Supplementary Materials

Theoretical Foundations and Foundational Work

1. Hierarchical Patch Dynamics Paradigm

The hierarchical patch dynamics paradigm [1] Wu and Loucks (1995) holds that an ecosystem can be viewed as a multi-level hierarchy of patch mosaics. An ecosystem's overarching dynamics derive from emergent properties of concurrent patch dynamics occurring at each level in a hierarchy. Across the temporal scales of a hierarchy, regional spatial patterns of biota, geology, geomorphic processes, and climate provide top-down constraint on ecological patterns and processes occurring at a meso-scale. Likewise, fine-scale patterns of endemic disturbances, topography, environments, vegetation, and other ecological processes provide critical bottom-up context for patterns and processes occurring at a meso-scale. At all spatial and temporal scales of the hierarchy, ecosystems exhibit transient patch dynamics and non-equilibrium behavior. This is due to stochastic properties of the supporting land and climate systems and ecosystem processes at each level. Lower level processes are incorporated into the next higher-level structures and processes, and this happens at all levels.

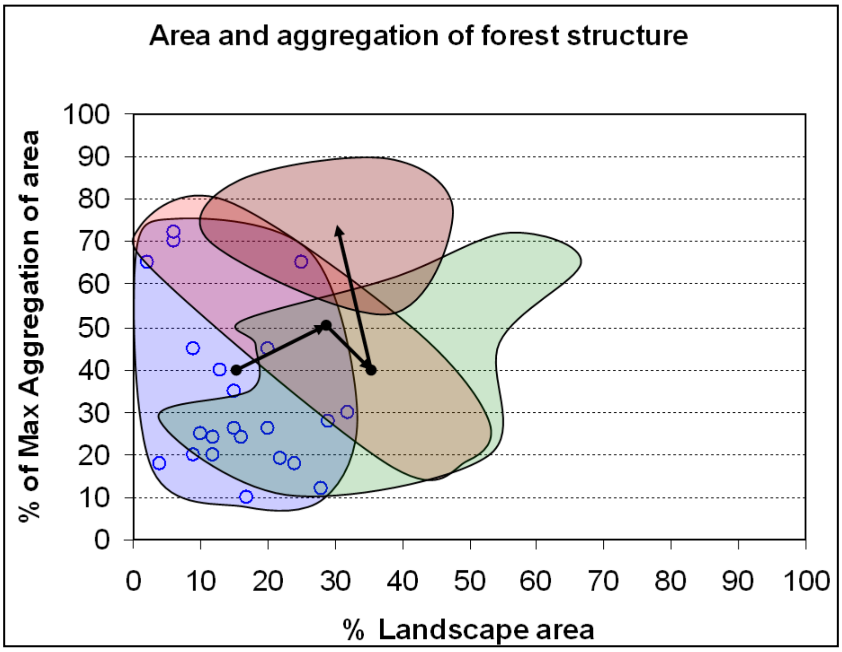
Thus, landscape patterns at each level in a hierarchy are never the same from year to year, and they never repeat in the same arrangements. However, transient dynamics are manifest as envelopes of pattern conditions at each level (a natural range of variation, NRV), owing to the recurring patterns and interactions of the dominant top-down and bottom-up spatial controls [2,3]. Thus, patterns don't repeat in the same spatial arrangements but they exhibit predictable spatial pattern characteristics, for example, in the percentage area in different cover species, size class, or structural conditions, the range in patch sizes, or the dispersion of unique patch types.

Moreover, because contexts and constraints are non-stationary, the processes and patterns they reflect are non-stationary as well. In a warming climate, for example, the envelope of pattern conditions at each level in a patch dynamics hierarchy may be reshaped by the strength and duration of warming, all in the context of existing patterns. Reshaping within a level can be figuratively represented as an envelope of conditions that drifts directionally in a hyper-dimensional phase space. Because this is impossible to illustrate, we illustrate a simpler cartoon of conditions shifting in a 2-dimensional phase space (Figure S1). Relatively small amplitude and short term changes (multi-annual to multi-decadal) in climatic inputs will do little to reshape the envelope, but large amplitude and long term changes (centenary to multi-centenary and longer) have much greater likelihood of significantly reshaping pattern envelopes.

2. Previous Work on Evaluating Changes in Landscape-Level Spatial Patterns

In Hessburg *et al*. [4], the authors present a landscape evaluation approach to estimating the extent to which present-day forest landscape patterns have changed from the variety of conditions that existed before the era of modern management (~1900). Their goal was to approximate the range and variation of these recent historical patterns, use that knowledge to evaluate present forest conditions, and assess the trajectory and ecological importance of any significant changes.

Figure S1. Graphical representation of how landscape area and aggregation of area of a single forest structural component might vary in phase space (for example, old multilayered forest or stand initiation structure) as the climate of an ecoregion shifts. Within the concept of historical or natural range of variation, clouds or envelopes of conditions exist for a multiplicity of conditions in phase space for any number and combination of structural and compositional features, across a broad range of metrics, and no two are alike. The same is true for current and future ranges of variation. This broad dimensionality is readily captured in data space, quantified, and then used to detect significant changes in spatial patterns and variability in those patterns.



