	
CA	Alpine, open, forest park	FM	Moist (mesic) forb land
CC	Western redcedar	FS	Subalpine or alpine forb land
CD	Douglas-fir	FW	Wet forb land
CE	Subalpine fir, Engelmann spruce		
CF	Silver or noble fir	Grasslands:	
CH	Western hemlock		
CJ	Western juniper	GA	Annual grasslands
CL	Lodgepole pine	GB	Bunchgrasses
CM	Mountain hemlock	GM	Mesic (forest zone) grasslands
CP	Ponderosa, Jeffery pine	GR	Rhizomastous grass-sedge
CR	Red fir	GS	Subalpine, alpine grasslands
CS	Sitka spruce		
CW	Grand or white fir	Meadows (wet) grass-sedge:	
Hardwood tree species:		MD	Dry meadow
		MM	Moist meadow
HA	Alder	MS	Subalpine or alpine
HB	Bigleaf maple	MT	Tule, standing water
HC	Cottonwood-ash bottoms	MW	Wet meadow
HL	Canyon live-oak tree size		
HO	Oak, Oregon or black	Shrublands:	
HQ	Quaking aspen		
HT	Tanoak tree size	SC	Chaparral
		SD	Dry shrubland (sagebrush)
		SM	Mesic (forest zone) shrubland
		SS	Subalpine, alpine shrubland
		SW	Wet shrubland

[a] Codes are from Hall 1995.

Table 13-Seral classification code, source, and criteria (table 3)

Code	Source	Criteria
C	Classified	Seral status is classified from an investigation or research study that has characterized seral status in the PNC being evaluated.
E	Estimated	Seral status has been estimated based on the observer's best analysis of the vegetation.
A	Altered	Disturbance has changed the historic PNC resulting in a soil or vegetation threshold being crossed; an estimation of seral status may not be possible.

Table 14-Seral status code, source, and criteria (table 4)

Code	Source	Criteria
P	PNC	The potential natural community under existing environment; seral species scarce to absent.
L	Late seral	PNC species are dominant, but sera[species still persist.
M	Mid seral	PNC species are approaching equal proportions with seral species.
E	Early seral	Clear dominance of seral species; PNC species absent or very low in cover; absence of a life-form layer such as absence of trees in a forest PNC.
X	None	A life-form is not present or status is not determined.
D	Depauperate	Low canopy cover in a life-form due to dense woody cover (that is, stem exclusion stage)(fig. 1).

Coding Systems

Seral status and structure by life-form layer are illustrated by using an example of PSME/PHMA/THOC. Stand condition is as follows: the tree life-form layer has ponderosa pine (PIPO) dominant at 21 to 32 in diameter breast height (d.b.h.) and 20 percent canopy cover with Douglas-fir (PSME) in the understory at 1 to 20 in d.b.h. and 30 percent canopy cover; the shrub layer has-bittercherry (PREM) dominant at 7 ft tall and 15 percent cover with spiraea (SPBE) at 18 in tall and 25 percent cover; and the herb layer is dominated by pinegrass (CARU) at 50 percent cover with meadowrue (THOC) at 20 percent cover.

Seral status-Code seral status by life-form layer as follows, using the PSME/PHMA/THOC example:

1. List a two-letter PNC code (for example, **CD** for Douglas-fir).
2. List a one-letter code for source of seral status (**C** for a successional classification from an investigation).
3. List a one-letter code each for seral status of the tree, shrub, and herb layers (that is, **L** for late seral tree layer, **M** for mid seral shrub layer, and **P** for PNC herb layer).

The code would be: **CDCLMP**

Seral status for a single life-form layer; the example of PSME/PHMA/THOC:

The code would be: **CDCL**

Structure-Code structure by life-form layer as follows, using the PSME/PHMA/THOC example:

1. List a two-letter code for PNC (for example, **CD** for Douglas-fir).
2. List a two-letter code for tree size (for example, **LT** for large-diameter trees).
3. List a one-letter code for tree cover (for example, **M** for moderate).
4. List a one-letter code for tree strata (for example, **U** for uneven sized).

