Stemilt-Squilchuck Landscape Evaluation

Final Report

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Introduction

The eastern Cascades of Washington State is an incredibly diverse and complex ecoregion that supports abundant fish and wildlife, a wide range of forest and rangeland plant communities, and provides an array of critical ecosystem services including water, wood products, forage for grazing, and a wide variety of recreational opportunities. Ranging from the crest of the Cascades down to the shrub-steppe of the Columbia Basin, the variability in the forests and rangelands of the east Cascades are driven by the interplay of topography, precipitation, soils, and disturbances such as fire, insects, flooding, and wind (Hessburg and Agee 2003, Stine et al. 2014).

Forests across western North America are experiencing an increasing amount and severity of wildfires (Westerling et al. 2006, Westerling 2016). Past management practices, including timber harvest and fire suppression, have resulted in increased risks of uncharacteristically severe wildfire, escalating fire suppression costs, and risks to communities (Hessburg et al. 2000a, Lehmkuhl et al. 2013, Hessburg et al. 2015). The resulting shifts in tree species composition and increases in forest density have resulted in decreased resilience of forests to drought and fire for many of the regions forests, and this occurs at a time when climate change is projected to increase drought stress and wildfire risks (Hessburg et al. 2000a, Littell et al. 2010, Haugo et al. 2014, Spies et al. 2018a).

Across much of the inland western US and within the eastern Cascades, the challenges facing our forested ecosystems have prompted a new management focus to emerge. Ecological restoration, defined as “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed” (SER 2004), is being applied to assist forest ecosystems across a patchwork of private, state, tribal and federal land ownerships (Gaines et al. 2012, USFS 2012, Hessburg et al. 2015, Haugo et al. 2016, Spies et al. 2018b). Examples include, the Okanogan-Wenatchee National Forest Restoration Strategy (USFS 2012, Hessburg et al. 2013, Cannon et al. 2018) that is being applied to guide restoration actions on national forest lands, and the Washington Department of Natural Resources 20-year strategic plan (WA DNR 2017). Both of these guiding documents were built upon a common set of restoration principles (Hessburg et al. 2015).

The Washington Department of Natural Resources recently released a 20-year strategic plan to restore forest health in eastern Washington (WA DNR 2017). The plan outlines a process for maximizing the effectiveness of forest health treatments by coordinating and prioritizing forest restoration activities across watersheds, ownerships, and large landscapes. The strategic plan uses a process, referred to as a landscape evaluation, for assessing the condition of a landscape or watershed, and to identify restoration opportunities and priorities (WADNR 2017). Specifically, a landscape evaluation is a data driven approach to understanding the current condition of a landscape and its level of resilience to future disturbances and climate change (Hessburg et al. 2013, 2015; Cannon et al. 2018). A landscape evaluation is conducted across landownerships and provides a common basis and language for stakeholders and land managers to assess and balance a range of resources, risks, and tradeoffs, and to design strategic and cost effective treatment plans (WA DNR 2017).

We conducted a landscape evaluation for the Stemilt and Squilchuck subwatersheds in support of forest restoration planning for the Chelan County Natural Resources Department and the Stemilt Partnership. The Stemilt Partnership was established in 2007 and includes a broad coalition of agriculture, wildlife, recreation, development and conservation interests. The Partnership worked closely with Chelan County and The Trust for Public Land to develop a community vision and landscape strategy for the entire Stemilt-Squilchuck watershed (TPL 2007). Some of the issues and goals identified in the Stemilt Partnership Vision document relate to this landscape evaluation:

- Water availability is influenced by vegetation conditions.
- The conservation of wildlife is influenced by how habitats for key species are distributed across the landscape.
- Fire risk to homes, communities, and future developments is influenced by the composition and spatial arrangement of forest structure and fuels.

In addition, subsequent to the completion of the vision document, Chelan County and the Stemilt Parternship expressed interest in landscape restoration planning. This landscape evaluation provides important information that can be used, in combination with other data detailed in the Vision Document, in support of forest restoration planning in the Stemilt-Squilchuck watershed.

Our objectives in conducting this evaluation were to: 1) assess key ecosystem indicators of forest and landscape resiliency, 2) use the indicators to assess landscape conditions and determine how forest and landscape resiliency could be restored, 3) assess the risk to homes and infrastructure associated with forest conditions, and 4) identify forest restoration opportunities to reduce fire risks and restore forest resilience, and provide information that can be used to establish priorities for active forest management.

Evaluation Area and Reference Landscapes

The landscape evaluation area includes two 6th Code Subwatersheds (HUC 12) that lie to the south and west of the City of Wenatchee (Fig. 1). These two subwatersheds are a combined 38,960 acres in size and include 7% federal lands, 14% Washington Department of Natural Resources, 12% Washington Department of Wildlife, 8% Chelan County, and 60% private land. Additional details about the watershed can be found in the Stemilt Partnership Vision Document and associated appendices (TPL 2007).

The forested portion of the landscape evaluation area is primarily composed of ponderosa pine (23%) and Douglas-fir (18%) forests. The dominant structure is a mid-successional forest condition (YFMS) that occurs on 29% of the landscape evaluation area. There is a very limited amount of old forest-multistoried forest, and no old forest-single-storied structure.

Hessburg et al. (2000b) used information from 7,496 watersheds across the interior Columbia Basin to group them into 53 Ecological Subregions (ESRs). The ESRs represent a broad classification of bio-geo-physical settings, and each ESR in eastern Washington has a corresponding set of 8-20 reference subwatersheds where historical landscape conditions have been reconstructed (Hessburg et al. 1999). Thus, historic reference conditions for the Stemilt-Squilchuck planning area were derived through comparison with historic data from subwatersheds in the same ESR (ESR 11). Data from subwatersheds in the next warmer and drier ESR (ESR 90) were used to develop the future reference conditions following methods described in Gartner et al. (2008).

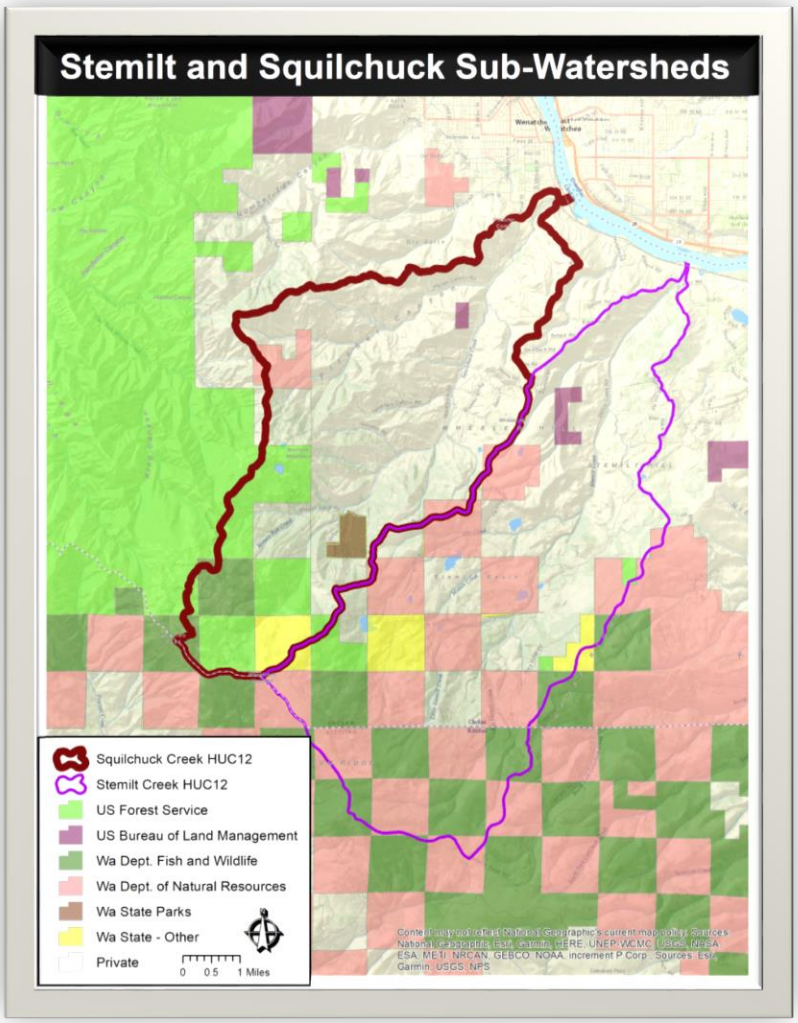

Figure 1. Map showing the land ownership in the Stemilt and Squilchuck subwatersheds.

