J. For. XX(X):1–13
doi: 10.1093/jofore/fvy034

geospatial technologies

Using GIS and the Ecosystem Management Decision Support Tool for Forest Management on the Okanogan-Wenatchee National Forest, Washington State

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As forests continue to experience uncharacteristically severe fires and insect outbreaks, forest restoration activities are critical to maintaining ecosystem services such as fish and wildlife habitats while restoring natural processes such as fire return interval. Large-scale forest restoration projects help land managers meet restoration goals for multiple resources and allow planning efforts to become more efficient by analyzing whole watersheds. Restoration activities are critical to enhance forest resiliency while anticipating the impacts of a warmer, drier climate. This article discusses a geospatial process for prioritizing restoration areas using an ArcMap extension called Ecosystem Management Decision Support (EMDS). Five resource criteria were evaluated to prioritize restoration project areas in two adjoining subwatersheds on the Entiat Ranger District in Washington state: vegetation, fire risk, insect risk, wildlife habitats, and an assessment of aquatic/road interactions. Using models generated from EMDS, a road network evaluation, and in accordance with the National Environmental Policy Act, forest managers designed a landscape level restoration project where 19,700 hectares were analyzed, with 3,896 hectares identified as priority for restoration activities. Identifying priority restoration areas and interpreting model outputs with metrics lead to the development of stand treatments to meet restoration goals (e.g., forest tree thinning, prescribed fire, and road closures).

Keywords: GIS, forest management, Ecosystem management decision support, forest restoration

Many forested landscapes of the American West have been altered during the past two centuries of development, resource exploitation, management practices, and fire suppression (Hessburg and Agee 2003). These factors have left forests vulnerable to uncharacteristically severe wildfires and extensive outbreaks of forest insects and diseases (Hessburg and Agee 2003). A warming climate also contributes to the vulnerability of landscapes to severe wildfire and insect epidemics (IPCC 2007). Forest restoration activities are critical to restoring landscape resiliency by addressing the natural processes and functions of fire while also conserving habitats for focal fish and wildlife species (Gaines et al. 2010, Hessburg et al. 2015).

Described in the 2012 Okanogan-Wenatchee National Forest Restoration Strategy (hereafter, FRS) (USDA Forest Service 2012), direction from management and current policies point toward an adaptive approach to ecosystem management and forest restoration. Adaptive resource management acknowledges that uncertainty exists in the response of a particular resource to management actions (Collins et al. 2010) and that those management objectives may require multiple treatments to be reached. The FRS approach is a transparent process for landscape ecological management that involves testing, monitoring and evaluating applied strategies, and incorporating new knowledge based on scientific findings and the needs of society (Collins et al. 2010). Forest restoration treatments are generally limited to tree thinning and prescribed fire; they may also include planting desired species to encourage a more resilient landscape (USDA Forest Service 2012). Other forest restoration objectives using the FRS may focus on invasive plants, livestock, or stream restoration by rehabilitating, relocating, or removing roads to hasten increases in ecological function (USDA Forest Service 2012).

Numerous assessments of the Okanogan-Wenatchee National Forest

Received March 22, 2018; accepted June 22, 2018; published online August 10, 2018.

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(OWNF), resulting in a long list of peer-reviewed publications, show: (1) increased susceptibility to uncharacteristically large and severe fires, (2) uncharacteristically severe insect outbreaks, and (3) that habitats are declining for late-successional and old forest–associated species (Lehmkuhl et al. 1994, Hessburg et al. 1999a, Franklin et al. 2007). To restore forest sustainability for future generations and increase resiliency to tolerate disturbance events without collapsing, the OWNF developed the FRS to implement a pathway to meet these goals. The FRS was designed to inform land managers of the scientific basis for restoration needs and objectives, and it outlines an approach to an integrated landscape evaluation of forest resources with three primary objectives: 1) to provide context for restoration activities, 2) to identify logical priority project areas, and 3) to describe ecological outcomes from treatments. Designed specifically to meet restoration objectives on the OWNF, the FRS approach has been adapted for use on other forests within the Pacific Northwest Region (Oregon and Washington).

The FRS method involves using a geographic information system (GIS) with an extension tool called Ecosystem Management Decision Support (EMDS) to complete the landscape evaluation. The EMDS modeling framework supports decisions of environmental analysis and planning at multiple geographic scales (Mountain View Business Group 2017). The EMDS system is useful for providing an integrated landscape assessment to generate a logic model of derived attributes based on current forest conditions and a decision model for prioritizing areas with respect to ecological ranges of variability for each resource (Hessburg et al. 2004, Hessburg et al. 2013).

The purpose of this article is to present a case study that evaluates this ecological approach to project planning and the utility of the EMDS system to assess resource conditions that influence landscape patterns, processes, habitats, and resiliency. In addition, we recognize the ecological and economic efficiencies gained by evaluating relatively large landscapes starting at the subwatershed level (i.e., 6th Hydrologic Unit Code, approximately 4,000–16,000 hectare). While the steps of the FRS planning approach are well documented, this article is focused on the implementation of key components of the FRS on the Entiat Ranger District in an effort to describe project planning efficiencies and improvements related to meeting the requirements of the National Environmental Policy Act (NEPA) for landscape-level restoration projects.

Making Better Decisions

Tools such as GIS can help to address complexity; however, integrating data layers into forest management alternatives remains a challenge. The EMDS supports a two-phase integrated approach to conduct a landscape evaluation. The analysis (logic) phase examines the state of the system by comparing current conditions with reference conditions to help establish priorities, while the decision support phase of EMDS integrates multiple variables to help land managers consider the locations and types of treatments to implement (USDA Forest Service 2012). Knowledge-based solutions in a GIS environment provide resource managers the opportunity to objectively analyze broad and complex values in ecosystem management that involve abstract concepts that depend on interdependent states and processes (Reynolds 2001). Research has shown that knowledge-based systems can be successfully applied in the development of logic models for integrated evaluations of social, economic, and ecological information to support strategic forest planning (Reynolds 2005, Humphries et al. 2008, Jensen et al. 2009, Hessburg et al. 2013). Benefits from the logic-based approach to decision-making include: 1) an approach to problem specification expedited by model development that can encourage communication of the model to nontechnical audiences, 2) effective use of partial information, and 3) the availability of metrics for evaluating missing information to optimize how data gaps are filled (Reynolds 2001, Humphries et al. 2008, Jensen et al. 2009).

The EMDS extension in ArcMap has been successfully utilized for several research objectives. Previous analyses using EMDS have involved making recommendations to the US National Criteria and Indicators for evaluating forest ecosystem sustainability, assessing forest vegetation patterns against historical reference conditions, measuring the potential for severe wildfire, and evaluating the suitability of land units for conservation purposes (Reynolds and Hessburg 2005, Reynolds 2005, Hessburg et al. 2007, Humphries et al. 2008). Prior research using EMDS applications were fundamental to the development of the FRS and provides an objective framework for integrating multiple resource values (Hessburg et al. 2013).

The EMDS is a primary tool in the landscape evaluation because of th following factors: 1) it allows synthesis of large amounts of diverse information, 2) analytic steps used by an interdisciplinary team are transparent and repeatable, and 3) treatment options can be evaluated with EMDS using a "gaming" approach that models the outcomes of possible restoration actions (USDA Forest Service 2012). Using EMDS for forest planning is not a solution to ecosystem management and ecological assessment; however, it does suggest an objective starting point and pathway from which managers can assess forest and aquatic restoration on a landscape scale (Reynolds 2001). Using this method to determine the ecological state of a watershed, each resource can be placed in the context of social and ecological values to better inform decision-making.

