A Structural Classification for Inland Northwest Forest Vegetation

Kevin L. O'Hara and **Penelope A. Latham,** *School of Forestry, University of Montana, Missoula, MT 59812;*
Paul Hessburg, *and* **Bradley G. Smith,** *Pacific Northwest Research Station, USDA Forest Service, Wenatchee, WA 98801.*

Existing approaches to vegetation classification range from those based on potential vegetation to others based on existing vegetation composition, or existing structural or physiognomic characteristics. Examples of these classifications are numerous, and in some cases, date back hundreds of years (Mueller-Dumbois and Ellenberg 1974). Small-scale or stand-level multiple resource management has used potential vegetation/site classifications for several decades (Daubenmire and Daubenmire 1968, Layser 1974, Pfister and Arno 1980, Ferguson et al.1989). At broader scales, ecosystem management efforts are aided by classifications of forest vegetation that provide simple representations of vegetation composition and structural attributes that change over time and space (Oliver 1992, Swanson and Franklin 1992, McComb et al. 1993, Oliver et al. 1994, Turner et al. 1995). However, over broad areas in the Inland Northwest, rugged mountainous topography, contrasting geologic substrates, and a highly variable maritime influence from the Pacific coast combine to create wide variety in vegetation types and productivities.

Ecosystem managers in the Inland Northwest need a classification system based on biologically significant vegetative characteristics that capture this variation, and one that is comprised of variables that describe structural conditions important to achieving management objectives. Existing potential vegetation classification systems provide useful representations of the effects of soils and climate on vegetation composition, but do not reflect differences in disturbance history. In most western forests, disturbances are a primary factor affecting the composition and structure of vegetation (Oliver 1981, Habeck 1987, Agee 1993). In addition, potential vegetation classes cannot be directly identified through remote sensing and therefore require modeling and expensive ground surveys for validation.

In this paper, we examine some alternative vegetation classification systems following the framework presented by Kimmins (1987) for vegetation classification except that we only discuss categories that include systems commonly used in the Inland Northwest. We advocate the use of a structural or physiognomic vegetation classification based on the biological process of stand development which can be used across variable spatial scales.

Structure is an ecologically significant attribute of vegetation considered to have three major components (Kershaw 1964): (a) vertical structure; (b) horizontal structure; and (c) quantitative structure. Quantitative structure may be further specified according to life forms, floristics, or size-class distributions (Mueller-Dombois and Ellenberg 1974). The distribution of life forms has been suggested as a fundamental axis contributing to the coexistence of species and the organization of ecosystems (Cody 1986). Mueller-Dombois and Ellenberg (1974) state that structural similarities between communities provide a basis for the comparison of functions.

We believe a structural vegetation classification based on stand development processes reflects fine- and coarse-grained processes which operate across stands and landscapes. At small scales such as at the stand or patch level, a structural classification would be useful for creation of vegetation structures which meet specific resource management objectives. At larger spatial scales, a structural classification can serve as the basis for predicting and planning for vegetation change over time. Further, a simple classification with a small number of classes can reduce the complexity of landscape-scale modeling and planning. For example, a hypothetical area with 10 forest vegetation types and 10 vegetation development classes has 100 possible vegetation units. Compounded by variations in rate of growth or progression through these 10 classes caused by site, disturbance, management treatment, and spatial characteristics of vegetation units, a sizable planning problem is created. Finally, at global scales, remotely sensed vegetation classifications will likely be limited to physiognomic structural parameters (Running

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et al. 1994). These global-scale structural classifications can be linked to smaller-scale classifications facilitating consistency in hierarchical ecosystem planning and implementation efforts.

