Modeling responses of forest landscapes to alternative management scenarios in the East Fork Coquille watershed, Oregon

Landscape Scenario Analysis Project (LSAP)

Final Report

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by

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PREFACE

The information in this publication is preliminary in nature and has not been peer-reviewed. The project summary is provided with the understanding that the data are not guaranteed to be correct or complete. Users are cautioned to consider carefully the provisional nature of these data and information.

Introduction

Forest ecosystems in the Pacific Northwest represent a dynamic convergence of terrestrial and aquatic ecosystems within a shifting mosaic of natural and anthropogenic influences. Because forested landscapes are spatially complex and temporally variable, it is difficult to interpret scientific results and make management decisions based on site-specific analysis without considering the spatial and temporal context of potential future management activities and ecosystem patterns and processes, such as forest succession and landscape disturbance (Swanson and Sparks 1990, Swanson and Franklin 1992). Recognizing the need to understand pathways of forest succession under different management scenarios across a patchwork forest types (riparian and upslope), researchers and managers have begun to use spatially explicit tools for visualizing and understanding the impacts of human and natural disturbances on forest ecosystems at a landscape scale (Cissel et al. 1998, Cissel et al. 1999, Kurz et al. 2000, Bettinger 2001). Spatial modeling with alternative management scenarios can be an effective tool for understanding landscape dynamics and balancing multiple land uses (e.g., timber harvest, recreation, and aquatic conservation) in a complex matrix of public and private lands.

Federal resource managers in the Pacific Northwest have been increasingly driven to consider the influence of landscape pattern and structure in response to several trends of the last decade. Watershed analysis was mandated in the Northwest Forest Plan (USDA and USDI 1994) and completed on most watersheds in the first five years of the plan. While these analyses provide a useful context to establish watershed restoration priorities and conduct cumulative effects assessments, they generally stop short of assessing future landscape management options. Informal and formal consultation required under the Endangered Species Act for both terrestrial and aquatic species is now an ongoing part of resource management and is most effective where future landscape structure can be projected and communicated. Managers must anticipate and respond to new information generated through science, which has increasingly identified the importance of landscape processes (e.g., disturbance propagation, delivery of materials stored in terrestrial ecosystems to aquatic ecosystems, dispersal of organisms) to resource conditions and outputs of interest.

Landscape management scenarios provide a useful means to integrate science concepts with management objectives at the watershed scale, which is relevant to both managers and scientists (e.g., 5th-field hydrologic unit code [HUC]). Potential scenarios may be built on existing scientific and management information and thus provide a way to depict landscape change in response to management and disturbance (Swanson et al. 2003). These spatially explicit landscape models project alternative futures over space and time and provide a context for evaluating management options at multiple spatial and temporal scales (Kurz et al. 2000, Spies et al. 2002). One of the values of landscape modeling is that it can provide a vehicle for synthesizing scientific information collected among multiple disciplines. Biological data collected by ecologists can be combined with physical data on patterns of disturbance (e.g., timber harvest, fire, mass wasting) to develop and test hypotheses about processes of landscape change. Information on species response and wildlife habitat requirements can be incorporated directly into the spatial models to assess potential impacts of alternative management scenarios on sensitive species and biological communities (Liu et al. 1995). Specific models have been already been developed to evaluate species conservation in complex forest landscapes (Liu 1993). In a recent example of how landscape modeling can be used to integrate scientific research and forest management, McCune et al. (2003) used a spatially explicit model for forecasting the occurrence of lichen species under alternative forest management plans.

Project description

The primary goals of this project were to develop a landscape scenario modeling and analysis capability within the Cooperative Forest Ecosystem Research (CFER) program at Oregon State University and the Forest and Rangeland Ecosystem Science Center (FRESC), and to provide science support to initial BLM landscape scenario analyses. Landscape scenarios were developed in coordination with the BLM Coos Bay District, which is currently engaged in landscape analysis for an environmental assessment (EA) of activities designed to enhance late-successional reserves (LSR) in the Brummit Creek study area in East Fork Coquille watershed (Figure 1). The objectives of the project were to (1) facilitate integration and synthesis of CFER data, models, and expertise in a landscape context, (2) provide a vehicle for ongoing interaction with BLM districts regarding the implications of alternative landscape management approaches, and (3) explore the capability of landscape modeling for evaluating broad-scale impacts of management actions on forest ecosystems. Spatial and tabular data generated in the project will be used by the BLM Coos Bay District to evaluate the potential effects of wind disturbance, density management thinning, and other forest and riparian treatments on forest cover and structural characteristics. The models described in this report should be viewed as a first step towards evaluating potential impacts of various management scenarios and are intended to be a tool for visualizing landscape change and generating discussion on management options. In this sense, the models are not predictive of actual future conditions because they are dependent on assumptions specific to the goals of the project. It is expected that model development will proceed beyond the initial analyses presented in this report. Through continued cooperation among CFER and BLM ecologists and resource managers, the models will be modified iteratively and incrementally, with capabilities and improvements added over time.

Methods

Spatially explicit landscape modeling consists of four basic components: a geographic information system (GIS), stakeholder involvement (i.e., managers and scientists), alternative scenario analysis, and evaluation and monitoring (Theobald and Hobbs 2002). Links between scientists and managers in landscape scenario modeling ensure that information flows freely between all parties involved. Spatial modeling with a GIS is a key component in the system because it provides a visual, intuitive interface that makes it possible for scientists to (1) present different management options and (2) demonstrate how these scenarios play out in a dynamic landscape. The landscape modeling approach allows scientists and managers to provide feedback both in the development of alternative management scenarios and in the refinement of the spatial models.

Several landscape scenario models have been created for management application in Pacific Northwest forests. Two are available for general use and have been applied in several areas in Oregon: the Tool for Exploratory Landscape Scenario Analysis/Vegetation Dynamics Development Tool (TELSA/VDDT), and the Landscape Management System (LMS) (Kurz et al. 2000, Barrett 2001, McCarter 2001). They each have strengths and weaknesses. For example, LMS is a set of modeling tools that integrate landscape-level spatial information, stand-level inventory data, and distance-independent individual tree growth models to project changes through time across forested landscapes. This software offers a more sophisticated set of tools