Site Description

This analysis was conducted on the Entiat Ranger District, located on the

Management and Policy Implications

The integration of the data and analyses presented in this paper provided a broader and more informed platform for decision making. Identifying departures for each resource and relating a prioritization model to those metrics have improved our approach to planning restoration treatment areas by connecting resource values in a meaningful way. This integrated approach is critical to designing beneficial stand-level prescriptions to meet resource goals. The ability to combine multiple resources provides direction on how prescription planning can be focused to produce desired outcomes across a large landscape. In particular, the FRS approach increased efficiencies 1) for field work, including botany surveys, fuels monitoring, and vegetation treatment prescription, 2) for providing a complete landscape analysis for prioritizing project areas for multiple NEPA projects, 3) to include multiple land ownerships and agencies in restoration goals, and 4) to establish landscape-level monitoring for successful adaptive management practices.

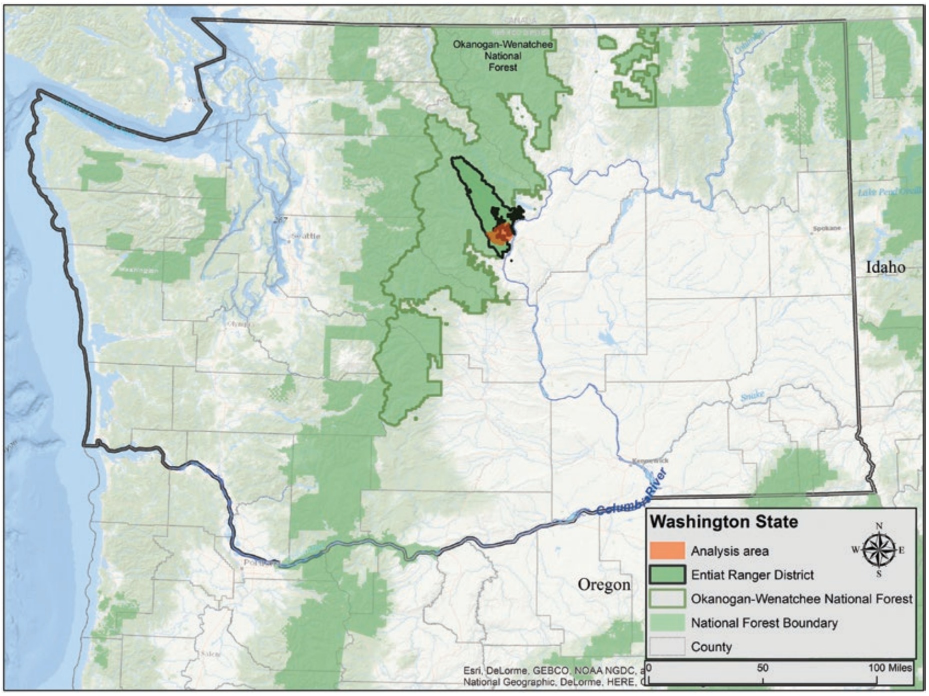

Figure 1. Washington State, with counties, and Okanogan-Wenatchee National Forest. This national forest is on the eastern slope of the Cascade Mountain Range. The Entiat Ranger District is centrally located on the forest.

Okanogan-Wenatchee National Forest (OWNF) (Figure 1). The OWNF encompasses more than 1.6 million hectares, stretching about 290 kilometers from the border of Canada southward along the east side of the Cascade Mountains. Elevations within the study area range from 300 meters at the confluence of the Entiat and Columbia rivers to 2,000 meters on Entiat Ridge. Regional precipitation varies from 13 to 36 centimeters of moisture annually, with approximately half falling as snow (National Weather Service 2012).

The Entiat Ranger District is centrally located on the OWNF and has experienced five very large fires (>20,234 hectares) and hundreds of smaller fires since 1970. Fire-prone ecosystems that have experienced recent wildfire are of particular interest for designing restoration projects. Wildfire-burned landscapes provide an opportunity to restore the process of fire by returning fire activities to areas where fuel accumulations have already been reduced, resulting in fires lower in severity. The fire regime in the lower elevations of the Entiat Ranger District is primarily comprised of Fire Regime I (fire frequency at 0–35 years with low to mixed severity [less than 75% of the dominant overstory vegetation is replaced]) and Fire Regime II (fire frequency at 0–35 years with high severity [stand replacement where greater than 75% of the dominant overstory vegetation is replaced]) (Morgan et al., 2001). This is a ponderosa pine (*Pinus ponderosa*)–dominated forest at lower elevations and on south-facing aspects. The higher elevations host large and old western larch (*Larix occidentalis*), grand fir (*Abies grandis*), lodgepole pine (*Pinus contorta*), and sagebrush (*Artemisia* spp.) mixed with remnant ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*) that survived over a century of commercial logging and multiple wildfire events. Douglas-fir is present across the entire landscape.

Forest Service GIS data illustrate the extent of the 1988 Dinkelman wildfire, which burned over 20,600 hectares in the study area. Following the wildfire, salvage logging operations harvested trees on over 2,000 hectares that were later planted with ponderosa pine, Douglas-fir, and western larch. Lodgepole pine naturally seeded this area after the fire because of previous seed sources and the physiology associated with fire temperatures opening serotinous cones.

The current vegetation condition is dominated by young trees, which generally develop at landscape scales following disturbance events such as wildfire or insect outbreaks. The homogenous nature of these type of stands tends to limit functional habitats and increase insect and disease pathways. The insects evaluated in this analysis include western spruce budworm (*Choristoneura occidentalis*), which prefer any size of spruce (*Picea* species) or Douglas-fir conifers, particularly those that are densely stocked, and Douglas-fir beetle (*Dendroctonus pseudotsugae*), which prefer larger, densely stocked, and weaker trees.

This landscape provides habitat for a wide variety of wildlife species including Canada lynx (*Lynx canadensis*) and the northern spotted owl (*Strix occidentalis caurina*), both of which are listed as "threatened" species. In addition, there are habitats for the American marten (*Martes americana*) and whiteheaded woodpecker (*Picoides albolarvatus*). Formal habitat-associated models for the northern spotted owl, American marten, and whiteheaded woodpecker were included in the decision support system structure. However, because lynx are such a wide-ranging species, they are evaluated beyond the subwatershed scale (ILBT 2013). Spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are listed as "endangered" in the entire Upper Columbia River Basin. Roaring Creek provides critical habitat for spring Chinook spawning and was also considered in project planning.

Methods

The methods involved in this research are described in detail in the 2012 Restoration Strategy (USDA Forest Service 2012, Hessburg et al. 2013). The EMDS extension tool is capable of independently weighting and assessing multiple resource values simultaneously. One of the key components

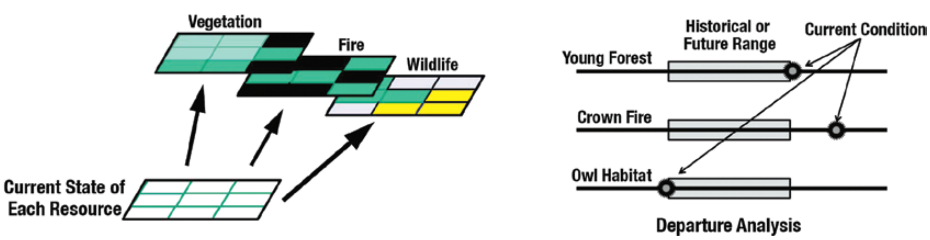

Figure 2. Landscape evaluation and ranges of variability illustration.