Existing Vegetation Approach

Forest cover types, or dominant tree vegetation types, were among the first classifications based solely on existing vegetation in the United States. Historically, forest cover types were often named for an economically important species which might be present at a fairly low level of abundance, ignoring a more abundant but less valuable species. At present, cover types are identified by the predominant tree species based on basal area, and must be of "distinctive character" and occupy a large area (Eyre 1980). Although these methods are easily understood and stands are easily classified, they are not considered to be "geared to ecological management of forest lands" (Wellner 1989). Additional shortcomings arise when one cover type covers large, diverse geographic areas or when stands with many species have no clear dominant constituent.

Potential Vegetation ("Climax") Approach

The earliest vegetation classification specific to the Inland Northwest was Daubenmire's habitat type system (Daubenmire 1952, Daubenmire and Daubenmire 1968). This system, and the many biogeographic and plant association studies that followed, were attempts to characterize vegetation found in diverse inland environments (see Ferguson 1989 and Krajina 1965 for examples). These systems follow the prevailing successional paradigm where vegetation change is assumed to be directional towards a theoretically stable climax plant association. A series of communities are assumed to succeed each other in a relay fashion, converging toward climax. The habitat type classification essentially attempts to discern dominant over- and understory species in the climax community through evaluations of the relative abundance and reproductive success of various indicator species. These species are then grouped and associated with specific site attributes permitting the vegetation association to be used as a site or land classification tool (Daubenmire and Daubenmire 1968, Layser 1974, Pfister and Arno 1980).

The emphasis in these climax vegetation-based classifications is on potential vegetation rather than current vegetation. Daubenmire and Daubenmire (1968) considered currently dominant trees in the overstory of minor importance compared to the species reproducing successfully in the understory. Present vegetation was assumed to be too unstable and unpredictable for classification: a view still held for some ecosystem management uses (Pfister 1993).

In recent years, a reexamination of climax theory and the concept of stability as it applies to ecosystems suggests the classification of vegetation based on potential climax may be arbitrary (Egler 1954, Drury and Nesbit 1973, Connell and Slatyer 1977, Christensen 1988, Pickett and McDonnell 1989, Botkin 1990, Oliver and Larson 1990, Sprugel 1991, Cook 1996, as well as the initial criticism of Gleason 1926). Many of the questions regarding the adequacy of the succession/climax paradigm revolve around the implied stability of climax ecosystems: succession towards climax was considered the norm, and disturbances were disruptions of the normal successional process. In many environments, and particularly the Inland Northwest, disturbances are the norm, and development to a truly stable climax is rare or absent Habitat types and potential natural vegetation then become, as stated by Mueller-Dombois and Ellenberg (1974), "idealistic schemes that cannot be expected to fit reality." Hence, potential vegetation classifications are based on a trend towards climax rather than the climax itself (Pfister and Arno 1980). Recent stand development studies in the inland Northwest and elsewhere suggest this logic may be flawed as well These studies indicate many shade-tolerant trees previously thought to have established beneath the overstory and, therefore, to be reproducing successfully in the understory, were actually trees of the same age or cohort as the overstory that were simply outgrown (Oliver and Larson 1990, Cobb et al 1993, O'Hara 1995). Instead of reproducing successfully, these species are outcompeted and relegated to subordinate crown positions where their greater shade tolerance enables them to survive. They will not dominate unless through differential longevity (Egler 1954) they outlast their overstory competitors. This is unlikely in many Inland Northwest environments where shade intolerant species are long-lived, and shade tolerant species, particularly those subjected to competitive stress (Castello et al. 1995), tend to be more prone to a variety of insects and pathogens (Hessburg et al 1994). Thus "climax" vegetation is often more prone to disturbance than preclimax vegetation. Hence classifying one set of species as inherently more stable than another is tenuous.

