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# Trends in terrestrial plant communities and landscape health indicate the effects of alternative management strategies in the interior Columbia river basin

Miles A. Hemstrom<sup>a,\*</sup>, Jerome J. Korol<sup>b</sup>, Wendel J. Hann<sup>c</sup>

<sup>a</sup>USDA Forest Service, Interior Columbia Basin Ecosystem Management Project, 4th Floor, PO Box 3623, Portland, OR 97208, USA

<sup>b</sup>USDA Forest Service, Interior Columbia Basin Ecosystem Management Project, Walla Walla, WA, USA

<sup>c</sup>USDA Forest Service, Washington Office, Office of Fire and Aviation Management, Leadville, CO, USA

## Abstract

Current and potential future conditions of terrestrial plant communities and landscape health were modeled for three alternative public land management strategies in the interior Columbia river basin. Landscape health was defined as an integration of the degree to which vegetation and disturbance conditions resemble native patterns and support levels of human activity. The range of vegetation and disturbance variability for a period before the middle 19th century was used as a basis for comparison of current and future regimes to the “historical” system. Departure from the “historical” regime in wildland environments was found to be related to altered disturbance patterns, especially changed fire regimes, forest insect and disease levels and excessive livestock grazing effects. Overall, mid-seral forests are currently more prevalent than they were in the past and old forests, especially single-layer structural types, are less abundant. Non-native plant species and altered plant community composition conditions exist across broad areas of rangelands. Landscape health has declined substantially in many areas. Proposed management strategies that emphasize maintenance and restoration activities in a hierarchical landscape approach should generate improved landscape health conditions over the next 100 years. However, the massive scale of changes to disturbance and vegetation patterns from historical to current times and the cost of implementing restoration activities make dramatic improvement unlikely. © 2001 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

Evaluating long-term consequences of land management strategies across large areas poses several problems (Johnson, 1997; Johnson et al., 1999; Haynes et al., in press). Consistent data on basic ecological characteristics are often not available. Ecological relations may not be well described in the

literature. The objectives and goals of land management may not be explicitly stated in ways that allow quantitative analysis. Yet, strategic decisions are often predicated on estimates of long-term effects.

The Interior Columbia Basin Ecosystem Management Project (ICBEMP) study area, hereafter called the Basin,<sup>1</sup> covers approximately 58 million hectares

<sup>1</sup>The Basin is defined as those portions of the Columbia river basin within the United States and east of the crest of the Cascades, and those portions of the Klamath river basin and the Great basin in Oregon.

\* Corresponding author. Tel.: +1-503-808-2835;

fax: +1-503-808-2622.

E-mail address: mhemstrom@fs.fed.us (M.A. Hemstrom).

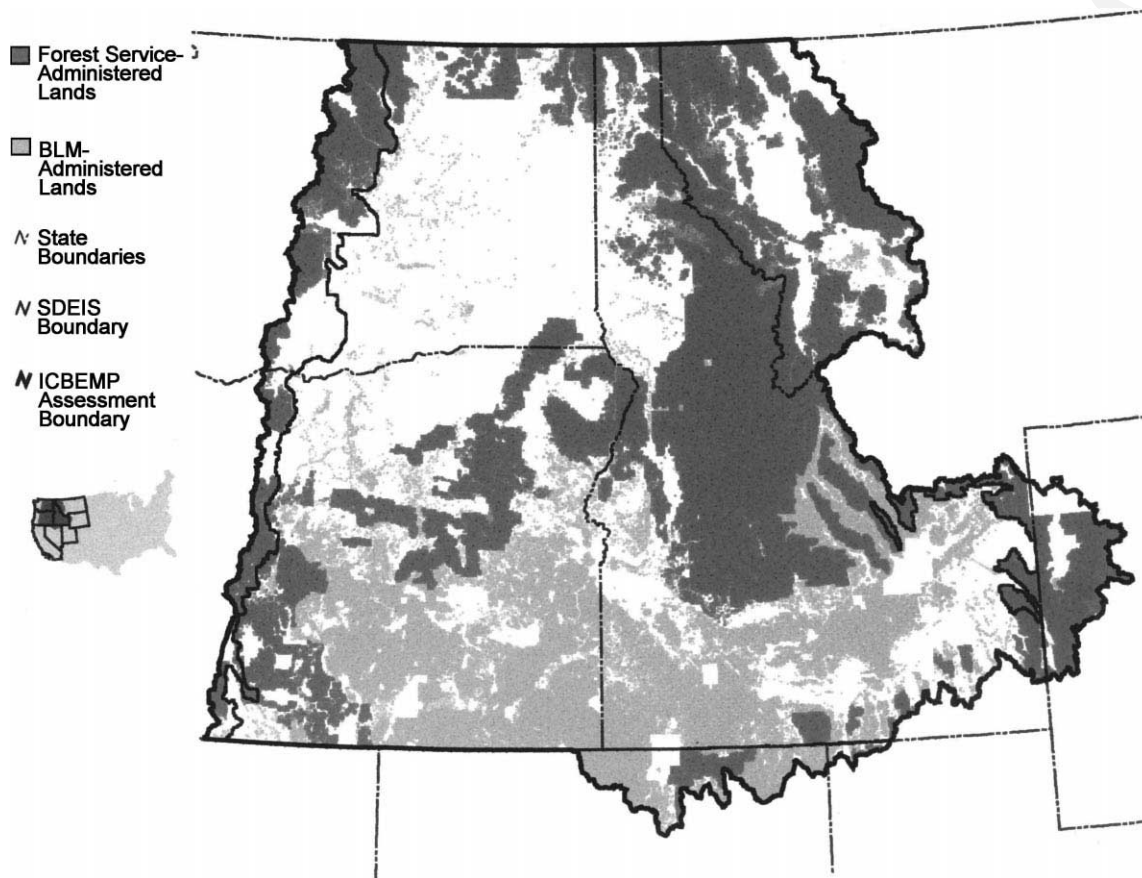


Fig. 1. The interior Columbia river basin assessment area, SDEIS analysis area, and FS and BLM administered lands.

(ha) in several states (Fig. 1). Public lands managed by the US Department of Agriculture (USDA), Forest Service (FS), and US Department of the Interior (USDI), Bureau of Land Management (BLM) account for 53% of the Basin area (Quigley and Arbelbide, 1997). Through a process subject to extensive public review, the ICBEMP has produced a set of three management alternatives (S1, S2, S3). These are outlined in a Supplemental Draft Environmental Impact Statement (SDEIS) (USDA and USDI, 2000).

We used extent of terrestrial communities and an integrated set of proxy variables to compare the effects of federal land management strategies in the study area over 100 years of implementation. We call this integrated perspective on long-term effects across large landscapes “landscape health”. Our definition of landscape health is driven by the context of our

analysis: the condition and trend of integrated ecological, social and economic conditions of lands administered by the FS and BLM in the study area over 100 years or more. Our definition includes human uses in healthy landscapes because the legal foundations for managing these lands explicitly include human uses. We found that landscape health, as we define it, should improve on most lands over that period. Many terrestrial communities, especially forested communities, trend toward historical amounts and toward the objectives stated in the alternative management strategies. This trend is not universal. Conditions in some terrestrial communities remain static or even continue to decline over the long term, at least according to our projections.

Alternative S1 adapts existing management activities and direction to include recent requirements for

managing threatened and endangered species habitat, key aquatic and riparian species and habitat conservation measures, and current agency direction. Alternative S2 focuses on restoring landscape functions and processes using a set of spatially prioritized sub-basins. It requires the FS and BLM to use a multi-scale<sup>2</sup> analysis of biological and physical features before initiating most field activities. Alternative S3 is similar to alternative S2, but decreases the focus on multi-scale analysis in the near-term. Alternative S3 spends fewer resources on intermediate analysis efforts, and proportionally more resources directly to field activities. See USDA and USDI (2000) for a complete discussion of these alternatives.

## 2. Methods

We developed models to estimate likely changes in terrestrial plant communities and landscape health on the approximately 31 million ha of FS and BLM administered land affected by the three management alternatives over 100 years of implementation. Our approach included (1) modeling historical, current and future terrestrial community and disturbance conditions, and (2) developing an index based on our definition of landscape health and computing current and future landscape health indices under the three proposed alternative management strategies.

### 2.1. Base vegetation data

We used potential vegetation types, cover types and structural stages at a resolution of 1 km<sup>2</sup> developed by Hann et al. (1997) for a Basin-wide ecological assessment (Quigley and Arbelbide, 1997). Potential vegetation types identify different vegetation environments based on broad differences in moisture, temperature, soil, and terrain as a function of ecoregion (Bailey,

1995), and elevation, slope, and life form (forest, woodland, shrubland, grassland). Potential vegetation types are named after indicator species, such as “dry Douglas-fir with ponderosa pine” or “big sage mesic-east”. They remain constant unless permanent changes in basic ecosystem properties substantially alter native succession rates, create new disturbance pathways and cover types, or remove the potential for native disturbance pathways and cover types (Daubenmire, 1968; Franklin and Dyrness, 1973; Hann et al., 1997). Permanent changes include soil loss, increased average temperature, or decreased average precipitation. Invasions of non-native annual grasses, e.g., produce altered succession and disturbance paths.