Landscape Evaluation Process

The process used for the Stemilt-Squilchuck landscape evaluation relies on established science protocols to assess forested vegetation, habitat for focal wildlife species, fire risk and fuels, and forest health (forest insect and disease hazard), and water quality in order to identify opportunities and priorities for restoration treatments and enhance landscape integrity and forest and watershed resiliency (USFS 2012, Hessburg et al. 2013, Cannon et al. 2018). This process is based on the concept that a stand by stand approach to forest restoration without establishing a landscape context for the location, amount, and type of restoration treatments will not lead to resilient forest landscapes (Hessburg et al. 2015, Haugo et al. 2016, Spies et al. 2018b). The landscape evaluation process provides a framework to directly apply the seven principles of landscape restoration described in detail in Hessburg et al. (2015):

Principle 1: Important ecological processes (e.g., fish and wildlife dispersal, hydrology, and the frequency, severity, and extent of disturbances such as fire, insects, disease, wind and floods) operate across spatial scales – from tree neighborhoods to regional landscapes. *Implication: planning and management must incorporate and link the tree neighborhood, patch, drainage/hillslope, local landscape, and regional landscapes.*

Principle 2: Topography provides a natural template for vegetation and disturbance patterns across the landscape hierarchy scales. *Implication: use topography to guide restoration treatments.*

Principle 3: Disturbance and succession drive ecosystem dynamics. *Implication: focus on restoring inherent fire/disturbance regimes and vegetation and successional patterns; other ecological processes will follow.*

Principle 4: Predictable distributions of forest-patch–sizes naturally emerge from interactions between climate, disturbances, topography, and vegetation. *Implication: focus on restoring the natural distribution of forest patch sizes across landscapes.*

Principle 5: Patches are "landscapes within landscapes". *Implication: restore characteristic tree clump and gap patterns within stands/patches.*

Principle 6: Widely distributed large, old trees provide a critical ecological backbone for forest landscapes. *Implication: Retain and promote the development of large/old trees and post-disturbance large snags and downed wood.*

Principle 7: Traditional patterns of land ownership and management disrupt inherent landscape and ecosystem patterns. *Implication: develop restoration projects that effectively work across ownership and management allocations.*

Table 1. Components included in the Stemilt-Squilchuck Landscape Evaluation.

Landscape Evaluation Component	General Description of the Analyses
Vegetation Composition and Structure	An analysis showing how current forested vegetation (structure, composition, spatial arrangement) has departed from historical and future references conditions. Future conditions are based on a warmer and drier climate scenario.
Fire Modeling and Risk Assessment	An evaluation showing how fire would likely move across the landscape given prevailing winds, topography, and current fuel conditions, and the risks these conditions would pose to existing homes and infrastructure. A finer-scale analysis showing how current fire severity and behavior has departed from historical and future fire severity and behavior. Future conditions are based on a warmer and drier climate scenario.
Forest Health and Drought Stress	An analysis showing how the current hazard of common forest insects and diseases are distributed across the landscape compared to historical and future references conditions. Future conditions are based on a warmer and drier climate scenario.
Focal Wildlife Species: Pileated Woodpecker, Whiteheaded Woodpecker, Northern Goshawk.	An analysis showing how current habitats for focal wildlife species (amount, spatial arrangement) are departed from historical and future references conditions. Future conditions are based on a warmer and drier climate scenario.
Other Wildlife Species of Interest: Rocky Mountain Elk	An assessment of elk habitat quality based on vegetation conditions to provide forage and, habitat security, and terrain.
Water Quality-Potential Sediment Delivery from Roads to Streams	A model that incorporates terrain, soil types, roads, and streams to highlight road segments with the greatest potential to deliver sediment to streams.

Vegetation/Forest Health and Drought Stress/Wildlife Habitats

Current vegetation conditions within the Stemilt and Squilchuck subwatersheds were mapped across ownerships through interpretation of recently acquired (2017) high-resolution digital, stereo-imagery. Successional patches (stands) were delineated and for each patch, attributes were assigned that were then used to identify vegetation composition and structure (see Fig. 2. Structural Classes), wildlife habitats, fire and fuels, and insect and disease susceptibility (Table 1). Interpretations of the high-resolution imagery were drafted, field reviewed, and subsequently refined and finalized.

The next step in the evaluation process compares the current conditions within each subwatershed to two reference conditions: the Historic Range of Variability (HRV) to provide insights into how these landscapes functioned in the past, and the Future Range of Variability (FRV) which provides a glimpse of how these landscapes are likely to change given a warmer and drier climate (Hessburg et al. 2013, Haugo et al. 2016). FRV is a "climate change analogue" reference condition that estimates the range of conditions that may develop within a landscape if historic ecosystems were allowed to adapt naturally to a predicted warmer-drier climate (Gartner et al. 2008, Keane et al. 2009). By comparing current conditions to both HRV and FRV reference conditions, managers are able to objectively assess options that mimic patterns and processes under which species evolved, but also consider what resilient landscapes may look like in the future (Hessburg et al. 2013, 2015; Cannon et al. 2018).

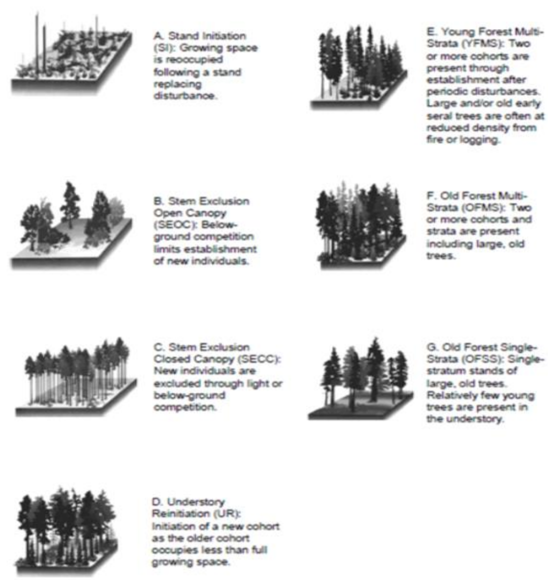

Figure 2. Forest Structural Classes (based on O'Hara et al. 1996) derived from the high-resolution imagery interpretation and used in the landscape evaluation to compare current conditions to reference conditions.

An important component of the landscape evaluation process is a comparison of the abundance of a forest type, wildlife habitat, fire risk, etc., to reference conditions, and being able to assess how the spatial patterns may have departed for each of these variables. "Spatial pattern" refers to the size, shape, and configuration of patches of vegetation, wildlife habitat, fuels, insect habitat, etc. Spatial patterns are key drivers of ecosystem processes and functioning (Hessburg et al. 2015). For example, simply evaluating the amount of pileated woodpecker habitat within a subwatershed does not tell you whether the habitat is fragmented into many small patches or concentrated into a few large patches, which in-turn influences habitat connectivity and wildlife movement. Similarly, the distribution of forest patches with high canopy closure and high fuels loads has significant influence on how fire moves across the landscape (Hessburg et al. 2015). To assess the spatial pattern in the landscape evaluation process, spatial metrics, in addition to the overall abundance (Table 2), were used to compare the current condition of vegetation, wildlife habitat, wildfire risk, and insect and disease susceptibility to historical and future spatial patterns.

Table 2. Metrics used to assess spatial pattern in the Stemil-Squilchuck landscape evaluations.