The authors developed an approach to estimating the non-equilibrium conditions associated within a meso-scale landscape in a forest patch dynamics hierarchy. For simplicity, they termed the conditions for the climatic period ending in the early 20th-century, reference conditions; typical variation in these conditions was termed reference variation (RV). They chose as their estimate of RV, the median 80% range of a diagnostic set of five class and nine landscape spatial pattern metrics [5], because most historical observations typically clustered within this middle range. The class metrics were: the percentage of the total landscape area (%LAND), patch density per 10,000 ha (PD), mean patch size (MPS, ha), mean nearest-neighbor distance (MNN, m), and edge density (ED, m × ha-1). The landscape metrics were: patch richness (PR) and relative patch richness (RPR), Shannon's diversity index (SHDI) and Hill's transformation of Shannon's index (N1) [6], Hill's inverse of Simpson's λ, N2, [6,7], Simpson's modified evenness index, and Alatalo's evenness index, R21, [8], a contagion index (CONTAG); and an interspersion and juxtaposition index (IJI). They supplemented the FRAGSTATS source code [5] with the equations for computing the N1, N2, and R21 metrics. We chose this set of landscape metrics to capture a wide range of pattern attributes that would enable us to detect key changes under differing management or disturbance regimes.

The focal level of the study was forest landscapes of meso-scale watersheds and their spatial patterns of structure, species composition, fuels, and wildfire behavior attributes. Structural classes were an approximation of stand succession and development phases. Cover types reflected forest overstory species and mixes. Estimates of surface and canopy fuels reflected the available fuels to support wildfires and either surface or crownfire behavior. They focused on patterns of living and dead vegetation at this level because many of the most important changes in the dynamics of altered forest ecosystems are reflected in the living and dead structure of the affected structural and compositional landscapes [9]. They stratified landscapes into ecoregions to reflect top-down biogeoclimatic constraint on forest structural patterns and related disturbances [10]. Study landscapes were 4,000 to 12,000 ha subwatersheds.

They developed a repeatable quantitative method (Table S1) for estimating RV in historical forest vegetation patterns and of vulnerability to disturbance. The objective was to estimate RV so that they could evaluate the direction, magnitude, and potential ecological importance of the changes observed in present-day forest landscape patterns [22–24]. To automate this approach, they programmed a departure analysis application in the Ecosystem Management Decision Support (EMDS) system that compared the spatial pattern conditions of a test landscape with the estimated RV that would be expected within its ecological subregion [18,20]. Via automation, this analysis could be repeated for any number of subwatersheds within the same ecoregion. By means of the comparison with RV, they could identify vegetation changes that were beyond the range of the RV estimates. Changes that fell within the range of the RV estimates were assumed to be within the natural variation of the interacting land and climate system, and dominant ecosystem processes. Changes that were beyond the range of RV estimates were termed "departures" that could be explored in more detail for their potential ecological implications.

They also programmed transition analysis on the test landscapes' historical and current maps of cover type and structural class to discover the path of each significant change. To conduct transition analysis, they converted the polygon maps of historical and current cover type and/or structural class to raster format (30-m resolution). These raster maps were combined such that each pixel had a historical and current cover type (and/or structural class) identity. They computed the number of pixels for each unique type of historical-to-current transition, divided this number by the total number of pixels, and multiplied that result by 100 to derive a percentage of the subwatershed area in a transition type.

Using departure and transition analyses, they were able to highlight a variety of important changes to the test landscape. For example, they found that timber harvests had converted much area dominated by the ponderosa pine (*Pinus ponderosa*) cover type to Douglas-fir (*Pseudotsuga menziesii*); regeneration harvest had highly fragmented forest cover; and old forests of the western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Douglas-fir, and ponderosa pine zones had suffered significant depredation from selective and regeneration harvesting (18% reduction in area).

Departure and transition analyses of fuel loading, wildfire rate of spread, crownfire potential, flame length, and fireline intensity attributes under prescribed and wildfire (90th percentile) burn scenarios depicted an historical landscape that displayed large contiguous areas with very high fuel loading and high potential for crown fires under an average wildfire scenario, typically high to extreme flame lengths, and high to extreme fireline intensities. This ordinarily high fire danger could be accounted for by a preponderance of moist to wet growing environments, very low fire frequency, and a typically high fire severity.

Table S1. Outline of methods used in Hessburg *et al.* [4] for estimating departure of present forest landscape patterns from historical (circa. 1900) reference conditions.