Stand Structure or Physiognomic Approaches

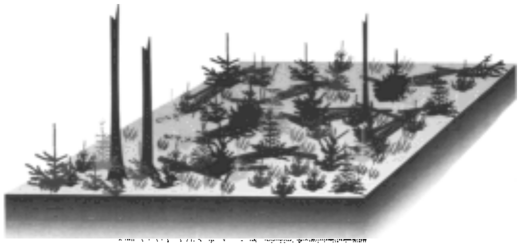
Vegetation classifications based on physiognomic characteristics represent one of the oldest forms of vegetation classification (Mueller-Dombois and Ellenberg 1974). One of the first efforts to characterize vertical forest structure in the Inland Northwest was Thomas's (1979) description of structural development for forest stands in the Blue Mountains of Oregon and Washington. These stages described the sequential development of stands following clearcutting, and barring disturbance, as proceeding through dense seedlings and saplings, saplings and poles, poles, small sawtimber, large sawtimber, and old growth. Whereas these stand conditions are primarily representations of vertical structure, their quantification is usually based on average diameter at breast height.

Other structural classifications followed. O'Hara et al (1990) used ten structural stages similar to Thomas's stages to describe stand development in a silvicultural expert system in eastern Washington. Similar structural stages have been used as labels in successional pathway descriptions by Davis et al. (1980), Kessell and Fischer (1981), Arno et al. (1985), Bradley et al. (1992), and others in the Inland Northwest Their principal shortcoming is that such classifications were based primarily on arbitrary tree diameter classes rather than on any biologically significant structural features such as canopy cover or diameter size classes linked to wildlife habitat. Alternatively, canopy cover alone is difficult to measure with consistency, and little information is available on structural requirements for most wildlife species.

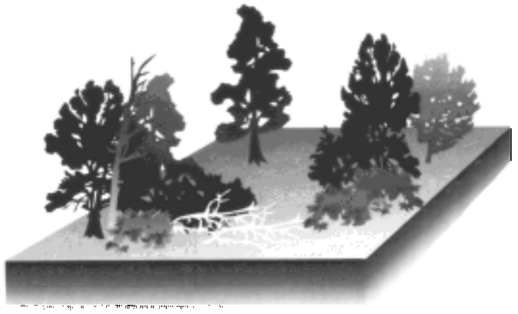
A series of four process-based stand development stages were developed by Oliver (1981) to describe even-aged (single-cohort) stand development following stand replacement disturbances. These stages were defined primarily by availability of and competition for growing space. The *stand initiation* stage, for example, begins with a stand replacing disturbance and ends when growing space is fully occupied. Growing space refers to all the resources needed by a tree to exist on a given site (Oliver and Larson 1990). *Closed stem exclusion* is the period when intense competition from the existing trees precludes new regeneration. During *understory reinitiation*, the even-aged stand begins to break down, and a new cohort or age class becomes established. The final stage, *old growth*, is defined by a uniformity of processes and an absence of trees originating from allogenic disturbances (Oliver 1981, Oliver and Larson 1990). These stages are biologically based and observable in most forest types developing from catastrophic disturbance; however, they have not previously been defined by any quantitative criteria. Quantification would differ by forest cover type as stands from different cover types will move through the development stages at different rates and possess a variety of structural features depending upon initial conditions. In addition, stands may not move sequentially from one stage to another. For example, a multi-aged stand might be formed when a stand alternates between stem exclusion and understory reinitiation structures. Although Oliver's (1981) stages were originally not intended as a classification tool, no other stand structural classification system offers stages defined by processes. Recently, when discussing landscape management, Oliver (1992) proposed using these structural stages to define vegetation types over landscape units.

Oliver's (1981) stand development stages have an advantage in that they describe processes leading to structures with the potential to be quantified. McNicoll (1994) used discriminant analysis to identify variables and values of variables to classify western redcedar *(Thuja plicata)* stands in western Montana to Oliver's four stand development stages. Validation of these functions on an independent data set demonstrated that canopy cover by size class could be used to classify stands correctly 92% of the time. McNicoll's results provide a decision system for classification of stands into structural stages that are biologically based and can be used to classify stands over broad areas for ecosystem analysis efforts.