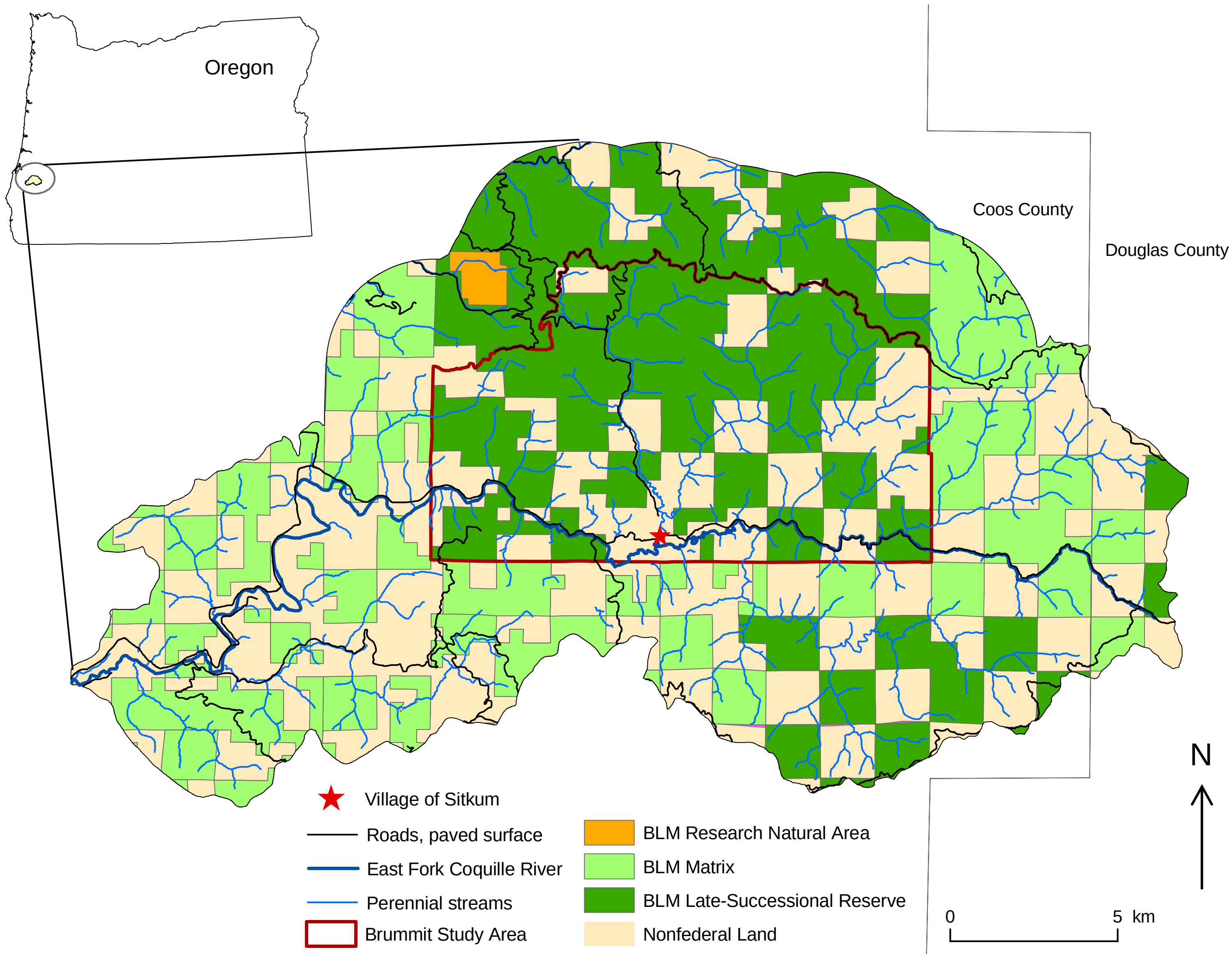

Figure 1. Land ownership patterns and spatial boundaries of the E.F. Coquille and Brummit study areas, Oregon.

for forest stand projection than TELSA/VDDT. However, it is not designed specifically for incorporating disturbance probabilities into landscape management scenarios and contains less flexibility to represent landscape management objectives and constraints.

We used TELSA/VDDT in this project because of its focus on landscape pattern, its ease of use and flexibility, and its greater capability to represent interactions of disturbance and management at landscape scales. At present, neither model contains adequate capability to represent linkages among terrestrial and aquatic ecosystems. These capabilities will have to be added over time. Several other landscape models exist, and we will continue to evaluate their capability and availability as the project develops. For example, the Coastal Landscape Analysis and Modeling Study (CLAMS) has conducted a spatially explicit analysis of forest and landscape dynamics in a large portion of the Oregon Coast Range (Spies et al. 2002). This approach to assessing forest ecosystem patterns and processes is effective for informing management decisions at the regional level. However, the spatial extent of CLAMS may be too large for addressing issues of forest management and habitat conservation at intermediate scales (e.g., 5th-field HUC) where management decisions are typically made. The tools provided in TELSA/VDDT are designed to address management questions at these intermediate scales, and thus they offer managers and scientists the opportunity to bridge the gap between regional landscape models and site-specific scientific research.

Models in TELSA/VDDT represent landscape management scenarios as combinations of stand types, successional pathways, management regimes, and disturbance regimes. Stands are represented as polygons in ArcView Version 3.x (Environmental Systems Research Institute [ESRI]), and pathways describing changes in stand type over time and in response to management and disturbance are defined for each stand type. The flexibility of TELSA/VDDT makes it possible to develop model structures suitable for different ecological settings and management applications. For example, the set of forest cover classes can be simple or complex depending on whether the emphasis is on modeling growth or community dynamics (Swanson et al. 2003, Reger et al. 2004). The TELSA/VDDT software package also contains numerous mechanisms to control management and disturbance at landscape scales based on mapped characteristics (e.g., fire regime, rain-on-snow zone, Northern spotted owl home range, aquatic large wood source area). Landscape scenarios can be represented at a very coarse resolution initially and then refined over time as skills and insight are acquired.

Study area

Modeling was conducted at two spatial scales in the East Fork Coquille study area located southeast of Coos Bay in the Oregon Coast Range (Figure 1). The larger of the two study areas, the E.F. Coquille, covers 42,591 ha and extends 3 km north of the actual E.F. Coquille watershed boundary. The additional area north of the E.F. Coquille watershed boundary was included to encompass wildlife habitat that occurred on both sides of the watershed divide. The smaller Brummit EA study area is nested within the E.F. Coquille boundary and has an area of 11,603 ha.

The E.F. Coquille study area ranges in elevation from sea level to 900 m and is located in the mid-coastal sedimentary subdivision (level- IV ecoregion) of the Coast Range ecoregion (level III) (Omernik 1987, Pater et al. 1998). This region of western Oregon is underlain by massive beds of siltstone and sandstone. The steep, dissected topography of the region is prone to mass movement and high fluvial erosion rates when vegetative cover is removed. Forest vegetation in the study area is a mix of two types: Douglas-fir (*Pseudotsuga menziesii*)/deciduous and Douglas-fir/western hemlock (*Tsuga heterophylla*) (Loy et al. 2001). The Douglas-fir/deciduous vegetation type occurs in drier and interior areas of the Coast Range and in the earlier successional stages leading to western hemlock dominance. Broadleaf species in this type include red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*) in wetter sites, and Oregon white oak (*Quercus garryana*), madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflora*), and Oregon myrtle (*Umbellularia californica*) on drier sites. The Douglas-fir/western hemlock vegetation type is composed primarily of Douglas-fir, with western hemlock becoming more dominant over time in undisturbed, moist sites. Broadleaf species, red alder and bigleaf maple, are common in riparian areas.

Land ownership in the E.F. Coquille study area is primarily BLM LSR (32%) and matrix land (25%) interspersed in a checkerboard pattern with nonfederal (42%) lands consisting mainly of privately owned industrial forest (Figure 1). The Brummit EA is composed of BLM LSR (61%) and privately owned industrial forest (39%).

Successional pathways

Forest vegetation cover types, structural stages, and successional pathways were derived from the literature and from field observations of existing vegetation in the E.F. Coquille study area. Cover types were identified based on the dominant overstory tree species, where dominance was defined by percent canopy cover. A secondary species was included in the cover type if it constituted greater than 20% of the total cover. Structural stages were based on local knowledge of existing vegetation in the study area (C. Sheridan and F. Price, BLM Coos Bay District, Oregon, unpublished data) and on literature for forests of the Pacific Northwest (Hemstrom and Logan 1986, Carey and Curtis 1996, Franklin et al. 2002). To represent existing forest vegetation as accurately as possible, 22 cover types and 29 structural stages were combined to create 56 state classes (i.e., unique cover type and structural stage combinations) (Tables 1 and 2). Nonforest state classes (shrub, agricultural, urban, water, and barren lands) were included in the model as static variables for map display only (i.e., no changes in size or cover class over time).

In TELSA/VDDT, successional pathways specify the natural progression of forest vegetation cover type/structural stage (state class) over time in the absence of natural disturbance (e.g., fire, wind, or landslides) and timber harvest. For the purposes of modeling, successional pathways were simplified by making assumptions about vegetation patterns specific to the E.F. Coquille study area. The pathways developed for the E.F. Coquille and Brummit EA study areas represent an extensive effort by BLM Coos Bay District forest ecologists to synthesize field observations and published literature on forest vegetation in the Pacific Northwest. Successional pathways employed in the model were categorized into six pathway types: (1) traditional, semi-open pathway (Carey and Curtis 1996, Franklin et al. 2002); (2) open conifer pathway (Poage and Tappeiner 2002); (3) open conifer with legacies (Carey and Curtis 1996, Poage and Tappeiner 2002); (4) dense pathway (plantations); (5) red alder/conifer pathway (Hemstrom and Logan 1986, Deal and Wipfli 2004); and (6) western hemlock pathway (Hemstrom and Logan 1986). Transitions from one state class to another occurred in a linear fashion with the passage of time. Detailed information on the successional pathways used in TELSA/VDDT is available from the authors on request.

Spatial data layers

Spatial data with forest attributes (state class, stand age, and years in state class) are required to model spatial patterns of forest vegetation change in TELSA. Multiple spatial data products were used to create a map of landscape units (a polygon shape file in ArcView) for the

Table 1. Conifer cover types and structural stages used in modeling forest vegetation in the E.F. Coquille study area. State class is a numerical code indicating the structural stage (first two digits) and cover type (last four digits).