Landscape Metric	General Description
Relative Patch Richness	The number of different patch types relative to the number of patch types present
Patch Richness	The number of different patch types on the landscape
Shannon's Diversity Index	The proportional abundance of each patch types across all patch types, and is sensitive to rare patch types. SHDI = 0 when the landscape contains only 1 patch (i.e., no diversity). SHDI increases as the number of different patch types (i.e., patch richness, PR) increases and/or the proportional distribution of area among patch types becomes more equitable
Hill's Index (N1)	A transformer of SHDI, this index is more suited to describing the more common patches, discounting the more rare patch types
Hill's Index (N2)	A transformer of Simpson's Index, this index discounts the rare patch types even more than N1
Modified Simpson's Evenness Index	The observed modified Simpson's diversity index divided by the maximum modified Simpson's diversity index for that number of patch types. Sensitive to rare patch types being present.
Alatalo's Evenness	The ratio between the numbers of "very abundant" and "abundant" patch types
Contagion Index	The observed contagion over the maximum possible contagion for the given number of patch types. When edge density is very low, for example when a single class occupies a very large percentage of the landscape, contagion is high and vice versa. In addition, note that contagion is affected by both the dispersion and interspersion of patch types. Low levels of patch type interspersion (i.e., inequitable distribution of pairwise adjacencies results in high contagion, and vice versa.
Interspersion and Juxtaposition Index	Based on patch adjacencies, not cell adjacencies like the contagion index, but rather isolates the interspersion or intermixing of patch types
Percent Landcover	Total percent of the corresponding patch type within the landscape area
Largest Patch Index	The percentage of the landscape comprised by the largest patch
Patch Density	The number of patches of the corresponding patch type divided by the total landscape area, multiplied by 10,000 and 100 to convert to 100 hectares. Patch density often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches
Mean Patch Size	The average patch size of a corresponding patch type within the landscape area
Edge Density	The sum of the lengths (m) of all edge segments in the landscape, divided by the total landscape area (m2), multiplied by 10,000 (to convert to hectares). ED includes a user-specified proportion of internal background edge
Mean Nearest Neighbor	The average distance from nearest patches of the corresponding patch type (meters)
Aggregation Index	A combination of PD, MPS, and MNN

Another important tool used to assess the potential impacts of climate change on forest conditions is an evaluation of soil moisture deficit (Lutz et al. 2010, Kane et al. 2015). Soil moisture deficit is based on topographic position and soil water holding capacity and provides an estimate of vegetation stress due to a lack of seasonal water. Soil moisture deficit has been correlated with a range of important ecological attributes including forest structure and composition, fuel moisture, and fire behavior (Lutz et al. 2010, Kane et al. 2015).

Fire Modeling and Risk Assessment
The Quantitative Wildfire Risk Assessment process (see Scott et al. 2013, Ager et al. 2014, Gilbertson-Day et al. 2018 for details) was incorporated as part of the landscape evaluation. The risk assessment relies on vegetation and fuels data derived from the photo-interpretation, terrain, fire modeling, and information on the location of homes and other infrastructure to develop maps showing areas of various levels of risk to wildfires. This information, in combination with other landscape evaluation data, were used to identify priority areas for treatments to address fire risks.

Species of Management Interest – Rocky Mountain Elk
Rocky Mountain elk (*Cervus elaphus nelsoni*) were selected by the Stemilt Partnership as a Species of Management Interest. Elk habitat quality was assessed based on variables known to influence elk habitat use (see Rowland et al. 2018). The key components of the elk habitat assessment included vegetation, roads, terrain, and cover (see Appendix A for more details). This assessment provides an interim evaluation until other elk habitat modeling that is underway is completed.

Water Quality-Potential Sediment Delivery from Roads to Streams
Erosion from road surfaces can increase streambed fine sediment, which affects aquatic habitat, macroinvertebrate populations, fish spawning habitats, and water quality (Luce and Black 1999, Wondzell 2001). In addition, fine sediment from roads can make streambeds and banks more susceptible to erosion during high flow events (Luce and Black 1999, Wondzell 2001). The GRAIP-Lite (Geomorphic Road Analysis and Inventory Package) tool (NetMap 2017) was used to identify road segments that have the highest potential to deliver fine sediments to streams. In addition, field surveys of road conditions can be used to identify areas where there is visual evidence of erosion of the road surface and other erosional issues (e.g., failed culverts, gullies, landslides). Field data are then used in combination with GRAIP-Lite to identify and prioritize road segments for maintenance, rehabilitation, and restoration.

Collaboration on the Landscape Evaluation
A critical component of the landscape evaluation process is the collaboration between our landscape evaluation team and representatives from the Stemilt Partnership. We are extremely grateful for all of the time, input, and information our team received during the process. The collaboration aided tremendously in shaping the breadth and focus of the landscape evaluation process. The following table (Table 3) provides an overview of the collaborative process, including a list of participants and key meeting dates.

Table 3. The collaboration process for the Stemilt-Squilchuck landscape evaluation, including participants (in alphabetical order) and meeting dates.

Collaboration Participants (in Alphabetical Order)	
Name	**Representing**
Ben Alworth	Matheson Orchards
Carmen Andonaegui	WA Department of Fish and Wildlife
Mike Barajas	US Forest Service
Nolan Brewer	WA Department of Natural Resources
David Cass	WA State Parks
Matt Eberlein	WA Department of Fish and Wildlife
Jerry Holm	Home Owners
Mike Kane	Chelan County Natural Resources
Mike Kaputa	Chelan County Natural Resources
Eric Koenig	AFM
Larry Leach	WA Department of Natural Resources
John Lehmkuhl	Matheson Orchards
Pete Lopushinsky	WA Department of Fish and Wildlife
Erin McKay	Chelan County Natural Resources
Rod Pfeifle	WA Department of Fish and Wildlife
Dave Pope	Scout-a-vista
Cindi Tonasket	WA Department of Natural Resources
Meg Wallmow	WA Department of Natural Resources
Brad Whiting	Mission Ridge Ski Area
Luke Machtolf	Northwest Management
Collaboration Meetings	
Date	**Primary Purpose**
June 12, 2018	Overview of the Landscape Evaluation Process
November 13, 2018	Review and feedback on preliminary landscape evaluation results
January 14, 2019	Review and feedback on process to determine restoration priorities
March 11, 2019	Review and feedback on preliminary prioritization results and discussion about elk habitat assessment
May 8, 2019	Elk habitat subgroup meeting to provide review and feedback of the assessment methods
May 28, 2019	Field trip to see projects that are being planned and implemented
May 29, 2019	Final meeting to review landscape evaluation restoration priorities

Landscape Evaluation Results

Stemilt Subwatershed

The Stemilt subwatershed is 21,222 acres in size and includes a diversity of land ownerships: 2,108 acres-County, 3,609 acres-WDFW, 4,806 acres-WADNR, 445 acres-USFS/BLM, and 10,254 acres-private. The dominant forest cover types in the Stemilt subwatershed area ponderosa pine (25%), Douglas-fir (14%), subalpine fir (12%), and larch (11%). The primary structure types include young-forest-multistory (30%), stem-exclusion-open-canopy (20%), and understory-reinitiation (15%). The non-forest types include shrub over 12% of the subwatershed and a combination of agriculture/rock/water that occurs on 17% of the subwatershed.

Vegetation Composition and Structure

Cover Type

The amount of larch and subalpine fir cover types are above references conditions but are highly fragmented (Table 4). There are opportunities to increase the amount of ponderosa pine cover type in the subwatershed, which would also address the potential for increased moisture deficits that are projected as a result of climate change.

Structure Class

There is currently a high amount of mid-successional (YFMS) forest that could be managed to increase closed canopy (SECC) and old forest structure classes (OFMS, OFSS)(Table 4). There is an opportunity to increase patch sizes as the current spatial arrangement of structure classes is highly fragmented compared to reference conditions. Large tree structures, which are often the most resilient to disturbances and climate change, are lacking across much of the landscape.