Step	Action	Reference(s)
1	Stratified Inland Northwest U.S. subwatersheds (5,000 to 10,000 ha) into ecological subregions using a published hierarchy	[11] Hessburg *et al.* 2000b
2	Mapped the historical vegetation of a large random sample of the subwatersheds of one subregion (ESR4 – the Moist and Cold Forests subregion) from 1930s -1940s aerial photography	[12] Hessburg *et al.* 1999a
3	Statistically reconstructed the vegetation attributes of all patches of sampled historical subwatersheds that showed any evidence of prior timber harvest	[13] Moeur and Stage 1995
4	Ran spatial pattern analysis on each reconstructed historical subwatershed calculating a finite, descriptive set of class and landscape metrics in a spatial analysis program (FRAGSTATS)	[5,12] McGarigal and Marks 1995 Hessburg *et al.* 1999a
5	Observed the data distributions from the spatial pattern analysis output of the historical subwatersheds and defined reference conditions based on the typical range of the clustered data	[12,14] Hessburg et al. 1999a, 1999b
6	Defined reference variation as the median 80% range of the class and landscape metrics for the sample of historical subwatersheds	[12,14,15] Hessburg *et al.* 1999a, 1999b, 1999c
7	Estimated ESR4 reference variation for spatial patterns of forest composition (cover types), structure (stand development phases), modeled ground fuel accumulation (loading), and several fire behavior attributes	[10,12,14–17] Hessburg *et al.* 1999a, 1999b, 1999c Huff *et al.* 1995 O'Hara *et al.* 1996 Hessburg et al. 2000a
8	Programmed ESR4 reference conditions into a decision support model (EMDS)	[18–21] Reynolds 1999a, 1999b Reynolds 2001a, 2001b
9	Mapped the current vegetation patterns of an example watershed, Wenatchee_13, from the Wenatchee River basin, also from ESR4	[12] Hessburg et al. 1999a
10	Objectively compared a multi-scale set of vegetation maps of the example watershed with corresponding reference variation estimates in the decision support model	[12,14] Hessburg *et al.* 1999a, 1999b

Large fires were rare events and they were likely driven by extreme or severe climatic events. However, current conditions showed that past management activities in the test landscape had reduced the likelihood of large stand-replacing fires with the introduction of nearly 50 clearcut units.

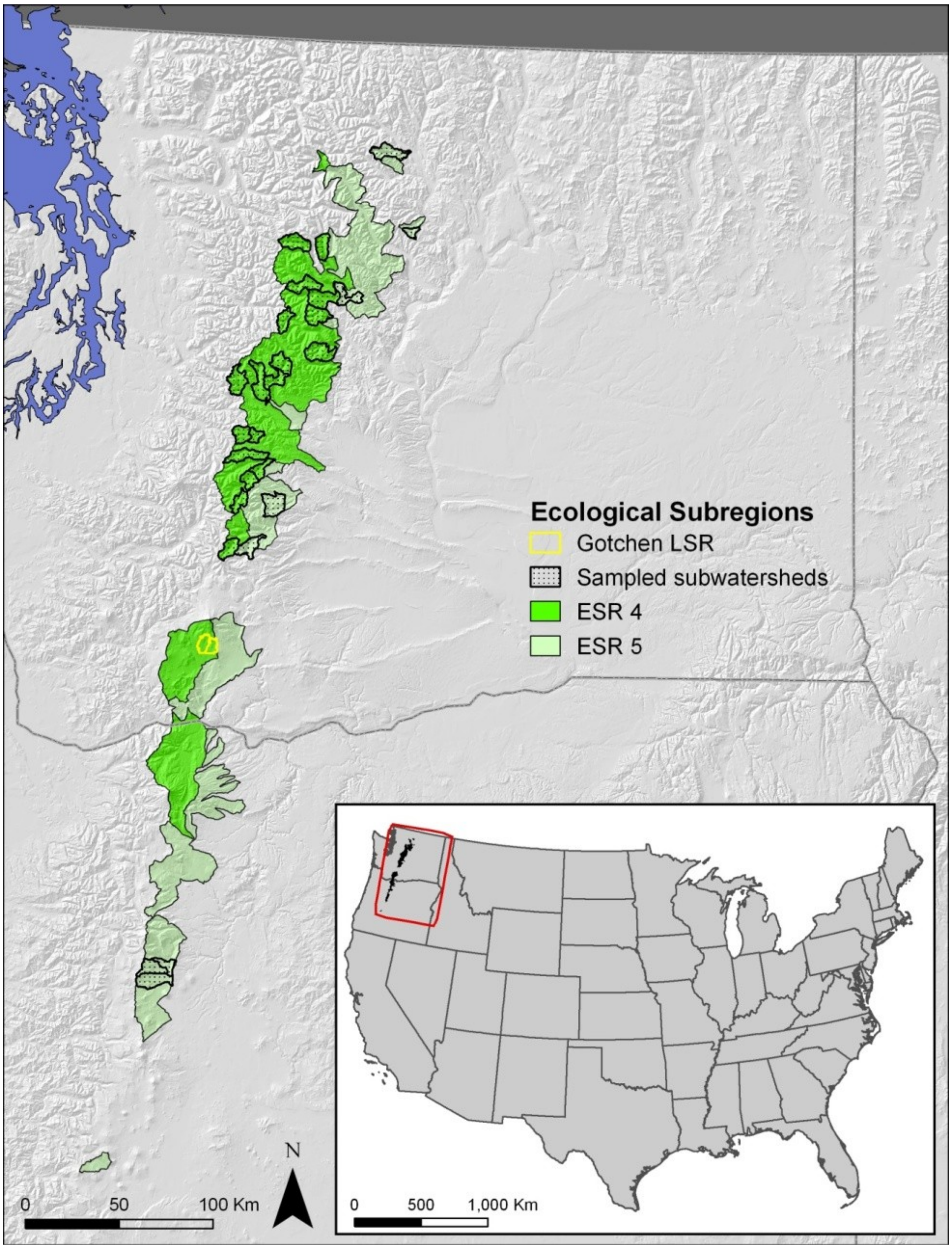
Departure analysis using landscape metrics showed poor correspondence between the present-day combined cover type-structural class mosaic and the estimates of RV. Timber harvesting had increased patch type richness, diversity, dominance, evenness, interspersion, and juxtaposition of structural class patches, and reduced overall contagion in the cover type-structural class mosaic well beyond RV estimates. The historical landscape was simply patterned, consisting of fairly large patches borne of infrequent, large, high severity fires. Management had made it more complexly patterned and fragmented.

