WHITE PAPER

USDA Forest Service | Pacific Northwest Region | Umatilla National Forest

WHITE PAPER F14-SO-WP-SILV-10

A Stage Is A Stage Is A Stage…Or Is It? Successional Stages, Structural Stages, Seral Stages

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INTRODUCTION

A landmark book called "Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington" was published in 1979 (Thomas 1979). This book examined effects of management activities on wildlife habitat, particularly impacts of timber management practices on large, free-ranging ungulates (e.g., deer and elk).

Among other things, the Blue Mountains book also attempted to correlate wildlife habitat with vegetation seral status by using a successional stage classification system. As a result of the book's popularity with natural resource managers, use of its successional stage classification became widespread for the Blue Mountains (fig. 1).

Shortly after release of the *Wildlife Habitats* book, Umatilla National Forest initiated a planning process in response to National Forest Management Act of 1976. A planning process consumed an entire decade and culminated with publication of a Land and Resource Management Plan (e.g., Forest Plan) in 1990 (USDA Forest Service 1990).

A Land and Resource Management Plan (Forest Plan) for Umatilla National Forest (USDA Forest Service 1990) established specific standards related to seral (successional) stages for three management allocation areas (A10, C4, and E2). A seral stage system used by the Forest Plan is the same as a successional stage system described in the *Wildlife Habitats* book (Thomas 1979).

In response to a petition from Natural Resources Defense Council to halt timber harvest in old-growth forests of eastern Oregon and eastern Washington (March 1993), and after an Eastside Forest Ecosystem Health Assessment was released in draft form (April 1993), Pacific Northwest Region of USDA Forest Service issued interim planning direction known as Eastside Screens in August of 1993 (USDA Forest Service 1994a, USDA Forest Service 1995).

Figure 1 – Successional stages for coniferous forest ecosystems (adapted from Thomas et al. 1979). After a stand-initiating disturbance event, it is assumed that a new forest develops by passing through successive and predictable stages. This figure shows a six-stage chronosequence, beginning with a grass-forb stage and culminating in a late-seral, old-growth stage. These successional stages have the following interpretation:

Grass-forb: dominant vegetation is herbaceous (grasses and forbs); downed logs are present but not decayed.

Shrub-seedling: dominant vegetation is woody shrubs and/or seedlings; downed logs are present but not decayed.

Pole-sapling: dominated by trees usually less than 40 years old; self-thinning is not yet occurring; even-height canopy; logs on ground are beginning to decay.

Young: dominated by trees usually less than 80 years old; self-thinning process is beginning to occur; downed logs are moderately decayed; understory vegetation is beginning to reappear.

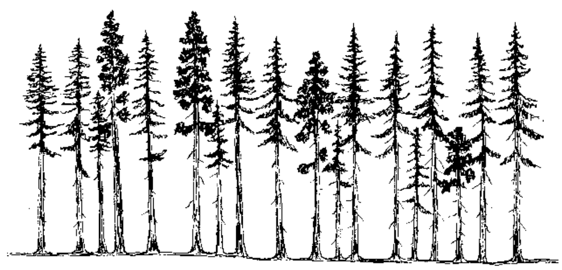
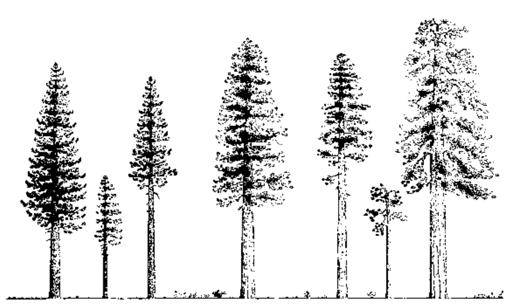
Mature: dominated by trees generally less than 140 years old; self-thinning is occurring; both decayed and undecayed (new) logs are on the ground; some snags are present; understory vegetation is well established.

Old-growth: dominated by trees generally greater than 140 years old; understory vegetation is well established; snags are present; heart rot (stem decay) and other signs of decadence are present; all tree ages and heights are represented; abundant decayed and undecayed logs are found on the ground.

Eastside Screens require that proposed timber sales be evaluated by using three screens, one of which is an “ecosystem standard.” This ecosystem screen requires a landscape-level assessment of historical range of variability (HRV) for structural stages (table 1), including a determination of how existing structural stage amounts compare to their historical ranges.

