WHITE PAPER

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Is Elk Thermal Cover Ecologically Sustainable?

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INTRODUCTION

Historically, a basic tenet of wildlife biology is an idea that providing dense vegetative cover for thermal protection enhances survival of wild ungulates by moderating effects of harsh weather and minimizing an animal's energy required for thermoregulation. Most studies supporting a thermal cover hypothesis are based on observational studies of elk habitat selection (Thomas et al. 1979).

However, a recent study conducted in the Blue Mountains of northeastern Oregon tested a thermal cover hypothesis by monitoring body mass and composition of elk exposed to one of four cover levels for four winter and two summer season-long experiments. This study found that thermal cover does not significantly improve energetic status and productive performance of elk (Cook et al. 1998).

Instead, results of Cook and others (1998) suggest that observational studies of elk habitat selection might be related more to other habitat needs such as forage availability or security. In this context, providing dense vegetative cover enabling elk to feel safe (e.g., security cover) is considered a crucial ecosystem service, particularly during hunting seasons and other periods when humans are frequent visitors to elk habitat.

THERMAL COVER

Satisfactory thermal cover for Rocky Mountain elk is defined as "a stand of coniferous trees at least 12 m (40 ft) tall and exceeding an average of 70 percent crown closure." Marginal thermal cover is defined as a stand of trees 10 or more feet tall with an average crown closure of at least 40 percent (Thomas et al. 1979, Thomas et al. 1988).

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[1] This white paper was originally prepared for an 'HEI Summit' meeting held at the Umatilla National Forest Supervisor's Office on January 27, 2005.

This white paper attempts to answer one specific question about elk cover:

Is the stand density required for <u>*satisfactory*</u> *elk cover, expressed as crown closure, considered to be biologically feasible and ecologically sustainable?*

Information presented below indicates that sustainability of satisfactory elk cover depends on at least three factors:

1) Potential vegetation of a site – a measure or indicator of a site's 'carrying capacity' regarding forest density (moist sites can support more density than dry sites);
2) Species composition of a site (its existing forest cover type); and
3) Ecological role (successional status) of each forest type because late-seral tree species can sustain high density levels better than early-seral species.

POTENTIAL VEGETATION CONCEPTS

Potential vegetation is an underlying foundation on which the biological landscape is constructed. It functions as a biophysical template because it reflects an integrated influence of geology, soils, and climate on vegetation conditions. Potential vegetation controls which tree species, and proportions of each, that can exist for any suite of physical site factors (each combination of physical site factors results in a slightly different temperature and moisture regime).

As an example of this concept, consider a warm dry setting: Engelmann spruce or subalpine fir will not be found there because these conditions exceed their temperature and moisture tolerances and, for the same reason, the proportion of ponderosa pine in a warm dry landscape will be at least five times greater than the proportion of western larch or lodgepole pine.

FOREST PLAN DIRECTION

Umatilla National Forest's Land and Resource Management Plan (USDA Forest Service 1990b) provides standards and guidelines for 25 management areas. Only 9 of 25 areas (36%) include management direction for elk habitat, but acreage associated with the 9 areas comprises 79% of the Forest's lands outside Wilderness (table 1).

Forest Plan characterizes potential vegetation by using four 'working groups' – ponderosa pine, north associated, south associated, and lodgepole pine. During the planning process, each plant community type on the Forest (as described in Hall 1973) was assigned to a working group.

A total of 17 forested plant community types (Hall 1973) occurred on the Forest: 4 were assigned to ponderosa pine working group, 10 were assigned to north associated and south associated working groups (north associated includes Pomeroy and Walla Walla Ranger Districts; south associated includes Heppner and North Fork John Day Ranger Districts), and 3 were assigned to lodgepole pine working group (see Forest Plan FEIS appendix, page K-5, in USDA Forest Service 1990a).

Table 2 shows how current plant associations (as described for upland forest sites in Johnson and Clausnitzer 1992) can be assigned to Forest Plan working groups.

Table 1. Elk habitat standards from Umatilla National Forest Plan.

		SATISFACTORY COVER STANDARDS					
Management Area	HEI Standard	Minimum Cover[1]	Desired Cover[1]	P. Pine W Grp[2]	Other W Grp[2]	Total Cover[1]	Area (M Acres)[5]
A10	60	15	20	50%	70%	30	3.3
C3	70	10	15-20	50%	70%	30	152.8
C3A	70	10	15-20	50%	70%	30	8.2
C4	60[3]	15	20	70%	70%	30	258.9
C7	45	10	15-20	None[4]	None[4]	30	105.3
C8	70	10	15-20	50%	70%	30	98.5
E1	30	None	None	None[4]	None[4]	None	91.4
E2	45	10	15-20	50%	70%	30	199.5
F4	60	10-15	20	50%	70%	30	35.0

Notes: Summarized from Umatilla National Forest Plan (USDA Forest Service 1990b).

[1] Minimum, desired, and total cover columns show percentage of a management area that will be managed to provide elk cover; minimum and desired columns pertain to satisfactory cover only, whereas 'total cover' column pertains to all elk cover components combined.

[2] These columns provide crown closure percentage that a forested portion of a management area must have in order to qualify as satisfactory cover. Note that a crown closure of 50% was often used to define satisfactory cover for a ponderosa pine working group (P. Pine), rather than 70% value used for other working groups (north associated, south associated, lodgepole pine).

[3] Management area C4 established a specific exception for Rhea Creek area, where HEI must be at least 90.

[4] Management areas C7 and E1 provided no criteria (canopy cover, tree height, etc.) for identifying forest stands qualifying as satisfactory or marginal cover.

[5] Acreages for management areas were taken from page 4-94 in Forest Plan.

The Forest planning process recognized that potential vegetation (as characterized by using four working groups) varies across the Forest, and that certain standards and guidelines needed to reflect this variation. Nine Forest Plan management areas have elk habitat standards, and six of them modified criteria for satisfactory cover to reflect differences between ponderosa pine working group and the other three working groups (see table 1, footnote 2).

FOREST DENSITY CONCEPTS

Forest density is a characterization of tree stocking for an area. It can be expressed as a 'stand density index' or in some other measure of relative density, or it can be quantified in absolute terms as a number of trees per acre or as an amount of basal area, wood volume, canopy cover, or a variety of similar metrics (Powell 1999).

Canopy cover is sometimes termed canopy closure, crown cover, or crown closure, depending on context. But, please be careful – not all these terms refer to the same thing! Canopy cover is a forest density metric used extensively in ecological studies. It is defined as vertical projection of vegetation foliage onto the ground surface when viewed from above. Canopy cover provides a quantitative and rapid characterization of vegetation abundance but it has limitations when compared with other forest density metrics.