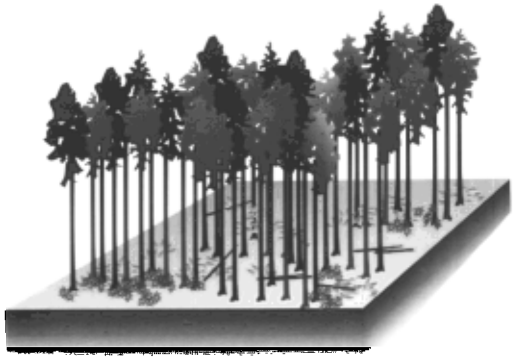
Despite the utility of a stand structure approach based on Oliver's (1981) stages of stand development, many common Inland Northwest forest structures do not fit within any of Oliver's (1981) four stages. We expanded Oliver's classification to seven classes to include a greater variety of structural conditions (Figure 1). "Classes" are used to describe these structural categories because "stages" implies sequen-



A. Stand Initiation
Definition: **Growing space is reoccupied following a stand replacing disturbance.**
Description: **1 canopy stratum (may be broken or continuous); 1 cohort of seedlings or saplings; grass, forbs, shrubs may also be present.**



B. Open Stem Exclusion
Definition: **Underground competition limits establishment of new individuals.**
Description: **One broken canopy stratum which includes poles or smaller trees; grasses shrubs or forbs may also be present.**



C. Closed Stem Exclusion
Definition: **New individuals are excluded through light or underground competition.**
Description: **Continuous closed canopy, usually one cohort; poles, small or medium trees present. Suppressed trees, grasses, shrubs, and forbs may be absent in some cover types.**

Figure 1. Schematic representation of proposed stand structure classes with definition and description. Stand initiation, closed stem exclusion, understory reinitiation, and old forest multi-strata are adapted from Oliver (1981).

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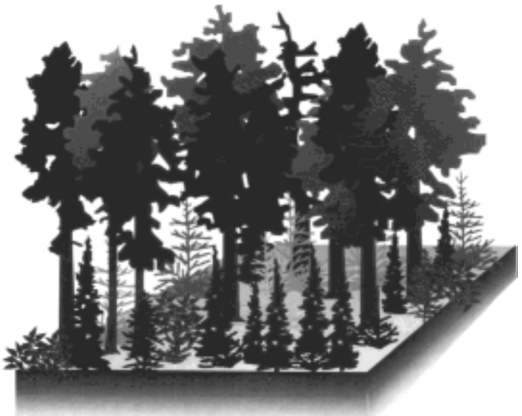
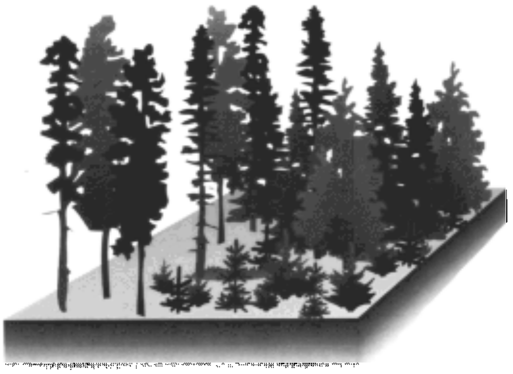
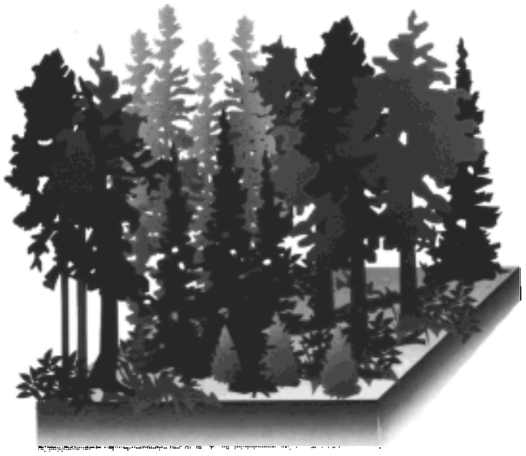