Structure Class X Potential Vegetation

The amount of mid-successional (YFMS) structure classes are currently above reference conditions within the Dry Forest (Table 4). There is an opportunity to create older forest (OFSS) and closed canopy (SECC) structural classes while also improving patch sizes and spatial arrangement.

In the Mesic Forest there is an opportunity to manage mid-successional (YFMS) structure classes to increase the amount and patch sizes of understory re-initiation (UR), old forest structures (OFMS, OFSS), and complex-early successional patches (SI).

In the Cold Forest, the amount of mid-successional (YFMS, UR) and open canopy (SEOC) forest structure is high relative to reference conditions. There is an opportunity to increase closed canopy forest structures (SECC) and complex-early successional forest patches (SI).

Table 4. The forest vegetation variables that are departed from reference conditions (HRV-Historic Range of Variability, FRV-Future Range of Variability) for the Stemilt subwatershed.

Vegetation Variable	Current	HRV	FRV
Cover - Acres			
Subalpine fir	2,610	0-917	0-726
Western larch	2,313	0-1,145	0-715
Structure - Acres			
Stand Intiation	441	0-4,843	0-3,202
Stem Exclusion Closed Canopy	51	0-1,802	0-1,587
Young Forest Multistory	6,449	0-8,187	0-1,789
Old Forest Single Story	250	0-4,968	0-4,410
Old Forest Multistory	0	0-1,184	0-783
Dry Forest - Acres			
Young Forest Multistory	2,905	0-2,056	0-1,897
Stem Exclusion Closed Canopy	0	0-170	0-148
Old Forest Single Story	0	0-433	0-270
Mesic Forest - Acres			
Stand Initiation	0	0-1,566	0-1,328
Understory Reinitiation	11	44-5,057	0-3,903
Old Forest Multistory	0	0-4,804	0-3,709
Old Forest Single Story	0	0-624	0-501
Cold Forest - Acres			
Stand Initiation	81	0-872	0-214
Understory Reinitiation	2,808	0-1,204	0-817
Stem Exclusion Open Canopy	1,038	0-458	0-433
Stem Exclusion Closed Canopy	0	0-393	0-354
Young Forest Multistory	2,313	0-509	0-335

Forest Health

A variety of forest insects and diseases were assessed based on forest structure and composition, and the spatial arrangement of forest types. This evaluation does not map the distribution of current forest insects and diseases, but rather identifies areas where the potential disease or insect hazard is high, moderate, or low based on the forest structure and composition. These hazard ratings are compared to historic and future reference conditions to assess forest health. The forest health hazard measures included Douglas-fir beetle, Douglas-fir dwarf mistletoe, fir engraver, mountain pine beetle, western larch dwarf mistletoe, and western pine beetle. The results showed that the amount of forest area rated as high risk for mountain pine beetle is above both the historic and future reference conditions (Table 5). The amount of area rated as high and moderate hazard for western larch dwarf mistletoe was also above both the historic and future reference conditions (Table 5).

Table 5. Forest insects and disease hazard ratings that are departed from reference conditions in the Stemilt subwatershed.

Insect/Disease	Acres Current	HRV Acres	FRV Acres
Mountain Pine Beetle – High Hazard	2,483	0-2,271	0-955
Western Larch Dwarf Mistletoe – Moderate Hazard	4,987	0-955	0-721
Western Larch Dwarf Mistletoe – High Hazard	530	0-127	0-42

Moisture Deficit

The potential influences of a warmer and drier climate on the soil moisture deficit show considerable changes in the amount of area capable of supporting forest (moisture deficit <300) and shifts in the distribution of forest types (Fig. 3). In the Stemilt subwatershed, projected changes to soil moisture deficits could reduce the amount of area capable of sustaining forest by 14%. There could be an increase in the amount of Dry Forest by 10%, and a decrease in the amount of moist-cold and moist-dry forests by 24%. These are important conditions to consider when designing forest management strategies to restore landscape resiliency.

Fuels and Fire Risk

The vegetation data were used to assess a variety of metrics that relate to fuels and fire behavior in the Stemilt subwatershed. These metrics include Flame Length, Fuel Loading, Fire Line Intensity, Rate of Spread, and Crown Fire Potential. In all cases, the current condition of fuels and potential fire behavior at the landscape scale are within the historical and future reference conditions.

However, nearly half of the Stemilt subwatershed is composed of private land resulting in a considerable amount of urban interface where current fuels conditions create considerable risks to existing homes and other infrastructure (Table 6). Consequently, there is a need for thoughtful and detailed planning to create landscape and site-specific conditions that reduce the risk to homes and other infrastructure (Agee and Skinner 2005). In addition, creating defensible space adjacent to at-risk structures should be a critical component of future fire planning (Cohen 2000, Syphard et al. 2014).

Table 6. Fire risk derived from the Quantitative Risk Assessment showing the acres by risk category for each ownership in the Stemilt subwatershed.

Risk Category	Land Ownership				
	Private	County	State	Federal	Total(%)
Very High	729	488	2,729	280	4,226 (20%)
High	2,000	388	2,102	59	4,549 (21%)
Moderate	2,770	405	1,508	5	4,688 (22%)
Low	2,213	812	1,839	76	4,940 (23%)
Rock/Water/Non					2,817 (13%)

classified		

Wildlife Habitat

Focal Wildlife Species

Habitats for wildlife species associated with open-canopy forest conditions (e.g., white-headed woodpecker) are currently present in amounts that are similar to reference conditions but are fragmented. These species would benefit from increased abundance of large trees and increased patch sizes. Habitats for wildlife species associated with closed-canopy forest conditions (e.g., northern goshawk, pileated woodpecker) in Dry and Mesic Forests are currently present in amounts below reference conditions and could benefit from increases in the amount and patch sizes of these habitats. Numerous wildlife species would benefit from restoration of large trees, old forest habitats (OFSS, OFMS), and increased patch sizes.

Species of Management Interest - Elk Habitat

The elk habitat quality assessment showed that approximately 9,260 acres (44%) of the Stemilt subwatershed is in a low habitat quality condition, 9,930 acres (47%) is in a moderate habitat quality condition, and 2,025 acres (9%) is in a high quality condition. The habitat quality could be enhanced by reducing the impacts of roads to create additional security habitat and by creating more openings in mesic and moist forest types to create better forage conditions.

Water Quality – Potential Sediment Delivery from Roads to Streams

The analysis showing the potential for sediment delivery from roads to streams within the Stemilt subwatershed showed that 19 (10%) miles of road have a high potential to deliver sediment, 44 (25%) miles have a moderate potential, and 116 (65%) miles have a low potential. This analysis is similar to results for other subwatersheds showing that typically 10-15% of the road network has the greatest potential to deliver sediment to streams. This provides a means of focusing additional fieldwork to assess and validate these results.

Squilchuck Subwatershed

The Squilchuck subwatershed is 17,763 acres in size and includes a diversity of land ownerships: 903 acres-City/County, 1,060 acres-WDFW, 539 acres-WDNR, 2,255 acres-USFS, and 13,006 acres-private. The primary cover types in the Squilchuck subwatershed include Douglas-fir (22%) and ponderosa pine (21%). Young-forest-multistory (28.5%) is the primary structure type. The non-forest vegetation is primarily composed of shrub (28%) and a combination of agriculture/rock/water (17%).

Vegetation Composition and Structure

Cover Type

The amount of forest cover types are similar to references conditions but are highly fragmented.

Structure Class

There is currently a high amount of mid-successional (YFMS) forest relative to reference conditions (Table 7) that could be managed to increase old forest (OFMS, OFSS) and complex-early successional structure classes (SI). There is an opportunity to increase patch sizes as the current spatial arrangement of structure classes is highly fragmented compared to reference conditions. Large tree structures, which are often the most resilient to disturbances and climate change are lacking across much of the landscape.