Table 2. Cross-walk table relating plant associations to Forest Plan working groups.

Plant Association Common Name	Ecoclass Code	Potential Vegetation Group	Working Group
Douglas-fir/big huckleberry	CDS821	Dry Upland Forest	North/South Associated
Douglas-fir/birchleaf spiraea	CDS634	Dry Upland Forest	North/South Associated
Douglas-fir/common snowberry	CDS624	Dry Upland Forest	North/South Associated
Douglas-fir/elk sedge	CDG111	Dry Upland Forest	North/South Associated
Douglas-fir/mallow ninebark	CDS711	Dry Upland Forest	North/South Associated
Douglas-fir/mountain snowberry	CDS625	Dry Upland Forest	North/South Associated
Douglas-fir/oceanspray	CDS611	Moist Upland Forest	North/South Associated
Douglas-fir/pinegrass	CDG112	Dry Upland Forest	North/South Associated
Douglas-fir/Rocky Mountain maple-mallow ninebark	CDS722	Moist Upland Forest	North/South Associated
Grand fir/big huckleberry	CWS212	Moist Upland Forest	North/South Associated
Grand fir/birchleaf spiraea	CWS322	Dry Upland Forest	North/South Associated
Grand fir/Columbia brome	CWG211	Moist Upland Forest	North/South Associated
Grand fir/elk sedge	CWG111	Dry Upland Forest	North/South Associated
Grand fir/false bugbane	CWF512	Moist Upland Forest	North/South Associated
Grand fir/grouse huckleberry	CWS811	Cold Upland Forest	North/South Associated
Grand fir/grouse huckleberry-twinflower	CWS812	Moist Upland Forest	North/South Associated
Grand fir/oakfern	CWF611	Moist Upland Forest	North/South Associated
Grand fir/Pacific yew/queencup beadlily	CWC811	Moist Upland Forest	North/South Associated
Grand fir/Pacific yew/twinflower	CWC812	Moist Upland Forest	North/South Associated
Grand fir/pinegrass	CWG113	Dry Upland Forest	North/South Associated
Grand fir/queencup beadlily	CWF421	Moist Upland Forest	North/South Associated
Grand fir/Rocky Mountain maple	CWS541	Moist Upland Forest	North/South Associated
Grand fir/swordfern-ginger	CWF612	Moist Upland Forest	North/South Associated
Grand fir/twinflower	CWF312	Moist Upland Forest	North/South Associated
Lodgepole pine/pinegrass	CLS416	Cold Upland Forest	Lodgepole Pine[1]
Ponderosa pine/bitterbrush/elk sedge	CPS222	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/bitterbrush/Idaho fescue-bluebunch wheatgrass	CPS226	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/bitterbrush/Ross' sedge	CPS221	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/bluebunch wheatgrass	CPG111	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/common snowberry	CPS524	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/elk sedge	CPG222	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/Idaho fescue	CPG112	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/mountain big sagebrush/ Idaho fescue-bluebunch wheatgrass	CPS131	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/mountain mahogany/elk sedge	CPS232	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/mountain mahogany/Idaho fescue-bluebunch wheatgrass	CPS234	Dry Upland Forest	Ponderosa Pine

Plant Association Common Name	Ecoclass Code	Potential Vegetation Group	Working Group
Ponderosa pine/mountain mahogany/ Wheeler's bluegrass	CPS233	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/mountain snowberry	CPS525	Dry Upland Forest	Ponderosa Pine
Ponderosa pine/pinegrass	CPG221	Dry Upland Forest	Ponderosa Pine
Subalpine fir/big huckleberry	CES311	Moist Upland Forest	North/South Associated
Subalpine fir/elk sedge	CAG111	Cold Upland Forest	North/South Associated
Subalpine fir/false bugbane	CEF331	Moist Upland Forest	North/South Associated
Subalpine fir/grouse huckleberry	CES411	Cold Upland Forest	North/South Associated
Subalpine fir/grouse huckleberry/Jacob's ladder	CES415	Cold Upland Forest	North/South Associated
Subalpine fir/queencup beadlily	CES314	Moist Upland Forest	North/South Associated
Subalpine fir/rusty menziesia	CES221	Cold Upland Forest	North/South Associated
Subalpine fir/twinflower	CES414	Moist Upland Forest	North/South Associated

Sources/Notes: Plant associations are ordered by using their common names; codes and scientific names for associations are provided in Powell et al. (2007). Ecoclass codes are used to record plant associations on field forms and in computer databases; Ecoclass codes are listed in Hall (1998). Potential vegetation group (PVG) is a mid-scale hierarchical unit of potential vegetation; assignments of plant associations to PVGs is shown in Powell et al. (2007). Working groups are a mid-scale unit of potential vegetation established by 1990 Umatilla NF Forest Plan (USDA Forest Service 1990b); assignment of plant community types (a precursor of contemporary plant associations) described by Hall (1973) for Blue Mountains to working groups is described in appendix K of Final Environmental Impact Statement for 1990 Forest Plan (see page K-5 specifically).

[1] Any lodgepole pine plant community type from Johnson and Clausnitzer (1992) should also be assigned to a lodgepole pine working group.

Thermal cover guidelines for Rocky Mountain elk habitat for Blue Mountains of northeastern Oregon and southeastern Washington were characterized by using canopy cover (Thomas et al. 1979, Thomas et al. 1988). Thermal cover guidelines were differentiated into two categories: marginal cover and satisfactory cover (a forage HEI component does not provide thermal cover).

FOREST DENSITY EXPRESSED AS CANOPY COVER

In 1994, Pacific Northwest Research Station published a research note establishing suggested Blue Mountains stocking levels. This research note differed from previous efforts because stocking recommendations were presented for 7 tree species and a total of 66 plant associations: 42 associations for Blue-Ochoco province and 24 associations for Wallowa-Snake province (Cochran et al. 1994).

Apparently, forest density (stocking) guidelines have not been developed to this level of detail anywhere else in North America (Powell 1999).

The research note (Cochran et al. 1994) provides a tremendous amount of detail; for Blue-Ochoco province, there are potentially 294 unique stocking recommendations (e.g., 7 species × 42 plant associations = 294 combinations). This level of fine-scale detail is both unnecessary and problematic when evaluating satisfactory elk cover at a broad scale (such as entire Umatilla National Forest).

To support a variety of strategic assessment and planning needs, fine-scale plant associations used by Cochran et al. (1994) were recently aggregated into two mid-scale potential vegetation hierarchical units: plant association groups (PAG), and potential vegetation groups (PVG).