3. Evaluating Vegetation Departure under Climate Change

Gärtner *et al*. [25] demonstrated a practical approach to evaluating current multi-scale landscape vegetation patterns with reference to two climate scenarios: one was retrospective, representing a pre-management era climate; a second was prospective, representing change to a warmer and drier climate. Development of reference conditions for current and future analogue climate scenarios was based on the same process outlined in section 2. They used decision-support modeling in EMDS [26] to set treatment priorities among the landscape elements and select alternative treatment areas. The analysis did not seek to accurately predict climate change, but to interpret landscape consequences given a plausible scenario. They used a logic model, designed in NetWeaver Developer® (Rules of Thumb, Inc., North East, PA)[1] [27] [the use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service], to assess landscape departure from the two sets of reference conditions and a decision model developed in Criterium DecisionPlus® (CDP) [28] to illustrate how various landscape conditions could be prioritized for management treatments in light of two climate scenarios, taking into account not only considerations of landscape departure, but also logistical considerations pertinent to forest managers. Their methods represented a hedging approach managers might use to determine how best to proceed with restorative management in an uncertain climatic future.

The study area encompassed the 6070 ha Gotchen Late-Successional Reserve (LSR) [29, 30] , and adjacent lands totaling 7992 ha. The Reserve is located east of the crest of the Cascade Mountain Range in Washington State, USA, on the Gifford Pinchot National Forest (Figure S1). The study area is part of a regional network of LSRs established as one component of the Northwest Forest Plan, which required protection of the northern spotted owl (*Strix occidentalis caurina*) and other associated species with an adequate distribution and arrangement of late-successional habitats [31].

Figure S1. Location of the Gotchen Late-Successional Reserve (study area) and Ecological subregions (ESR) 4 the subregion of the study area. ESR 5 is shown as the subregion immediately to the east of ESR 4 along the west-east temperature and precipitation gradient [10] (Hessburg *et al*. 2000a).



In this application, the authors evaluated landscape departure of two landscapes, comprising the bulk of the study area, from RV associated with one historical and one future climate reference condition. As in the applications discussed in section 2 above, the reference conditions represented broad envelopes of vegetation conditions common to an ecoregion. The landscapes were evaluated relative to these reference conditions in EMDS. They evaluated outputs from the decision model to determine which landscape should be treated first, and which landscape treatments might be most effective at favorably altering conditions in light of the two climate references.

The study area fell in ESR 4, as described above in Figure S1 [11]. To consider the natural landscape patterns that might occur under a climate-change scenario, the authors adopted a change scenario involving a climatic shift to predicted drier and warmer conditions. Moreover, because limiting factors for forest growth, tree mortality, and high wildfire risk are often associated with protracted dry periods, this comparison was more realistic and timely.