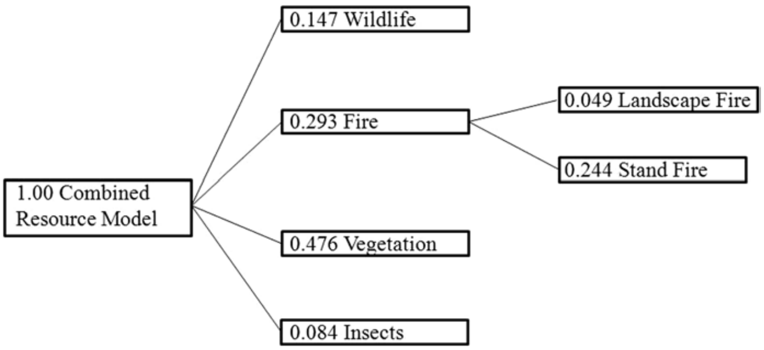

Figure 3. EMDS model with resource criteria weight shown.

of the FRS is the implementation of a landscape evaluation. As Reynolds and Hessburg (2005) describe, landscape-level assessments concerned with the restoration of ecosystems may be based on a set of ecological indicator measures against reference conditions for those same indicators. The FRS uses a set of ecological indicators that includes reference conditions for vegetation (including structure/composition and insect vulnerability), landscape fire movement (including stand-level influences), and focal wildlife/aquatic species habitats and distribution (USDA Forest Service 2012, Hessburg et al. 2013).

A future iteration of the EMDS tool used in the FRS will include an assessment of road network/aquatic interactions that will be fully integrated with the terrestrial assessment for the landscape evaluation. For this study, the aquatic/road interactions assessment was accomplished using a suite of tools from the NetMap aquatic platform to assess habitat connectivity, potential for sediment delivery from roads, and identify intrinsic potential habitat for Chinook salmon (Benda et al. 2007). In addition, a road network evaluation called a Minimum Roads Analysis was completed for the study area. This analysis evaluated each road in the watersheds to identify the need for roads to meet resource and other management objectives as described in relevant land and resource management plans. These data were manually incorporated into the general analysis (not using EMDS) by the Dinkelman project interdisciplinary team fisheries biologist and road engineers.

Evaluating landscape patterns (e.g., species cover types and patch size), processes (e.g., wildfire, insects, and disease), and functions (e.g., wildlife habitat) relied on a comparison of current landscape conditions to a set of reference conditions (Hessburg et al. 1999, Gartner et al. 2008). The two references conditions are based on estimates of the historic or natural range of variability (NRV) of each resource within the Ecological Subregion (ESR) for the area (Hessburg et al. 2000, Hessburg et al. 2004), and the future range of variability (FRV) based on methods described in Gartner et al. (2008) using a model that predicts a warmer, drier climate. The use of FRV provides a climate analog that allows managers to gain insights into how changing climate may influence landscape pattern and composition (Gaines et al. 2012, Hessburg et al. 2015)

The majority of the lower Entiat River watershed resides in ESR 11, which establishes the historical baseline for the landscape's NRV. As Hessburg et al. (2000) specifically describe, ESR 11 is within the range between the Okanogan Highlands–Eastern Cascade Section: dry to moist precipitation conditions, warm temperature conditions, moist forest to dry forest potential vegetation group, and moderate solar radiative flux. For example, departure data derived from the logic model in EMDS can be measured by comparing current forest structure (i.e., percentages of each structure type) to the NRV in ESR 11. Landscapes within ESR 11 use ESR 90 as a proxy (i.e., forested and warmer/drier than ESR11) to represent the FRV in the EMDS analysis (see Hessburg et al. 2013 for further explanation).

Table 1. Roaring Creek subwatershed: ESR 11/90 stand structure attribute table.

OBJECTID	ESR	CLASS	Percent Land Value Calculated	Percent Land Significant Change	Percent Land Change Calculated	Percent Land Minimum 80th	Percent Land Maximum 80th	Percent Land Minimum 100th	Percent Land Maximum 100th
1	ESR11	si	61.36	1	+	0.01	20.4	0	28.75
2	ESR11	seoc	13.69	2		3.94	46.15	0	53.48
3	ESR11	secc	0.10	2		0.01	8.22	0	13.65
4	ESR11	ur	2.94	2		1.91	50.37	0.55	83.33
5	ESR11	yfms	16.39	2		0.77	38.6	0	43.97
6	ESR11	herb	1.26	2		0.32	40.46	0	44.51
7	ESR11	shrub	4.06	2		0.01	30.08	0	43.78
8	ESR11	other	0.21	2		0.01	15.28	0	43.13

OBJECTID	Future ESR	Future CLASS	Future Percent Land Value Calculated	Future Percent Land Significant Change	Future Percent Land Change Calculated	Future Percent Land Minimum 80th	Future Percent Land Maximum 80th	Future Percent Land Minimum 100th	Future Percent Land Maximum 100th
1	ESR90	si	61.3585	1	+	0.01	17.35	0	28.75
2	ESR90	seoc	13.6879	2		0.01	41.06	0	53.49
3	ESR90	secc	0.0956	2		0.01	6.7	0	13.65
4	ESR90	ur	2.9428	2		0.01	42.57	0	83.33
5	ESR90	yfms	16.3902	2		0.01	27.7	0	43.97
6	ESR90	herb	1.2569	2		1.02	40.38	0	43.94
7	ESR90	shrub	4.059	2		0.01	72.99	0	93.4
8	ESR90	other	0.209	2		0.01	43.91	0	71.62

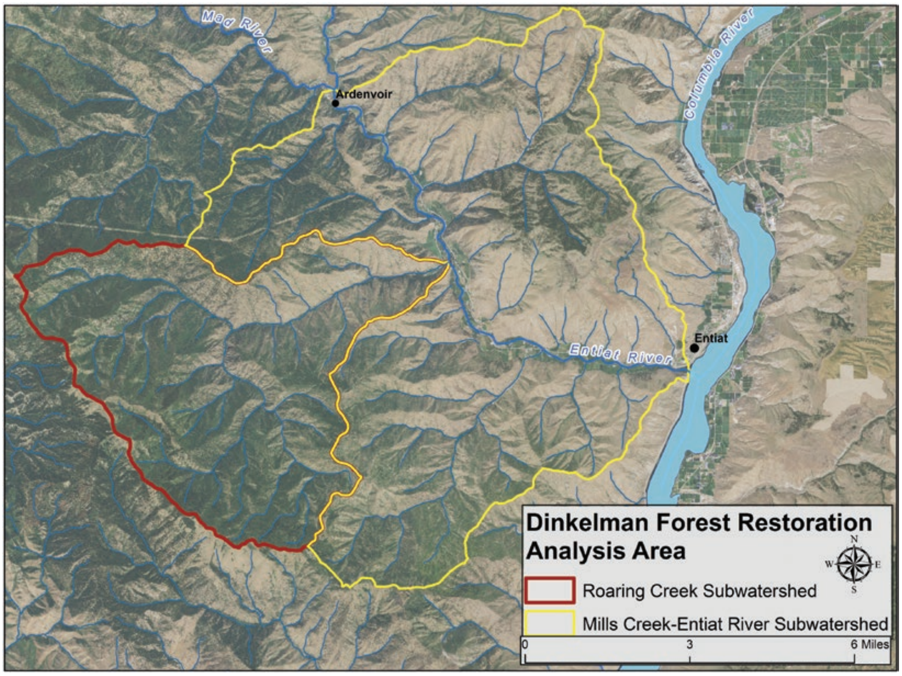

Figure 4. National Aerial Imagery Program 2011, 1-meter resolution, with Roaring Creek and Mills Creek-Entiat River subwatersheds.