State class	Cover type	Structural stage
012004	Douglas-fir	Ecosystem initiation [1]
012007	Douglas-fir/red alder	Ecosystem initiation [1]
022016	Douglas-fir/shrub	Ecosystem initiation - open
032004	Douglas-fir	Ecosystem initiation - legacies
042004	Douglas-fir	Ecosystem initiation - late
052010	Douglas-fir/western hemlock	Competitive exclusion [1]
062013	Douglas-fir/mixed conifer	Competitive exclusion - late
062059	Western hemlock/mixed conifer	Competitive exclusion - late
072059	Western hemlock/mixed conifer	Competitive exclusion - legacies
082010	Douglas-fir/western hemlock	Understory reinitiation [1]
082013	Douglas-fir/mixed conifer	Understory reinitiation [1]
092010	Douglas-fir/western hemlock	Understory reinitiation - late
092058	Western hemlock/western redcedar	Understory reinitiation - late
112060	Western hemlock/mixed broadleaf	Understory reinitiation - open
122010	Douglas-fir/western hemlock	Developed understory [1]
132010	Douglas-fir/western hemlock	Developed understory - late
142013	Douglas-fir/mixed conifer	Botanically diverse [1]
152013	Douglas-fir/mixed conifer	Vertical diversification
152014	Douglas-fir/mixed broadleaf	Vertical diversification
152052	Western hemlock	Vertical diversification
162013	Douglas-fir/mixed conifer	Fully functional
172010	Douglas-fir/western hemlock	Biomass accumulation - open
182010	Douglas-fir/western hemlock	Biomass accumulation - closed
192013	Douglas-fir/mixed conifer	Biomass accumulation - legacies
202007	Douglas-fir/red alder	Canopy closure
202010	Douglas-fir/western hemlock	Canopy closure
232007	Douglas-fir/red alder	Maturation
232057	Western hemlock/salmonberry	Maturation
242014	Douglas-fir/mixed broadleaf	Horizontal diversification
252052	Western hemlock	Pioneer cohort loss
472004	Douglas-fir	Ecosystem initiation - overstocked
472059	Western hemlock/mixed conifer	Ecosystem initiation - overstocked
482004	Douglas-fir	Canopy closure - overstocked
482059	Western hemlock/mixed conifer	Canopy closure - overstocked
492013	Douglas-fir/mixed conifer	Competitive exclusion - overstocked
492059	Western hemlock/mixed conifer	Competitive exclusion - overstocked

[1] See Carey and Curtis (1996).

Table 2. Broadleaf and nonforest cover types and structural stages used in modeling forest vegetation in the E.F. Coquille study area. State class is a numerical code indicating the structural stage (first two digits) and cover type (last four digits).

State class	Cover type	Structural stage
	Broadleaf	
11056	Salmonberry	Ecosystem initiation [2]
12044	Red alder/conifer ≤ 20 TPA[1]	Ecosystem initiation [2]
12045	Red alder/conifer >20 TPA	Ecosystem initiation [2]
12050	Red alder/Oregon myrtle/bigleaf maple	Ecosystem initiation [2]
52044	Red alder/conifer ≤ 20 TPA	Competitive exclusion [2]
52045	Red alder/conifer >20 TPA	Competitive exclusion [2]
52050	Red alder/Oregon myrtle/bigleaf maple	Competitive exclusion [2]
62051	Red alder/mixed broadleaf	Competitive exclusion - late
82044	Red alder/conifer ≤ 20 TPA	Understory reinitiation [2]
82045	Red alder/conifer >20 TPA	Understory reinitiation [2]
182045	Red alder/conifer >20 TPA	Biomass accumulation - closed
182046	Red alder/salmonberry	Biomass accumulation - closed
202044	Red alder/conifer ≤ 20 TPA	Canopy closure
202045	Red alder/conifer >20 TPA	Canopy closure
232046	Red alder/salmonberry	Maturation
	Nonforest	
11065	Dry shrub	Ecosystem initiation [2]
434513	Pasture/hay land	Agricultural
444507	Urban land	Urban
454501	Water	Water
464049	Rock/barren lands	Rock

[1] Trees per acre (TPA).

[2] See Carey and Curtis (1996).

E.F. Coquille study area. Information on forest cover type, stand age, and structural characteristics was obtained from the BLM Forest Operations Inventory (FOI) database. Because these data were only available for BLM lands, forest cover type data for nonfederal lands were evaluated from four different Landsat Thematic Mapper (TM) image products: (1) the Interagency Vegetation Mapping Project (IVMP) (1996); (2) the Western Oregon Digital Imagery Project (WODIP) (1993); (3) the Coast Landscape Modeling Study (CLAMS) (1996); (4) and the Stand Replacement Disturbance Mapping Project (SRD) (1972-2002) (Cohen et al. 2002). Data on stand age for nonfederal lands were interpreted from aerial photographs and mapped in a GIS by the BLM Coos Bay District.

To determine the most appropriate imagery to use in creating a forest cover map for nonfederal lands in the study area, vegetation classifications from IVMP, WODIP, and CLAMS imagery were compared to vegetation data in BLM FOI polygons. The strengths and weaknesses of the various image products varied depending on the purpose for which they were developed. Because the cover types we used in TELSA/VDDT were based on dominant canopy cover (Tables 1 and 2), the imagery was used to determine only the dominant vegetation signature. This information was then compared to the vegetation data derived from the BLM FOI polygons. Although the vegetation classifications of IVMP, WODIP, and CLAMS were not developed to provide detailed information at a local scale, all three image types performed remarkably well at detecting the amount of conifer-dominant cover.

The IVMP was very good at quantifying conifer cover but not at separating broadleaf cover from recently cut areas. Ninety percent of the conifer-dominant area in FOI was classified as greater than 50% conifer cover by the IVMP, but only 23% of the broadleaf-dominant area in FOI was classified as greater than 50% broadleaf cover. The low classification accuracy of the IVMP for broadleaf cover was related to the way the IVMP evaluated recently cut areas. For example, 25% of the area (on BLM land) classified by the IVMP as greater than 50% broadleaf cover was recently cut (birth date 1986-1996).

The WODIP imagery was good at quantifying conifer cover, adequate at quantifying broadleaf cover, and very good at separating broadleaf cover from recently cut areas. Seventy-three percent of the conifer-dominant area in FOI was classified as conifer by WODIP, and 42% of the broadleaf-dominant area in FOI was classified as broadleaf. A particular strength of WODIP data was that it generally did not classify recently cut areas as broadleaf. Only 7% of the area (on BLM land) classified by WODIP as broadleaf was recently cut. This was important for modeling in TELSA/VDDT because broadleaf-dominant cover types had very different pathways than recently cut areas, which were typically managed for conifer production.

Vegetation classes in CLAMS imagery were very different from IVMP and WODIP. The CLAMS imagery was developed using the gradient-nearest-neighbor approach (Ohmann and Gregory 2002) and probably represented vegetative conditions the most accurately of the three image products. However, it was difficult to compare CLAMS to the other imagery because CLAMS data provided much more information on mixed cover types (conifer/broadleaf). Classification accuracies of CLAMS for conifer and broadleaf cover were 64 and 30%, respectively. The classification accuracy of CLAMS for conifer cover was low compared to IVMP and WODIP. Moreover, CLAMS broadleaf classification accuracy was only slightly better than IVMP and not any better than WODIP. However, after considering the high percentage of forest cover classified by CLAMS as mixed (conifer/broadleaf), we determined that CLAMS most likely provided the most accurate information on forest cover type. In addition, the CLAMS imagery was also good at separating broadleaf-dominant cover from recently cut areas. Only 10% of the stand area (on BLM land) classified by CLAMS as broadleaf was recently cut (birth date 1986-1996).

As a result of these comparisons, we concluded that CLAMS provided the most useful representation of forest cover type on private lands. The WODIP imagery also provided very good information on forest vegetation and has the added advantage of being available outside of the CLAMS study area, which is limited to the central and northern portion of the Coast Range. However, the statistical rigor of the vegetation classification method (Ohmann and Gregory 2002) and the more recent image acquisition date of the CLAMS imagery (1996 as opposed to 1993 for WODIP) made it preferable for modeling vegetation in the E.F. Coquille study area.

The final steps in building a spatial data layer of forest cover type involved updating the FOI stand ages with the SRD imagery and developing crosswalks from the FOI polygons and the CLAMS imagery to the state classes in Tables 1 and 2. The SRD imagery provided information on stand replacement disturbance from clearcuts and fire during a 30-year period (1972-2002). No significant fires had occurred in the study areas, so all stand replacement disturbances were from clearcuts. Landscape units (polygons) that did not have young stand ages in the FOI but were depicted as clearcuts in the SRD were updated based on the year of disturbance specified in the imagery.