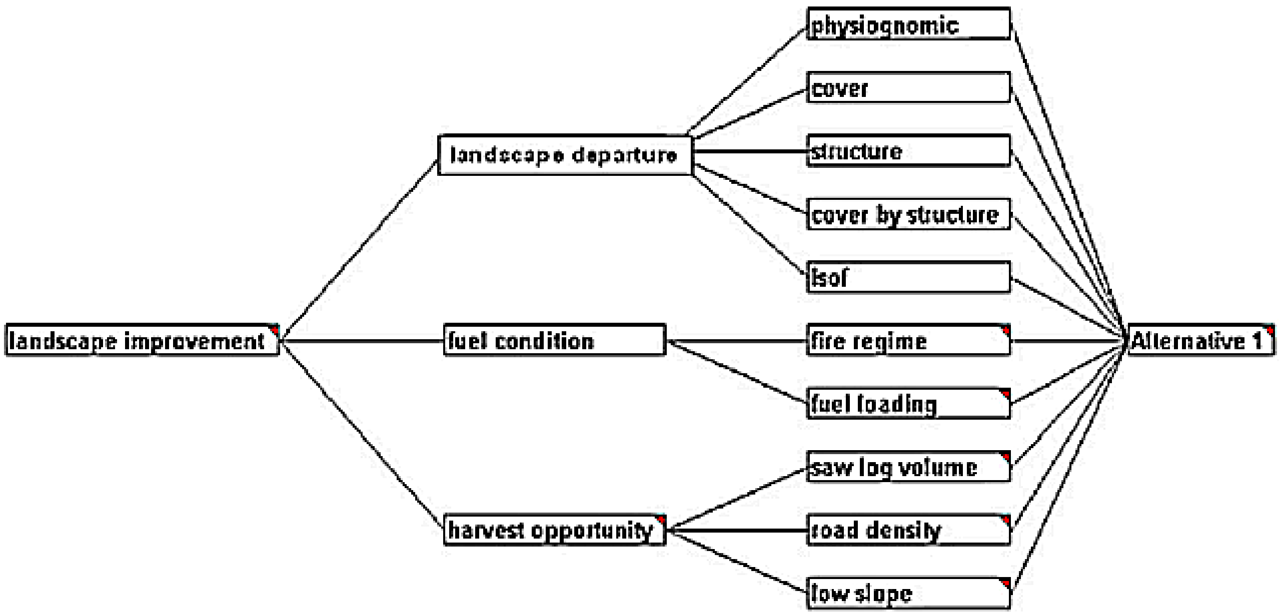
Empirical data from the next drier and warmer ecoregion (ESR 5) were used as a reference set to simulate the climate-change scenario (an analogue climate condition) for the study area. They reasoned that use of ESR 5 for these climate-change reference conditions was rational for several reasons: (1) ESR 5 sat adjacent to ESR 4 on the west to east climatic gradient of temperature and precipitation (Figure S1); (2) ESR 5 received more solar radiation during the growing season and was drier than ESR 4; (3) ESR 5 was composed of the same forest species and structural conditions as were found in ESR 4 and was ordinarily influenced by fire regimes that are more similar to those forecast for a warming and drying climate-change scenario [32–34]; and (4) ESR 5 landscapes had existed for a long time under these warmer and drier climatic conditions such that conditions reflected the natural spatio-temporal variation in landscape patterns that would exist under the influences of succession, disturbance, and the local climate.

Climatic conditions in ESR 5 represented a significant difference in total annual precipitation and average growing season daytime solar radiative flux [11]. ESR 5 was characterized as a warm (5–9 °C annual average temperature), moderate solar (250–300W·m-2 annual average daylight incident shortwave solar radiative flux), moist (400–1100 mm/year total annual precipitation), moist and cold forests (predominantly occupied by moist and cold forest potential vegetation types) subregion, but subwatersheds included dry forests [35].

To map RV of ESRs 4 and 5, subwatersheds were randomly selected to represent at least 10% of the total subwatersheds and area of each subregion. For each selected subwatershed, the authors mapped pre-management era vegetation by interpreting representative stereo aerial photographs. The resulting vegetation features enabled them to derive forest cover types [36], and structural classes [17], using methods detailed in Hessburg *et al.* [37]. Five different vegetation features were used to characterize the attributes of the historical subwatersheds of ESRs 4 and 5. The five features were the physiognomic condition, the cover-type condition, the structural class condition, the combined cover type by structural class condition, and the late-successional and old forest condition. Five class and nine landscape metrics generated by FRAGSTATS [5] were chosen to display spatial relations within classes and landscapes of these features. The metrics were the same as those outlined in section 2 above.

In a first phase, the authors evaluated landscape departure of the two subwatersheds in terms of departure of current conditions from the two climatically defined reference conditions. In a second phase, they determined which of the two subwatersheds exhibited a higher priority for restoration. The decision model for assigning restoration priorities included three primary criteria: landscape departure, fuel condition, and harvest opportunity (Figure S2). All subcriteria of landscape departure were measures of evidence from the landscape analysis performed with the NetWeaver logic engine.

Figure S2. Decision model to prioritize subwatersheds for landscape restoration.