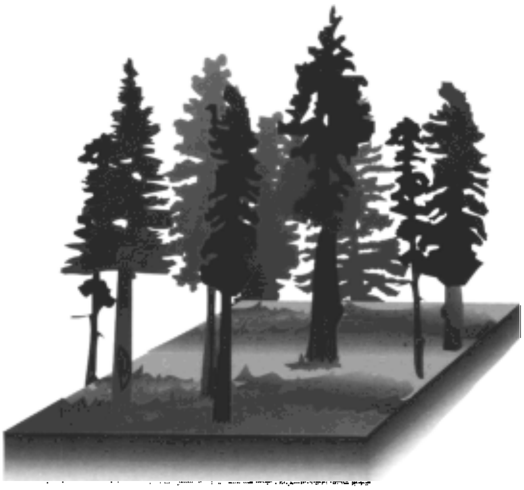
D. Understory Reinitiation
Definition: **Initiation of new cohort as older cohort occupies less than full growing space.**
Description: **Broken overstory canopy with formation of understory stratum; two or more cohorts. Overstory may be poles or larger trees; understory is seedlings, saplings, grasses, forbs, or shrubs.**



E. Young Multi-Strata
Definition: **Two or more cohorts present through establishment after periodic disturbances including harvest events.**
Description: **Multi-aged (multi-cohort) stand with assortment of tree sizes and canopy strata present but very large trees absent. Grasses, forbs, and shrubs may be present.**



F. Old Forest Multi-Strata
Definition: **Two or more cohorts and strata present including large, old trees.**
Description: **Multi-aged stand with assortment of tree sizes and canopy strata present including large, old trees. Grassses, forbs,and shrubs may be present.**



G. Old Forest Single-Stratum
Definition: **Single stratum of medium to large, old trees of one or more cohorts. Structure maintained through nonlethal burning or management.**
Description: **Broken or continuous canopy of medium to large, old trees. Single or multi-cohort. Understory absent or consisting of some seedlings, saplings, grasses, forbs, or shrubs.**

Figure 1 (continued)

tial development. The additional classes include: *open stem exclusion* where crown cover appears to be constrained by below-ground competition (Figure 1B); *young multi-strata* created by a series of minor disturbances (including harvest treatments) which may not fit into an old-forest class because of the absence of large trees (Figure 1E); and *old forest single-stratum* that consists of multi-aged trees in a single-canopy layer maintained by frequent low intensity surface fire, grazing, or both (Figure 1G). "Old forest" is used to avoid alternative connotations of the term "old growth," which has become more of a social rather than an ecological construct. These seven classes are used within cover type designations to describe structural change. Each cover type includes a subset of the seven classes since all classes do not occur in all cover types.

Recommendations

Broad-scale ecosystem planning and analysis of landscapes require vegetation classification tools that: (1) allow elucidation of vegetation patterns through time; (2) are responsive to biotic and abiotic processes that lead to those patterns; and (3) are sufficiently flexible to reflect ecosystem change due to changing climate, invasion of exotic species, disturbance, migration of species, and anthropogenic influences. A common vegetation classification system to facilitate understanding and implementation of ecosystem management objectives at different scales should be available to resource managers and planners. This system should allow discrimination among existing vegetation structures such that discrete structures can be quantified, change over time can be predicted, and resource values assigned.

All three types of vegetation classification described here have utility for ecosystem management and the potential to fit into an integrated ecological land classification framework (e g., Bailey 1988). We believe an open-ended, nondeterministic, biologically based structural classification combined with existing vegetation (cover type) has the greatest potential to meet these objectives. Such a shift has the potential benefit of placing the emphasis of classification on existing conditions and processes and specifically on vegetation structure which increasingly is the basis for describing resource management objectives (O'Hara et al. 1994).