Crosswalk development from FOI to cover types and structural stages was based on “ES” and “LM” codes. Information in the “ES” field included cover condition, overstory dominant and secondary species, size, stocking class, and birth date. Stand density was determined from the “LM” field, where values 1, 2, and 3 indicated open, middle, and dense structural pathways, respectively. Over 600 “ES” codes were condensed into the state classes listed in Tables 1 and 2. In assigning state classes (cover type and structural stage) to FOI polygons, we identified two limitations of the FOI data: (1) vegetative information was biased towards merchantable trees, and (2) information on the presence of secondary tree species was inconsistent. However, these limitations were not significant in the broader scope of the modeling effort which was to evaluate general landscape patterns rather than predict timber production.

Scenario development

Landscape management scenarios were developed through discussions between CFER and BLM landscape ecologists, forest ecologists, and resource managers. The first landscape model encompassed the entire E.F. Coquille study area and evaluated three different management scenarios: (1) succession only (no management actions; provided a basis for comparison with subsequent scenarios), (2) management similar to the Northwest Forest Plan (NWFP) with density management thinning and hardwood conversion on LSR stands 25-50 years of age, and 60-year regeneration harvest rotations with full riparian reserves on BLM matrix lands, and (3) management roughly patterned after natural disturbance by fire (landscape dynamics) with a 300-year rotation on north-facing slopes, 150-year rotation on south-facing slopes (both with 15-20% retention of live trees), and reduced (33 m) riparian reserves (Table 3). In all three scenarios, timber harvest on private lands was modeled on 40-year rotations with a minimum age of 35 years at first cut. These three scenarios provided an opportunity to evaluate broad-scale patterns of forest change in response to management approaches.

The second landscape model focused more on the specific management needs of the BLM Coos Bay District to develop an EA in the Brummit study area, which is currently managed by the BLM for late-successional forest characteristics. The goals of this model were to evaluate the effectiveness of density management and hardwood conversion prescriptions for creating late-successional forest structure and to examine potential spatial and temporal interactions of wind disturbance with various thinning activities. Detailed descriptions of the eight different Brummit scenarios are provided in Table 3. As in the E.F. Coquille model, the succession-only scenario provided a basis against which various management options could be compared.

Various management types and one type of natural disturbance (wind) are listed in Table 4. Thinning prescriptions were complex and case specific in the Brummit scenarios because they reflect actual management actions considered by the BLM Coos Bay District. The majority of the 20 management types listed in Table 4 were applied in the Brummit scenarios, whereas the E.F. Coquille scenarios were relatively simple (codes 1002, 1060, 1009, and 1017). Wind damage that occurred as a result of the ice storm during winter 2004 provided the impetus to incorporate natural disturbance patterns in the Brummit model. In the scenarios with wind (see Table 3), ten percent of the study area experienced wind disturbance (heavy wind disturbance; code 3530) over the 100-year modeling horizon, in which 90% of the disturbance events were 10-100 ha in size, and 10% were 100-1000 ha in size. Wind was used in a limited number of scenarios (Brummit study area only) because initial model runs indicated that wind had a visual impact equaling the effects of different management scenarios, which confounded the primary goal of seeing differences among management practices.

Other natural disturbances, including insect mortality, wildfire, and flooding, were also considered for modeling. However, modeling insect mortality required fine-scale disturbance data and would have been difficult to model over large areas. Naturally-occurring wildfire is historically rare in the E.F. Coquille watershed and therefore was not included in the models. Flooding is known to have significant local impacts in riparian forests of the Coast Range, and we initially attempted to model its effects in the E.F. Coquille study area. However, the high density of narrow flood-prone areas along stream corridors in the study area exceeded the processing capability of TELSA using the available computer hardware.

Spatially explicit landscape modeling

The spatial component of landscape modeling occurred in TELSA, which is a software program that links ArcView maps of forest vegetation characteristics and management areas(planning zones and withdrawn areas) with successional pathway information in a relational

Table 3. Alternative landscape management scenarios for the E.F. Coquille and Brummit Environmental Assessment (EA) study areas in the BLM Coos Bay District, Oregon.

Scenario	Natural disturbance	Management
E.F. Coquille		
1. Succession (no action)	None	No action on BLM land; clearcut private lands with 40-year rotation; 35-year minimum age at first cut; harvest on private lands same in all scenarios.
2. Less intensive (NWFP) [1]	None	Density management (DMT) and hardwood conversion in all 25-50-year-old stands in late-successional reserves (LSR); 60-year rotation on BLM matrix lands; full riparian reserves; no management on Research Natural Areas.
3. Landscape dynamics	None	Different rotation lengths based on slope aspect (i.e., presumed historical fire frequency): 300 years (north-facing) and 150 years (south-facing); BLM lands (LSR and matrix) clearcut with 15-20% overstory retention; private lands managed with traditional clearcut.
Brummit EA		
1. Succession (no action)	None	No action on BLM land; clearcut private lands with 40-year rotation; 35-year minimum age at first cut; harvest on private lands same in all scenarios
2. More intensive (preferred)	None	DMT and hardwood conversion in *all* EA units (individual prescriptions); thinning in first- and second-order riparian reserves; management on stands only up to 80 years of age.
2a. Wind #1	Wind	Same as scenario 2 but with wind and delayed DMT. [2]
2b. Wind #2	Wind	Same as scenario 2 but with wind and no delayed DMT.
2c. Delayed DMT	None	Same as scenario 2 but with delayed DMT and no wind.
3. Less intensive	None	Same as scenario 2 but only has DMT and hardwood conversion in *some* EA units (individual prescriptions), and includes a no-thinning zone (red alder/conifer >20 TPA cover type and/or stands greater than or equal to 60 years of age).
3a. Full riparian reserves	None	Same as scenario 3 but includes full riparian reserve buffers (i.e., no thinning in first- and second-order riparian reserves).
4. Full DMT	None	Density management thinning and hardwood conversion on all eligible BLM land, including riparian reserves (EA units not considered).

[1] Scenario similar to Northwest Forest Plan management.
[2] Delayed DMT is a management type in which all non-EA units become eligible for thinning after the model has run for 10 years.

Table 4. Management types and natural disturbances used in modeling alternative landscape management scenarios in the E.F. Coquille study area.

Code	Name	Description
1002	CC_Prep	Clearcut (traditional clearcut, with site preparation, and planting Douglas-fir at high densities)
1003	CC_RET_GT	Clearcut (green-tree retention w/o legacy structure) [1]
1005	CC_RET_GT+Snags+DW	NWFP clearcut (green-tree retention with snags and downed wood)
1009	CC_PLNT_Minors	NWFP clearcut of stands without legacy structures
1017	CC_HW_DMT	Clearcut of hardwoods, standard thinning of remaining conifers
1018	CC_N_15-20%RET	Clearcut with 15-20% retention of green trees (Landscape dynamics scenario - northerly aspect)
1019	CC_S_15-20%RET	Clearcut with 15-20% retention of green trees (Landscape dynamics scenario - southerly aspect)
1023	PCT_126-150tpa	Precommercial thinning - standard (retaining 126-150 trees/acre)
1031	PCT_VarTPA_Low	Precommercial thinning - LSR (variable retention with low relative density)
1058	DMT_Light	Density management thinning (light)
1060	DMT_Hvy	Density management thinning (heavy)
1063	GAPcreationLight	Gap creation (light)
1064	GAPcreationHvy	Gap creation (heavy)
1068	VARthinLowLegLow	Variable thinning (retaining low trees/acre and low-volume legacy structure)
1069	VARthinLowLegHigh	Variable thinning (retaining low trees/acre and high-volume legacy structure)
1072	VARthinHighLegLow	Variable thinning (retaining high trees/acre and low-volume legacy structure)
1074	DTR_DMT	Dominant tree retention, density management thinning
1075	DTR_DMT_LEG	Dominant tree retention, density management thinning with legacies
1090	WL_Presc1	Wildlife prescription 1 (small-scale manipulations in young-mature stands, e.g., snag creation, single-tree buffering)
1093	WL_Presc4	Wildlife prescription 4 (small-scale gap creation/manipulation in older stands)
3530	WindDisturbHvy	Wind disturbance (heavy)

[1] Legacy structure includes snags and downed wood.

database in Microsoft Access. Input maps in the Brummit and E.F. Coquille models included withdrawn areas (nonforest, protected areas for wildlife and research, and riparian buffers), and planning zones (land ownership boundaries, management areas such as BLM matrix and LSR, and fire-prone areas on south-facing slopes). The spatial module in TELSA used Avenue scripts in ArcView to carve the landscape into polygons along all boundaries of the input maps. The landscape was then tessellated into smaller irregularly shaped polygons that determine the spatial grain (approximately nine ha) at which natural disturbances occur across the landscape.