As managers began working with Eastside Screens, points of confusion soon arose. Do Screens’ entities called structural stages relate to successional stages from Thomas (1979) and as used in the Umatilla Forest Plan (USDA Forest Service 1990)? And, do successional stages and structural stages have any relationship to seral stages (fig. 2) of forest vegetation (Hall et al. 1995)? Finally, do these various stages relate to potential vegetation, existing vegetation, or both?

Table 1: Description of forest structural stages.

	**Stand Initiation.** Following stand-replacing disturbance, growing space is occupied rapidly by vegetation that either survives a disturbance or colonizes an area. Survivors survive a disturbance above ground, or initiate new growth from underground organs or seeds present onsite. Colonizers disperse seed into disturbed areas, it germinates, and new seedlings become established. One stratum of tree seedlings and saplings is present in this stage.
	**Stem Exclusion.** Trees initially grow fast and occupy their growing space, competing strongly for sunlight and moisture. Because trees are tall and reduce light, understory plants are shaded and grow slowly. Species needing sunlight usually die; shrubs and herbs may go dormant. In this stage, establishment of new trees is precluded by a lack of sunlight (stem exclusion closed canopy) or by a lack of moisture (stem exclusion open canopy).
	**Understory Reinitiation.** A new tree cohort eventually gets established after overstory trees begin to die or because they no longer fully occupy their growing space. This period of overstory crown shyness occurs when tall trees abrade each other in wind (Putz et al. 1984). Regrowth of understory vegetation occurs, trees begin stratifying into vertical layers, and a moderately dense overstory with small trees beneath is eventually produced.
	**Young Forest Multi Strata**. In this stage, three or more tree layers have become established as a result of minor disturbances (including tree harvest) causing progressive but partial mortality of overstory trees, thereby perpetuating a multi-layer, multi-cohort structure. This stage features a broken overstory layer with a mix of tree sizes present (large trees are scarce); it provides high vertical and horizontal diversity (O'Hara et al. 1996).
	**Old Forest.** Many age classes and tree layers mark this stage featuring large, old trees. Snags and fallen trees may also be present, leaving a discontinuous overstory canopy. The drawing shows single-layer ponderosa pine created by frequent surface fire on dry sites (old forest single stratum). Cold or moist sites, however, generally have multi-layer stands with large trees in an uppermost stratum (old forest multi strata).

Sources/Notes: Based on O'Hara et al. (1996), Oliver and Larson (1996), and Spies (1997); other ecologists described process-based stages by using slightly different names (see appendix 1).