Appendix 1 shows how plant associations and other fine-scale potential vegetation types were aggregated into these mid-scale hierarchical units (Powell et al. 2007).

A research note (Cochran et al. 1994) provided recommended stocking levels by using a relative density metric called 'stand density index.' Before I could evaluate sustainability of satisfactory elk cover (by using suggested stocking levels from the 1994 research note), I needed to translate stand density index values into their corresponding canopy cover percentages. This was accomplished in four steps (Powell 1999):

1. Stand density indexes from Cochran et al. (1994) were converted into their equivalent 'trees per acre' values;
2. Trees per acre values were converted into their equivalent 'basal area per acre' values;
3. Basal area per acre values were converted into their equivalent 'canopy cover percentages' by using equations from an elk cover study (Dealy 1985); and
4. Calculated canopy cover percentages for each combination of tree species and plant association were averaged to derive estimated canopy cover percentages by PAG and PVG.

After completing these calculations, it was then possible to compare satisfactory elk cover criteria (70% and 50%) with recommended stocking levels from Cochran et al. (1994) to evaluate whether satisfactory cover could be considered sustainable and, if so, for which combinations of tree species and potential vegetation group (PVG).

FOREST DENSITY THRESHOLDS

Figure 1 shows a generalized stand development trajectory and it illustrates five important forest density thresholds. Threshold 'benchmarks' are important for this analysis because *I assumed that sustainable stands would avoid stocking levels associated with a self-thinning zone*.

Note that occasional forays into a self-thinning zone are to be expected during forest development (and this is an important process for creating small snags and coarse woody debris), but stands will not spend the majority of their time there.

Nature uses fire, insects, and other disturbance processes to reduce high stocking levels and move stands out of a self-thinning zone; Armillaria root disease, Douglas-fir beetle, Douglas-fir tussock moth, fir engraver, Indian paint fungus, mountain pine beetle, spruce beetle, western pine beetle, and western spruce budworm all respond positively to high stocking levels (see table 1 in Powell 1999).

I assumed that long-term sustainability was represented by stocking levels where intertree competition was not severe enough to kill trees. This means that density levels above a ‘lower limit of self-thinning zone’ (see fig. 1) are unsustainable if experienced for a long time period. Density levels remaining below a lower limit of self-thinning zone are assumed to be sustainable for long planning horizons.

I took calculated canopy cover values by tree species and potential vegetation group and displayed them in a chart format, using two colors to differentiate between sustainable and unsustainable stocking-level zones.

Colored lines portraying satisfactory and marginal cover (as canopy cover values) were then superimposed on canopy-cover stocking charts, allowing a reader to quickly discern whether elk cover objectives were occurring in a sustainable or unsustainable portion of suggested Blue Mountains stocking levels.

One chart was produced for each of three upland forest potential vegetation groups (dry, moist, and cold upland forest PVGs). These charts are presented as figures 2-4.

RESULTS FOR DRY-FOREST SITES

Figure 2 indicates that when defined by using 70% canopy cover, grand fir and interior Douglas-fir forest types can provide satisfactory cover on dry-forest sites. However, the forest type occupying most dry sites under a properly functioning historical disturbance regime was ponderosa pine (it occupied 50-90% of dry-forest sites as based on an historical range of variability concept).

Figure 2 clearly shows that for dry-forest stands comprised mostly of ponderosa pine, a 70% canopy cover objective is not biologically feasible, even for a maximum density stocking level (and maximum density is an extreme, and rarely encountered, stocking level in wild stands).

For dry upland forest PVG, Forest Plan satisfactory cover objective for ponderosa pine working group (50% canopy cover) is also not sustainable because it occurs in an unsustainable portion of ponderosa pine stocking levels (see fig. 2).

Note that it is not appropriate to consider other dry-forest cover types (Douglas-fir, western larch, lodgepole pine, or grand fir) when evaluating a 50% objective because those species do not occur in a ponderosa pine working group (ponderosa pine is the **only** (climax) tree species associated with four plant community types (Hall 1973) used to define a ponderosa pine working group; see Forest Plan FEIS, appendix K, for working group composition).

A dry upland forest PVG includes two plant association groups defined by using a temperature-moisture matrix approach: ‘warm dry’ and ‘hot dry.’ Since a warm dry PAG occupies much more acreage in the Blue Mountains than a hot dry PAG, warm dry canopy cover values were examined to gauge their sustainability for dry-forest environments (fig. 5).

Figure 5 indicates that for a warm dry PAG, 50% canopy cover is a threshold value separating sustainable and unsustainable density zones. Since 50% canopy cover is a lower limit (minimum value) of satisfactory cover for ponderosa pine sites (as defined by Forest Plan), this finding indicates that ponderosa pine stocking levels must occur in an ‘unsustainable zone’ to provide satisfactory cover, even for a warm dry portion of the dry upland forest PVG.

Figure 2 indicates that for a dry upland forest PVG, a marginal cover objective (40%) is marginally sustainable for ponderosa pine forest cover type, and fully sustainable for other forest cover types associated with this PVG.

RESULTS FOR MOIST-FOREST SITES

Figure 3 indicates that for a moist upland forest PVG, satisfactory cover is sustainable for interior Douglas-fir, Engelmann spruce, grand fir, and subalpine fir forest cover types. When occurring on moist-forest sites, ponderosa pine, western larch, and lodgepole pine cover types cannot be relied upon to provide satisfactory cover on a sustainable basis. Figure 3 indicates that any of the seven forest cover types can reliably meet a marginal cover objective (40%) on a sustainable basis.

RESULTS FOR COLD-FOREST SITES

Figure 4 indicates that for a cold upland forest PVG, satisfactory cover is sustainable for interior Douglas-fir, Engelmann spruce, grand fir, and subalpine fir forest cover types. When occurring on cold-forest sites, ponderosa pine, western larch, and lodgepole pine cover types cannot be relied upon to provide satisfactory cover on a sustainable basis. Figure 4 indicates that any of the seven forest cover types can reliably meet a marginal cover objective (40%) on a sustainable basis.