Structure Class X Potential Vegetation

In the Dry Forest, current conditions show that the amount of early-successional (SI) and old forest (OFMS, OFSS) vegetation types are currently low in abundance compared to reference conditions (Table 7). Mid-successional (SEOC, YFMS) forest structure could be managed to create early or old forest structure classes, depending on site conditions.

Structure Classes in the Mesic Forest show an abundance of mid-successional classes (YFMS) relative to reference conditions (Table 7). These forest classes could be managed to create more closed-canopy forest (SECC) and old forest (OFMS, OFSS) structures, and complex-early successional forest (SI).

In the Cold Forest, the abundance of mid-successional forest (YFMS) is high relative to reference conditions (Table 7). There is an opportunity to manage mid-successional forest to create more closed-canopy (SECC) and older forest (OFMS) structure classes, and complex-early successional forest (SI).

Table 7. The forest vegetation variables that are departed from reference conditions (HRV-Historic Range of Variability, FRV-Future Range of Variability) for the Squilchuck subwatershed.

Vegetation Variable	Current	HRV	FRV
Cover - Acres			
Subalpine fir	567	0-767	0-607
Structure - Acres			
Stand Intiation	282	0-4,053	0-2,680
Stem Exclusion Closed Canopy	49	0-1,508	0-1,329
Young Forest Multistory	5,066	0-6,853	0-4,929
Old Forest Single Story	0	0-908	0-655
Old Forest Multistory	0	0-4,158	0-3,691
Dry Forest - Acres			
Stand Initiation	0	0-1,494	0-1,281
Understory Reinitiation	0	0-2,398	0-2,003
Stem Exclusion Closed Canopy	0	0-142	0-124
Old Forest Multistory	0	0-559	0-451
Old Forest Single Story	0	0-362	0-300
Mesic Forest - Acres			
Stand Initiation	282	0-1,312	0-1,112
Understory Reinitiation	245	37-4,232	0-3,266
Stem Exclusion Open Canopy	330	0-6,685	0-3,954
Stem Exclusion Closed Canopy	49	0-1,261	0-1,456
Old Forest Multistory	0	0-4,021	0-3,108
Old Forest Single Story	0	0-522	0-419
Cold Forest - Acres			
Stand Initiation	0	0-730	0-179
Understory Reinitiation	955	0-1,008	0-684
Stem Exclusion Open Canopy	369	0-384	0-362
Stem Exclusion Closed Canopy	0	0-329	0-297
Young Forest Multistory	1,488	0-426	0-282
Old Forest Multistory	0	0-162	0-34

Forest Health

A variety of forest insects and diseases were assessed based on forest structure and composition, and the spatial arrangement of forest types. This evaluation does not map the distribution of current forest insects and diseases, but rather identifies areas where the potential disease or insect hazard is high, moderate, or low based on the forest structure and composition. These hazard ratings are compared to historic and future reference conditions to assess forest health. The forest health hazard measures included Douglas-fir beetle, Douglas-fir dwarf mistletoe, fir engraver, mountain pine beetle, western larch dwarf mistletoe, and western pine beetle. The results showed that the amount of forest area rated as high risk for mountain pine beetle is above the future reference conditions (Table 8). The amount of area rated as high and moderate hazard for western larch dwarf mistletoe was above both the historic and future reference conditions. Conversely, the area rated as high hazard for western pine beetle in the Squilchuck subwatershed is below the historic reference condition but within the future reference condition (Table 8).

Table 8. Forest insect and disease hazard ratings that are departed from reference conditions in the Squilchuck subwatershed.

Insect/Disease	Acres Current	HRV Acres	FRV Acres
Mountain Pine Beetle – High Hazard	1,510	0-1,900	0-800
Western Larch Dwarf Mistletoe – Moderate Hazard	1,723	0-800	0-604
Western Larch Dwarf Mistletoe – High Hazard	337	0-1,066	0-35
Western Pine Beetle – High Hazard	320	550-6,697	0-6,164

Moisture Deficit

The potential influences of a warmer and drier climate on the soil moisture deficit show considerable changes in the amount of area capable of supporting forest (moisture deficit <300) and shifts in the distribution of forest types in the Squilchuck subwatershed (Fig. 3). Based on projected changes to soil moisture deficits, the amount area capable of supporting forest cover could decrease by 20%. There could be a decrease in the amount of Dry Forest by 5%, and a decrease in the amount of moist-cold and moist-dry forests by 14%. These are important conditions to consider when designing forest management strategies to restore landscape resiliency.

Fuels and Fire Risk

The vegetation data were used to assess a variety of metrics that relate to fuels and fire behavior in the Squilchuck subwatershed. These metrics include Flame Length, Fuel Loading, Fire Line Intensity, Rate of Spread, and Crown Fire Potential. In all cases, the current condition of fuels and potential fire behavior at the landscape-scale are within the historical and future reference conditions.

However, nearly three-quarters (73%) of the Squilchuck subwatershed is composed of private land resulting in an abundance of urban interface. Forest conditions in the Squilchuck subwatershed currently create considerable risk to homes and other infrastructure (Table 9). Consequently, there is a need for thoughtful and detailed planning to create landscape and site-specific conditions that reduce the risk to homes and other infrastructure (Agee and Skinner 2005). In addition, creating defensible space adjacent to at-risk structures should be a critical component of future fire planning (Cohen 2000, Syphard et al. 2014).

Table 9. Fire risk derived from the Quantitative Risk Assessment showing the acres by risk category for each ownership in the Squilchuck subwatershed.

Risk Category	Land Ownership				
	Private	**County**	**State**	**Federal**	**Total(%)**
Very High	2,614	325	325	516	3,780 (21%)
High	2,770	150	408	517	3,845 (22%)
Moderate	1,341	147	427	606	2,521 (14%)
Low	2,511	278	464	591	3,844 (22%)
Rock/Water/ Nonclassified					3,820 (21%)

Wildlife Habitat

Focal Wildlife Species

Habitats for wildlife species associated with open-canopy forest conditions (e.g., white-headed woodpecker) are currently present in amounts that are similar to reference conditions but are fragmented. These species would benefit from increased abundance of large trees and increased patch sizes. Habitats for wildlife species associated with closed-canopy forest conditions (e.g., northern goshawk, pileated woodpecker) in Dry and Mesic Forests are currently present in amounts below reference conditions and could benefit from increases in the amount and patch size. Numerous wildlife species would benefit from restoration of large tree and old forest habitats (LSOF) and increased patch sizes.

Species of Management Interest – Elk Habitat

The elk habitat quality assessment showed that approximately 10,105 acres (57%) of the Squilchuck subwatershed is in a low habitat quality condition, 7,100 acres (40%) is in a moderate habitat quality condition, and only 550 acres (3%) is in a high quality condition. The habitat quality could be enhanced by reducing the impacts of roads to create additional security habitat and by creating more openings in mesic and moist forest types to create better forage conditions.

Water Quality – Potential Sediment Delivery from Roads to Streams

The analysis showing the potential for sediment delivery from roads to streams within the Squilchuck subwatershed showed that 22 (15%) miles of road have a high potential to deliver sediment, 34 (24%) miles have a moderate potential, and 87 (61%) miles have a low potential. This analysis is similar to results for other subwatersheds showing that typically 10-15% of the road network has the greatest potential to deliver sediment to streams. This provides a means of focusing additional fieldwork to assess and validate these results.