Cover types reflect the dominant species in upper canopy layers at any point in time. Structural stages depict the horizontal and vertical arrangement of vegetative structures (e.g., canopy cover in various tree diameter classes) and are related to temporal stand development patterns (Oliver, 1981, as modified by O’Hara et al., 1996).

Vegetation disturbances in the Basin vary widely as a function of climate, topography, vegetation types, and human uses. We included fire severity and fire interval, recent fire occurrence, road density, grazing, and other human activities as disturbances. Fire and human activities are, perhaps, the major disturbance agents operating in the Basin (Hann et al., 1997). Fire disturbances in forests range from frequent, low-intensity events in drier forests to very infrequent, high-intensity events in some moist, cold forests. Rangelands experience variable fire regimes as well, depending on fuels and ignition sources. Human disturbances to plant communities include, among others: timber harvest, livestock grazing, road building, recreational activities, prescribed and accidental fire ignition, unintentional introduction of non-native plants, herbicide spraying, seeding of native and non-native plants, mechanical treatments, and conversion to urban or agricultural uses.

### 2.2. Models

Our analysis, built on the work of Hann et al. (1997), used two models and several data sources (Fig. 2). Plant community succession was modeled using the Vegetation Development Dynamics Tool (VDDT; Beukema and Kurz, 1995) and the Columbia

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<sup>2</sup>Broad scale landscapes and analyses covered large drainage basins (millions of ha or more) and used 1 km square pixel resolution. Intermediate (or Mid)-scales covered sub-basins to subwatersheds (tens of thousands to millions of ha) and mapped features on 1:24 000 aerial photographs. Fine scale analyses and maps covered subwatersheds to individual vegetation stands (tens of ha to tens of thousands of ha) and involved data ranging from aerial photographs at 1:24 000 to 1:12 000 and stand-level plot data.

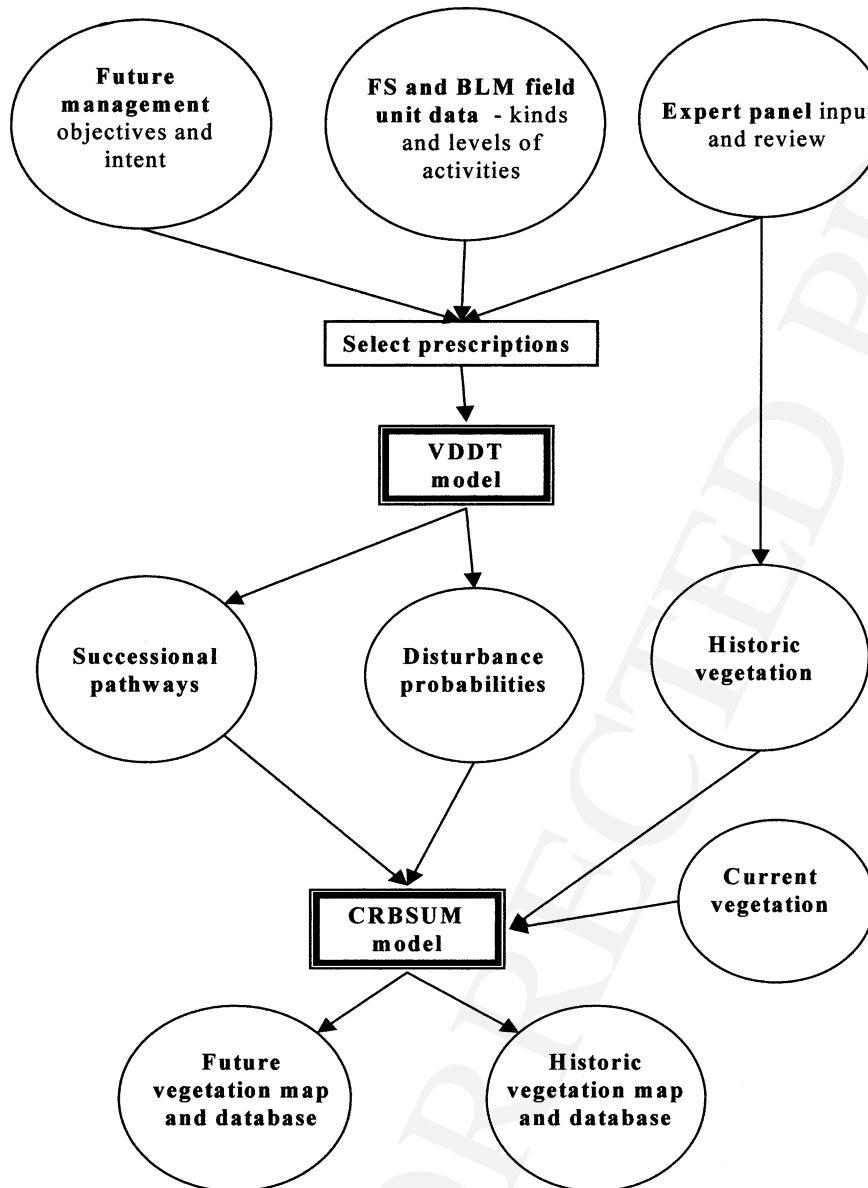


Fig. 2. Flow of information and modeling used to generate historic, current and future terrestrial communities and estimates of landscape health for the SDEIS management alternatives in the interior Columbia river basin.

River Basin Succession Model (CRBSUM; Keane et al., 1996).

VDDT, a transition probability model, links vegetation communities along multiple pathways of successional development and disturbance (after Kessell and Fischer, 1981) through time without regard to

spatial distribution. Individual potential vegetation types can be modeled for variable periods, ranging to more than 300 years. Transition probabilities and disturbance paths must be explicitly stated in model formulation for each potential vegetation type. Disturbance probabilities are expressed annually. Unfor-

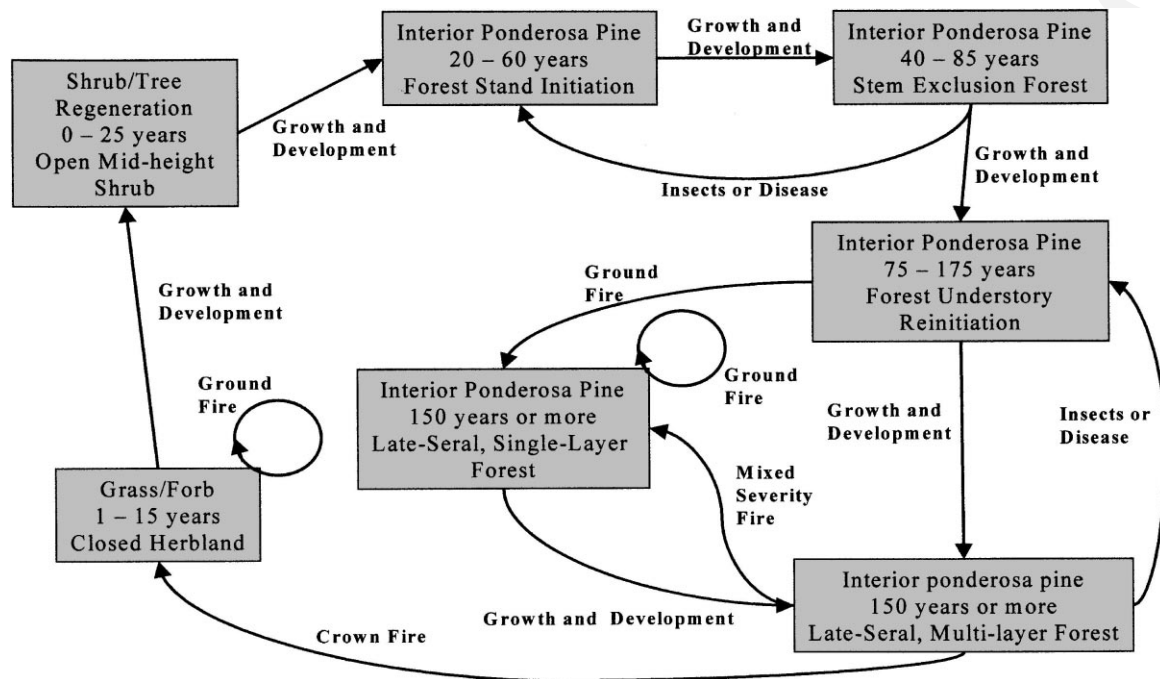


Fig. 3. Simplified succession and disturbance model for the historic scenario of the interior ponderosa pine potential vegetation type.

