The Pacific Northwest Regional

Gap Analysis Project

Final Report on Land Cover Mapping Methods

MRLC Mapzones 2 and 7

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Table of Contents-Section 1

Tables and Figures—Section 1

Tables:

Figures:

Introduction

In its "coarse filter" approach to conservation biology (Jenkins 1985, Noss 1987) gap analysis relies on maps of dominant land cover as the most fundamental spatial component of the analysis for terrestrial environments (Scott et al. 1993). For the purposes of the Gap Analysis Program (GAP), most of the land cover of interest can be characterized as natural or semi-natural vegetation defined by the dominant plant species.

Vegetation patterns are an integrated reflection of physical and chemical factors that shape the environment of a given land area (Whittaker 1965). Often vegetation patterns are determinants for overall biological diversity patterns (Franklin 1993, Levin 1981, Noss 1990) which can be used to delineate habitat types in conservation evaluations (Specht 1975, Austin 1991). As such, dominant vegetation types need to be recognized over their entire range of distribution (Bourgeron et al. 1994) for beta-scale analysis (*sensu* Whittaker 1960, 1977). Various methods may be used to map vegetation patterns on the landscape, the appropriate method depending on the scale and scope of the project. Projects focusing on smaller regions, such as national parks, may rely on aerial photo interpretation (USGS-NPS 1994). Mapping vegetation over larger regions has commonly been done using digital imagery obtained from satellites, and may be referred to as land cover mapping (Lins and Kleckner 1996).

Generally, land cover mapping is done by segmenting the landscape into areas of relative homogeneity that correspond to land cover classes from an adopted or developed land cover legend. Technical methods to partition the landscape using digital imagery-based methods vary. Unsupervised approaches involve computer-assisted delineation of homogeneity in the imagery and ancillary data, followed by the analyst assigning land cover labels to the homogenous clusters of pixels (Jensen 2005). Supervised approaches utilize representative samples of each land cover class to partition the imagery and ancillary data into clusters of pixels representing each land cover class. Supervised clustering algorithms assign membership of each pixel to a land cover class based on some rule of highest likelihood (Jensen 2005). Supervised-unsupervised hybrid approaches are common and often offer advantages over both approaches (Lillesand and Kieffer 2000).

It is important to point out that a land cover map is never considered a perfect representation of the landscape. Improvements to land cover maps can, and should be made as additional “ground truth” information about actual land cover components and spatial patterns is acquired through time. These improvements should be based on independent assessments of the map’s quality (Stoms 1994).

This chapter is divided into three main sections. The first section discusses land cover map development. It begins by providing background information on the regional division of labor and the regional land cover legend. It then focuses on our land cover mapping methods, including a description of data sources, the land cover modeling approach, and the general flow of the mapping process. It concludes with a description of the resulting land cover map product. The second section describes the process of validating the land cover product. Background information on our approach is presented along with descriptions of the methods and results of the land cover product validation. The final section provides a discussion of the land cover mapping experience in general. In this section we discuss some of the “lessons learned” from the regional mapping effort with hopes that future mapping efforts of this nature will benefit from our experience.

Land Cover Classification

Background:

Land Cover Legend:

The US National Vegetation Classification System (US-NVCS) has been adopted by the Federal Geographic Data Committee as the classification standard for all federal mapping projects (FGDC 1997) [1]. A nested hierarchical structure of the US-NVCS defines classification units at the highest levels as heterogeneous units based solely on vegetative physiognomy and at the lower levels as more narrow and homogenous floristic units (Table1). The upper physiognomic levels of the NVCS framework are adapted from the World Physiognomic Classification of Vegetation (UNESCO 1973) and later modified for application to the United States by Driscoll et al. (1983, 1984). The lower floristic levels (e.g. Alliance and Association) are based on both structural and compositional characteristics of vegetation derived by Mueller-Dombois and Ellenberg (1974). The Nature Conservancy, and now NatureServe—along with the network of Natural Heritage Programs—have worked with others since 1985 on the systematic development, documentation, and description of vegetation types across the United States (Grossman et al. 1994, 1998). NatureServe and the Natural Heritage Network have been improving upon this system in recent years with significant funding supplied by GAP. Products from this on-going effort include a hierarchical vegetation classification standard (FGDC 1997) and the description of vegetation Alliances for the United States (Drake and Reid et al. 1999, Sneddon et al. 1994, Weakley et al. 1996). An alliance is a physiognomically uniform group of Associations sharing one or more dominant or diagnostic species, that as a rule are found in the uppermost strata of the vegetation (see Mueller-Dombois and Ellenberg (1974). The basic assumptions and definitions for this system have been described by Jennings (1993) and Grossman et al. (1998).

Link to FGDC standard	***Hierarchy level***	***U.S. National Vegetation Classification***	***Ecological Systems***
Included		Division Order	
Included	Physiognomic levels	Formation Class Formation Subclass Formation Group Formation Subgroup Formation	
Hierarchically linked			Ecological Systems
Proposed	Floristic levels	Alliance Association	

Table 1. Hierarchical structure of the U.S. National Vegetation Classification and the linkage with Ecological Systems.

[1] The FGDC set standards and policy for vegetation classification and map products to enable agencies to collect, report and map vegetation information in a standard format (FGDC 1997). Although the policy for applying the standard is only through the formation level (physiognomy only), agencies are encouraged to aid in the development of the floristic alliance and the association levels (FGDC 1997, pg. 4, 7). FGDC recognized that mapping applications need to be based on the requirement of the project "The specific application of this standard to any mapping activities is dependent on the goals and objectives of the mapping activities…the classification standard merely sets a hierarchical list of classes that should be intelligently employed by the user based on the specifications and limitations of their particular mapping program" (FGDC 1997, pg. 9). Thus, the current FGDC standard is primarily for *describing and classifying* vegetation, whereas mapping units will reflect (1) the needs of the mapping project, (2) the technical tools, methods, and data available for mapping, and (3) the interactions of those factors with the vegetation classification concepts. The nested hierarchical structure was intended to ease applications of these classification concepts to the many and varied circumstances of vegetation mapping. At the time of its adoption, however, there had been limited experience in its mapped application at each hierarchical level. Because of difficulties in mapping at all levels, 'compliance' with the FGDC standard almost always requires some sort of crosswalk between resultant mapping units and classification units from one or more levels of the current FGDC hierarchy.

When the first regional project (SWReGAP) began in 1999 the intended thematic mapping unit was the NVC alliance. However, recognizing that over 500 alliances occur in the project area and that many alliances would be difficult to map as they do not occur in large and distinctive patches, we anticipated the need for a "meso" scale thematic mapping unit. In response to this need, a regionally consistent meso-scale land cover legend, NatureServe developed the Terrestrial Ecological Systems Classification framework for the conterminous United States (Comer et al. 2003). Ecological Systems are defined as "groups of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates and/or environmental gradients" (Comer et al. 2003). Although distinct from the US-NVC, the vegetation component of an Ecological System is described by one or more NVC alliances or associations, though this relationship is not strictly hierarchical. While the Ecological System concept emphasizes existing dominant vegetation types, it also incorporates physical components such as landform position, substrates, hydrology, and climate. In this manner, Ecological System descriptions are modular, having multiple diagnostic classifiers used to identify several ecological dimensions of the mapping unit (Di Gregorio and Jansen 2000). Diagnostic classifiers include environmental and biogeographic characteristics, which are incorporated in the Ecological System name thus providing descriptive information about the system through a standardized naming convention. More detailed information about the Terrestrial Ecological Systems Classification for the United States is available at *http://www.natureserve.org/publications/usEcologicalsystems.jsp*.