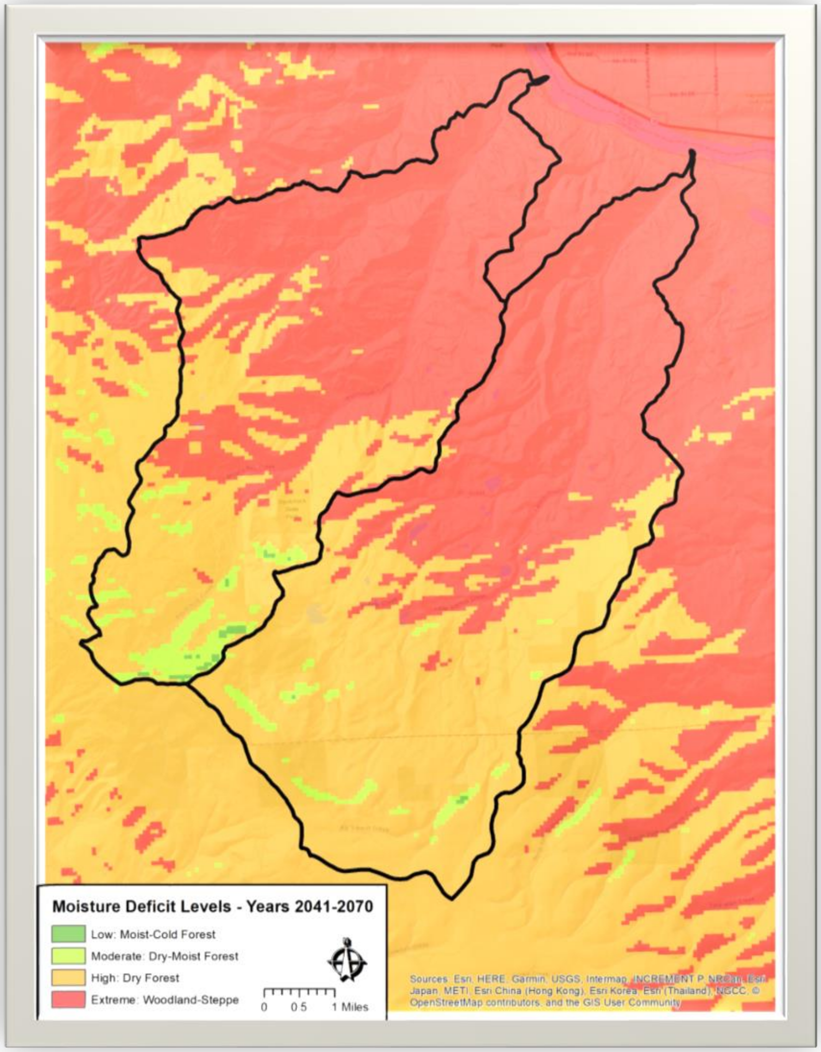

Figure 3. Map showing the distribution of general forest types (potential vegetation) within the Stemilt-Squilchuck landscape evaluation areas. These estimates are based on changes to the soil moisture deficit that may result from a warmer-drier climate at year 2041-2070.

Landscape Prescription

The Stemilt/Squilchuck planning area has received extensive treatments in the past 20 years that have reduced fire risk and forest health hazards. Over half (60%) of the planning area is composed of private land resulting in a considerable amount of urban interface. Consequently, there is a need for thoughtful and detailed planning to create landscape and site-specific conditions that reduce the risk to homes and other infrastructure (Agee and Skinner 2005).

Reduce Risk of Fires to Homes and Other Infrastructures

- Create defensible space adjacent to at-risk structures should be a critical component of future fire planning (Cohen 2000, Syphard et al. 2014).
- Continue to implement the Community Wildfire Protection Plans (CWPP Steering Committee 2015).
- Create more resilient landscapes in areas adjacent to private lands, homes, and other infrastructures.

Increase Forest, Habitat and Landscape Resiliency

- Increase the amount of ponderosa pine cover type within the dry and mesic forests to create conditions that are more sustainable given projected changes in forest cover and soil moisture.
- Overall, forest types with open to moderate (e.g., SEOC, YFMS) canopy closure comprises about 78% of the evaluation area, which reduces the risk of high intensity fire and drought-related mortality. Dense forest (e.g., SECC) makes up a small portion of the current forested landscape but provides valuable wildlife habitat. Manage for dense forest habitats on north slopes, in valley bottoms, and riparian areas where it is most sustainable.
- The planning area is heavily dominated by small and medium sized forest structures (YFMS, UR, SEOC), with a limited amount of old forest (OFSS, OFMS). There is a considerable need to increase the amount of large tree open and closed forest habitats. Large, early seral trees in the dry and mesic forest types would be the most resistant to fires and the effects of climate change.
- Wildlife species associated with closed-canopy forests (e.g., SECC) and old forests (OFMS, OFSS) would benefit from treatments that restore the amount (increase closed-canopy on 1,000-2,000 acres; increase old forest habitats by 2,000-4,000 acres) and spatial arrangement (create larger more contiguous patches) of these habitats. The location of these habitats could be tailored to the landscape locations where they would be the most sustainable, such as valley bottoms and north slopes for closed-canopy habitats.
- Based on the results of this landscape evaluation, there are approximately 8,000 acres of very high and 10,000 acres high priority areas (Table 10, Fig. 4) that could be treated to improve landscape resiliency, enhance forest health, restore wildlife habitats, and address forest fragmentation.
    - Approximately 6,200 acres of treatment (e.g., prescribed fire) in Dry Forest could occur in existing open forest habitats (such as SEOC) to maintain open forest conditions and promote the development of large tree structures. About 3,000 of these acres occur in the Stemilt subwatershed and 3,200 acres in the Squilchuck subwatershed (Fig. 4).
    - Approximately 11,800 acres of treatment could occur in Dry and Cold Forests, within mid-successional structure (YMFS, UR) to develop forest structures that are below reference conditions, such as complex early-successional conditions and old forest conditions. About 7,600

of these acres occur within the Stemilt subwatershed and 4,200 acres in the Squilchuck subwatershed.

Table 10. A summary of the landscape restoration treatment opportunities and priorities for the Stemilt-Squilchuck planning area. Additional treatment priorities to develop Defensible Space near homes and infrastructure may be needed and are identified in the Community Wildfire Protection Plan.

Ownership	Treatment Priority[1]			
	Low[1]	**Moderate**	**High**	**Very High**
County	159	1,180	898	774
WDFW	215	1,163	1,966	913
WADNR	396	1,827	1,914	1,196
USFS/Federal	197	908	979	634
Private	13,040	1,425	4,325	4,343
Totals	14,007	6,503	10,082	7,860

1/Does not mean treatments to create Defensible Space are not needed or a priority. Refer to the Community Wildfire Protection Plan for these areas.

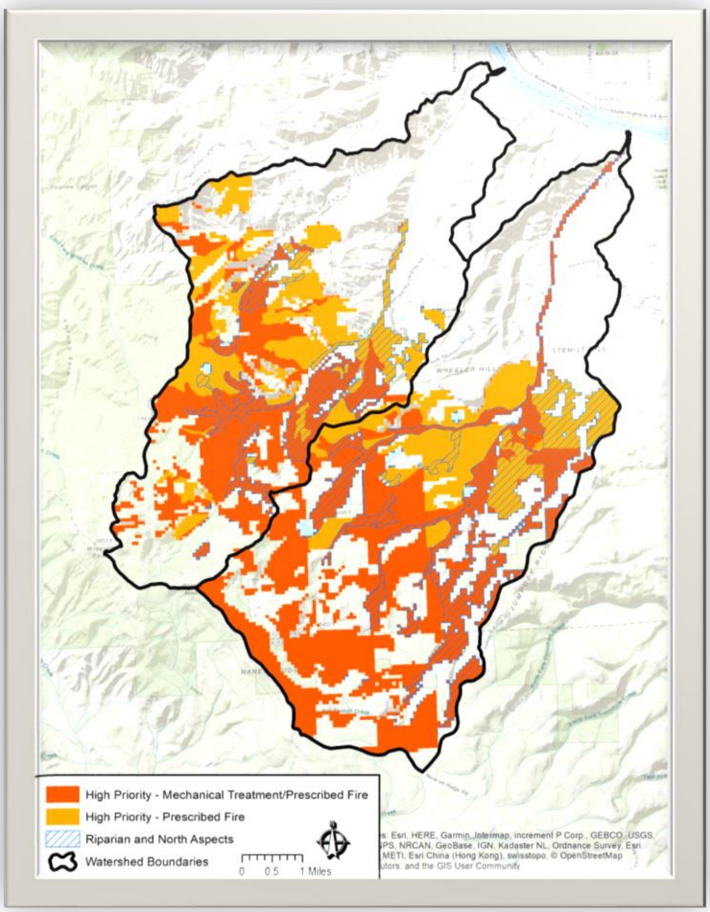

Fig. 4. Map showing the priority treatment areas for each subwatershed by potential treatment type.