Unfortunately, empirical data do not exist at sufficient resolution across the Basin to calibrate or test VDDT models in a statistically rigorous way. Model formulation, i.e., explicit statement of plant communities, disturbances, succession and associated probabilities, came from a combination of local empirical data and expert opinion (Fig. 3) (Hann et al., 1997). Therefore, Hann et al. (1997) convened panels of experts to develop and test VDDT models, using existing, localized empirical data, information from the literature, and expert opinion. Hann attempted to avoid bias by inviting recognized experts from a variety of academic, research and management agencies. Panels developed specifications for plant communities within potential vegetation types, disturbances and their probabilities, and successional paths and rates. The VDDT model was used to project long-term proportional representation of plant communities given model specifications for each potential vegetation type. Expert panels then reviewed model projections and made adjustments so that modeling results were consistent with panel consensus about likely

vegetation conditions. We adapted the VDDT models developed by Hann et al. (1997) to project vegetation conditions under various disturbance and management regimes.

Wildfire (lethal, mixed severity, and non-lethal), mortality from insect and pathogen epidemics in forests, wild ungulate grazing, non-native plant species invasion, domestic livestock grazing, timber harvest (clearcutting, thinning, group selection, shelterwood cuts and others), and the use of herbicides in rangelands to control plant species composition were included in our VDDT models. In addition, information on kinds and levels of management activities from FS and BLM field units, and descriptions of desired future vegetation conditions and treatments under the SDEIS alternatives were used to develop successional and disturbance pathways and calibrate disturbance probabilities.

CRBSUM (Keane et al., 1996) uses plant community proportions and disturbance probabilities from VDDT to produce spatially explicit representations of plant communities and disturbances. It uses stochastic

elements and vegetation communities to project disturbances and represent vegetation across landscapes, in this case with 1 km<sup>2</sup> resolution. Due to stochastic processes, CRBSUM model results more closely resemble related VDDT models as area increases and more pixels are included. Consequently, our spatial results are more likely to resemble projections from VDDT models, and the underlying expert formulation, for larger vegetation types and communities. Projections for small potential vegetation types or plant communities include considerable random variation.

### 2.2.1. Modeled current vegetation

Current vegetation conditions were modeled from relationships of potential vegetation to landforms and climatic features and interpretations of 1 km<sup>2</sup> satellite imagery. Some aspects of current vegetation composition, structure, disturbances, and landscape patterns were developed by relating 1 km<sup>2</sup> satellite imagery data, landforms and climatic surrogates (elevation, aspect, slope steepness, precipitation patterns, and temperature patterns) to an aerial photograph interpretation in a subsample of 330 subwatersheds (Hessburg et al., 1999). Because data resolution is coarse, cover types and structural stages were relatively simple, broad classes. The base data included 41 cover types and 25 structural stages (Hann et al., 1997) across the entire Basin. Forest structural stages, e.g., included seven classes ranging from stand initiation forest to late seral multi-storied forest (Table 1).

In total, 164 combinations of cover types and structural stages occurred within the terrestrial communities we analyzed.

### 2.2.2. Modeled historical vegetation

Historical potential vegetation is different from current potential vegetation in areas where conversion to agriculture and urban uses, invasive non-native plants, severe soil erosion, or other factors have changed site potential at the broad-scale. VDDT and CRBSUM model runs output historical cover types and structure stages when calibrated with estimated climatic, topographic, plant community and disturbance path parameters for the several centuries prior to the extensive alteration of vegetation and disturbances following Euro-American settlement of the Basin (Hann et al., 1997). The historical ranges for vegetation conditions and disturbance regimes were estimated through a combination of 400-year model runs, expert opinion as discovered through a formal panel process, and physical and biological data for the Basin (Hann et al., 1997). Models were run annually for 400 years with the same set of successional pathways and disturbances, because examination of model outputs indicated the results were relatively insensitive to initial vegetation conditions when run over a sufficiently long period.

We used the central 50% (conditions that fell within  $\pm 25\%$  of mean values) of the projected historical range as the normal or expected range of historical conditions. The choice of expected historical range

Table 1  
Simplified general characteristics of forest structural types in the interior Columbia river basin (see Hann et al., 1997 for more detail)

Structure class	Canopy cover <sup>a</sup>				
	Sapling trees <sup>b</sup>	Pole trees <sup>c</sup>	Small trees <sup>d</sup>	Seedling and medium trees <sup>e</sup>	Large trees <sup>f</sup>
Early seral	At least 10%	Sum is less than 20%			Less than 30%
Mid-seral	Variable	Variable but sum generally at least 20%			Less than 30%
Late seral, single-layer	Sum not more than 20%				At least 30%
Late seral, multi-layer	Sum at least 20%				At least 30%

<sup>a</sup> Canopy cover is vertical projection of crowns as seen from above and is  $\leq 100\%$ .

<sup>b</sup> Seedling and sapling trees are less than 12.6 cm, diameter breast height.

<sup>c</sup> Pole trees are between 12.7 and 22.6 cm, diameter breast height.

<sup>d</sup> Small trees are between 22.7 and 40.4 cm, diameter breast height.

<sup>e</sup> Medium trees are between 40.5 and 53.1 cm, diameter breast height.

<sup>f</sup> Large trees are at least 53.2 cm, diameter breast height.

plays a large part in analyses that compare historical, current and future conditions. We chose the central 50% of the simulated historical range, which included 70–90% of the predicted variability and excluded extreme fluctuations. Other choices for historical range (e.g.,  $\pm 10$  or  $\pm 40\%$  of the mean or different time periods) could be used. Wide historical ranges (e.g.,  $\pm 40\%$ ) obscure differences between historical, current and future conditions while narrow ranges emphasize them. While our projections from the CRBSUM model were for individual  $1 \text{ km}^2$  pixels, we aggregated historic ranges by potential vegetation group across the study area. Summarizing historical range results across large landscapes reduces the effects of fine-scale variability (Wimberly et al., 2000).

Initial conditions were summarized from timber survey and agricultural potential mapping done between about 1850 and 1900 (Losensky, 1995).<sup>3</sup> Hessburg et al. (1999) attempted to validate historical vegetation and disturbance conditions in a randomly selected subset of 330 small subwatersheds<sup>4</sup> in the Basin. They mapped vegetation, roads, fuels, and associated attributes from the earliest aerial photographs available in an attempt to describe mid-scale historical conditions. In addition a variety of sites were selected where late 1800s and early 1900s photographs were available. Sites were located and photographs repeated to help clarify changes from earlier conditions (Losensky, 1995, see Footnote 3). Examinations of changes in vegetation structure and composition from these data helped verify interpretations made at broad scales. While these efforts did not provide a statistically valid sample of historical conditions, they did allow examination and clarification of vegetation patterns that might have existed in historical times.

### 2.2.3. Modeled future vegetation

Future vegetation conditions for each of the three land management strategies under evaluation were

<sup>3</sup> Losensky, B.J., 1995. A description and photographic record of the historical vegetation of the Columbia river basin. Completion Report, Contract INT-94951-RJVA (irregular pagination). US Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Science Laboratory, Missoula, MT.

<sup>4</sup> Subwatersheds are drainage basins that average about  $80 \text{ km}^2$  in size in the interior Columbia river basin.

simulated by developing different sets of disturbance types, probabilities and successional paths to reflect varying kinds, rates and spatial occurrence of management activities. Different sets of VDDT and CRBSUM models were then developed for different combinations of management activities or themes. For example, an active restoration management theme in non-wilderness areas has a different set of disturbances and disturbance probabilities than passive or commodity-oriented approaches. We call each combination of disturbances and pathways a “prescription”, following common usage in the field. We used 17 different prescriptions to model historical and future vegetation conditions based on current vegetation, potential vegetation types, land ownership, and general management regime (e.g., wilderness, non-wilderness) (Table 2).

Current levels and trends of management activities, including timber harvest, livestock grazing, fire suppression, stand management, and others were summarized from information supplied by field administrative units (National Forests and BLM Districts) for the last 10 years, or for relatively recent management changes, the last 3–5 years. These levels and trends of management activities were used in choosing which VDDT model prescriptions should be applied to each  $1 \text{ km}^2$  pixel in estimating current levels and types of disturbance. They were also used, in conjunction with an explicit interpretation of the three alternative management strategies, to select future management prescriptions for modeling future vegetation and disturbance conditions. Future budget estimates were provided by the team drafting the SDEIS (EIS team) for each of the three management alternatives being evaluated. We estimated costs of the management prescriptions that could be applied and distributed those prescriptions across landscapes according to priorities and emphases supplied by the EIS team until projected funding levels were reached. Our intention was to model restoration and other prescriptions as they might actually be applied based on limited resources. In alternatives S2 and S3, e.g., we applied restoration prescriptions to land areas hierarchically, derived from SDEIS spatial priorities, until available estimated restoration funds were exhausted. Our projections used VDDT and CRBSUM models and estimated long-term (100-year) futures.