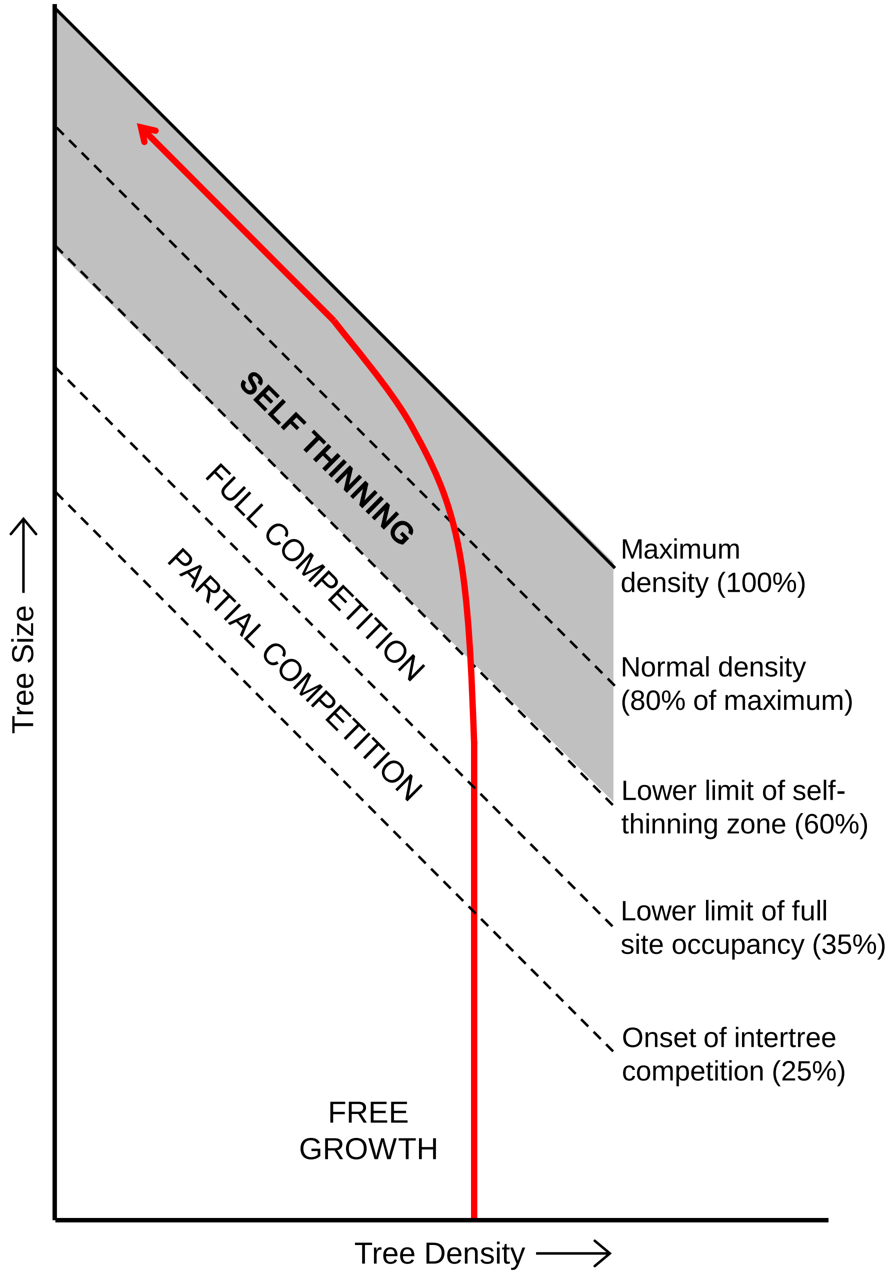
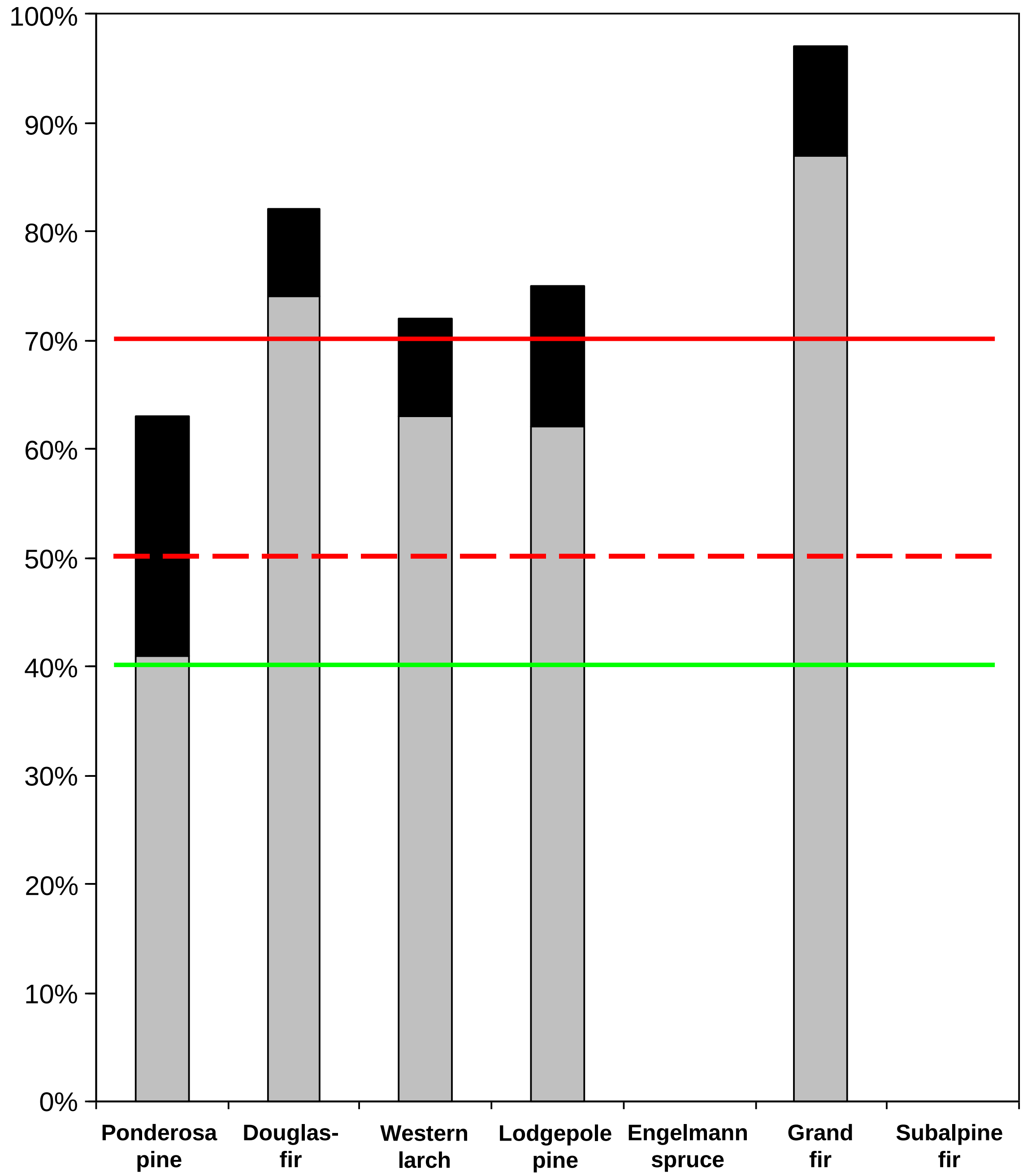