The models were run on a personal computer with Pentium 4 processor (3.2 GHz) with one GB of RAM. Because the number of polygons was large (particularly for the E.F. Coquille study area) and the models were run with annual time steps for durations of 100-200 years, a computer with a fast processor reduced the amount of time required to generate output to less than one hour per run. Output stand ages were grouped in categories relevant to BLM managers (0-20, 20-40, 40-80, 80-200, and 200+ years). Spatial and tabular data were displayed in classes indicating cover type (conifer, broadleaf, and nonforest) and structural stage: early (ecosystem initiation, competitive exclusion, canopy closure, and biomass accumulation); mid (understory reinitiation, developed understory, botanically diverse, and maturation); and late (vertical diversification, fully functional, horizontal diversification, and pioneer cohort loss).

Results

Maps generated by the models were useful for visualizing the effects of natural and anthropogenic disturbances on forest stand structure and for generating discussion among scientists and managers regarding the implications of management actions. Patterns resulting from the three alternative landscape management scenarios in the E.F. Coquille model showed that a timber harvest regime patterned after potential natural disturbances (landscape dynamics scenario) created a more patchy landscape with smaller areas of late-successional forest than the NWFP scenario (Figure 2). A key difference between the two scenarios was the distribution and extent of mid-successional forest on BLM matrix lands. The overall “darker” impression of the NWFP scenario derived from the extensive late-successional forest cover within the Brummit study area. In contrast, the landscape dynamics scenario resulted in a more balanced distribution of mid- and late-successional forest within and outside the LSR. The succession-only scenario yielded the greatest amount of mid- and late-successional forest after 200 years. A comparison of temporal trends in forest characteristics by scenario revealed that although the NWFP initially developed more mid- and late-successional forest after 100 years, the landscape dynamics scenario eventually surpassed the NWFP after 200 years (Figure 3).

In the Brummit study area, the more intensive scenario generated forest patterns that were not noticeably different at a coarse scale from the succession-only scenario (Figures 4-6). Even the more dramatic effects of wind and delayed density management thinning (DMT) versus full DMT were difficult to detect when they were compared to forest patterns resulting from the succession-only scenario. Thus, the effects of various thinning approaches had a limited effect on the visual appearance of the landscape in the Brummit study area, particularly when management was limited to only the Brummit EA harvest units, which made up only 10% of the total land area. However, closer examination of temporal trends in stand composition and structure revealed that the proposed management actions of the more intensive scenario resulted in faster transition rates to mid- and late-successional stages than the succession-only scenario, particularly after 40 to 80 years (Figure 7). The fastest transition to mid- and late-successional forest structure occurred under the full DMT, wind #1 (wind and delayed DMT), and delayed DMT scenarios, with the fastest rate of change occurring between 40 and 80 years (Figures 7 and 8).

Discussion

Spatially explicit landscape modeling provided a means to evaluate what landscapes may look like under different natural and anthropogenic disturbance regimes. The information generated by the models was useful for visualizing the general direction of landscape change in response to management actions and for promoting discussion among scientists and resource managers. Maps depicting various scenario outcomes were helpful for comparing alternative management scenarios, but the conditions of the scenarios should be considered carefully before generalizations can be made about management actions. For example, direct comparison of the NWFP and landscape dynamics scenarios in the E.F. Coquille study area was complicated by the different proportions of LSR and matrix lands in the two scenarios. The NWFP scenario differentiated between BLM LSR and matrix lands, whereas the landscape dynamics scenarios did not. Thus, the spatial distribution of forest cover types after 200 years of management (Figure 2) was expected to be quite different under the two scenarios, given the pattern of LSR

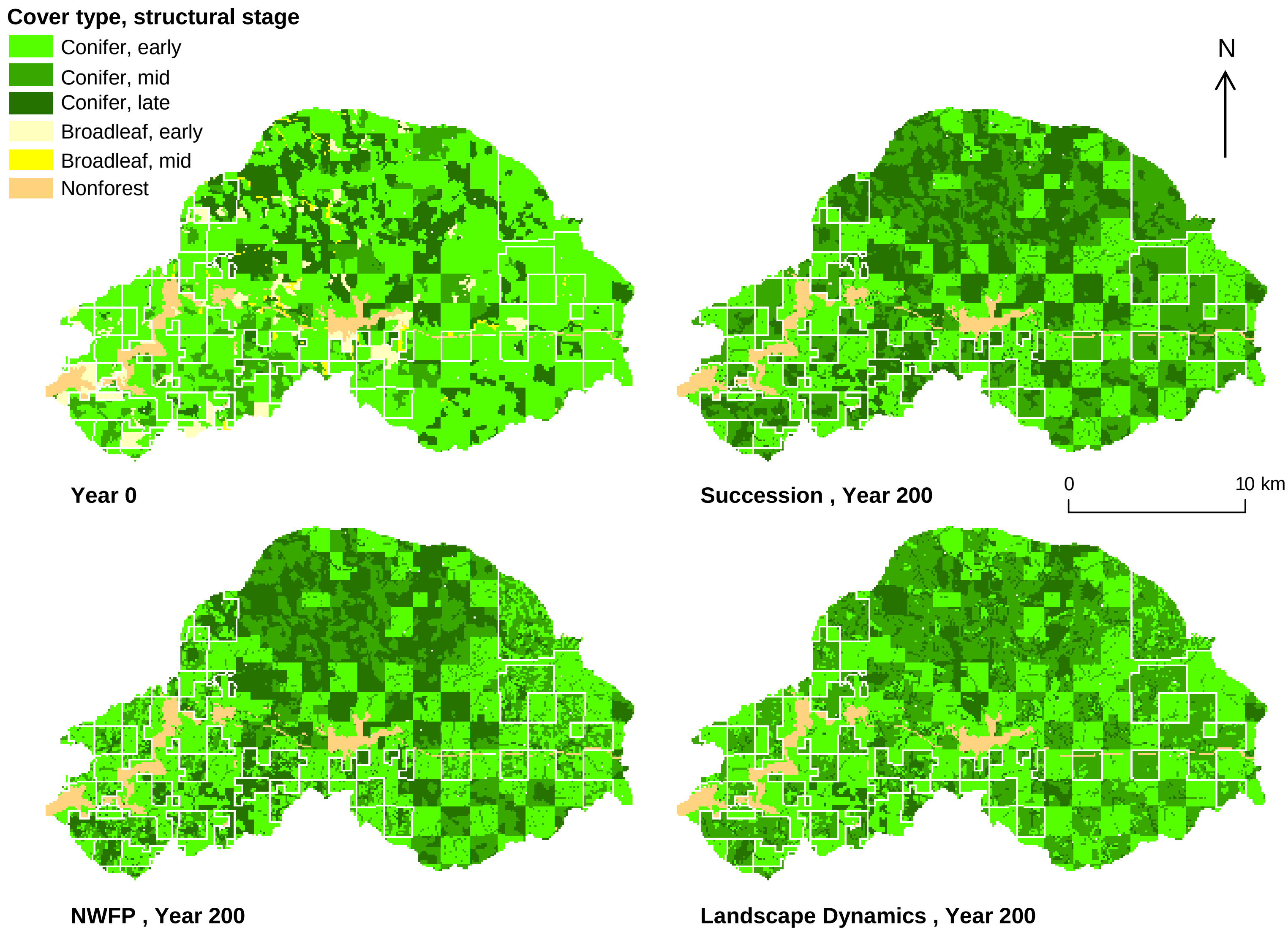

Figure 2. Alternative landscape management scenarios and initial forest vegetation conditions (year 0) in the E.F. Coquille study area (see Table 3 for scenario descriptions). The scenarios simulate natural disturbance and timber harvest over a 200-year time period. White outlines indicate BLM matrix land boundaries.