Table 2  
Management prescriptions and interpretations of management, disturbance or succession factors that are the primary cause of ecological change on FS and BLM administered lands in the interior Columbia river basin<sup>a</sup>

Prescription	Category	Activity level		Disturbance agent								
		All human	Mechanical treatment	Succession	Wildfire	Insects and diseases	Wildfire suppression	Livestock grazing	Prescribed fire	Non-native plants	Timber harvest	
Historical	Historical	Historical	Historical	X	X	X						
A1	Restoration	Moderate	Minimal	X	X	X			X			
A2	Restoration	Moderate	Moderate	X	X	X			X			
A3	Restoration	High	High	X	X	X			X			
N1	Restoration	Low	Minimal	X	X	X			X			
N4	Restoration	Low	Low	X	X	X			X			
C1	Reserve	Minimal	Minimal	X	X		X	X				
N6	Reserve	Minimal	Minimal	X	X		X	X				
P1	Reserve	Minimal	Minimal	X			X	X	X	X		
C3	Commodity	High to very high	High				X	X		X		X
C2	Commodity	High	High	X			X	X		X		X
N2	Commodity	Low	Low	X			X	X		X		
N3	Commodity	Moderate	Moderate	X			X	X		X		X
N5	Commodity	Moderate	Moderate	X			X	X		X		X
N7	Commodity	Low	Low	X			X	X		X		
N8	Commodity	Moderate to high	Moderate to high				X	X		X		X
P2	Commodity	Low to moderate	Low to moderate	X			X	X		X		
P3	Commodity	Very high	Very high	X			X	X		X		X

<sup>a</sup> Historical prescriptions include disturbance rates over many centuries prior to about 1850 with native American uses. Restoration prescriptions include restoration and maintenance treatments designed at a landscape scale to restore or mimic succession and disturbance processes. Reserve prescriptions characteristically use passive management techniques in wilderness and semi-primitive or roadless areas. Commodity prescriptions emphasize commodity production, maintenance or restoration management and commodities and other values.

#### 2.2.4. Aggregating results

Our analysis produced estimated historic, current and future conditions for a large set of cover types, structure stages and disturbances.<sup>5</sup> For purposes of examining terrestrial communities and landscape health, we aggregated these into simpler categories. Potential vegetation types were aggregated into cold forests, moist forests, dry forests, and upland shrublands and herblands (see Hann et al., 1997, for more detail). Forest structural stages were similarly aggregated into early seral forest, mid-seral forest, and late seral forest (Table 1). We split late seral forests into two categories (late seral, single-storied and late seral, multi-storied), based on important differences in habitat for terrestrial vertebrates (Wisdom et al., 2000).

### 2.3. Landscape health analysis

#### 2.3.1. Developing an index

We generated an index called “landscape health” to integrate ecological and human use characteristics across the Basin at the broad scale. Ecosystem health, landscape health, forest characteristics across the Basin at the broad scale. Ecosystem health, landscape health, forest health, rangeland health and other similar concepts require explicit definition if they are to provide a useful basis for analysis. While these concepts are commonly used (e.g., NRC, 1994), sufficiently explicit definition for quantitative analysis is often not supplied. Our definition of landscape health follows Hann et al. (1997): “the best fit of the dynamic interactions of human land use, biodiversity, and ecosystem health, i.e., in balance with the limitations of the biophysical system and inherent disturbance processes”. This definition, like others before, does not lend itself to analysis without additional clarification. It specifically includes human uses, as well as biological diversity and the inherent or “natural” capabilities and conditions of the land, as a part of healthy landscapes. It constrains a “healthy” landscape to one that is within the limitations of the

<sup>5</sup> Hemstrom, M.A., Hann, W.J., Gravenmier, R.A., Korol, J.J., 2000. Draft landscape effects analysis of the SDEIS alternatives. In: Science Advisory Group. Draft March 2000. Science Advisory Group effects analysis for the SDEIS alternatives. US Department of Agriculture, Forest Service, and US Department of the Interior, Bureau Land Management, Interior Columbia Basin Ecosystem Management Project, Boise, ID.

“inherent” vegetation and disturbance conditions. It also does not require healthy landscapes to mirror natural conditions. The definition assumes that maintenance of natural processes and patterns along with human uses are consistent with the legal mandates of the FS and BLM (e.g., National Forest Management Act, 1976; Federal Land Policy and Management Act, 1976).

Our index combines divergence of vegetation and disturbance regimes from natural patterns, as defined by the historical condition, and human uses. We did not establish a single threshold for evaluating landscape health. Rather, we depicted landscape health on a sliding scale that we broke, for convenience, into classes. Our assumption was that the degree to which certain landscape characteristics resemble “natural” vegetative and disturbance conditions and provide for human uses, as described in the legal foundations that direct land management, determines landscape health.

Our basis for inherent biological and environmental conditions was a range of conditions from the historical vegetation and disturbance projections produced by Hann et al. (1997). We chose the central 50% of the historical range of variation of a selected set of landscape variables. These variables were produced from VDDT and CRBSUM outputs for our historical vegetation and disturbance simulations.

#### 2.3.2. Current and future landscape health classification

The current health of landscapes was based on a classification (very high, high, moderate, low and very low) from a multivariate ordination of combinations of landscape variables, generated from VDDT model and CRBSUM model outputs, used to indicate current health conditions (Table 3). Optimum landscape health, or “best fit” in our definition, exists where land use values were high, native species habitats had a high condition rating, risks to water quality and clean air were low, risk of non-native plant and noxious weed invasion was low, and departure of forest, rangeland health, and fire and fuel conditions from the historical system was low. A current landscape health class was assigned to each of the 7467 subwatersheds in the Basin.

We projected future trends in landscape health over 100 years of implementation of each of the three

Table 3  
Variables used to assess current landscape health (from Quigley and Arbelbide, 1997 except as otherwise noted)

Condition factor category	Condition factor
Land use	<p>Timber harvest indicated by current timber value, potential timber value, relative importance of timber harvest to social and economic status, levels of timber harvest, risk of severe fire behavior, opportunities for biomass production, opportunities for restoration activities, landscape vegetation patterns, road densities, ownership, and wilderness designation</p> <p>Livestock grazing as indicated by livestock grazing potential, importance of livestock grazing to social and economic status, soil susceptibility to erosion, susceptibility to hydrologic disturbance, levels of livestock grazing, vulnerability to non-native plant invasion, ownership, and wilderness designation</p> <p>Recreation value indicated by current recreation value, recreation use, severe fire risk,<sup>a</sup> watershed condition,<sup>b</sup> socioeconomic growth potential, current opportunities to use fire and fuel as management treatments and ownership</p> <p>Urban–rural wildland fire interface condition indicated by geographic location of settled urban and rural areas relative to wildlands, fire risk levels, ownership pattern, and human socioeconomic conditions</p> <p>Tribal, treaty and trust resources indicated by ownership; tribal, trust and treaty land use; departure of vegetation and disturbance patterns from historical conditions;<sup>c</sup> vulnerability of hydrologic systems to disturbance; water quality; desirability of environments to humans; and availability of important tribal resources</p> <p>Community resiliency indicated by human ecological resiliency, socioeconomic conditions, economic resiliency, timber harvest opportunities, livestock grazing opportunities, urban and rural interfaces, and ownership<sup>d,e</sup></p>
Ecosystem health	<p>Water quality indicated by status of fish communities</p> <p>Air quality indicated by the potential for temperature inversions (smoke concentration) and potential particulate production from fires</p> <p>Fire and fuel conditions indicated by current potential for severe fire behavior based on vegetation and fuel patterns</p> <p>Forest health indicated by forest vulnerability to insect and disease mortality, departure from historic disturbance regimes, and departure from historical vegetation patterns</p> <p>Range land health indicated by current rangeland vulnerability to disturbance, soil sensitivity, departure from historical disturbance and vegetation patterns, and vulnerability to invasion by non-native plants</p> <p>Watershed condition as indicated by current hydrologic vulnerability to disturbance, departure from historical disturbance and vegetation patterns, risk of severe wildfire, road densities, and ownership patterns</p> <p>Noxious weeds indicated by vulnerability to invasion by non-native plants, current rangeland vegetation health, current risk of severe fire, and ownership</p>
Native species diversity	<p>Aquatic system and species indicated by status and distribution of native fish, land ownership patterns, road densities, dams and mines</p> <p>Source habitat status for low-elevation, old-forest related species<sup>f</sup></p> <p>Source habitat status for generalist old-forest related species<sup>f</sup></p> <p>Source habitat status for species related to mosaics of forest and non-forest<sup>f</sup></p> <p>Source habitat status for species related to grass lands and open shrub lands<sup>f</sup></p> <p>Source habitat status for species related to early seral forests<sup>f</sup></p> <p>Source habitat status for sagebrush shrub land related species<sup>f</sup></p>

<sup>a</sup> A proxy for potential for impact to visual resources from fire.