No single variable will adequately describe vegetation characteristics. An effective vegetation classification system will incorporate a set of variables to characterize vegetation into groups or classes which can be arranged hierarchically corresponding to their utility in a landscape planning format: the variables chosen must be responsive to changes in scale. However, what is important at one scale may not be important at another, and variables important for one resource value may not be important for another (Bailey et al. 1978, Wiens and Milne 1989, Turner et al. 1995). For example, the primary variables in the classification system should be those most important for distinguishing vegetation at intermediate or meso scales (1:24,000 to 1:100,000) such as dominant cover type and structural characteristics. At finer scales, variables should reflect vegetation characteristics important to implementation of resource objectives but should be linked to broader-scale vegetation characterization. At broader scales, structural classes can be collapsed into larger physiognomic groups. This vegetation classification structure would facilitate effective ecosystem management by building direct linkages between landscape classifications for ecosystem planning and fine scales where ecosystem management will be implemented.

We recommend adoption of a new hierarchical vegetation classification with seven structural classes (Figure 1) that reflect vegetation development. Lower levels in the hierarchy can expand these seven classes to define specific finer grained stand structure attributes. For example, a wildlife habitat classification at a fine scale might refine the structural classes to include more detail on crown cover to describe specific habitat requirements of certain wildlife. A timber classification might refine all classes by adding levels of relative density. Such a classification of forest stand structure may serve as a unifying tool to meet timber, wildlife, water, or recreation objectives, and for describing stand or ecosystem conditions for long-term assessment and monitoring efforts.

A feature common to all vegetation classification systems is their inability to satisfy all potential users. All three types of Inland Northwest vegetation classifications described have shortcomings that make one classification system more appropriate for some uses than another. As ecological classifications are ultimately interpretive, it is essential that a scheme be chosen that clarifies the ecological attributes, processes, and dynamics appropriate to the objectives and values for which landscapes are managed. Ecosystem management objectives include not only traditional socioeconomic objectives related to commodity production, but more comprehensive objectives such as maintenance of biodiversity, promotion of forest health, and maintenance of ecosystem processes (Oliver 1992, O'Hara et al. 1994, Salwasser 1994, Turner et al. 1995, Castello et al. 1995).

Integration of various classification schemes has been a part of vegetation classification for decades. It can be seen in use of structural stages and potential vegetation by Arno et al. (1985), vegetation layers and potential vegetation by Steele (1984), and cover types and structural stages by the Columbia River Basin Assessment Project. Such integrations lead to some new uses of terminology: for example, changes in structure or physiognomic condition have been described as successional changes. We suggest that changes in structure be described as structural or stand development changes to avoid confusion with changes in community composition that have been traditionally described as successional.

The most commonly used classification systems in the Inland Northwest are based on potential natural vegetation. The basic premise of these systems is a deterministic succession to a climax community represented by species present in the understory (Cook 1996). Christensen (1988), in discussing the "demise" of the classical succession/climax paradigm stated "we may now conclude that a grand unified theory of community succession such as that envisioned by Clements and Odum is not possible or even desirable. The bottom-line message to those who must manage natural ecosystems is that the world is considerably less tidy than we thought. Furthermore, this untidyness may be an integral part of maintenance of many ecosystems." Although many researchers have tried to modify the succession paradigm and to redefine its terminology, we believe it is time to move towards a new paradigm centered on a vertical structure and linked to floristic composition (cover type).

Potential natural vegetation classification systems may have value if the presence of certain species is interpreted as an environmental indicator not linked to the climax concept. For example, the well-recognized progression of different "climax" species with elevation in Inland Northwest environments is indicative of an environmental gradient. These, or other, plant species can serve as useful indicators of the presence of environmental or site conditions which they require, but not for the future development of any hypothetical community. In this sense, the interpretation may be correct, but the underlying concepts are flawed.

A structural classification system based on the reality of vegetation development characterized by biological potentials and ecological constraints is recommended rather than one based on an idealized community type that seldom occurs on Inland Northwest landscapes.

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