Figure 1 – Generalized development trajectory for an even-aged (single-cohort) forest stand. Initially, trees are too small to use all of a site's resources and they experience a period of free growth (everyone's happy because no intertree competition is occurring). Eventually, roots and crowns begin to interact and an 'onset of intertree competition' threshold has been reached. As a stand continues growing through a partial competition period, trees eventually capture all growing space and a 'lower limit of full site occupancy' threshold is breached. Beyond this point, full competition occurs between trees. As time passes and competition intensifies, stands enter a self-thinning zone by crossing a 'lower limit of self-thinning zone' threshold. In a self-thinning zone, a tree can only increase in size after neighboring trees relinquish growing space by dying. Many trees are dying as a stand passes a 'normal density' threshold and begins to approach maximum density. Note that this stand trajectory bends sharply left as it tracks along a maximum density line.



HRV %	50-90	5-15	0-10	0-5	N.A.	1-10	N.A.

Figure 2 – Forest density expressed as canopy cover percentages for dry upland forest potential vegetation group. Black portion of each column shows a zone of unsustainable density; gray portion indicates sustainable density levels. Green line marks a lower limit of marginal elk cover; red dashed line is a lower limit of satisfactory cover for ponderosa pine working group, and solid red line is a lower limit of satisfactory cover for working groups other than ponderosa pine. 'HRV Percent' information provides a proportion (as ranges with upper and lower limits) for each cover type expected for large landscapes (15,000-35,000 acres) that are in synchrony with their historical disturbance regime (HRV percentages are adapted from Morgan and Parsons 2001).

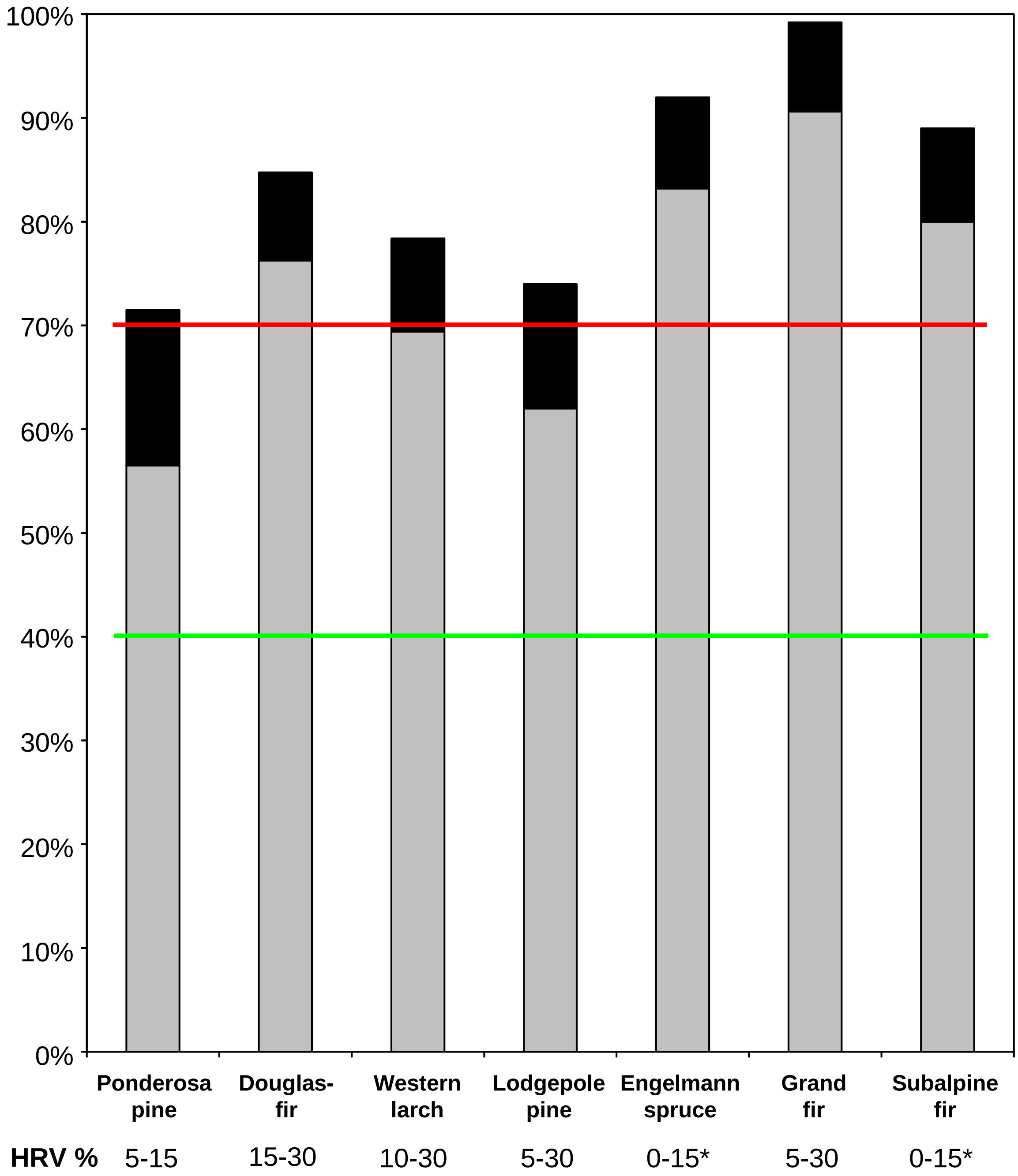


Figure 3 – Forest density expressed as canopy cover percentages for moist upland forest potential vegetation group. Black portion of each column shows a zone of unsustainable density; gray portion indicates sustainable density levels. Green line marks a lower limit of marginal elk cover; solid red line is a lower limit of satisfactory cover. 'HRV Percent' information provides a proportion (as ranges with upper and lower limits) for each cover type expected for large landscapes (15,000-35,000 acres) that are in synchrony with their historical disturbance regime (HRV percentages are adapted from Morgan and Parsons 2001).

* These HRV ranges are the same because Engelmann spruce and subalpine fir are combined as one 'spruce-fir' forest cover type.