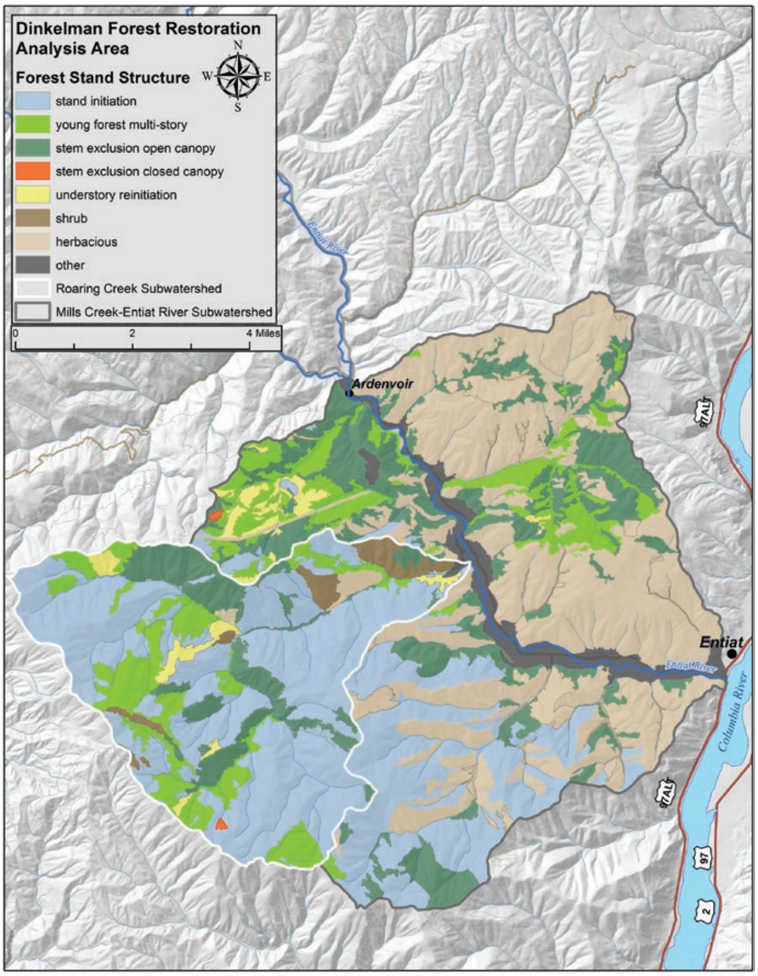

Figure 5. Stand structure from photo interpretation for the Dinkelman analysis area.

Departure Maps

Departure conditions were generated for each resource in the EMDS analysis (i.e., vegetation, fire vulnerability, insect vulnerability, and focal wildlife species habitats). The comparisons of current conditions with NRV and FRV were derived as part of the decision support structure in EMDS. In addition, the combined logic and decision model in EMDS develops a prioritization of vegetation polygons based on stand and landscape metrics, such as the land cover percentage and connectivity of habitats, to identify potential treatment areas. The model outputs for the analysis in EMDS can be viewed spatially as feature classes in ArcMap and can read in the form of a feature class attribute table. Resource conditions with higher departure values represent class types that are most different from the NRV and FRV, while those resource attributes within the reference ranges are not considered departed (Figure 2).

The final priority models integrate each weighted resource (Figure 3). The EMDS includes a tool called Criteria Decision Plus that supports relative weighting of multiple resources to show integrated priorities. The weight of resources may be altered as resource priorities change (e.g., fire components in the wildland urban interface or endangered species' habitats). Specific to this FRS analysis, the vegetation component is assigned the highest weight at nearly 48% because of the high influence on other resources. Vegetation structure and pattern influence potential for insect outbreaks, fire severity and extent, and species habitat characteristics and functions.

Beyond the spatial display on the maps, the attribute tables generated by the model reveal the current condition for each resource in stand metrics (e.g., percentage of cover in subwatershed) showing comparison to the NRV and HRV for 80th and 100th percentiles (Table 1). A closer examination of the stand-level departures within the related attribute tables reveal how the departure metrics can be interpreted at the landscape level while considering ranges of variability for each resource. To assess the spatial arrangement of each resource, a set of landscape metrics were selected to address spatial statistics affecting evenness, diversity, contagion, and relative patch richness (McGarigal et al. 2002). Considering departures and recognizing why they exist leads to prescription planning to influence changes in the trajectory of landscape and stand development.

Unlike vegetation, insect vulnerability, and stand-level fire attributes, which are derived from photo interpretation, the landscape fire spatial model displays raster data across each entire subwatershed. As described in the FRS, the landscape-level fire risk assessment model is done at the subbasin (4th level HUC, approximately 700 square miles). FlamMap fire modeling software uses forest-wide fuels layers, 90th percentile fuel moistures, and representative weather conditions to combine with custom wind grids that are used as inputs to the model. The landscape model is repeatedly ignited with 1,000 random fire starts at a time and allowed to burn for six hours, until the majority of the landscape has been exposed to fire (~50,000 modeled ignitions). Each model is filtered to find clusters of pixels that create more meaningful outputs and multiple maps for each subbasin, including fireline intensity, crown fire activity, rate of spread, and flame length. The stand-level photo interpretation derives fire departures including risk of crown fire, rate of spread, flame length, and fuel consumption.

The FRS highlights focal wildlife species that were selected to represent a range of ecosystem and habitat conditions (Suring et al. 2011, Gaines et al. 2017). Habitat relations information (Gaines et al. 2017) were used to derive and map habitats from photo interpretation data. Habitats for focal wildlife species were assessed both in terms of the amount of habitat and the spatial arrangement (Hessburg et al. 2013). For this analysis in ESR 11, only three focal species exist: northern spotted owl, whiteheaded woodpecker, and the American marten.

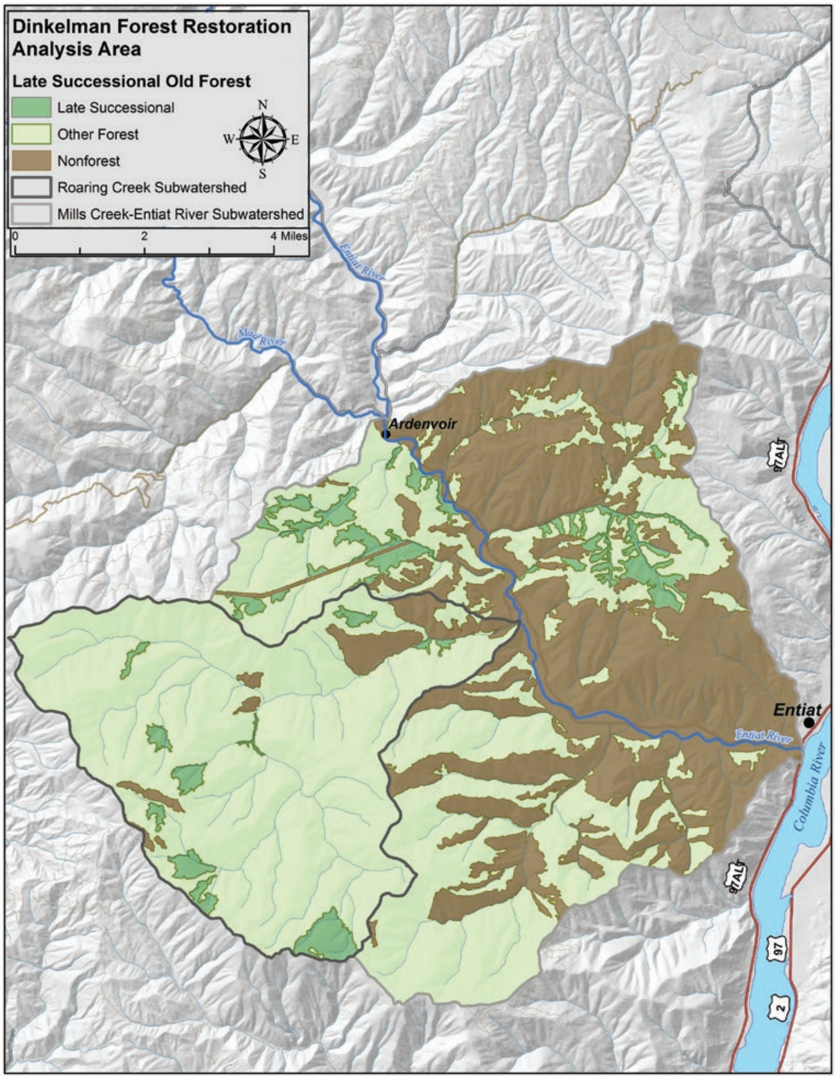

Figure 6. Current late successional old forest structure map for Roaring and Mills-Entiat subwatersheds.