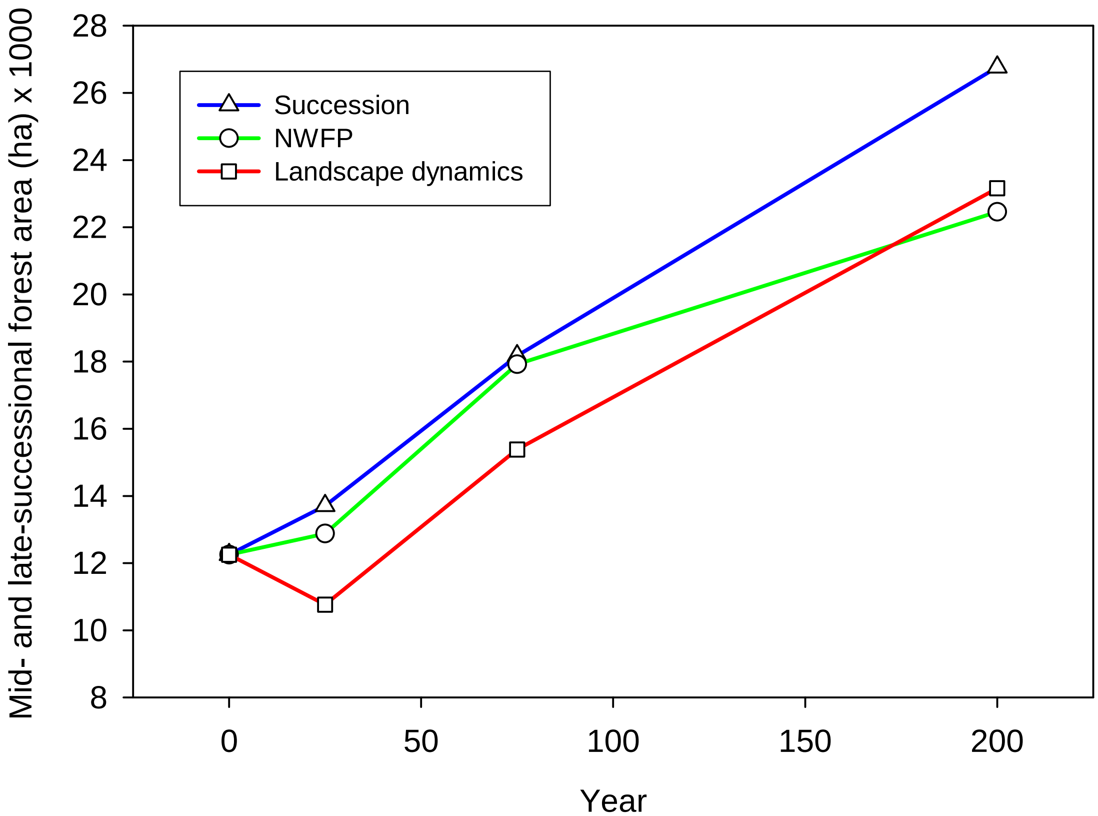

Figure 3. Temporal trends and transition rates to mid- and late-successional stages under different landscape management scenarios in the E.F. Coquille study area (see Table 3 for scenario descriptions).

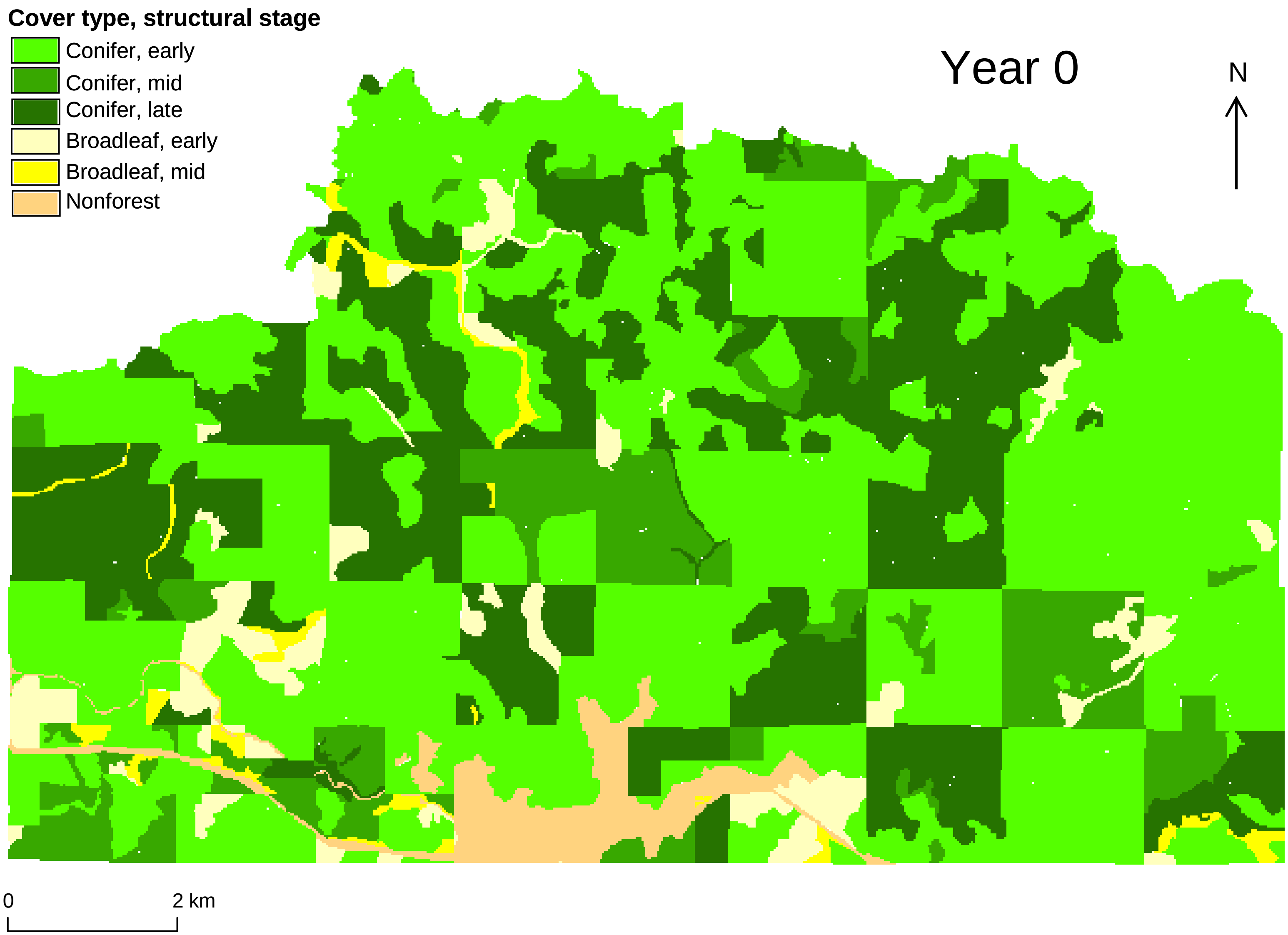

Figure 4. Initial forest vegetation conditions in the Brummit study area (year 0).