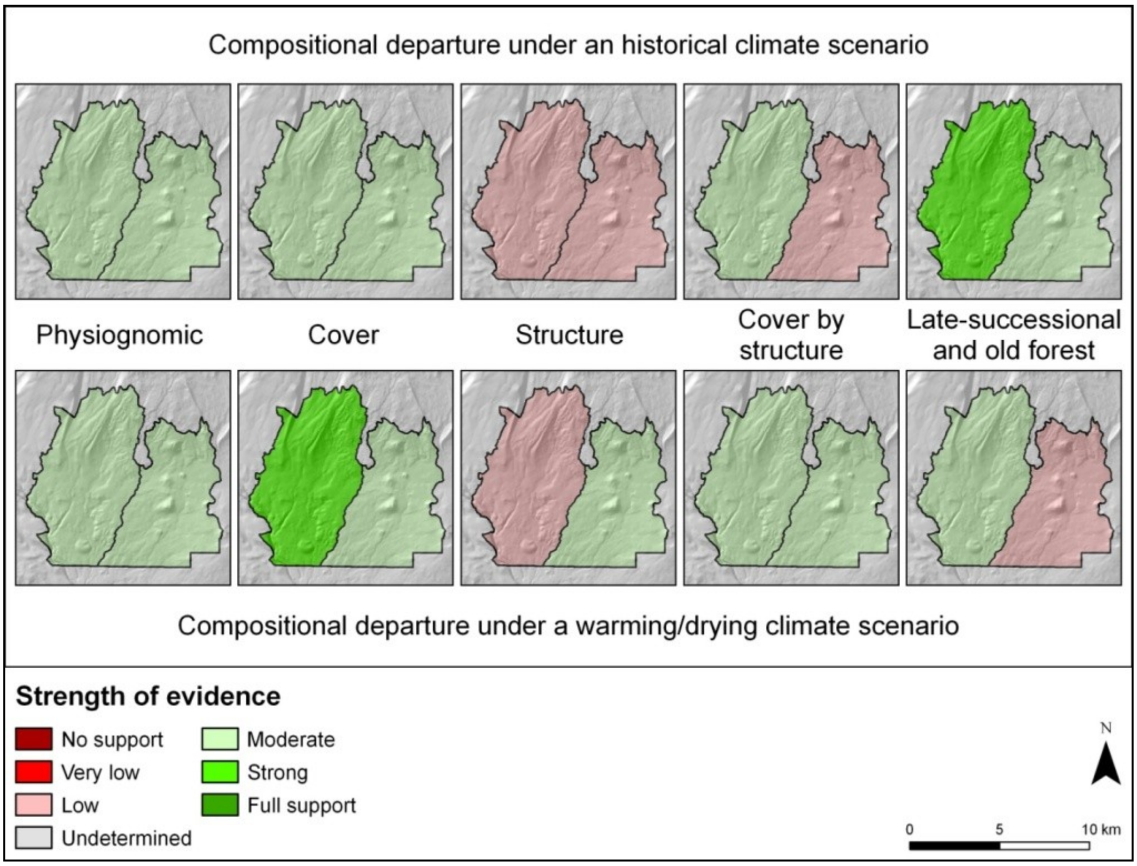


Subcriteria of fuel condition and harvest opportunity represented attributes of subwatersheds that were not part of the logic-based evaluation, but were included in the decision model as logistical considerations for management (Figure S2). Fuel condition was evaluated in terms of probable fire regime and fuel loading. Harvest opportunity was evaluated in terms of available merchantable volume, road density, and proportion of subwatershed area with slope ≤10%. The slope specification was intended not so much as a feasibility but cost criterion, indicative of areas with easy access for ground-based harvesting and yarding equipment. Road density and slope were calculated from a digital elevation model and map layers provided by the Forest. Fire regime was calculated as the proportion of the subwatershed that had a fire regime condition class >1. Fire regime condition class depicted the degree of departure from historical fire regimes [38].

Stand-level tree-inventory data were collected following Hummel and Calkin [30]. From the stand-level data, the authors estimated fuel load and sawlog volume in each subwatershed using available plot data sets. The proportion of subwatershed area with a high fuel loading was calculated as the proportion of plots with a fuel load class >1, following methods of Ottmar *et al.* [39]. Sawlog volume (mean m3 × ha-1) in stands was calculated with NED-2 [40], based on tree lists from the plot data.

The authors found little or no significant change in physiognomic or cover type conditions among the two test subwatersheds, but surprisingly, the evidence for no change actually increased in the western subwatershed under the climate-change scenario, indicating that current spatial patterns of cover types, while not departed from ESR 4 historical conditions, would actually be closer to conditions that would be anticipated under the warming/drying climate-change scenario (Figure S3). Similarly, they found significant evidence for structural class departures in both subwatersheds when historical reference conditions were considered, but departures were somewhat less evident in one of the two subwatersheds when the RV for the climate-change scenario was considered. Results for cover type by structure evaluation were analogous (Table S2). Evidence for limited late-successional/old forest departure was strong in both subwatersheds using the historical RV scenario, but declined in both subwatersheds under the climate-change scenario, indicating that warmer and drier conditions would likely favor expanded area of these structures.

Figure S3. Illustration of the landscape departure evaluation of the current Gotchen landscape relative to reference conditions representing pre-management era (above) and future warming climates (below). Each of the small figures shows the two subwatersheds of the Gotchen landscape; the coloring displays the degree of departure under the historical (upper) and warming (lower) climate conditions.



To determine which of the two subwatersheds had the highest priority for landscape restoration, the authors applied the decision model and its primary criteria to the selection process (Figure S2). The eastern-most of the two evaluated subwatersheds received a higher priority rating for landscape improvement in the context of both the historical climate and climate-change scenarios. The overall decision score under the historical reference scenario was highest for the eastern subwatershed, but scores were nearly identical for the climate-change scenario. On balance, the two subwatersheds were found to be in relatively good condition, regardless of the climatic reference (Table S2).

Contributions of harvest opportunity and fuel condition to restoration priority were essentially the same for both subwatersheds in either scenario. The only features that changed the overall decision score were related to landscape departure. Scores for landscape pattern departure differed slightly between the historical reference and climate-change scenarios, and in both cases the contributions of late-successional/old forest had the most impact on treatment priority.