<sup>b</sup> A proxy for desirability of watershed for recreational uses.

<sup>c</sup> A proxy for changes in availability of resources related to vegetation.

<sup>d</sup> Crone, L.K., Haynes, R.W. (2000), see Footnote 7.

<sup>e</sup> Horne and Haynes (1999).

<sup>f</sup> Wisdom et al. (2000).

management alternatives using an index that incorporated the following five indicators:

1. the departure of vegetation composition, structure, landscape pattern and disturbance regimes from the historical range, as discussed in Section 2.2;
2. density (and changes in density) of roads on a per area basis (Hemstrom et al., 2000, see Footnote 5);
3. the current condition and trend in aquatic habitat condition (Rieman et al., 2000);<sup>6</sup>
4. levels of management activity, including restoration, as described in each of the three management alternatives (USDA and USDI, 2000) and budget targets as described by the EIS team; and
5. the similarity of future management activities, interpreted from disturbance probabilities and vegetation transitions in VDDT models used to simulate future vegetation conditions, to vegetation transitions and disturbance regimes characteristic of local environmental conditions under historical conditions.

Contributions to future landscape health for each factor were positive, by definition, if: (1) The composition, structure, landscape pattern and disturbance regimes of vegetation was trending toward the median of the historical range of variability. (2) Road densities, on a per area basis, were decreasing. (3) Aquatic habitat was in an improving trend. (4) Human land uses (livestock grazing, timber harvest, recreation and other uses) or restoration activities were increasing. (5) Management activities were more congruent with local environmental, disturbance and vegetative patterns.

Our future landscape health trend index was a simple, linear, unweighted combination of these factors. Each factor varied from  $-1$  (maximum negative contribution to future landscape health) to  $+1$  (maximum positive contribution). A composite index that summarized these variables was calculated for each subwatershed. Each subwatershed was assigned a

future landscape health trend (decreasing, stable, increasing).

Obviously, these factors cannot all be maximally positive or maximally negative at once. For example, management activities and restoration may require road access. The balance between increasing human uses and restoration activities (both positive landscape health attributes according to our definition) with high road densities and attendant sediment delivery to aquatic systems (a negative landscape health effect) is subsumed in the simple, linear, non-weighted combination of factors in our composite index.

A weighting system could be devised to reflect different value systems (e.g., more positive effect from human uses or more positive effect from the tendency toward historical conditions), but we had no basis for weighting any of the factors more than the others. One could argue that since two factors (human uses, and, to a lesser extent, restoration activities) reflect human economic production while the other four reflect natural conditions, the index is inherently weighted toward “natural” systems and conservation of biodiversity. However, the improved trend to historical ranges, improved fit of management and restoration activities to the inherent disturbance regime, and reduction of negative road effects is associated with reduction in risk of catastrophic events (such as wildfire, insect and disease epidemics, and floods). Reduction in these events generally has substantial benefit to human values. Aquatic system improvements, trend to historical ranges, and road density reduction has combined benefits that aid in conserving and restoring native species and reducing the risk of species extirpation, which some may argue is a human value.

### 3. Results

#### 3.1. Terrestrial communities

As modeled, shrublands and herblands have declined about 10% from historical to present conditions (Table 4), mostly from afforestation of previously open lands and invasion of non-native plant species. Fire suppression has been sufficiently effective to allow tree regeneration and encroachment in previously open herblands and shrublands (Hann et al., 1997). Non-native plants (e.g., annual grasses) now

<sup>6</sup>Rieman, B., Howell, P., Clayton, J., Peterson, J., Thurow, R., Barta, A., Sedell, J., Lee, D., Thompson, B., 2000. Draft aquatic effects analysis of the SDEIS alternatives. In: Science Advisory Group. Draft March 2000. Science Advisory Group effects analysis for the SDEIS alternatives, p. 216. US Department of Agriculture, Forest Service, and US Department of the Interior, Bureau Land Management, Interior Columbia Basin Ecosystem Management Project, Boise, ID.

Table 4

Vegetation structure compared to historical conditions for the historical and current periods and the long-term future under three alternative management strategies on FS and BLM administered lands in the interior Columbia river basin

Period	Percent of historical amount					
	Shrubland and herbland	Early seral forest	Mid-seral forest	All late seral forest	Late seral, single-layer forest	Late seral, multi-layer forest
Historical	100	100	100	100	100	100
Current	90	94	130	67	43	90
Alternative S1 long term	93	90	113	100	39	155
Alternative S2 long term	93	91	106	110	63	153
Alternative S3 long term	93	90	107	108	57	156

dominate extensive areas that were previously native shrub and herblands. Our projections indicate that upland herb and shrublands increase only slightly over the long-term under all three alternative management strategies, but probably will not reach historical levels (Table 4) or management objectives. Funding levels are likely to limit restoration activities on herblands and shrublands. Funding levels, as provided by the EIS team, do not appear sufficient to offset the effects of continued fire suppression (and consequent afforestation), livestock grazing, and invasive non-native plant species in rangelands.

Our modeling indicates that early seral forests have declined about 10% from historical levels on FS and BLM administered lands (Table 4) in the study area. Early seral cold and dry forests have increased slightly from historical levels but early seral moist forests have declined by approximately one-third (Tables 5–7). Early seral forests continue to decline over the long-term under all three alternatives, mostly as a consequence of continued fire suppression and reduced levels of even-aged timber management on

FS and BLM administered lands in the Basin. Early seral dry forests drop below current but remain above historical levels in the long term. Early seral moist forests also decline over the long-term in all three alternatives and remain far below historical amounts. Early seral cold forests decline from the current conditions over the long-term in all alternatives, but remain above the historical levels. Cold forests tend to be in higher-elevation areas dominated by wilderness where fire suppression will continue to occur.

Mid-seral forests are currently substantially above historical levels on FS and BLM administered lands in the Basin (Table 4). Large wildfires in the early 1900s and relatively high levels of even-aged timber management over the last 50 or more years generated high amounts of stand-replacement disturbance. Marked increases have occurred in mid-seral dry and moist forests while mid-seral cold forests have declined slightly (Tables 5–7). Nearly all the even-aged timber management and many large wildfires on FS and BLM administered lands over the last 50+ years has been in dry and moist forest types. All three alternatives are

Table 5

Cold forest vegetation structure compared to historical conditions for the current period and the long-term future under three alternative management strategies on FS and BLM administered lands in the interior Columbia river basin assessment area

Period	Percent of historical amount			
	Early seral forest	Mid-seral forest	Late seral, multi-layer forest	Late seral, single-layer forest
Historical	100	100	100	100
Current	122	88	77	106
Alternative S1 long term	117	93	129	59
Alternative S2 long term	122	90	128	58
Alternative S3 long term	120	92	126	60

Table 6

Dry forest vegetation structure compared to historical conditions for the current period and the long-term future under three alternative management strategies on FS and BLM administered lands in the interior Columbia river basin assessment area

Period	Percent of historical amount			
	Early seral forest	Mid-seral forest	Late seral, multi-layer forest	Late seral, single-layer forest
Historical	100	100	100	100
Current	122	132	183	26
Alternative S1 long term	114	120	210	35
Alternative S2 long term	114	112	174	68
Alternative S3 long term	93	113	186	59

projected to produce declines in mid-seral forests over the long-term as stand development moves mid-seral forests to late seral condition. Mid-seral forests decline the most in dry and moist forest types. Small increases could occur in cold forest as a result of fire, insect, and disease disturbance. In general, however, mid-seral forests remain above historical and current levels under all three alternatives.

Late seral forests have declined substantially below historical levels on FS and BLM administered lands in the Basin (Tables 5–7). Much of the stand-replacement wildfire and timber harvest disturbance over the last 50 or more years has occurred in late seral forests. Since 100–200 years are generally required for forests to achieve late seral structure in this region, most of those areas are currently in mid-seral condition. Our models indicate that late seral forests increase under all three alternatives and meet or surpass historical levels on FS and BLM administered lands in the long term. Much of the increase is projected to occur in moist forests. In general, alternatives S2 and S3 produce larger amounts of late seral forest than alter-

native S1 over the long term. This seems reasonable since aggressive restoration of late seral forest is not a driving objective under alternative S1, but is key in alternatives S2 and S3.