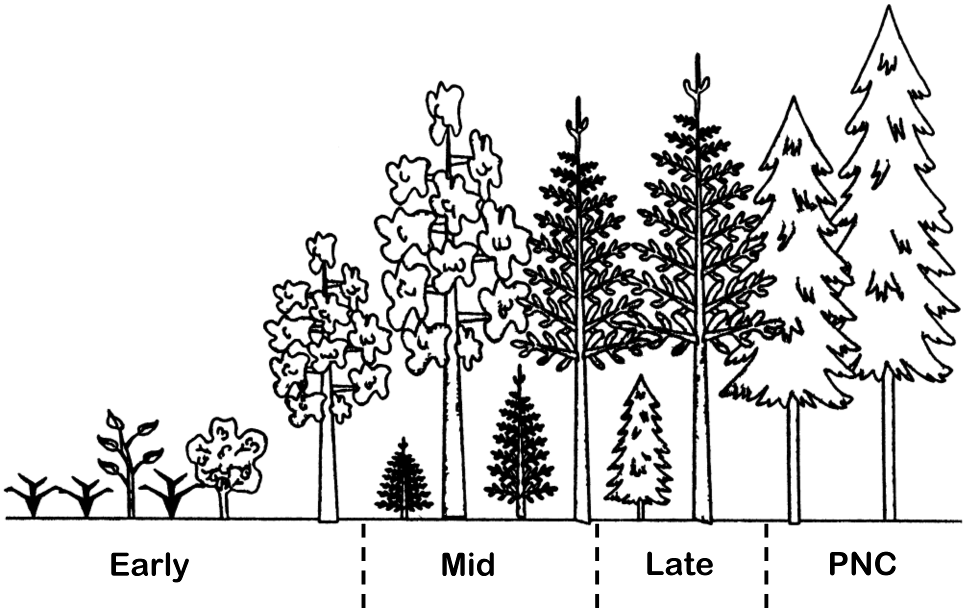


Figure 2 – Seral stages for a grand fir plant association of the Blue Mountains (figure adapted from USDA Forest Service 1994b). A series of stages shown in this diagram is called a sere. After a stand-initiating disturbance event such as crown fire or regeneration cutting, the resulting plant community transitions from a simpler, somewhat disorganized state (early-seral stage) to a relatively complex, highly organized state (potential natural community or PNC). An early-seral stage is initially dominated by grasses, forbs, and shrubs (some ecologists refer to this non-tree phase as a very-early stage), but shade-intolerant tree species also get established in this early-seral stage. A mid-seral stage has a mix of species, with early-seral species (ponderosa pine above) and mid-seral species (Douglas-fir above) present in almost equal amounts. Late-seral stands have both mid-seral and late-seral tree species present (above, grand fir is a late-seral species; note that a long-lived, early-seral species, western larch, is also shown as persisting into mid- and late-seral stages). Although PNC stands are uncommon in the Blue Mountains, they feature a composition where early- or mid-seral species are scarce or absent altogether (Hall et al. 1995).

Table 2 shows successional stages from Thomas (1979), structural stages on which Eastside Screens were based (O'Hara et al. 1996, Oliver and Larson 1996), and a seral status framework (Hall et al. 1995).

In table 2, a vertical line separates a successional stage column from structural stage and seral stage columns – this line was included because it is not appropriate to assume a one-to-one relationship between these stages (successional, structural, and seral).

<u>Bottom-line</u>: Although there are similarities between successional stage, structural stage, and seral stage, these classification systems are not identical and should not be considered interchangeable.

Table 2: Do successional stages relate to structural stages and seral stages?

Successional stage		Structural stage?		Seral stage?
Grass–Forb	➔	Stand Initiation	➔	Early
Shrub–Seedling	➔	Stand Initiation	➔	Early
Sapling–Pole	➔	Stem Exclusion	➔	Early/Mid
Young	➔	Young Forest	➔	Mid
Mature	➔	Understory Reinitiation	➔	Mid/Late
Old Growth	➔	Old Forest	➔	Late/PNC

Sources: Successional stages are from Thomas (1979); structural stages are from O'Hara et al. (1996) and Oliver and Larson (1996); seral stages are from Hall et al. (1995). A glossary provides definitions for each of these classification systems.

If successional stages, structural stages, and seral stages are not synonymous, how are they similar or different? Briefly, here are some similarities and differences:

- **A structural stage does not indicate seral status**. Seral stage is interpreted by using species composition of a stand, along with our understanding of its ecological role (seral status). To illustrate this concept further, consider two examples.

  a. Example 1: A forest stand on grand fir/elk sedge plant association has large-diameter ponderosa pines in an overstory, and small-diameter Douglas-firs and grand firs in an understory. Overstory pines have about the same canopy cover as understory firs and Douglas-firs combined.

  From the information provided, we know these things about this stand:

  √ The stand is established on a grand fir plant association, so grand fir is the climatic climax tree species, and it will eventually predominate in a potential natural community resulting from long-duration forest succession in the absence of future disturbance (Hall et al. 1995);

  √ Another relatively shade-tolerant tree species (interior Douglas-fir) will also be present in late-seral stands because it is functioning as a mid-seral species on this plant association; and

  √ Ponderosa pine is functioning as an early-seral tree species on this plant association, and it cannot maintain its overstory dominance if disturbance is excluded from this site for a long time period (Douglas-fir and ponderosa pine seral status implications are derived from Clausnitzer 1993, and Johnson and Clausnitzer 1992).

  We can conclude from these existing conditions that this stand currently has a mid-seral status because late-seral species are approaching equal proportions with early- and mid-seral species (see Hall et al. 1995, and the 'seral stage (status)' section of the glossary, for more information about how this seral-status determination was made).

The structural stage of this 2-layered stand would be *old forest multi-strata* if the ponderosa pines are over 21" DBH, or *understory reinitiation* if the overstory pines are less than 21" DBH (table 3 shows how these existing conditions would be assigned to a structural stage).

b. **Example 2:** Now let's suppose that a windstorm, bark beetles such as western pine beetle, or another top-down disturbance process kills most of the large ponderosa pines, leaving behind a mix of smaller grand fir and Douglas-fir trees.

   Since the composition now consists entirely of late-seral and climax tree species, this stand would classify as a late-seral or potential natural community (PNC) forest, even though it no longer contains any large-diameter trees.

   The structural stage would be stand initiation or stem exclusion, depending on the size and density of the new overstory layer (see table 3).