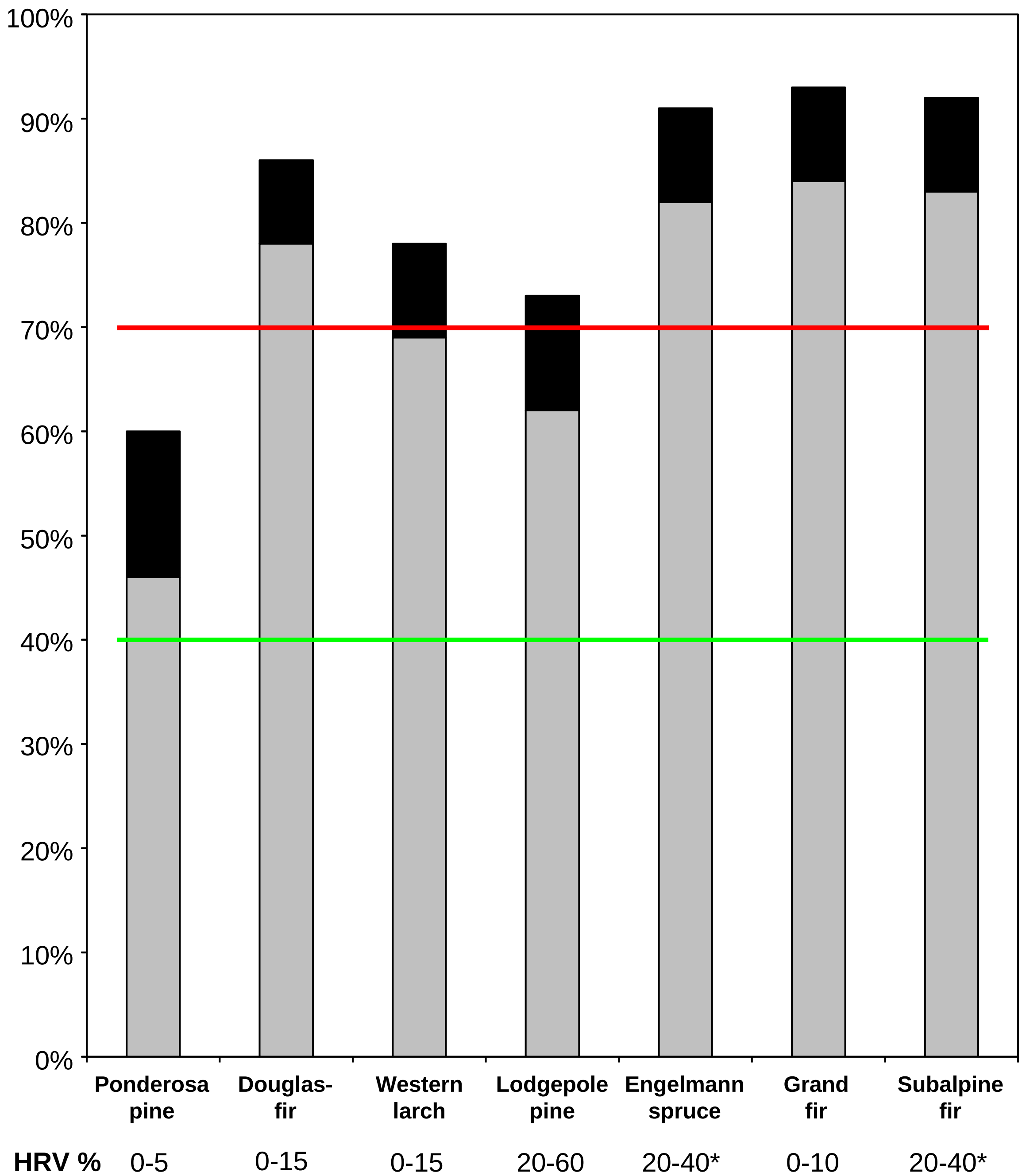


Figure 4 – Forest density expressed as canopy cover percentages for cold upland forest potential vegetation group. Black portion of each column shows a zone of unsustainable density; gray portion indicates sustainable density levels. Green line marks a lower limit of marginal elk cover; red line is a lower limit of satisfactory elk cover. 'HRV Percent' information provides a proportion (as ranges with upper and lower limits) for each cover type expected for large landscapes (15,000-35,000 acres) that are in synchrony with their historical disturbance regime (HRV percentages are adapted from Morgan and Parsons 2001).

* These HRV ranges are the same because Engelmann spruce and subalpine fir are combined as one 'spruce-fir' forest cover type.

Maximum Density (**67% canopy cover**)

VERY LOW VIGOR

Normal Density (**63% canopy cover**)

LOW VIGOR

Lower Limit of Self-Thinning Zone (**50% canopy cover**)

MODERATE VIGOR

Lower Limit of Full Site Occupancy (**42% canopy cover**)

HIGH VIGOR

Onset of Competition (**20% canopy cover**)

VERY HIGH VIGOR

Free Growth (**<20% canopy cover**)

Figure 5 – Canopy cover stocking levels for ponderosa pine on a ‘warm dry’ plant association group (PAG). This figure shows density thresholds from figure 1 expressed as canopy cover percentages. For ponderosa pine on a warm dry PAG, 50% canopy cover delineates a sustainable stocking-level zone from an unsustainable zone (e.g., 50% canopy cover corresponds with lower limit of a self-thinning zone).

APPENDIX 1: Upland forest potential vegetation groups and plant association groups (source: Powell et al. 2007)