The Forest Restoration Strategy Process

The Entiat Ranger District staff and interdisciplinary team identified two subwatersheds within the 1988 Dinkelman Fire area as an appropriate landscape for this analysis. This research area is called the Dinkelman Restoration analysis area and includes two 6th HUC subwatersheds (Mills Creek-Entiat River and Roaring Creek) (Figure 4). The two subwatersheds encompass 19,700 hectares. With respect to succession, particularly in fire-adapted ecosystems, this area is well suited for restoration activities including prescribed burning, mechanical thinning, and planting, where appropriate, to promote a more resilient landscape with habitats to accommodate a variety of plant and animal species.

The landscape evaluation is a primary component of the FRS process (USDA Forest Service 2012, Hessburg et al. 2013). The current landscape pattern was derived by aerial photo interpretation using National Agriculture Imagery Program (NAIP) 2009 aerial imagery (1-meter resolution) to delineate vegetation patches (> 4 hectares) with similar structure, cover, and composition. Tree clumps and crown differentiation were determined during photo interpretation to ensure consistency in attributing. Additional stand attributes recorded during photo interpretation included the number of canopy layers, riparian or wetland location, logging history, snag abundance, canopy cover, and nonforest species cover and type. Field verification of species type and size classes was confirmed by field visits when needed.

The EMDS then uses scripts to derive additional attributes including forest structure class, wildlife habitat, insect risk, and stand-level fire risk. These derived attributes are then compared with reference conditions to show priority areas for each resource (vegetation, fire risk, insect risk, wildlife habitat). Finally, EMDS integrates each resource into a map of combined priorities. Using NetMap and the Minimum Roads Analysis, the interdisciplinary team review priorities for roads and aquatics to develop an aquatic component for a complete analysis of the area.

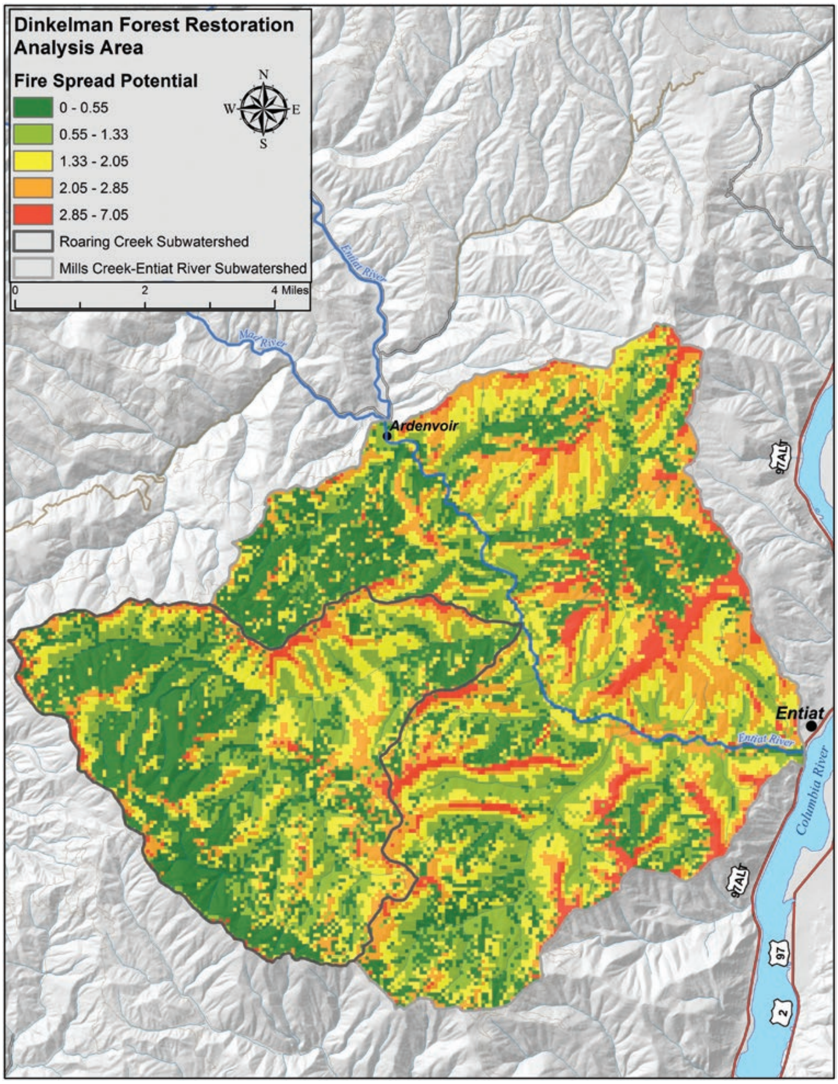

Figure 7. Fire spread potential for landscape fire.

From here, the team of resource specialists review individual and integrated priorities for each resource. Starting with the highest priority areas generated from EMDS, the team can examine landscape and class metrics to understand the output of the analysis. Metrics provide information about why certain areas are high priority. Specialists can use this to begin addressing and testing various treatment options. Based on this review, the team can develop a landscape diagnosis and prescriptions for each stand to meet restoration objectives.

Results

Landscape Evaluation (EMDS)

Vegetation. Vegetation stand structure and composition, determined by photo interpretation, are categorized into structure classes created by O'Hara et al. (1996). Figure 5 shows the current forest stand structure in the analysis area.

Stand initiation cover types for ponderosa pine, lodgepole pine, and Douglas-fir are currently overrepresented compared with reference conditions in both watersheds. One of the primary departure attributes in Roaring Creek includes young stands of lodgepole pine, which were not historically present in ESR 11. In the Mills-Entiat River watershed, western larch cover type was not historically present in ESR 11; hence, it is currently overrepresented. Future ranges of variability reflect similar vegetation departures as NRV. In both watersheds, the current condition reveals an overabundance of stand initiation structure type across the landscape that is highly departed for FRV for those cover species. Vast areas of a single cohort of stands will reduce structural diversity, limiting development of late-successional structures and becoming vulnerable to insect epidemics and fire over time (Camp et al. 1997).

Late successional forest structures are important habitat for a wide variety of wildlife species (Figure 6). Although late successional old forest (LSOF) structures are not abundant, they are within ranges of variability for both NRV and FRV. Total LSOF for each subwatershed was near 5 percent; normal ranges for NRV (ESR 11) are 1.6–26.2 percent area, while FRV (ESR 90) varies from 0.1–17.8 percent area.

Insect Vulnerability. Insect vulnerability is a function of the current vegetation structure and species cover. Within the analysis area, risk of insect outbreak was generally within normal ranges of variability, except for western spruce budworm in the Roaring Creek subwatershed, which was within but nearing the highest ranges of variability for the ESR. Western spruce budworm vulnerability is higher in the Roaring Creek subwatershed because of an abundance of Douglas-fir cover type, which this insect prefers. Most of the Douglas-fir beetle vulnerability falls into the low or moderate class because of the lack of large trees on the landscape (i.e., larger trees would be more favorable to Douglas-fir beetle).

Fire Vulnerability. The raster data from the landscape fire assessment is a visual guide to show mangers where the high rates of spreading or high rates of sending influence occur. Not surprisingly, ridge tops and ridge lines show the areas that are most prone to such attributes. Figure 7 shows the landscape fire spread potential for both subwatersheds. This data is incorporated into the fire component in EMDS, although the spatial output is useful for developing treatments to reduce the impact of these landscape fire attributes.

In contrast to landscape-level fire risk assessment, the class-level fire risk is a function of the stand-level attributes from the photo interpretation. Rate of spread (Figure 8) and probability for risk of crown fire are both within the range of variability for ESR 11. Most of these values are in the lower ranges because the young trees dominated the landscape. If more mature structures and multiple layers were present, the values would have increased.