These examples demonstrate that it may be difficult to make consistent interpretations from phrases such as *late and old structural stages* (this phrase comes from Eastside Screens; it refers to structural conditions where trees over 21 inches in diameter are common). *Late* traditionally refers to vegetation seral status in a classification system such as Hall et al. (1995), and yet *seral status conveys no explicit information about tree size or diameter*.

In example 1 above, the early-seral species (ponderosa pine) has the largest tree diameter and late-seral species (grand fir and interior Douglas-fir) the smallest. In example 2, late-seral species dominate the stand composition, and yet no trees of large diameter are present. [Therefore, we should be careful about assuming that late-seral or PNC forests always feature large-diameter trees.]

- **Successional stage is not the same as structural stage**. Thomas (1979) defined successional stages by using two criteria: tree size and stand age. His criteria included no explicit consideration of vertical stand structure (number of stand layers).

  A forest stand classified as Thomas' young successional stage (poles and small trees between 40 and 79 years old; see glossary) could be assigned to several structural stages depending on how many canopy layers it contains. If it has 2 layers, it would be *understory reinitiation* structural stage; if it has 3 or more layers, it would be an example of *young forest multi strata* structural stage (see table 3).

- **Successional stage does not relate directly to seral status**. Since successional stages are classified by using tree size (sapling, pole, etc.) and stand age, there is no consideration of ecological roles (seral status) of tree species in this classification system.

  If a stand is in a pole-sapling successional stage, we have no way of knowing what proportion of saplings and poles are early-seral tree species. We could assume they are early-seral species, in which case a pole-sapling successional stage has early-seral status. But what if they are actually late-seral species as described in example 2 above? In an example 2 scenario, a pole-sapling successional stage would have late-seral status.

Table 3: Matrix for assigning structural stages based on number of canopy strata and tree size.

Number of Canopy Strata (Layers)	SIZE CLASS OF UPPERMOST STRATUM (LAYER) Seedlings/Saplings (< 5" DBH)	Poles and Small Trees (5 to 20.9" DBH)	Medium Trees (> 21" DBH)
1	Stand Initiation	Stem Exclusion	Old Forest Single Stratum
2	Not Applicable	Understory Reinitiation	Old Forest Multi Strata
3 or more	Not Applicable	Young Forest Multi Strata	Old Forest Multi Strata

Source: Adapted from Stage et al. (1995).

Note that white paper F14-SO-WP-Silv-58, *Seral Status for Tree Species of Blue and Ochoco Mountains*, describes seral status concepts and principles in more detail, and it provides figures showing seral status by tree species, plant association, potential vegetation group, and plant series.

GLOSSARY

Historical range of variability. A characterization of fluctuations in ecosystem conditions or processes over time; an analytical technique used to define bounds of ecosystem behavior that remain relatively consistent (stable) through time (Morgan et al. 1994).

Seral stage (status): a stage of secondary successional development (secondary succession refers to an ecological process of progressive changes in a plant community after stand-initiating disturbance). Four seral stages are recognized: early seral, mid seral, late seral, and potential natural community (Hall et al. 1995).

Early Seral: clear dominance of early-seral ('pioneer') species (western larch, ponderosa pine, lodgepole pine, etc.) is present; PNC species are absent entirely, or found only in very low numbers.

Mid Seral: PNC species are increasing in a forest composition as they actively colonize a site; PNC species are approaching equal proportions with early-seral species.

Late Seral: PNC species are now dominant, although long-lived, early-seral tree species (ponderosa pine, western larch) may still persist in a plant community.

Potential Natural Community (PNC): biotic community that will presumably be established and maintained over time under present environmental and climatic conditions; early- or mid-seral species are scarce or absent in a plant composition.

Structural stage (class). A stage or recognizable condition relating to physical orientation and arrangement of vegetation; size and arrangement (both vertical and horizontal) of trees and tree parts. These structural stages have been described (O'Hara et al. 1996, Oliver and Larson 1996):

Stand initiation: one canopy stratum of seedlings and saplings is present; grasses, forbs, and shrubs typically coexist with trees.

Stem exclusion: one canopy stratum (layer) is present and comprised mostly of pole-sized trees (5-8.9" DBH). A canopy layer may be open (**stem exclusion open canopy**) on sites where moisture is limiting, or closed (**stem exclusion closed canopy**) on sites where light is a limiting resource.

Young forest multi strata: three or more canopy layers are present; size class of uppermost stratum is typically small trees (9-20.9" DBH). Large trees may be absent or scarce.

Understory reinitiation: two canopy strata are present; a second tree layer is established under an older overstory. Overstory mortality has resulted in growing space for establishment of understory trees.