Stand-Level Considerations

Within-Stand Spatial Variability

Patches or stands have been described as "landscapes within landscapes" (Hessburg et al. 2015), meaning that the spatial variability within a patch or stand is essential to a variety of important functions. For example, the spatial arrangement of trees within stands can influence habitat for wildlife (Gaines et al. 2007, 2010), how fire moves through a stand (Agee and Lolley 2006), or how forest diseases infect trees (Hessburg et al. 2008). Reconstructions of historic stand conditions provide insights into how forest restoration treatments can be designed to mimic natural patterns within-stand spatial variability (Harrod et al. 1999, Churchill et al. 2013a). Some of what we have learned includes the following:

- Clumpiness:
    - A clump is defined as two or more trees in close enough proximity that their crowns are interlocking (Long and Smith 2000).
    - Clump sizes generally range from about 0.01 acres to 0.5 acres (Harrod et al. 1999).
    - There should be a range of clump densities across a stand, with some in very high density being important for some ecological processes (e.g., snag creation).
- Canopy gaps:
    - Canopy gaps should range in size depending on the fire regime and have a negative exponential size distribution. Up to a third of a stand may exist as canopy gaps (Harrod et al. 1999).
    - Retaining occasional trees within gaps will reflect the complex recruitment and mortality processes that affect gaps.
    - Canopy gaps can be used to isolate dwarf mistletoe infected trees that may be retained for their age, size, or ecological function they provide.
- Complex patches:
    - Complex patches are small patches (generally less than 0.5 acres) within a stand and include more structural and species complexity than the surrounding area.
    - Complex patches are good areas to retain snags, down logs, and mistletoe brooms, if deemed needed for wildlife habitats.
    - Microsites, topography, and existing stand conditions may be used to determine locations to leave complex patches
- Churchill et al. (2013b) have developed a methodology, termed ICO (Individual, Clumps, and Openings), for determining the amount of ICOs appropriate to different forest types and can be used to inform the development of treatment prescriptions.

Large and Old Trees

Large and old trees were historically widely distributed across the forested landscapes of the eastern Cascades (Hessburg et al. 1999, 2015). These structures provide a variety of important ecological functions (e.g., wildlife habitat) and are often the most resilient to disturbances and climate change (Hessburg et al. 2015). There is strong scientific rationale for retaining old trees and for developing restoration treatments that restore the abundance of old trees across landscapes. The following are considerations to address the maintenance and restoration of large and old trees:

- Van Pelt (2008) provides a process, based on visual cues (does not require drilling to age trees), that is convenient and can be consistently applied to identify old trees.
- Retain existing large and old trees.
- Reduce their vulnerability to fire by removing fuels from around them or by using prescribed burn lighting pattern that limit heat intensity at the based of the tree.
- Reducing understory competition around old ponderosa pine trees by removing all or most of the younger trees within one to three times the drip line of the crown.

Road-Stream Interactions

- Use the newly acquired LiDAR data to update the roads and streams data layers.
- Use the results from GRAIP-Lite to focus field surveys on road segments with the greatest potential to deliver sediment to streams.
- Develop treatment prescriptions for each road segment that can be used to seek funding for project-level implementation.

Next Steps

The landscape evaluation results presented in this document a result of a year-long collaborative effort. In doing so, we met the following objectives: 1) We assessed key ecosystem indicators of forest and landscape resiliency (e.g., vegetation departures, fire risk, focal wildlife species habitats), and additional indicators identified through the collaborative process (e.g., elk habitat quality, potential sediment delivery from roads to streams). 2). We used the indicators to assess landscape and watershed conditions and identify opportunities to restore landscape and watershed resiliency. 3). Finally, we identified restoration opportunities and priorities that can be used to develop site-specific management objectives and implementation plans. These would likely include broad-scale application of prescribed fire and mechanical treatments to accomplish multiple objectives simultaneously (e.g., enhance wildlife habitat, elk forage, reduce fire risk and restore forest structure and composition). In addition, information can be used to reduce the impacts of roads on elk habitat and on water quality be focusing road restoration efforts on the portion of the road network that is having the greatest impact.

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Appendix A: Elk Habitat Quality Assessment

Introduction

Elk were identified as a Species of Management Interest by the Stemilt Partnership (TPL 2007). Therefore, elk were evaluated as one of several wildlife species in the Stemilt-Squilchuck Landscape Evaluation. The process used to evaluate elk habitat is documented in this appendix.

Some Key Assumptions

- The elk habitat assessment completed as a portion of the Stemilt-Squilchuck Landscape Evaluation provides and ***interim*** assessment of elk habitat quality until ongoing research on elk become available. There are two ongoing efforts of particular importance: the eastern Washington and Oregon elk habitat model that is likely to be adopted by the Forest Service, and the Colockum Elk Study being analyzed by the Washington Department of Fish and Wildlife.
- The elk habitat assessment relies on recent research showing the importance of late-summer/early-fall elk foraging habitat and elk habitat security on elk productivity and survival. This assumption is supported a considerable body of research (Cook et al. 2001, 2004, 2018, McCorquodale 2015) and is the scientific basis for other elk modeling efforts (Cook et al. 2018, Rowland et al. 2018, Wisdom et al. 2018). There are other important elk life history aspects (e.g., calving, winter elk ecology) that are not assessed in the landscape evaluation and would need to be addressed in other research.
- Some aspects of the elk assessment would benefit from additional field evaluation, specifically, the forage quality and quantity components.

Key Components of the Elk Habitat Assessment

There are four interacting components of the elk habitat assessment. These follow closely components described in Rowland et al. (2018) but rely on data available for the Stemilt-Squilchuck subwatersheds from the landscape evaluation. The four components described in more detail below include: nutrition, cover, habitat security, and terrain.

Nutrition

The primary goal of this component of the assessment is to identify the vegetation types that have the greatest potential to meet or exceed the minimum nutritional requirements for an elk cow/calf pair (Cook et al. 2018). Data on forage productivity and elk use from Lehmkuhl et al. (2013) were used to classify vegetation types derived from the landscape evaluation into forage quality categories (Table A-1). These categories are used to assess which vegetation types had the greatest potential to provide the best forage quality and quantity. The vegetation data from the landscape evaluation that were used included cover type, potential vegetation type, structure class, and canopy closure.

Table A-1. The vegetation types derived from the landscape evaluation and the forage quality categories.

Vegetation Type	**Forage Category**
Herb – Dry Forest PVG	Moderate
Herb – Mesic Forest PVG	High
Herb – Cold Forest PVG	High
Shrub – Dry Forest PVG	Moderate
Shrub – Mesic Forest PVG	High
Shrub – Cold Forest PVG	High
Stand Initiation – Dry Forest PVG	Moderate
Stand Initiation – Mesic Forest PVG	High
Stand Initiation – Cold Forest PVG	High
Stem Exclusion Open Canopy – Dry Forest PVG	Moderate
Stem Exclusion Open Canopy – Mesic Forest PVG	Moderate
Stem Exclusion Open Canopy – Cold Forest PVG	High
Stem Exclusion Closed Canopy – Dry Forest PVG	Low
Stem Exclusion Closed Canopy – Mesic Forest PVG	Low
Stem Exclusion Closed Canopy – Cold Forest PVG	Low
Young Forest Multi-Story >40%CC – Dry Forest PVG	Low
Young Forest Multi-Story >40%CC – Mesic Forest PVG	Low
Young Forest Multi-Story >40%CC – Cold Forest PVG	Low
Young Forest Multi-Story <40%CC – Dry Forest PVG	Low
Young Forest Multi-Story <40%CC – Mesic Forest PVG	Moderate
Young Forest Multi-Story <40%CC – Cold Forest PVG	Moderate
Old Forest Single Story – Dry Forest PVG	Moderate
Old Forest Single Story – Mesic Forest PVG	Moderate
Old Forest Multi Story – Dry Forest PVG	Low
Old Forest Multi Story – Mesic Forest PVG	Low
Old Forest Multi Story – Cold Forest PVG	Moderate
Hardwood	Moderate
Dry Shrub - nonforest	Moderate
Dry Grassland – non forest	Moderate
Agriculture/Cropland	Zero
Non-vegetated/Rock/Water	Zero