Wildlife Habitat. There are a host of focal wildlife species addressed in the FRS;

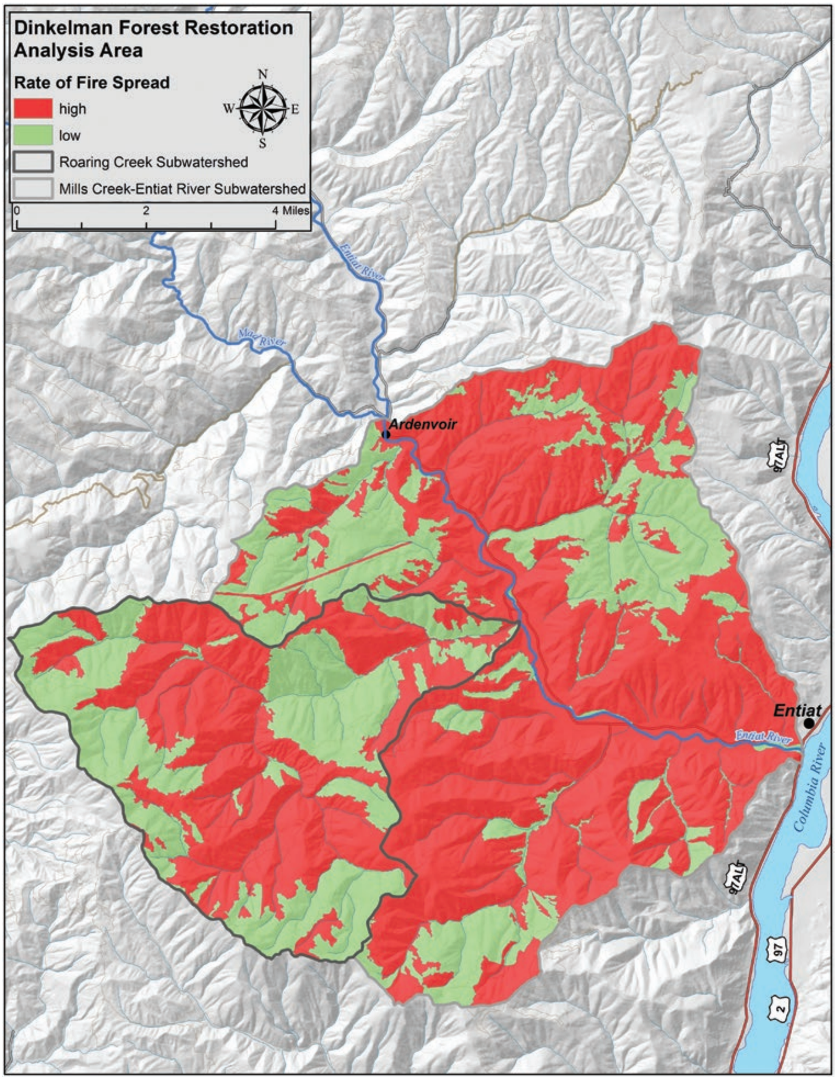

Figure 8. Rate of spread potential for stand fire.

however, this particular landscape only provides habitat structure for a limited number of these species. For ESR 11, the following hosted species were evaluated to determine if habitat exists now or could potentially be developed: American marten (Figure 9), northern spotted owl (Figure 10), and white-headed woodpecker (Figure 11). Current habitat conditions for these focal species were compared with the historical and future reference conditions to identify departures in the amount and connectivity of habitat. Each of these focal species requires large, old trees as part of their habitat. The Dinkelman wildfire significantly reduced the amount of suitable habitat by burning the majority of large trees in the analysis area. Potential habitats are projected by the cover type and the potential to grow large trees with suitable cover types within each stand.

In this analysis, whiteheaded woodpecker (WHWP) habitat is present, and potential habitat could be increased across a large area to encourage potential stand polygons of WHWP habitat. Comparing current conditions in ESR 11, WHWP habitat was within the ranges of variability. A small amount of northern spotted owl habitat was identified and was within NRV and FRV. Similar to northern spotted owl habitat, a limited amount of American marten habitat exists on this landscape and is currently within NRV and FRV.

Road Network and Aquatic Interactions

The road network evaluation referred to as the minimum roads analysis was completed at the watershed level (i.e., 5th HUC). This analysis identified the following: areas with the highest ecological priority for improving water quality, fish, and wildlife habitats; roads that are most at risk of failing over time; and mitigation measures for the identified roads at risk. The roads analysis for this project was completed in 2010 and identified several potential restoration opportunities within the analysis area (e.g., closures on unauthorized/unmaintained roads).

The minimum roads analysis identifies roads needed for access to forest resources while finding specific roads of high concern to aquatic resources. In general, these areas are where roads and streams intersect to produce higher amounts of erosion potential. The EMDS analysis shows prioritized stand polygons with the greatest potential to restore landscape conditions. By combining the information from these two separate analyses, mangers are able to identify specific road restoration options that may result in an increased level of function to aquatic resources while revising the forest system roads.

Landscape Treatment Area

An important objective of the Landscape Evaluation is to identify an area with the highest departures with respect to all resource concerns that can be effectively treated, thus focusing limited resources available for restoration actions. The selection of a priority landscape treatment area within the two watersheds encompasses 3,896 hectares (Figure 12) and was chosen because of a variety of resource concerns: existing and potential whiteheaded woodpecker habitat, vegetation departures particularly including stand initiation structure types, general lack of old-forest structure and habitat, land ownership boundaries (Forest Service, with one section of Washington State lands), and economic feasibility to access areas.

Road Network/Aquatic Restoration

The combined assessments from the NetMap and minimum roads analysis identified several roads within the Mills and Roaring Creek subwatersheds that will be closed to improve aquatic habitat and reduce maintenance costs on the existing road system. The roads will be closed in a NEPA Environmental Assessment decision document, separate from the Categorical Exclusion (CE) decision document resulting from the landscape assessment (e.g., thinning and prescribed fire).

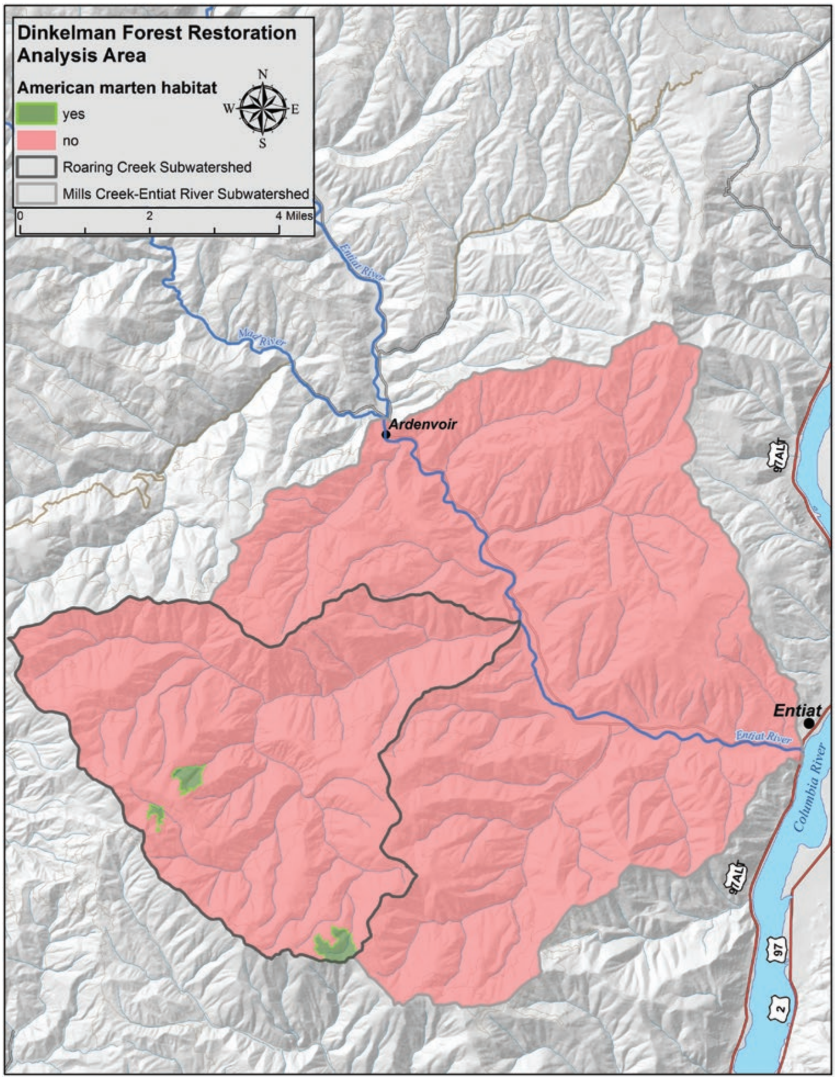

Figure 9. Current and potential American marten habitat for the Dinkelman analysis area.