Table S2. Contributions of *subcriteria* to decision scores of the eastern and western Gotchen watersheds when compared with the historical and future climate reference conditions.

	Historical reference		Climate change reference	
Watershed	**East**	**West**	**East**	**West**
Physiognomic condition	0.037	0.024	0.023	0.012
Structural condition	0.098	0.094	0.073	0.081
Cover type-structural condition	0.039	0.034	0.013	0.01
Late-successional/old forest condition	0.182	0.087	0.222	0.195
Fire regime condition	0.119	0.119	0.119	0.119
Fuel loading condition	0.089	0.094	0.089	0.094
Harvest opportunity	0.012	0.037	0.012	0.037
Overall decision score	0.576	0.489	0.551	0.548

References

1. Wu, J.; Loucks, O.L. From balance of nature to hierarchical patch dynamics: A paradigm shift in ecology. *Q. Rev. Biol.* **1995**, *70*, 439–466.
2. Hessburg, P.F.; Smith, B.G.; Salter, R.B. Detecting change in forest spatial patterns. *Ecol. Appl.* **1999**, *9*, 1232–1252.
3. Hessburg, P.F.; Smith, B.G.; Salter, R.B. *Using Natural Variation Estimates to Detect Ecologically Important Change in Forest Spatial Patterns: A Case Study of the Eastern Washington Cascades*; PNW Res. Pap. PNW-RP-514; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1999; p. 65.
4. Hessburg, P.F.; Reynolds, K.M.; Salter, R.B.; Richmond, M.B. Using a Decision Support System to Estimate Departures of Present Forest Landscape Patterns from Historical Conditions: An Example from the Inland Northwest Region of the United States. In *Emulating Natural Forest Landscape Disturbances: Concepts and Applications*; Perera, A.H., Buse, L.J., Weber, M.G., Eds.; Columbia University Press: New York, NY, USA, 2004; pp. 158–175.
5. McGarigal, K.; Marks, B.J. *FRAGSTATS: Spatial Pattern Analysis Program for Quantifying landscape structure*; General Technical Report PNW-GTR-351; U.S. Department of Agriculture,

Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1995; 122 p. Available online: http://www.umass.edu/landeco/research/fragstats/fragstats.html (accessed on 21 Feb 2013).

6. Hill, M.O. Diversity and evenness: A unifying notation and its consequences. *Ecology* **1973**, *54*, 427–431.
7. Simpson, E.H. Measurement of diversity. *Nature* **1949**, *163*, 688.
8. Alatalo, R.V. Problems in the measurement of evenness in ecology. *Oikos* **1981**, *37*, 199–204.
9. Spies, T.A. Forest structure: A key to the ecosystem. *Northw. Sci*. **1998**, *72*, 34–39.
10. Hessburg, P.F.; Smith, B.G.; Salter, R.B.; Ottmar, R.D.; Alvarado, E. Recent changes (1930's-1990's) in spatial patterns of interior northwest forests, USA. *For. Ecol. Manag*. **2000**, *136*, 53–83.
11. Hessburg P.F.; Salter, R.B.; Richmond, M.B.; Smith, B.G. Ecological subregions of the Interior Columbia Basin, USA. *Appl. Veg. Sci*. **2000**, *3*, 163–180.
12. Hessburg, P.F.; Smith, B.G.; Salter, R.B. Detecting change in forest spatial patterns. *Ecol. Appl*. **1999**, *9*, 1232–1252.
13. Moeur, M.; Stage, A.R. Most similar neighbor: An improved sampling inference procedure for natural resources planning. *For. Sci*. **1995**, *41*, 337–359.
14. Hessburg, P.F.; Smith, B.G.; Kreiter, S.D.; Miller, C.A.; Salter, R.B.; McNicholl, C.H.; Hann, W.J. *Historical and Current Forest and Range Landscapes in the Interior Columbia River Basin and Portions of the Klamath and Great Basins: Part I: Linking Vegetation Patterns and Landscape Vulnerability to Potential Insect and Pathogen Disturbances*; General Technical Report PNW-GTR-458; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1999; p. 357.
15. Hessburg, P.F.; Smith, B.G.; Salter, R.B. *Using Natural Variation Estimates to Detect Ecologically Important Change in Forest Spatial Patterns: A Case Study of the Eastern Washington Cascades*; PNW Res. Pap. PNW-RP-514; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1999; p. 65.
16. Huff, M.H.; Ottmar, R.D.; Alvarado, E.; Vihnanek, R.E.; Lehmkuhl, J.F.; Hessburg, P.F.; Everett, R.L. *Historical and Current Forest Landscapes of Eastern Oregon and Washington, Part II: Linking Vegetation Characteristics to Potential Fire Behavior and Related Smoke Production*; General Technical Report PNW-GTR-355; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1995; p. 43.
17. O'Hara, K.L.; Latham, P.A.; Hessburg, P.F.; Smith, B.G. A structural classification of Inland Northwest forest vegetation. *Western J. Appl. For*. **1996**, *11*, 97–102.
18. Reynolds, K.M. *EMDS Users Guide (version 2.0): Knowledge-Based Decision Support for Ecological Assessment*; General Technical Report PNW-GTR-470; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1999; p. 63.
19. Reynolds, K.M. *NetWeaver for EMDS User Guide (version 1.1): A Knowledge Base Development System*; General Technical Report PNW-GTR-471; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 1999; p. 75.
20. Reynolds, K.M. Using a logic framework to assess forest ecosystem sustainability. *J. For*. **2001**, *99*, 26–30.