Old forest: a predominance of large trees (> 21" DBH) is present in a stand with one or more canopy strata. On warm dry sites with frequent, low-intensity fires, a single stratum may be present (**old forest single stratum**). On cool moist sites without recurring underburns, multi-layer stands with large trees in an uppermost stratum may be present (**old forest multi strata**).

Successional stage: a stage or recognizable condition of a plant community occurring during its development from bare ground to climax (e.g., PNC seral status). In the Blue Mountains, successional stage has been determined by using two primary criteria: tree size class, and stand age. Coniferous forests progress through six recognized stages, as defined below (Thomas 1979).

Grass-forb: dominant vegetation is herbaceous (grasses, grass-like plants, and forbs); stand age: less than 10 years; downed logs are present but not decayed.

Shrub-seedling: dominant vegetation is woody shrubs and/or tree seedlings; stand age: less than 10 years; downed logs are present but not decayed.

Pole-sapling: dominated by trees in a sapling size class, pole size class, or both; stand age: 11-39 years; even-height canopy; logs on ground are beginning to decay.

Young: dominated by trees that are no longer poles, but have not yet reached maturity; stand age: 40-79 years; self-thinning process is beginning; downed logs are moderately decayed; understory vegetation is starting to reappear.

Mature: domination or predominance of mature, vigorous trees; stand age: 80-159 years; self-thinning process is occurring; both decayed and undecayed logs are present on ground; some snags are present; understory vegetation is well established.

Old Growth: a stand past full maturity and showing decadence – last stage in forest succession; stand age: 160 years and greater; understory vegetation is well established; snags are present; heart rot (stem decay) and other signs of decadence are common; all tree sizes and ages are represented to some extent; abundant decayed and undecayed logs are present on ground.

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Appendix 1: Alternative approaches for describing forest development phases (structural stages).

INCREASING TIME SINCE DISTURBANCE ↓

Watt 1947	Daubenmire & Daubenmire 1968	Bormann and Likens 1979	McCune and Allen 1985	Peet and Christensen 1987	Oliver and Larson 1996	O'Hara et al. 1996	Spies 1997
Pioneer	Invasion	Reorganization	Establishment	Establishment	Stand Initiation	Stand Initiation	Establishment
Building	Stagnation	Aggradation	Canopy Development	Thinning	Stem Exclusion	Stem Exclusion	Thinning
Mature	Resumption of Regeneration	Transition	Canopy Breakup	Transition	Understory Reinitiation	Understory Reinitiation	Transition
Degenerate		Steady State	Climax Recognition	Steady State	Old Growth	Young Forest Multi Strata	Shifting Mosaic
						Old Forest	

APPENDIX 2: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continually evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper,

specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of Blue Mountains dry forests: Silvicultural considerations
5	Site productivity estimates for upland forest plant associations of Blue and Ochoco Mountains
6	Blue Mountains fire regimes
7	Active management of Blue Mountains moist forests: Silvicultural considerations
8	Keys for identifying forest series and plant associations of Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created opening, minimum stocking, and reforestation standards from Umatilla National Forest Land and Resource Management Plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: A process paper
16	Douglas-fir tussock moth: A briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of Blue and Wallowa Mountains
21	Historical fires in headwaters portion of Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree

Paper #	Title
25	Important Blue Mountains insects and diseases
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: Some ecosystem management considerations
28	Common plants of south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of “Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins” – Forest vegetation
33	Silviculture facts
34	Silvicultural activities: Description and terminology
35	Site potential tree height estimates for Pomeroy and Walla Walla Ranger Districts
36	Stand density protocol for mid-scale assessments
37	Stand density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: Forestry direction
39	Updates of maximum stand density index and site index for Blue Mountains variant of Forest Vegetation Simulator
40	Competing vegetation analysis for southern portion of Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for Umatilla National Forest
42	Life history traits for common Blue Mountains conifer trees
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: Vegetation management considerations
46	Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in northern Blue Mountains: Regeneration ecology and silvicultural considerations
48	Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for Umatilla National Forest: A range of variation analysis
51	Restoration opportunities for upland forest environments of Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: An environmental education activity
55	Silviculture certification: Tips, tools, and trip-ups

Paper #	Title
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman National Forests
57	State of vegetation databases for Malheur, Umatilla, and Wallowa-Whitman National Forests
58	Seral status for tree species of Blue and Ochoco Mountains

REVISION HISTORY

November 2012: minor formatting and editing changes were made; appendix 2 was added describing the silviculture white paper system, including a list of available white papers.