Discussion

Interdisciplinary Team Decision-Making

Using EMDS to derive departure analyses provides an objective landscape evaluation, however, the model outputs in this analysis are subject to interpretation, demanding a collective effort from each of the resource managers on the interdisciplinary team. The departures that exist on the landscape as compared with reference conditions are dependent on accurate photo interpretation. This model is also very much dependent on the general representation of that landscape relative to its ESR, the NRV, and the assumption that future climate regimes are accurately represented by FRV (Hessburg et al. 2000, Gartner et al. 2008).

The combined resource model and other resource considerations, such as lynx habitat, guided the interdisciplinary team to set clearly defined restoration goals to address the departure of stand initiation (overrepresented in ponderosa pine, Douglas-fir, and lodgepole pine forest types) and the general lack of late successional old forest habitat. In addition, maintaining and developing large tree structure was a related restoration objective, based in part on enhancing habitats for focal wildlife species (e.g., whiteheaded woodpecker). While growing large trees and enhancing wildlife habitat are definable goals, the vehicle to reach this is by restoring natural processes (i.e., fire) and pattern (e.g., spatial arrangement of cover and structure types). Forest processes and patterns are fundamental for ecological functioning and for providing resilience to uncharacteristic disturbance events (e.g., wildfire, insect outbreaks) and climate changes (i.e., general warming).

Combined Prioritization of All Resources

The landscape evaluation integrates the results from the vegetation pattern and insect vulnerabilities, landscape and stand-level fire movement modeling, and wildlife habitats using EMDS. The EMDS tool considers interactions and trade-offs among resources to prioritize patches in which restoration treatments should have the greatest benefit, increasing resiliency for multiple resources. The aquatic/road interaction and the road network analysis were supplemental to the landscape evaluation (i.e., EMDS analysis), as these elements were considered when making final decisions for restoration priorities and actions.

The integrated results of the landscape evaluation were used by the district interdisciplinary team to identify high-priority patches to focus restoration objectives for NEPA project-level planning. The landscape evaluation is used to inform the development site–specific project objectives leading to purpose and need statements while transparently supporting proposed actions.

Stand-Level Prescriptions

The vegetation and habitat polygons identified within the landscape treatment area indicate their higher departure scores compared with other polygons in the study area. The primary objectives at the stand-level are generally to increase larger diameter trees by reducing smaller trees, particularly in the cover types dominated by ponderosa pine. Mechanical thinning (noncommercial), limited machine piling, and prescribed burning are the implementation tools identified to create more resilient landscape conditions and to restore habitats.

Thinning and prescribed fire have been used to restore whiteheaded woodpecker habitat (Gaines et al. 2007, 2010). Reducing tree density will hasten the growth of trees while limiting the potential for severe wildfire. In potential northern spotted owl stands, reducing tree density will not only accelerate the development of large trees but also improve resilience of these stands by reducing the threat of western spruce budworm and Douglas-fir beetle. Large and old trees that currently exist within the treatment area will benefit from the reduction of tree density by reducing severe wildfire potential and providing more resources on moisture-limited sites.

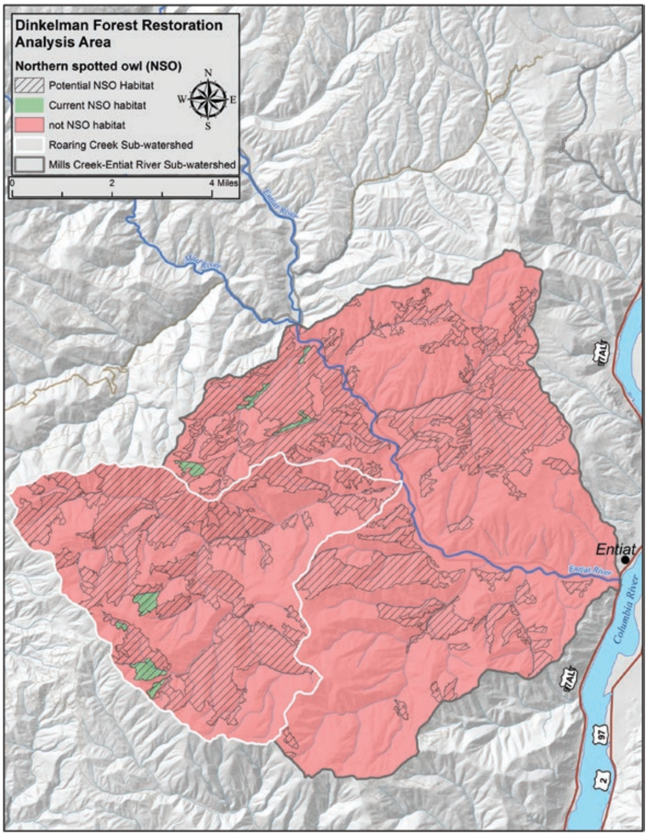

Figure 10. Current and potential northern spotted owl habitat for the Dinkelman analysis area.

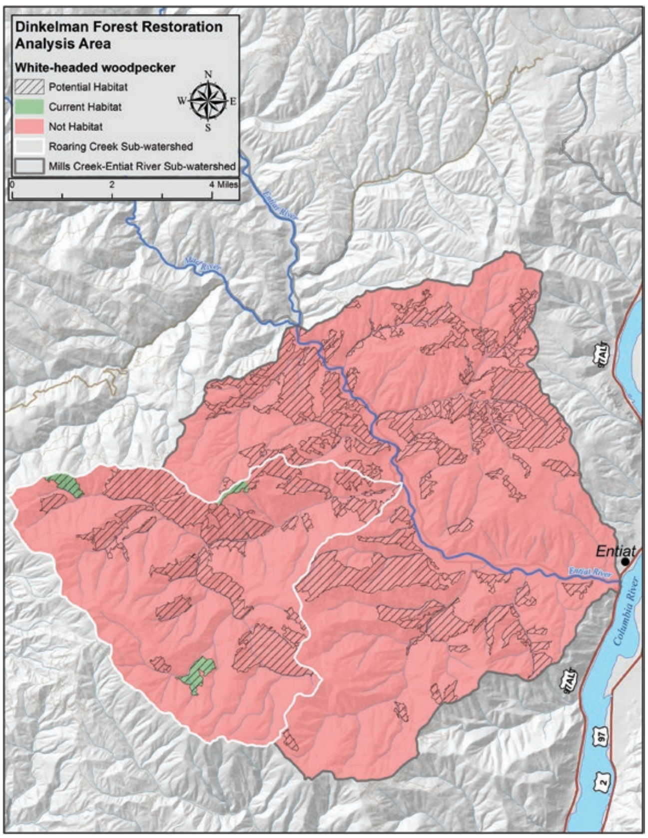

Figure 11. Current and potential whiteheaded woodpecker habitat for the Dinkelman analysis area.