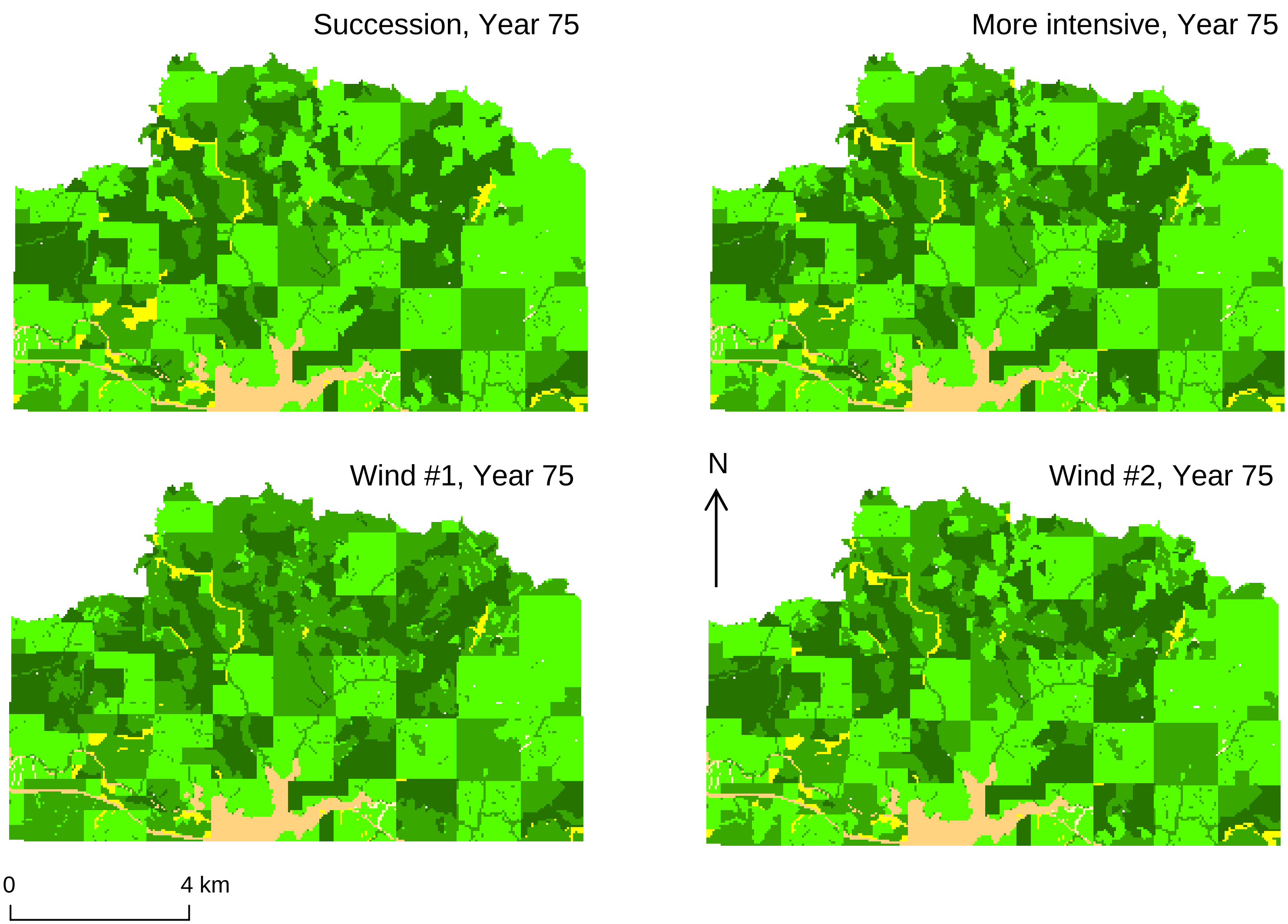

Figure 5. Alternative landscape management scenarios in the Brummit study area (see Table 3 for scenario descriptions). The scenarios simulate natural disturbance and timber harvest over a 100-year time period.

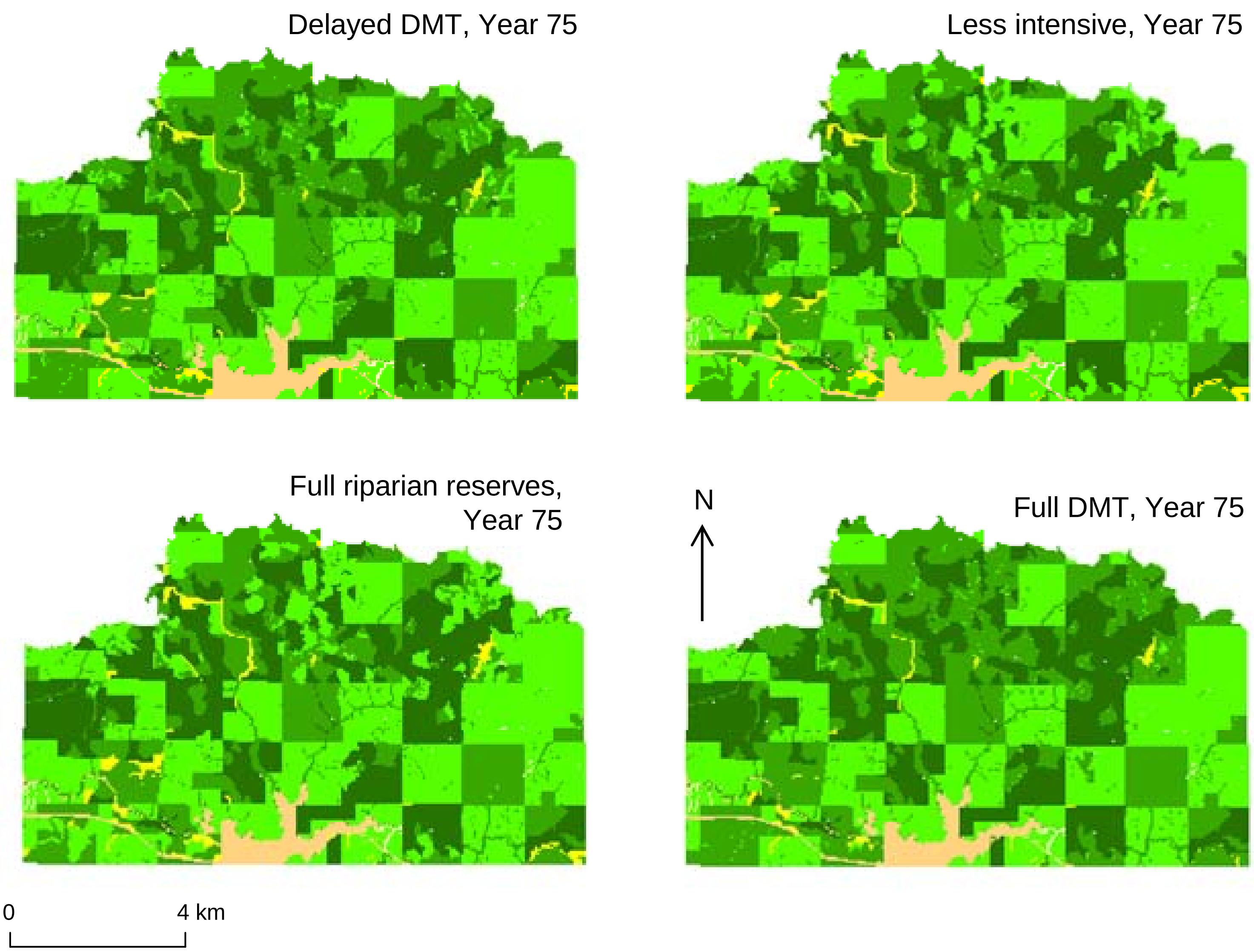

Figure 6. Additional alternative landscape management scenarios in the Brummit study area (see Table 3 for scenario descriptions). The scenarios simulate natural disturbance and timber harvest over a 100-year time period.

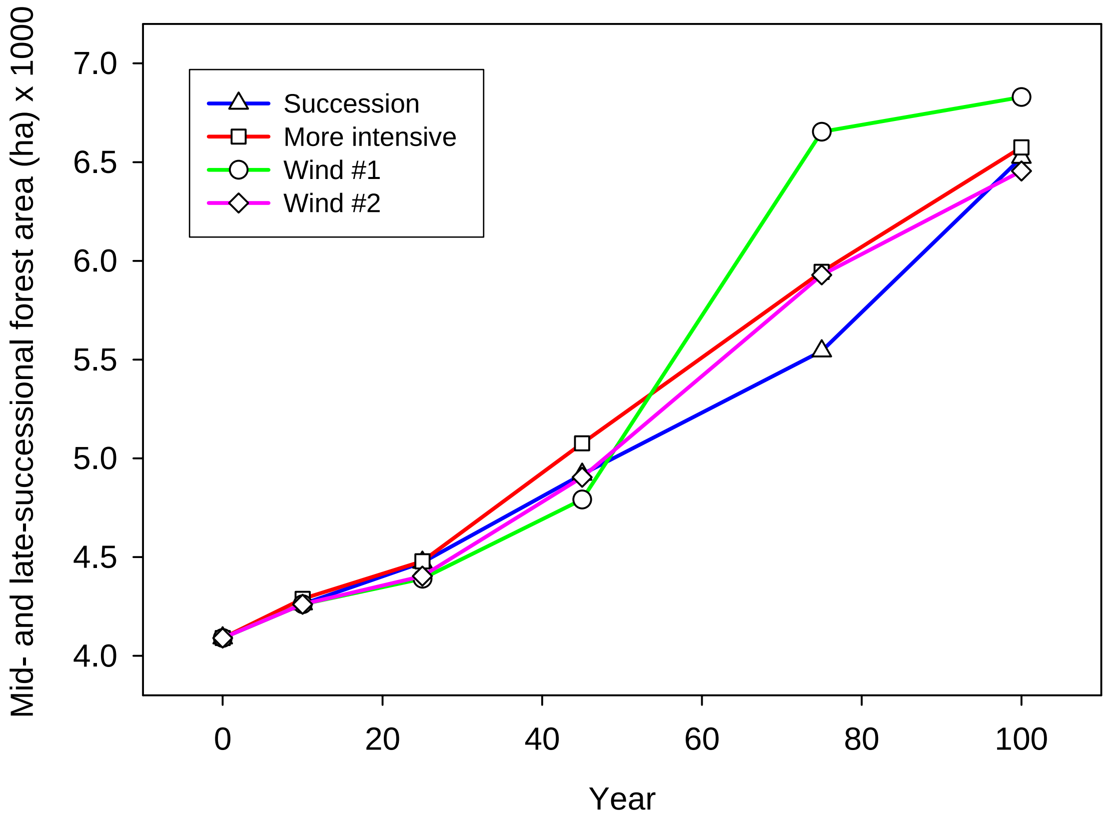

Figure 7. Temporal trends and transition rates to mid- and late-successional stages under landscape management scenarios 1-2b in the Brummit study area (see Table 3 for scenario descriptions).