Distance-to-Cover

Traditional views of the importance of cover to large ungulates, such as elk, have changed over time as a result of intensive research (Cook et al. 2005). Previously, cover was emphasized as an important component of habitat for elk with little attention paid to forage quality and quantity. Cover was traditionally thought to effect elk productivity and survival by mediating the effects of weather, creating warmer areas with less snow cover in the winter, and cooler, shaded areas in the summer. However, a considerable body of research has cast doubt on the relationship between cover and elk productivity and survival (see Cook et al. 2005 for a summary). Cover is still often shown to be an important variable in models of elk habitat but is usually expressed as a distance-to-cover measure (Rowland et al. 2018). The distance-to-cover metric better expresses the role cover plays in providing area for elk to hide in an seek security in close proximity to non-cover foraging areas. We defined cover as areas with medium to large trees with at least 70% canopy cover and used three distance bands from cover in our habitat quality assessment: >200 meters from cover, 101-200 meters from cover, and <100 meters from cover.

Habitat Security
Habitat security is defined as areas that have a relatively low level of human activities (Hillis et al. 1991). Secure habitats provide places where elk can escape harassment from humans, thus reducing their energy expenditures and increasing their survival. Several studies have shown that elk use areas near human activities less than areas farther from human activities (Gaines et al. 2003, Montgomery et al. 2012, Proffitt et al. 2013, McCorquodale 2013, Ranglack et al. 2017, Thurfjell et al. 2017). We used data provided by the WDFW (W. Moore, pers. comm.) to identify secure and not secure areas. Roads and their status (open vs closed) were attributed in our GIS and then distance buffers (Gaines et al. 2003) were applied to open roads. The size of the buffer along each side of a road was constrained by the adjacent topography so that buffers did not extend over ridges, causing an under representation of secure habitats. The entire planning area was classified as either secure if the area was located outside a buffer or non-secure if located within a buffer.

Terrain Steepness
Elk tend to use gentle terrain more that steep terrain (Rowland et al. 2018). We used digital terrain data to classify the planning area into gentle (<30 degrees), moderate (30-60 degrees), and steep (>60 degrees) slope steepness classes.

Habitat Quality Index
The variables described above were used to score each 30 x 30 m pixel in the planning area from 0-10 to identify areas of low to high habitat quality. The ranking of each of the variables is shown in Table A-2 with areas of the highest potential nutritional value, in close proximity to cover, in secure habitats, and on gentle terrain having the highest habitat quality (Index = 10). Conversely, areas with zero nutrition values, >200 meters from cover, in non-secure areas, and on steep slopes having the lowest habitat quality (Index = 0).

Table A-2. The variables and the variable weighting used to index elk habitat quality.

Variable	Weighting
Nutrition Classes	
Zero	0
Low	1
Moderate	2
High	4
Distance-to-Cover	
>200 m from cover	0
101-200 m from cover	1
<100 m from cover	2
Habitat Security	
Not-Secure	0
Secure	2
Terrain Steepness	
Steep	0
Moderate	1
Gentle	2

Results

The application of the elk habitat quality index showed that 19,370 acres (50%) of the assessment area is in a low habitat quality condition, 17,030 acres (44%) in a moderate habitat quality condition, and 2,575 acres (6%) in a high habitat quality condition (Fig. A-1). Most of the high-quality habitat is currently located in the Stemilt subwatershed portion of the assessment area. The habitat quality could be enhanced by reducing the impacts of roads to create additional security habitat and by creating more openings in mesic and moist forest types to create better forage conditions.

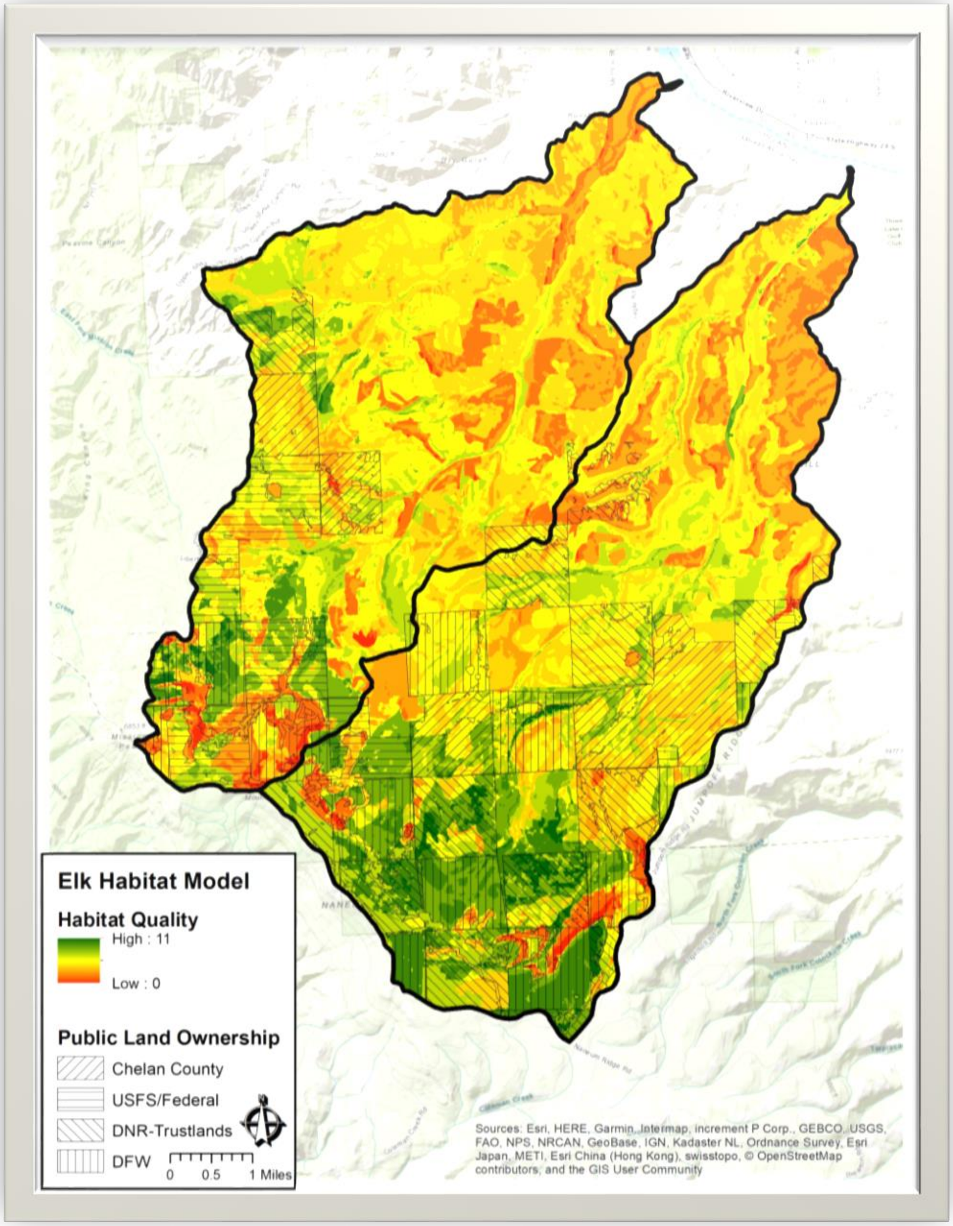

Fig. A-1. Elk habitat quality index score for the Stemilt-Squilchuck landscape evaluation area.

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