PVG	PAG	PVT Code	PVT Common Name	Ecoclass
Cold Upland Forest	Cold Moist	ABLA2/MEFE	subalpine fir/fool's huckleberry	CES221
		ABLA2/RHAL	subalpine fir/white rhododendron	CES214
		ABLA2-PIEN/LEGL	subalpine fir-Engelmann spruce/Labrador tea	CES612
		ABLA2-PIEN/MEFE	subalpine fir-Engelmann spruce/fool's huckleberry	CES2
		ABLA2-PIEN/RHAL	subalpine fir-Engelmann spruce/white rhododendron	CES215
		ABLA2-PIEN/SETR	subalpine fir-Engelmann spruce/arrowleaf groundsel	CEF336
	Cold Dry	ABGR/ARCO	grand fir/heartleaf arnica	CWF444
		ABGR/VASC	grand fir/grouse huckleberry	CWS811
		ABLA2/CAGE	subalpine fir/elk sedge	CAG111
		ABLA2/FEVI	subalpine fir/green fescue	CEG411
		ABLA2/JUDR	subalpine fir/Drummond's rush	CEG412
		ABLA2/JUPA (AVALANCHE)	subalpine fir/Parry's rush (avalanche)	CEG414
		ABLA2/JUTE	subalpine fir/slender rush	CEG413
		ABLA2/POPH	subalpine fir/fleeceflower	CEF511
		ABLA2/POPU	subalpine fir/skunkleaved polemonium	CEF411
		ABLA2/STOC	subalpine fir/western needlegrass	CAG4
		ABLA2/VASC	subalpine fir/grouse huckleberry	CES411
		ABLA2/VASC-PHEM	subalpine fir/grouse huckleberry-pink mountainheath	CES428
		ABLA2/VASC/POPU	subalpine fir/grouse huckleberry/skunkleaved polemonium	CES415
		ABLA2-PIAL/ARAC2	subalpine fir-whitebark pine/prickly sandwort	CAF324
		ABLA2-PIAL/CAGE	subalpine fir-whitebark pine/elk sedge	CAG133
		ABLA2-PIAL/FEVI	subalpine fir-whitebark pine/green fescue	CAG222
		ABLA2-PIAL/JUCO6	subalpine fir-whitebark pine/common juniper	CAS424
		ABLA2-PIAL/JUCO6-ARNE	subalpine fir-whitebark pine/ common juniper-pinemat manzanita	CAS423
		ABLA2-PIAL/JUDR	subalpine fir-whitebark pine/Drummond's rush	CAG3
		ABLA2-PIAL/JUPA-STLE2	subalpine fir-whitebark pine/Parry's rush-Lemmon's needlegrass	CAG132
		ABLA2-PIAL/POPH	subalpine fir-whitebark pine/fleeceflower	CAF2
		ABLA2-PIAL/POPU	subalpine fir-whitebark pine/skunkleaved polemonium	CAF0
		ABLA2-PIAL/RIMO2/POPU	subalpine fir-whitebark pine/mountain gooseberry/skunkleaved polemonium	CAS611
		ABLA2-PIAL/VASC/ARAC2	subalpine fir-whitebark pine/grouse huckleberry/prickly sandwort	CAS623
		ABLA2-PIAL/VASC/ARCO	subalpine fir-whitebark pine/grouse huckleberry/heartleaf arnica	CAS621
		ABLA2-PIAL/VASC/CARO	subalpine fir-whitebark pine/grouse huckleberry/Ross sedge	CAS622
		ABLA2-PIAL/VASC/FEVI	subalpine fir-whitebark pine/grouse huckleberry/green fescue	CAS625
		ABLA2-PIAL/VASC/LECOW	subalpine fir-whitebark pine/grouse huckleberry/Wallowa Lewisia	CAS627
		ABLA2-PIAL/VASC/OREX	subalpine fir-whitebark pine/grouse huckleberry/little ricegrass	CAS626
		ABLA2-PIAL/VASC-PHEM	subalpine fir-whitebark pine/grouse huckleberry-pink mountainheath	CAS624
		ABLA2-PIEN/LUHI	subalpine fir-Engelmann spruce/smooth woodrush	CEG131
		ABLA2-PIEN/POPU	subalpine fir-Engelmann spruce/skunkleaved polemonium	CEF426
		ABLA2-PIEN/VASC-PHEM	subalpine fir-Engelmann spruce/grouse huckleberry-pink mountainheath	CES427
		PIAL/ARAC2	whitebark pine/prickly sandwort	CAF322
		PIAL/CAGE	whitebark pine/elk sedge	CAG131
		PIAL/FEVI	whitebark pine/green fescue	CAG221
		PIAL/JUCO6-ARNE	whitebark pine/common juniper-pinemat manzanita	CAS422

APPENDIX 1: Upland forest potential vegetation groups and plant association groups (source: Powell et al. 2007)

PVG	PAG	PVT Code	PVT Common Name	Ecoclass
Cold Upland Forest (cont.)	Cold Dry (cont.)	PIAL/LUAR3	whitebark pine/silvery lupine	CAF323
		PIAL/RIMO2/POPU	whitebark pine/mountain gooseberry/skunkleaved polemonium	CAS512
		PIAL/VASC/ARAC2	whitebark pine/grouse huckleberry/prickly sandwort	CAS313
		PIAL/VASC/ARCO	whitebark pine/grouse huckleberry/heartleaf arnica	CAS312
		PIAL/VASC/LUHI	whitebark pine/grouse huckleberry/smooth woodrush	CAS311
		PICO(ABGR)/VASC/CARU	lodgepole pine(grand fir)/grouse huckleberry/pinegrass	CLS417
		PICO(ABLA2)/CAGE	lodgepole pine(subalpine fir)/elk sedge	CLG322
		PICO(ABLA2)/STOC	lodgepole pine(subalpine fir)/western needlegrass	CLG11
		PICO(ABLA2)/VASC	lodgepole pine(subalpine fir)/grouse huckleberry	CLS418
		PICO(ABLA2)/VASC/POPU	lodgepole pine(subalpine fir)/grouse huckleberry/polemonium	CLS415
		PIFL2/JUCO6	limber pine/common juniper	CAS511
		PSME/RIMO2/POPU	Douglas-fir/mountain gooseberry/skunkleaved polemonium	CDS911
		TSME/VAME	mountain hemlock/big huckleberry	CMS231
		TSME/VASC	mountain hemlock/grouse huckleberry	CMS131
	Cool Dry	ABGR/COOC2	grand fir/goldthread	CWF511
		ABLA2/ARNE/ARAC2	subalpine fir/pinemat manzanita/prickly sandwort	CES429
		ABLA2/CARU	subalpine fir/pinegrass	CEG312
		ABLA2/XETE	subalpine fir/beargrass	CEF111
		ABLA2-PIMO/CHUM	subalpine fir-western white pine/princes pine	CES8
		PICO/CARU	lodgepole pine/pinegrass	CLS416
		PICO(ABGR)/ARNE	lodgepole pine(grand fir)/pinemat manzanita	CLS57
		PICO(ABGR)/CARU	lodgepole pine(grand fir)/pinegrass	CLG21

APPENDIX 1: Upland forest potential vegetation groups and plant association groups (source: Powell et al. 2007)