Late seral, single-layer forests have declined more than 50% from historical levels on both FS and BLM administered lands in the Basin (Tables 5–7). Late seral, single-layer dry and moist forests, combined, have declined to one-third or less of their historical abundance. Single-layer forests tended to dominate late seral condition in dry forest types under historical conditions, a result of frequent under burning in the natural disturbance regime (Agee, 1993). Late seral, single-layer cold forests have increased about 5% from historical levels, due to lower levels of stand-replacement disturbance in high-elevation, cold forests. Late seral, single-layer forests increase to about two-thirds of their historical abundance over the long-term under alternatives S2 and S3. Recovery of late seral forests is projected to be relatively slow because development of late seral structure requires a century or more following stand-replacement disturbance. The

Table 7

Moist forest vegetation structure compared to historical conditions for the current period and the long-term future under three alternative management strategies on FS and BLM administered lands in the interior Columbia river basin assessment area

Period	Percent of historical amount			
	Early seral forest	Mid-seral forest	Late seral, multi-layer forest	Late seral, single-layer forest
Historical	100	100	100	100
Current	66	160	38	33
Alternative S1 long term	63	121	132	36
Alternative S2 long term	61	113	149	50
Alternative S3 long term	61	114	149	45

greatest increases result from restoration efforts in dry forests under alternative S2, but amounts will still remain below historical levels after 100 years. Late seral, single-layer forests continue to decline under alternative S1, especially in cold forests, as a result of increased fire, insect and disease disturbance.

Late seral, multi-layer forests have also decreased from historical levels on both FS and BLM administered lands across the Basin (Tables 5–7). Decades of fire suppression have allowed tree regeneration in the understory of dry forests, allowing development of multi-layer forests in areas that were historically in single-layer late seral structural condition. Increases in late seral, multi-layer dry forests were more than offset by extensive declines in the moist and cold forests as a result of timber harvest and wildfire. Late seral, multi-layered forests are projected to increase to more than historical amounts under all three management alternatives over the long term. Succession, stand development in existing mid-seral forests, and reduced amounts of stand-replacement disturbance in existing late seral forests drive projected increases. The largest increases occur in moist forests.

### 3.2. Landscape health

#### 3.2.1. Current landscape health

Landscape health is generally moderate or low on FS and BLM administered lands across the Basin at present (Fig. 4). Overall, areas with relatively high amounts of human use and road densities were related to greater departure of the vegetation from the historical range and poorer aquatic and terrestrial habitat conditions, possibly a result of past dominance of traditional commodity management activities and fire suppression, without consideration of the inherent disturbance regimes and native species habitats.

No subwatersheds dominated by FS or BLM administered lands in the Basin are currently in the high landscape health class. Lands in large wilderness are more likely to be in moderate landscape health than those outside wilderness, a consequence of the long-term effects of fire suppression, timber harvest, livestock grazing and other activities outside wilderness areas. High levels of these activities have resulted in pervasive changes to vegetation communities, landscape patterns and disturbance regimes. Only very limited areas with naturally infrequent disturbance

regimes and in mostly inaccessible terrain (such as alpine and subalpine wilderness areas) retain conditions similar to those that likely occurred historically. Some lands would have scored in the high category except that fire suppression (in forested environments) and livestock grazing (in rangeland environments) have produced pervasive effects. We assume that some levels of human use, if broad categories of vegetation conditions and disturbance regimes resembled natural patterns, would be compatible with high health condition, but we did not find any examples large enough to be visible at the broad scale. It is possible that the broad-scale resolution we used obscured the existence of healthy areas that might appear in mid-scale or fine scale analysis.

#### 3.2.2. Modeled future landscape health trends

Over the long term, continuation of the current management strategy (alternative S1) generates improving landscape health trends on over half the FS and BLM administered lands in the Basin (Figs. 5 and 6). Current direction includes relatively new requirements for protecting endangered species habitat, riparian vegetation, aquatic resources, and (in some parts of the Basin) late seral forests. However, strategies that emphasize existing use patterns, including currently existing direction and policy, produce substantially poorer improvements in landscape health than the other alternatives. Compared with alternative S1, the restoration approaches in alternatives S2 and S3 result in a greater proportion of land in stable and increasing landscape health trends. Improvements projected under alternatives S2 and S3 would be concentrated in focused restoration areas. Alternatives S2 and S3 place high priority on restoration across entire sub-basin areas, rather than relatively fragmented efforts under alternative S1. Landscape health outside focused restoration areas improves more slowly, remains stable, or, in some cases, declines under alternatives S2 and S3. Declines in landscape health appear to be driven by invasive non-native plants, altered fire regimes, continued high levels of livestock grazing and restricted funding for restoration.

Alternatives S2 and S3 improve landscape health, compared with alternative S1, by changing management goals, objectives and priorities to restoration in many areas. Alternative S2 produces larger improve-

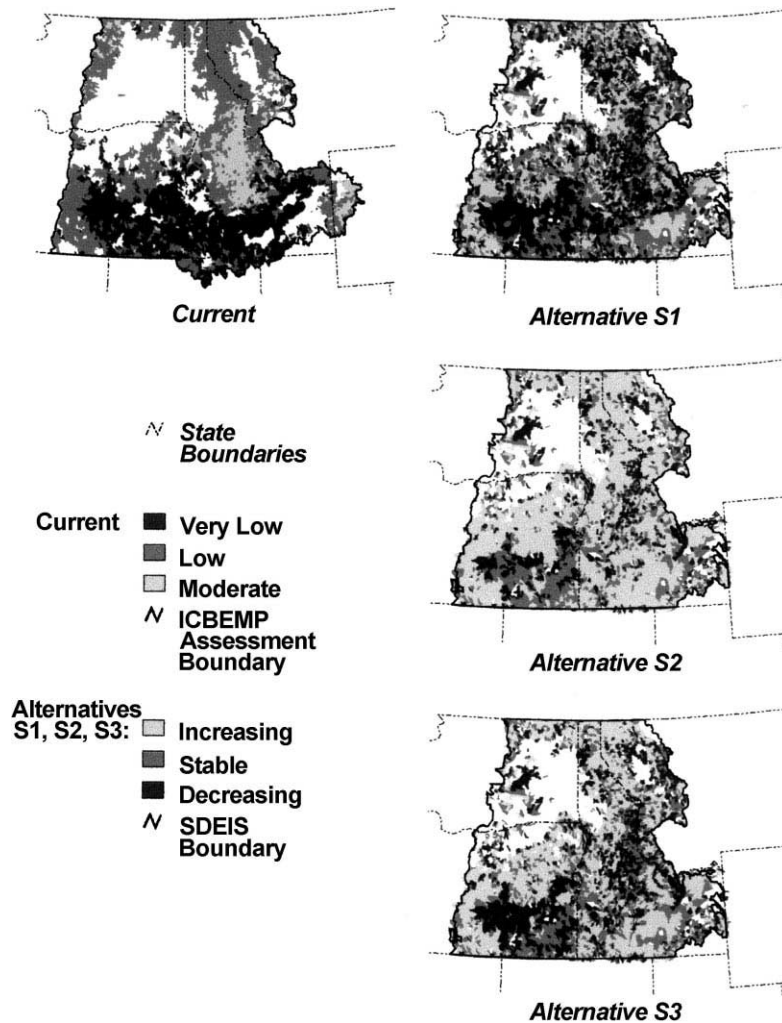


Fig. 4. Current landscape health conditions for FS and BLM administered lands in the interior Columbia river basin.

ments in landscape health than alternative S3 because it requires more intermediate-scale analysis. While intermediate-scale analysis requires time and funding, restoration efforts designed to step down from a broad-scale orientation and tie to conditions through an intermediate-scale are likely to be complementary and achieve restoration objectives more consistently over a large area. This improvement in cumulative efficacy results in cost-efficient treatments that more than offset the funds expended on intermediate-scale analysis. Management alternatives are more likely to achieve their stated goals when activities are tailored to landscapes by intermediate-scale analyses.

### 3.2.3. Landscape health and potential vegetation groups

The selection of particular areas for restoration focus, funds available for different kinds of restoration activities, probability of successful implementation of restoration activities, and efficacy of restoration activities in different environments affect our projections of vegetation and disturbance. Since potential vegetation groups stratify environmental, disturbance and potential plant communities (see Section 2.1), the proportions of potential vegetation groups in subwatersheds relate to restoration success and landscape health trend.

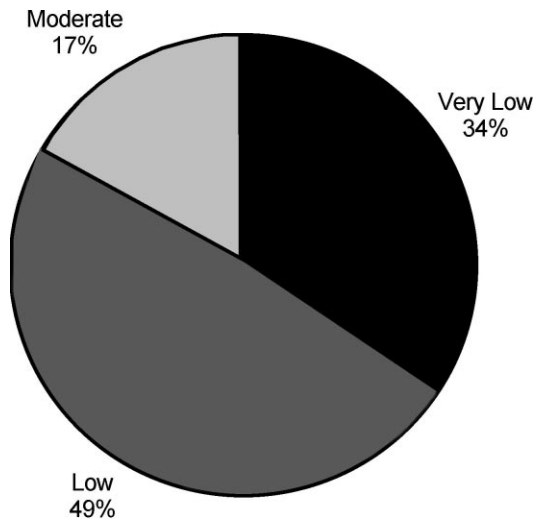


Fig. 5. Landscape health trends for three different management strategies on FS and BLM administered lands in the interior Columbia river basin. Alternative S1 represents current management policy while S2 and S3 show the effects of more active and focused restoration.