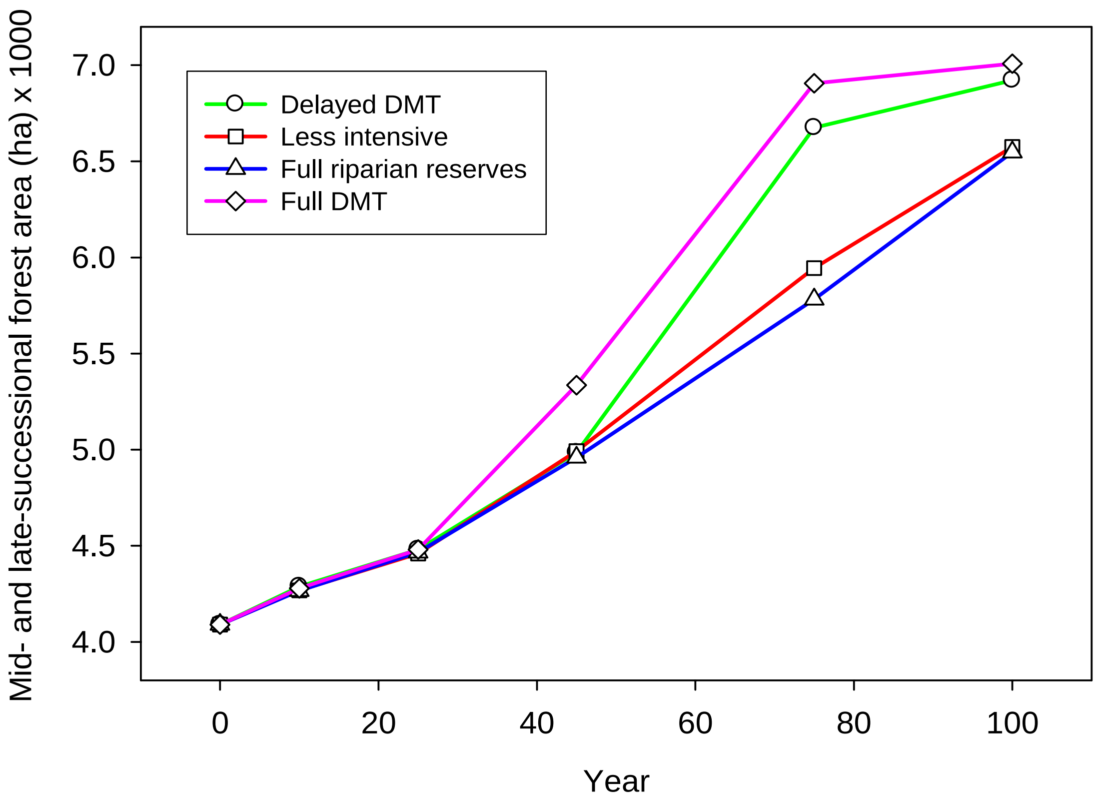

Figure 8. Temporal trends and transition rates to mid- and late-successional stages under landscape management scenarios 2c-4 in the Brummit study area (see Table 3 for scenario descriptions).

and matrix lands in the study area (Figure 1). Underlying model assumptions and patterns of land ownership need to be taken into account when comparing the results of different landscape management scenarios.

Landscape modeling with TELSA/VDDT provided a context for creative thinking and problem solving and may be an effective tool for the upcoming BLM resource management plan (RMP) revisions for western Oregon and Washington. The analyses conducted in this project were structured in part as a pilot effort to gauge the usefulness of landscape scenario models to (1) evaluate management strategies for potential use in RMP alternatives, and (2) evaluate data and tools that could be used to assess RMP alternatives. The RMP revisions will examine a range of alternatives that respond to management and public objectives and issues. Much new science has been conducted in the 10 years since the Forest Ecosystem Management Team (FEMAT), and new ideas for landscape management have been developed. Thus, there is a need to think creatively about potential landscape management approaches in the context of mixed-ownership watersheds typical of BLM-managed lands. A landscape scenario assessment model provides a means to visualize and communicate potential landscape and habitat patterns over space and time, and provides data on landscape conditions to drive resource assessments. Fifth-field watersheds are a useful scale to develop and evaluate landscape management strategies because they are large enough to assess habitats, species and watershed processes (e.g., cumulative watershed effects). These watersheds are also small enough to work with the highest resolution data available and maintain the spatial fidelity of the data. Initial modeling efforts could start with a fifth- or sixth-field watershed so that the data and tools could be developed and evaluated more easily, then later expanded to a larger watershed.

Much has also been learned about species and habitat needs, watershed processes, silviculture and other resources since the last round of RMP revisions. Methods for evaluation of resource effects produced by each alternative will have to be developed for the RMP revisions. Evaluations of effects in the RMP revisions will be strengthened if it is clear that estimates are based on current scientific understanding and data. A landscape scenario assessment project can help develop and evaluate potential resource effects and is flexible enough to accommodate improvements for assessing resource effects in the future.

Use of landscape scenario models could eventually be expanded to all of the affected districts so that each district would have the capability to evaluate the feasibility of RMP alternatives. RMP alternatives and timber harvest schedules may be constructed at a scale that prohibits thorough investigation of the implementation feasibility of the alternative. Past forest and resource management plans have suffered from a lack of spatial specificity even though project-level objectives and constraints are highly spatially specific. Use of a landscape scenario model can provide a linkage from large-scale plans to on-the-ground activities.

An important caveat of the modeling approach is the uncertainty involved in predicting alternative futures and resource effects. Spatially explicit landscape models are only approximations of complex natural systems and, therefore, vary in their realism, precision, and generality depending upon the purpose for which they were developed (Haefner 1996). The goal of modeling alternative landscape scenarios in this project was to achieve a general understanding of ecological patterns that are difficult or impossible to quantify over broad spatial and temporal scales. Given the uncertainties involved with forecasting future conditions over large areas, landscape modeling provided a qualitative assessment of planning alternatives. More rigorous, quantitative comparisons of ecological effects of landscape alternatives are difficult to obtain due to incomplete knowledge (Cissel et al. 1999).

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Hyperlinks

BLM Coos Bay District, http://www.or.blm.gov/coosbay/

BLM Resource Management Plan (RMP), http://www.or.blm.gov/NEPA-RMP/esstatus.htm

Coastal Landscape Analysis and Modeling Study (CLAMS), http://www.fsl.orst.edu/clams/

Cooperative Forest Ecosystem Research Program (CFER), http://www.fsl.orst.edu/cfer/

Ecoregion (level III), http://www.epa.gov/wed/pages/ecoregions/level_iii.htm

Ecoregion (level IV), http://www.epa.gov/wed/pages/ecoregions/level_iv.htm

Environmental Systems Research Institute (ESRI), http://www.esri.com/

ESSA Technologies Ltd., http://www.essa.com/index.htm

Forest and Rangeland Ecosystem Science Center (FRESC), http://fresc.usgs.gov/

Forest Ecosystem Management Team (FEMAT), http://pnwin.nbii.gov/nwfp/FEMAT/

Forest Operations Inventory (FOI), http://www.or.blm.gov/gis/resources/dataset.asp?cid=32

Hydrologic Unit Code (HUC), http://water.usgs.gov/GIS/huc.html

Interagency Vegetation Mapping Project (IVMP), http://www.or.blm.gov/gis/projects/ivmp.asp

Landscape Management System (LMS), http://lms.cfr.washington.edu/lms.php

Oregon State University (OSU), http://oregonstate.edu/

Stand Replacement Disturbance Mapping Project (SRD), http://www.fsl.orst.edu/larse/wov/88wov.html

Tool for Exploratory Landscape Scenario Analysis/Vegetation Dynamics Development Tool (TELSA/VDDT), http://www.essa.com/downloads/telsa/index.htm

Western Oregon Digital Imagery Project (WODIP), http://www.or.blm.gov/gis/resources/dataset.asp?cid=93