21. Reynolds, K.M. *Fuzzy Logic Knowledge Bases in Integrated Landscape Assessment: Examples and Possibilities*; General Technical Report PNW-GTR-521; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 2001; p. 24.
22. Keane, R.E.; Parsons, R.; Hessburg, P.F. Estimating historical range and variation of landscape patch dynamics: Limitations of the simulation approach. *Ecol. Model*. **2002**, *151*, 29–49.
23. Keane, R.R.; Hessburg, P.F.; Landres, P.; Swanson, F.J. The use of historical range and variability (HRV) in landscape management. *For. Ecol. Manag*. **2009**, *258*, 1025–1037.
24. Landres, P.; Morgan, P.; Swanson, F. Overview of the use of natural variability in managing ecological systems. *Ecol. Appl*. **1999**, *9*, 1279–1288.
25. Gärtner, S.; Reynolds, K.M.; Hessburg, P.F.; Hummel, S.S.; Twery, M. Decision support for evaluating landscape departure and prioritizing forest management activities in a changing environment. *For. Ecol. Manag*. **2008**, *256*, 1666–1676.
26. Reynolds, K.M.; Rodriguez, S.; Bevans, K. *User Guide for the Ecosystem Management Decision Support System, Version 3.0*; Environmental Systems Research Institute: Redlands, CA, USA, 2003; p. 89.
27. Miller, B.J.; Saunders, M.C. *The NetWeaver Reference Manual*; Pennsylvania State University, College Park, PA, USA, 2002; p. 55.
28. InfoHarvest, Inc. *Criterium DecisionPlus User's Guide, Version 3.0*; InfoHarvest: Seattle, WA, USA, 2001; p. 447.
29. Hummel, S.; Barbour, R.J.; Hessburg, P.F.; Lehmkuhl, J.F. *Ecological and Financial Assessment of Late-Successional Reserve Management*; PNW-RN-531; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, OR, USA, 2001; p. 25.
30. Hummel, S.; Calkin, D.E. Costs of landscape silviculture for fire and habitat management. *For. Ecol. Manag*. **2005**, *207*, 385–404.
31. ROD. *Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents within the Range of the Northern Spotted Owl*; GPO 1994-589-111/0001; U.S. Government Printing Office, Region No. 10; Washington, DC, USA, 1994; irregular pagination.
32. Gedalof, Z.; Peterson, D.L.; Mantua, N.J. Atmospheric, climatic, and ecological controls on extreme wildfire years in the northwestern United States. *Ecol. Appl*. **2005**, *15*, 154–174.
33. Littell, J.S.; McKenzie, D.; Peterson, D.L.; Westerling, A.L. Climate and wildfire area burned in western US ecoprovinces, 1916–2003. *Ecol. Appl*. **2009**, *19*, 1003–1021.
34. McKenzie, D.; Gedalof, Z.; Peterson, D.L.; Mote, P. Climatic change, wildfire, and conservation. *Cons. Bio*. **2004**, *18*, 890–902.
35. Hessburg, P.F.; James, K.M.; Salter, R.B. Re-examining fire severity relations in pre-management era mixed conifer forests: Inferences from landscape patterns of forest structure. *Landscape Ecol*. **2007**, *22*, 5–24.
36. Eyre, F.H., Ed.; *Forest Cover Types of the United States and Canada*; Society of American Foresters: Washington, DC, USA, 1980; p. 148.

37. Hessburg, P.F.; Smith, B.G.; Salter, R.B.; Ottmar, R.D.; Alvarado, E. Recent changes (1930s–1990s) in spatial patterns of interior northwest forests, USA. *For. Ecol. Manag*. **2000**, *136*, 53–83.
38. Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management*; Gen. Tech. Rep. RMRS-GTR-87; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: Fort Collins, CO, USA, 2002; p. 41.
39. Ottmar, R.D.; Vihnanek, R.E.; Wright, C.S. Stereo photo series for quantifying natural fuels. In *Volume I: Mixed-Conifer with Mortality, Western Juniper, Sagebrush, and Grassland Types in the Interior Pacific Northwest*; PMS 830; National Wildfire Coordinating Group, National Interagency Fire Center: Boise, ID, USA, 1998; p. 73.
40. Twery, M.J.; Knopp, P.D.; Thomasma, S.A.; Rauscher, H.M.; Nute, D.E.; Potter, W.D.; Maier, F.; Wang, J.; Dass, M.; Uchiyama, H.; *et al*. NED-2: A decision support system for integrated forest ecosystem management. *Comput. Electron. Agr.* **2005**, *49*, 24–43.