The code would be: **CDLTMU**

Table 156-Forest land structural classes (table 6)

Code	Class	Characteristics
Tree diameter classes:[a]		
SH	Shrub-herb	Trees, if present, less than 1 inch d.b.h.; area may be dominated by grasses, herbs, shrubs or bare ground; trees may dominate but are less than 1 inch d.b.h.
ST	Sapling trees	Trees from 1 to 4.9 inches d.b.h. (20 TPA[b])
PT	Pole trees	Trees from 5 to 8.9 inches d.b.h. (15 TPA)
MT	Medium trees	Trees from 9 to 20.9 inches d.b.h. (10 TPA)
LT	Large trees	Trees from 21 to 31.9 inches d.b.h. (10 TPA)
GT	Giant trees	Trees from 32 to 47.9 inches d.b.h. (5 TPA)
RT	Remnant trees	Trees larger than 48 inches d.b.h. (5 TPA)
Tree canopy cover classes:[c]		
N	None	Less than 10 percent canopy cover
O	Open	From 10 to 40 percent canopy cover
M	Moderate	From 40 to 69 percent canopy cover
D	Dense	Over 70 percent canopy cover
Tree strata classes:		
N	None	No tree life-form
E	Even strata	A single tree strata; less than 30 percent difference in size of trees
U	Uneven strata	Two or more tree strata; more than 30 percent difference in height between trees. To qualify as a strata, canopy cover in the strata must exceed 10 percent except for regeneration less than 1 inch d.b.h. where at least 100 established trees per acre (22 feet between trees) qualifies as a strata.

[a] Applies to the largest trees or tree species. A class is determined by the average d.b.h. of the number of trees per acre (TPA) shown.
[b] TPA = trees per acre.
[c] Applies to all tree strata added together. Canopy covers were derived as follows:
10 percent is the United Nations Educational, Scientific and Cultural Organization (UNESCO) minimum cover for identifying woodland or shrubland communities (Driscoll and other 1985).
10 to 40 percent constitutes an open stand and was derived from aerial photograph density estimates of "one-bar" stocking at 10 to 40 percent canopy cover.
40 to 70 percent constitutes a "two-bar" stocking definition and often approximates approach to thermal cover (Hall and others 1985).
Over 70 percent is thermal cover (Hall and others 1985) and has been coded as "three-bar" or fully stocked stands; UNESCO uses 67 percent cover for "forest" types as opposed to woodland.

Table 16-Shrubland structural classes (table 7)

Code	Class	Characteristics
Shrub height classes:[a]		
NS	No shrubs	Less than 10 percent canopy cover
LS	Low shrubs	Shrubs less than 1.7 feet tall (20 inches)
MS	Medium shrubs	Shrubs 1.7 to 6.5 feet tall
TS	Tall shrubs	Shrubs 6.5 to 16.5 feet tall
Shrub cover classes:[b]		
N	None:	Less than 10 percent canopy cover
O	Open:	From 10 to 25 percent canopy cover
M	Moderate:	From 26 to 66 percent canopy cover
D	Dense:	Over 67 percent canopy cover
Shrub strata classes:		
N	None	No shrub strata
E	Even strata	One shrub stratum; less than 30 percent difference in height
U	Uneven strata	Two or more shrub strata which may be made up of different heights; greater than 30 percent difference in height. A second shrub strata must have at least 25 percent of the total canopy cover.

[a] Height class is determined by the average height of the 20 tallest shrubs per acre (45-foot spacing). Shrub height classes were derived from United Nations Educational, Scientific and Cultural Organization (UNESCO) criteria (Driscoll and others 1984) as follows:
Less than 20 inches or 1.7 feet From 1.7 to 6.5 feet from Hall and others (1985) as big game hiding cover.
Height up to 16.5 feet as the break between shrubs and trees.
[b] Canopy cover applies to all shrubs added together. Shrub canopy covers are all derived from UNESCO criteria (Driscoll and others 1984).