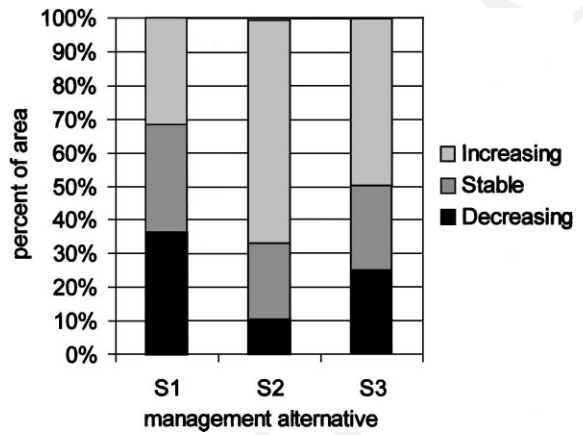


Fig. 6. Current conditions and future trends of landscape health in the interior Columbia river basin. Future trends are projections of three management alternatives over 100 years. Alternative S1 represents current management policy while S2 and S3 show the effects of more active and focused restoration.

Subwatersheds containing relatively high proportions of dry shrub and cold forest potential vegetation groups fare poorly under all management alternatives (Figs. 7–9). Several reasons contribute to the continuing decline in the health of subwatersheds with sub-

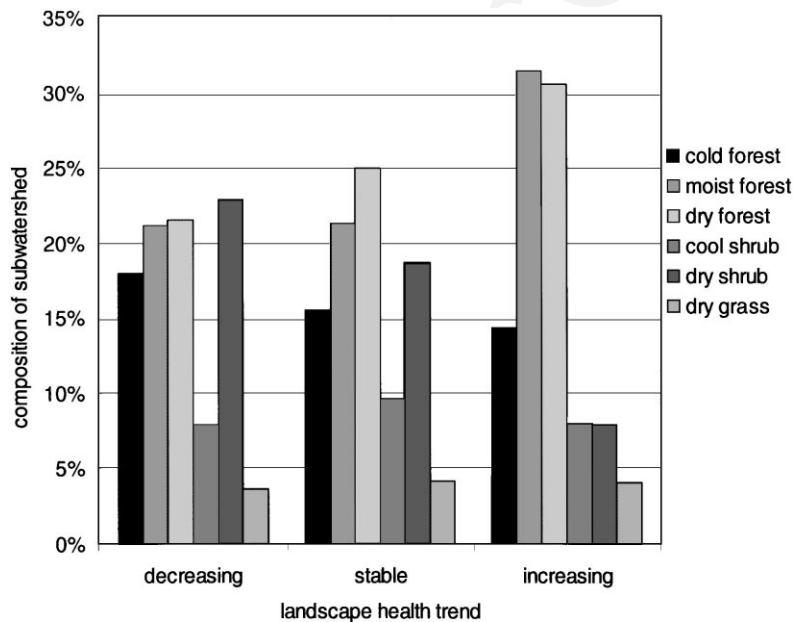


Fig. 7. Potential vegetation group composition of subwatersheds in decreasing, stable and increasing landscape health trends on FS and BLM administered lands in the interior Columbia river basin under management alternative S1.

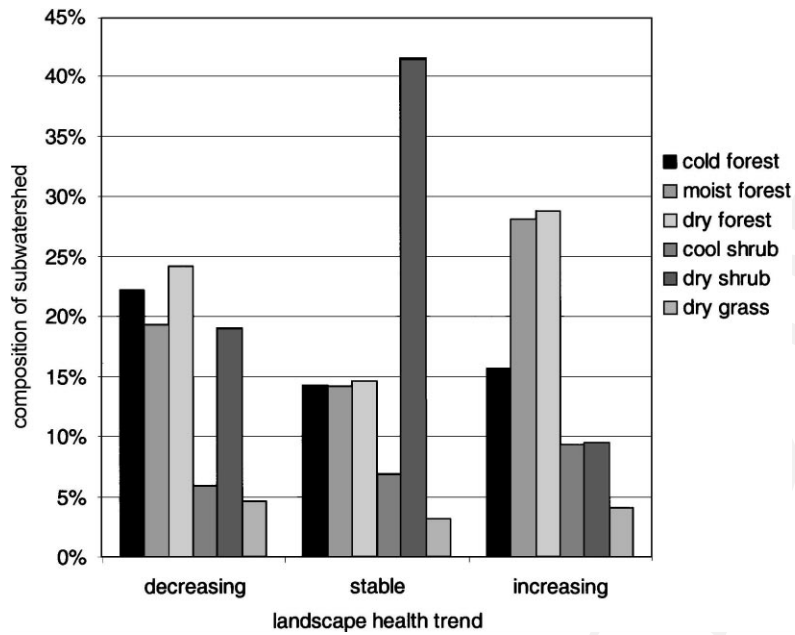


Fig. 8. Potential vegetation group composition of subwatersheds in decreasing, stable and increasing landscape health trends on FS and BLM administered lands in the interior Columbia river basin under management alternative S2.

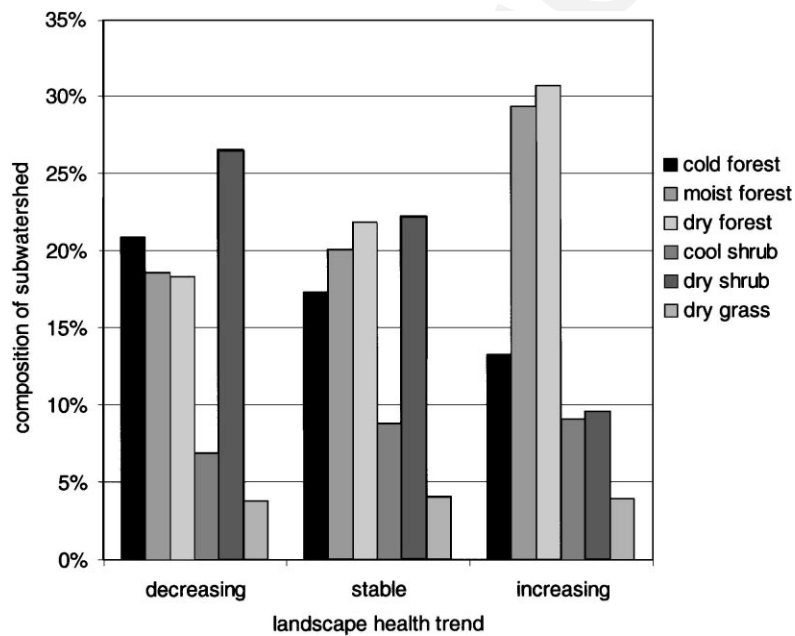


Fig. 9. Potential vegetation group composition of subwatersheds in decreasing, stable and increasing landscape health trends on FS and BLM administered lands in the interior Columbia river basin under management alternative S3.

stantial inclusions of dry shrublands. Many of these areas have been extensively grazed by livestock for decades. Grazing pressure changed the plant species composition by favoring less palatable species, reducing the cover of native plant species, allowing invasion by non-native plant species, and changing soil surface characteristics (Hann et al., 1997). In addition, altered fuel conditions due to changes in plant community composition and structure changed fire regimes from relatively infrequent, moderate intensity to more frequent events that kill most vegetation. This, in turn, allows increased invasion or dominance of non-native plants (Pellant, 1990). Recovery of soil characteristics may take several decades or longer, even if livestock grazing pressure is reduced and the dominance of non-native plants reversed. Vegetation and soil changes can be compounded by climate change (Tausch et al., 1993). In many cases, changes to soil and plant communities are of sufficient magnitude that sites can no longer recover historical vegetation communities within our modeling time frame (NRC, 1994; Tausch et al., 1993).

Continued declines in the health of subwatersheds with substantial inclusions of cold forest occur for several reasons (Figs. 7–9). Whitebark pine (*Pinus albicaulis* (Engelm.)), a historically important component of many cold, subalpine forests, is disappearing from many areas as a result of an introduced blister rust (*Cronartium ribicola*). Whitebark pine occupies an environmentally severe niche at upper elevational tree line where few other coniferous trees survive. It has important roles in the ecosystem that do not appear to be filled by alternative species. In addition, many cold forests are in wilderness or similar areas where fire suppression will continue. Over the long term, this results in a disruption of the normal disturbance regime and, due to changes in stand densities and fuels, insect and disease epidemics and intense wild-fires play an increased part in the disturbance regime. Since active forest management, other than use of wildland fire for resource benefit, is not allowed in many of these areas while fire suppression continues, disturbance regimes and their effects on forests increasingly depart from historical conditions.