PVG	PAG	PVT Code	PVT Common Name	Ecoclass
Moist Upland Forest	Cool Wet	ABGR/TABR/CLUN	grand fir/Pacific yew/queencup beadlily	CWC811
		ABGR/TABR/LIBO2	grand fir/Pacific yew/twinflower	CWC812
		ABLA2/STAM	subalpine fir/twisted stalk	CEF311
	Cool Very Moist	ABGR/GYDR	grand fir/oakfern	CWF611
		ABGR/POMU-ASCA3	grand fir/sword fern-ginger	CWF612
		ABGR/TRCA3	grand fir/false bugbane	CWF512
		PICO(ABGR)/ALSI	lodgepole pine(grand fir)/Sitka alder	CLS58
		POTR/CAGE	quaking aspen/elk sedge	HQG112
	Cool Moist	ABGR/CLUN	grand fir/queencup beadlily	CWF421
		ABGR/LIBO2	grand fir/twinflower	CWF311
		ABGR/VAME	grand fir/big huckleberry	CWS211
		ABGR/VASC-LIBO2	grand fir/grouse huckleberry-twinflower	CWS812
		ABGR-CHNO/VAME	grand fir-Alaska yellow cedar/big huckleberry	CWS232
		ABLA2/ARCO	subalpine fir/heartleaf arnica	CEF435
		ABLA2/CLUN	subalpine fir/queencup beadlily	CES131
		ABLA2/LIBO2	subalpine fir/twinflower	CES414
		ABLA2/TRCA3	subalpine fir/false bugbane	CEF331
		ABLA2/VAME	subalpine fir/big huckleberry	CES311
		ABLA2-PIEN/ARCO	subalpine fir-Engelmann spruce/heartleaf arnica	CEF436
		ABLA2-PIEN/CLUN	subalpine fir-Engelmann spruce/queencup beadlily	CEF437
		ABLA2-PIEN/LIBO2	subalpine fir-Engelmann spruce/twinflower	CEF2
		ABLA2-PIEN/TRCA3	subalpine fir-Engelmann spruce/false bugbane	CEF425
		PICO(ABGR)/LIBO2	lodgepole pine(grand fir)/twinflower	CLF211
		PICO(ABGR)/VAME	lodgepole pine(grand fir)/big huckleberry	CLS513
		PICO(ABGR)/VAME/CARU	lodgepole pine(grand fir)/big huckleberry/pinegrass	CLS512
		PICO(ABGR)/VAME/PTAQ	lodgepole pine(grand fir)/big huckleberry/bracken	CLS519
		PICO(ABLA2)/VAME	lodgepole pine(subalpine fir)/big huckleberry	CLS514
		PICO(ABLA2)/VAME/CARU	lodgepole pine(subalpine fir)/big huckleberry/pinegrass	CLS516
	Warm Very Moist	ABGR/ACGL	grand fir/Rocky Mountain maple	CWS912
	Warm Moist	ABGR/ACGL-PHMA	grand fir/Rocky Mountain maple-mallow ninebark	CWS412
		ABGR/BRVU	grand fir/Columbia brome	CWG211
		PSME/ACGL-PHMA	Douglas-fir/Rocky Mountain maple-mallow ninebark	CDS722
		PSME/ACGL-SYOR	Douglas-fir/Rocky Mountain maple-mountain snowberry	CDS725
		PSME/HODI	Douglas-fir/oceanspray	CDS611

APPENDIX 1: Upland forest potential vegetation groups and plant association groups (source: Powell et al. 2007)

PVG	PAG	PVT Code	PVT Common Name	Ecoclass
Dry Upland Forest	Warm Dry	ABGR/CAGE	grand fir/elk sedge	CWG111
		ABGR/CARU	grand fir/pinegrass	CWG112
		ABGR/SPBE	grand fir/birchleaf spiraea	CWS321
		JUSC2/CELE	Rocky Mountain juniper/mountain mahogany	CJS5
		PIPO/CAGE	ponderosa pine/elk sedge	CPG222
		PIPO/CARU	ponderosa pine/pinegrass	CPG221
		PIPO/CELE/CAGE	ponderosa pine/mountain mahogany/elk sedge	CPS232
		PIPO/ELGL	ponderosa pine/blue wildrye	CPM111
		PIPO/PUTR/CAGE	ponderosa pine/bitterbrush/elk sedge	CPS222
		PIPO/PUTR/CARO	ponderosa pine/bitterbrush/Ross sedge	CPS221
		PIPO/SPBE	ponderosa pine/birchleaf spiraea	CPS523
		PIPO/SYAL	ponderosa pine/common snowberry	CPS522
		PIPO/SYOR	ponderosa pine/mountain snowberry	CPS525
		PSME/ARNE/CAGE	Douglas-fir/pinemat manzanita/elk sedge	CDS664
		PSME/CAGE	Douglas-fir/elk sedge	CDG111
		PSME/CARU	Douglas-fir/pinegrass	CDG121
		PSME/CELE/CAGE	Douglas-fir/mountain mahogany/elk sedge	CDSD
		PSME/PHMA	Douglas-fir/mallow ninebark	CDS711
		PSME/SPBE	Douglas-fir/birchleaf spiraea	CDS634
		PSME/SYAL	Douglas-fir/common snowberry	CDS622
		PSME/SYOR	Douglas-fir/mountain snowberry	CDS625
		PSME/SYOR/CAGE	Douglas-fir/mountain snowberry/elk sedge	CDS642
		PSME/VAME	Douglas-fir/big huckleberry	CDS812
		PSME-PIPO-JUOC/FEID	Douglas-fir-ponderosa pine-western juniper/Idaho fescue	CDG333
	Hot Moist	PIPO/ARAR	ponderosa pine/low sagebrush	CPS61
	Hot Dry	PIPO/AGSP	ponderosa pine/bluebunch wheatgrass	CPG111
		PIPO/ARTRV/CAGE	ponderosa pine/mountain big sagebrush/elk sedge	CPS132
		PIPO/ARTRV/FEID-AGSP	ponderosa pine/mountain big sagebrush/Idaho fescue-wheatgrass	CPS131
		PIPO/CELE/FEID-AGSP	ponderosa pine/mountain mahogany/Idaho fescue-bluebunch wheatgrass	CPS234
		PIPO/CELE/PONE	ponderosa pine/mountain mahogany/Wheeler's bluegrass	CPS233
		PIPO/FEID	ponderosa pine/Idaho fescue	CPG112
		PIPO/PERA3	ponderosa pine/squaw apple	CPS8
		PIPO/PUTR/AGSP	ponderosa pine/bitterbrush/bluebunch wheatgrass	CPS231
		PIPO/PUTR/FEID-AGSP	ponderosa pine/bitterbrush/Idaho fescue-bluebunch wheatgrass	CPS226
		PIPO/RHGL	ponderosa pine/sumac	CPS9

Sources/Notes: Adapted from table 2 in Powell et al. (2007). PVG is potential vegetation group; PAG is plant association group; PVT is potential vegetation type; Ecoclass is a code used to record potential vegetation type determinations on field forms and in computer databases (Hall 1998).

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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 continuously 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

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