Management and Policy Implications

Economic and ecological efficiencies are gained by analyzing entire watersheds, and when combined with collaboration across land ownerships, restoration treatments can be designed to occur at a meaningful spatial scale. The Okanogan-Wenatchee National Forest hosted a large public meeting to include all potential partners, including other agencies, nonprofit organizations, and private land owners. Following that collaborative effort, the Dinkelman interdisciplinary team met with other land ownership entities within the analysis area to discuss potential treatment opportunities across property boundaries. This effort was an initial attempt to include other entities in the analysis and treatment objectives of the landscape evaluation, led by the Forest Service. Only one other land management agency or forested land owner was prepared to become involved with this project (i.e., Washington State Department of Natural Resources). Subsequent cross-boundary collaborative efforts continue to improve and have been successful in achieving an all-lands approach to landscape forest restoration using the FRS (Hessburg et al. 2015, Haugo et al. 2016). Continuous improvements in collaboration across land ownership will be important to create more resilient landscapes and reduce risks of catastrophic fires to surrounding communities (Hessburg et al. 2015).

The landscape evaluation, including the EMDS outputs, led to the identification of a relatively large potential landscape treatment area. Once the treatment area is established, each team specialist must analyze the effects of the proposed management actions on each resource to meet NEPA guidelines. With confidence in the EMDS outputs, specialists can design a more focused plan for data collection surveys to analyze effects. Once the plan is approved by the responsible official (i.e., district ranger), implementation of proposed restoration activities may commence. For this landscape scale NEPA planning effort, a number of benefits resulted from the forest restoration strategy approach to forest restoration planning.

The FRS improves management decisions by providing landscape evaluation that is supported by the following points:

- Multiresource landscape and stand-level metrics to quantify vegetation species and cover, current and potential wildlife

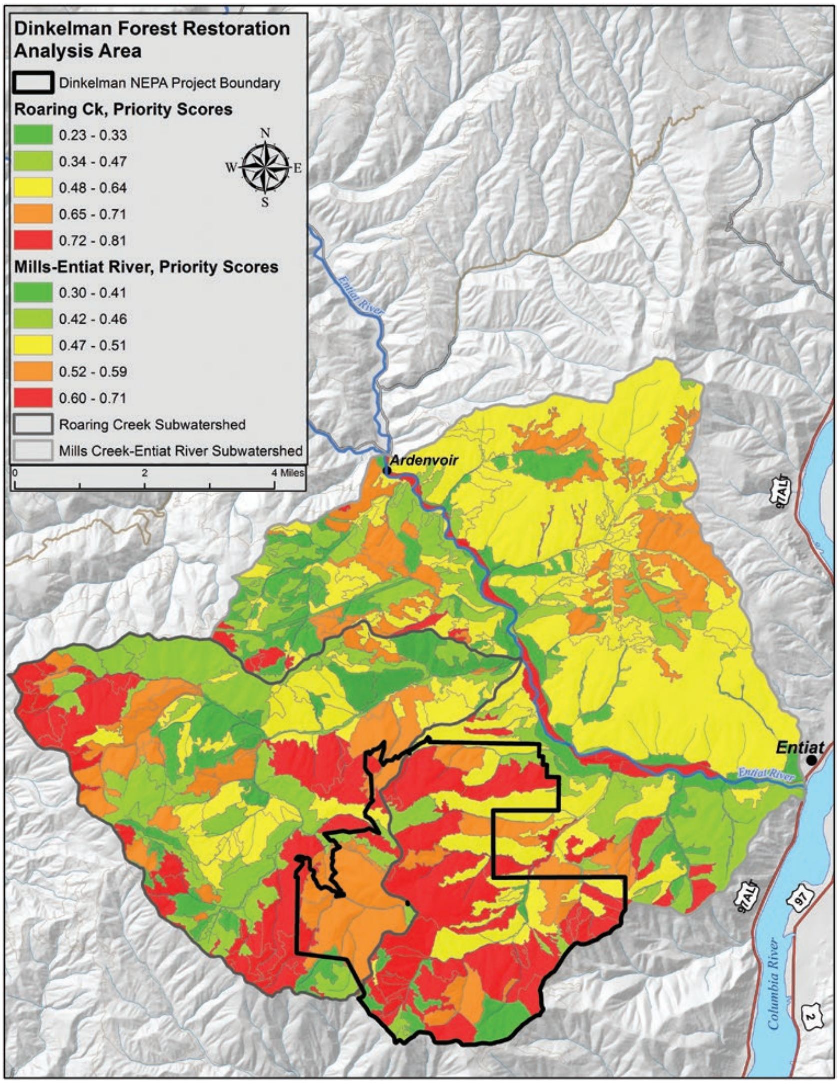

Figure 12. The combined resource model with the selected landscape treatment area.

habitats, and disturbance potential for insects and wildfire.
- Consideration of current conditions compared with natural and future ranges of variability for each resource.
- Combined resource model to inform complex interactions and restoration goals affecting multiple resources across two subwaterseds.

The combination of integrated multi-resource modeling and metric analysis provided a broader and more informed platform for decision-making. Identifying departures for each resource and relating a prioritization model to those metrics become the foundation for planning restoration treatment areas by connecting ecological resource values in a meaningful way, rather than focusing solely on individual resources that may degrade overall ecosystem function. This integrated approach is critical to designing beneficial stand-level prescriptions to meet restoration goals. The ability to combine multiple resources provides direction on how prescription planning can be focused to produce desired outcomes across a large landscape.

Improving landscape-level monitoring is one of the primary goals of the FRS, and it can be achieved by this adaptive management process. The landscape evaluation provides a baseline information for many resource areas. The photo interpretation layer describing vegetation conditions contributes significantly to this goal. Fuels monitoring data are ground-level data that will be affected directly by restoration activities, which can be easily tracked for future monitoring. In addition to the vegetation data, whiteheaded woodpecker surveys were completed in the analysis area that identified suitable or potential habitats. These data will be used to monitor effectiveness of restoration treatments with respect to enhancing habitats.

In particular, the FRS approach increased effectiveness and efficiencies in:

- Providing a complete landscape evaluation that can be used to support multiple NEPA projects.
- Integrating multiple resource disciplines, which reduce conflicts and limit alternatives from the interdisciplinary team.
- Including multiple land ownerships and agencies in restoration goals supported by a transparent landscape evaluation.
- Designing field work, including botany surveys, fuels monitoring, and vegetation treatment prescription planning with focused restoration goals.
- Developing treatment options, modeled in EMDS prior to final decision.
- Establishing landscape-level monitoring for successful adaptive management practices by recording current conditions at the first stage of the analysis.

Adaptive Management of the Forest Restoration Strategy

For this analysis, the FRS improved multiresource planning, establishing multi-ownership restoration goals and efficiencies in meeting NEPA requirements. Identifying and prioritizing critical areas help to improve terrestrial and aquatic habitats via multiresource modeling efforts. However, there are still improvements to be made to the FRS. Future versions of the FRS intend to include aquatic restoration objectives to provide more robust decision-making from a more complete landscape evaluation.

Conclusion

While successful application of the FRS is limited, the economic and ecological efficiencies are well noted. Classification of current vegetation conditions compared with NRV and FRV provide an objective, transparent, and repeatable process not previously available in an integrated decision support system. This systematic approach and decision support system identifies landscape departures and habitat potential, which allow managers to set clearly defined and prioritized restoration goals associated with specific geographic locations on

Figure 13. First completed restoration treatment in Dinkelman restoration analysis area (photo credit: Jamie Cannon).

relatively large spatial scales. Additionally, by accomplishing the landscape evaluation at a subwatershed level, the data may be used for multiple project-level decisions.

The Dinkelman Restoration CE was signed in 2013. The first entry after signing occurred in summer 2014, when the (human-started) Mills Canyon wildfire burned 2,626 hectares within the analysis area. The first restoration treatment units occurred in 2015, which focused specifically in stands that included medium and large trees (>16 inches diameter at breast height) to increase resilience to stand structure and contribute to improving whiteheaded woodpecker habitat. It was funded, in part, by a grant from State and Private Forest Health (see photo in Figure 13). In 2015, the Crum Canyon Restoration CE was signed using the same landscape evaluation.

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