Structure for a missing life-form layer; the example of PSME/PHMA/THOC logged:

1. List a two-letter PNC code (for example, **CD** for Douglas-fir).
2. List a two-letter shrub life-form layer code (for example, **TS** for tall shrub).
3. List a one-letter code for shrub cover (for example, **M** for moderate).
4. List a one-letter code for shrub strata (for example, **U** for uneven).

The code would be: **CDTSMU. Note** that a lower life-form layer means the taller layer is less than 10 percent cover or is absent.

Table 17-Herbland structural classes (table 8)

Code	Class	Characteristics
Herbland life-form:		
HE	Herbland	The only life-form present
Cover of herbs for all species, including cryptogams:[a]		
N	None	Less than 10 percent canopy cover
O	Open	From 10 to 25 percent canopy cover
M	Moderate	From 26 to 66 percent canopy cover
D	Dense	Greater than 67 percent canopy cover
Strata of herblands, including cryptogams:		
N	None	No herb life-form (bare ground)
E	Even strata	One strata of herbs; less than 30 percent difference in height; cryptogams must be less than 10 percent cover
U	Uneven strata	Two or more herb strata, greater than 30 percent difference in height; cryptogams at 10 percent or greater cover constitute a strata; canopy cover in a strata must exceed 10 percent.

[a] Canopy covers were all derived from United Nations Educational, Scientific and Cultural Organization criteria (Driscoll and others 1984).

Combining Seral Status and Structure

The example of PSME/PHMA/THOC is used again:

1. List the seral status code fist (that is **CDULMP**).
2. Enter a virgule(/) followed by structure and omit the two-letter PNC code (for example, **LTMU**).

The code would be: **CDCLMP/LTMU** for seral status in all three life-forms and structure for the tallest life-form.

The code would be: **CDCL/LTMU** for seral status it! the tallest life-form and structure for the tallest life-form.

3. Add structure of the other life-forms if desired:

The code would be: **CDCLMP/LTMU-TSMU-HEDU**

Combining PNC Association, Seral Status, and Vegetation Structure

List the PNC association code first, separated from seral status by a virgule (/), separate seral status from vegetation structure by another virgule, then list the structure codes by tree-shrub-herb layers. The Doug las-fir/ninebark/meadowrue example would be:

CDS721/CLMP/LTMU-TSME-HEDU

which is read as Douglas-fir/ninebark/meadowrue plant association as described by Steele and others (1981), which has been classified according to Steele and GeierHayes (1989) as late seral tree, mid seral shrub and PNC herb layers with large-diameter trees of moderate canopy cover and uneven strata, tall shrubs of moderate canopy cover and uneven strata, and an herbaceous layer that is dense in cover and of uneven strata.

Appendix D
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Hall, Frederick C.; Bryant, Larry; Clausnitzer, Rod; Geier-Hayes, Kathy; Keane, Robert; Kertis, Jane; Shlisky, Ayn; Steele, Robert. 1995. Definitions and codes for seral status and structure of vegetation. Gen. Tech. Rep. PNW-GTR-363. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 39 p.

Definitions and codes for identifying vegetation seral status and structure are desired for land management planning, appraising wildlife habitat, and prescribing vegetation treatment. Codes are only presented; they are not a system for determining seral status or stand structure. Terms defined are climax, potential natural community (PNC), succession, seral status, thresholds, altered PNCs, life-form layer, dominant species, successional indicator species, structure classes, cover, and strata. Plant communities may be divided into three life-form layers where appropriate: tree, shrub, and herb/cryptogam. Each layer may be appraised and coded separately for seral status, or a single code may be used. Coding is provided for plant community structure class according to size, cover, and strata in a life-form layer. Seral status and structure may be coded together.

Keywords: Seral status, succession, threshold, structure, life-form.

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