Landscape health generally increases over the long-term in subwatersheds dominated by other forested potential vegetation groups under all three management alternatives (Figs. 7–9). Succession and stand

development generate trends toward historical conditions in moist forests. Currently, high levels of mid-seral forests will move into late seral condition, restoring historical amounts of late seral forests in many areas. However, late seral, single-story forests will not return to historical levels while late seral multi-story forests may exceed historical abundance. Late seral, single-layer forests generally require frequent underburning, which is a relatively costly restoration activity. Late seral, multi-layer forests, on the other hand, can continue to develop in the presence of fire suppression and more passive management. Restoration management and stand development produce similar trends, though not to the same extent, in dry forests. While succession and stand development improve conditions in moist forests, dry forests will require high levels of active restoration to reverse the effects of decades of timber harvest and fire suppression. Restoration management can generate relatively high levels of human use (Crone and Haynes, 2000),<sup>7</sup> though kinds of uses and values may change from commodity-oriented approaches, and improve landscape vegetation and disturbance conditions.

Landscape health in subwatersheds with large inclusions of the cool shrub potential vegetation group improve under alternatives S2 and S3, but remain stable or decline slightly under alternative S1 (Figs. 7–9). Cool shrub potential vegetation occurs in relatively moist environments and respond to restoration more quickly than dry shrub environments.

Dry grasslands are not abundant on FS or BLM administered lands in the Basin. Most dry grasslands in the Basin are at low elevation and in private or other ownership. Most have been converted to dry land agriculture or other uses. Landscape health remains relatively static over the long-term in subwatersheds containing substantial dry grass lands (Figs. 7–9). These areas respond slowly to restoration treatments. Dominance of non-native plants, changed disturbance regimes, altered soil conditions, and continuing live-

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<sup>7</sup> Crone, L.K., Haynes, R.W. 2000. Draft socioeconomic evaluation of the EIS alternatives. In: Science Advisory Group. Draft March 2000. Science Advisory Group Effects Analysis for the SDEIS Alternatives, p. 66. US Department of Agriculture, Forest Service, and US Department of the Interior, Bureau Land Management, Interior Columbia Basin Ecosystem Management Project, Boise, ID.

stock grazing pressure reduce and slow the effects of restoration efforts.

#### 4. Discussion

The first permanent Euro-American settlements mark the start of substantial and accelerated alterations to the vegetation and associated disturbance regimes in the Basin. Livestock grazing pressure, invasive non-native plant species, timber harvest, fire suppression, fire initiation (burning for increased forage production or to clear vegetation) all began to push plant communities, successional patterns and disturbance regimes in new directions. Some of these new trajectories coincided with, and were compounded by, climate change (Tausch et al., 1993).

The effects of fire suppression in forested landscapes illustrate the magnitude of change that has occurred. Humans naturally wish to prevent the destruction of timber resources, homes and other structures by wildfire. Consequently, wildfires have been actively suppressed for several decades. The changed role of wildfire produced substantial alterations in successional paths and disturbance timing, intensity and severity. These, in turn, altered the successional trajectory and subsequent composition and structure of plant communities across large areas. Fires have become less frequent and more intense in most forested landscapes. Wildfire suppression generated substantial changes in fuels across very large landscapes that, in turn, generates wildfires that are infrequent, intense, and resistant to control. Changes of this magnitude to vegetation, fuels, and disturbance behavior are difficult to stop or reverse.

Shrub steppes and grasslands have also undergone substantial changes in vegetation composition, structure, and disturbance. In this case, interwoven and related driving factors include a combination of livestock grazing pressure, non-native plant species invasion, and changes to fire regimes and climate change. Much literature and debate exist on the nature, extent and direction of change in these environments (NRC, 1994; Task Group on Unity in Concepts and Terminology, 1995; Tausch et al., 1993). The influences in the Basin seem to be: (1) livestock grazing pressure, especially in the decades around 1900 and extending to more recent times in some locales, that reduced the

vigor and competitiveness of native plant species and changed soil conditions, (2) non-native plant species (e.g., *Bromus tectorum* (L.)) invasion and dominance, (3) increased flammability of vegetation so fires burn more frequently and intensely, and (4) abundant ignition sources (lightning and human-related). As a result, native plant communities have been altered or replaced across extensive shrub steppe and grassland landscapes. A new dynamic, involving different plant communities and disturbance regimes, is emerging. Unfortunately, due to changes in soil properties, the persistence of non-native plants and climate change, restoration of the previously existing plant communities is often very difficult or impossible (Task Group on Unity in Concepts and Terminology, 1995; Tausch et al., 1993). Massive successional and disturbance momentum has been generated in shrub steppes and grasslands across the study area. Only focused, and often expensive, effort seems likely to restore native plant communities, where that is possible and where it is a management goal.

We assumed that the restoration treatments would require substantial management investment, based on costs of similar activities in the past. Our model projections included likely future funding levels and spatial priorities from the descriptions of the alternatives. All three alternatives generally improve landscape health at the broad scale. Much of the improvement reflects the recovery of historical proportions of late seral forest in moist potential vegetation groups. Stand growth and succession, coupled with declines in timber harvest levels, allows development of nearly historical levels of late seral forest under all three alternatives. In addition, road densities are either static or declining on most lands administered by the FS and BLM.

It appears that the proposed management strategies will slow or stop the decline in landscape health across the Basin. Alternatives S2 and S3 reverse declines and restore landscape health in focused restoration areas. Restoration strategies that include more intermediate-scale analysis seem to provide a better fit of field activities to both finer-scale context and larger-scale priorities. Resulting field activities provide higher levels of landscape health stabilization and recovery. Given the magnitude of changed conditions on FS or BLM administered lands in the analysis area, restoration funding is a key limiting factor. The funding

levels provided, which constrained our modeling, do not appear sufficient to stop or reverse the decline in landscape health in some areas.

## 5. Conclusions

Terrestrial plant communities and disturbances differ substantially from historical conditions on FS and BLM administered lands in the Basin. Native shrublands and herblands have declined substantially. Communities dominated by non-native plants have increased. Late seral forests, especially single-layer forests, have declined dramatically. Mid-seral forests are substantially more abundant now than they were in our projections of historical conditions. The alternative management strategies evaluated could stop or reverse those trends in some areas and in some vegetation types on FS and BLM administered lands in the Basin. However, likely funding levels for restoration activities and the existing successional and change momentum across millions of acres in the Basin will make substantial recovery very difficult.

Landscape health, according to our definition, is low to moderate across nearly all the public land managed by the FS and BLM in the Basin. While we defined human land uses as positive attributes of landscape health, past types and levels of use have caused extensive changes that run counter to the historical ecological conditions that we use in evaluating landscape health.

Landscape health is projected to improve under all of the three proposed strategies for managing FS and BLM administered lands in the Basin. All the alternative strategies propose lower levels of commodity uses (while retaining commodity production), increased levels of ecosystem protection and restoration, and an improved fit of management activities to inherent disturbance regimes and biophysical limitations. The result is a combination of relatively high levels of human activity and movement of vegetation and disturbance regimes toward historical conditions in many areas. This result is not universal. Health of some lands, particularly rangelands, will remain static or decline as a result of restricted restoration funding, invasion of exotic plant species, changed fire regimes, and continued high levels of livestock grazing.

Management strategies that propose substantial shifts toward restoration and focus restoration in priority areas produce substantially larger improvements in landscape health, particularly in focused restoration areas. Additionally, though the difference between alternatives S2 and S3 was not large, emphasis on intermediate landscape analysis to develop context for field projects seems likely to produce more cost-effective results than implementing field projects directly.

Our analysis depicts landscape health across large landscapes to evaluate the effects of different broad strategic management approaches. The scale and resolution of our analysis seems adequate for that purpose, representing a balance between the desire for high-resolution information and the available funding and data. We adopted a definition of landscape health based on interpretations of the legal bases for managing FS and BLM administered lands in the interior Columbia basin. The same definition might not be appropriate for other ownerships, management goals, geographic areas or spatial scales. Since our base vegetation data were 1 km<sup>2</sup>, landscape health conditions at finer scales were not evident. An analysis or inventory at finer scales might reveal smaller areas in good condition.

Many challenges arise in the interface between science and public policy. Despite several weaknesses that plague efforts like ours, including reliance on expert opinion, uncertainty in modeled conditions, lack of spatial contagion in models, and integration of many factors into indices we projected long-term ecological conditions across large landscapes in ways that allowed policy makers to evaluate potential effects of their decisions. The strength of this and similar bioregional assessments is that they do allow integrated, broad-scale, relatively quantitative examination of long-term ecological effects (Johnson et al., 1999).

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