A few additional classes were used to describe transitional classes (i.e., areas recovering from disturbance), and also developed classes in MRLC mapzones 2 and 7 (Table 2).

Table 2: Landcover classes added to mapzones 2 and 7.

ESLF	Ecological System Name
11	Open Water
12	Ice-Snow
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
81	Pasture/Hay
82	Cultivated Crops
88	High Structure Agriculture
8501	Recently burned forest
8502	Recently burned grassland
8503	Recently burned shrubland
8601	Harvested forest-tree regeneration
8602	Harvested forest-shrub regeneration
8603	Harvested forest-grass regeneration
8604	Harvested forest-herbaceous regeneration

Methods:

We divided MRLC mapzones 2 and 7 into seven modeling regions. These correspond roughly to ecoregions (Figure 1, Omernick 1987). These divisions enabled us to better tune each model to regional trends in vegetation-environment relationships. They also allowed us to model fewer Ecological Systems within a single model, resulting in higher local accuracy. Finally, by allowing us to restrict the Ecological Systems to ecoregions, it limited one type of error: mapping geographically inappropriate Systems (e.g. California Montane Jeffrey Pine was restricted to MR's 5,6,7 and 10).

Within each modeling region, we constructed an Ecological Systems grid in a multi-step process. First, we built two Random Forest (RF) (Breiman 2001) models, one for forested Ecological Systems and one for nonforest Ecological Systems. (Random Forest models are an extension of classification and regression trees, integrating information from a large set of trees, each of which is built from a random subset of plot and explanatory variables.) We then applied a variety of ancillary spatial data to map those Ecological Systems that we could not model well. Ancillary data-sources varied from model-region to model-region according to data-availability and quality. Our need for ancillary information also varied according to how well our models mapped each Ecological System.

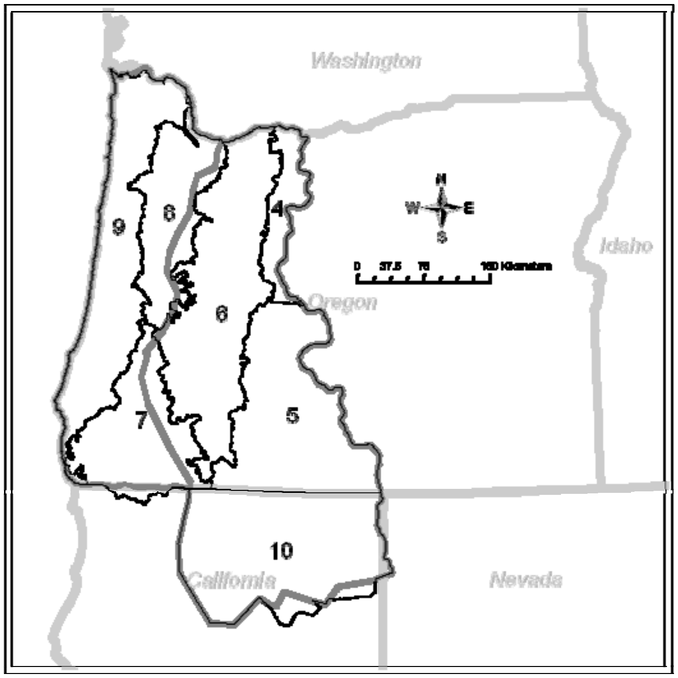

Figure 1: MRLC mapzones 2 and 7 are shown by dark gray lines. (Mapzone 2 is West of mapzone 7). Modeling regions are shown by thin black lines, and are labeled 4-10. Model region names are as follows: 4) East Cascades, North 5) East Cascades, South, 6) West Cascades, 7) Klamath/Siskiyou, 8) Willamette Valley, and 9) Coast Range.

MRLC Mapzones 2 and 7 Mapping Process:

Data Sources:

Plot Data used in RF Modeling

We developed a relational database containing regional forest inventory plots across all of Oregon and Washington. The plot database is used in several mapping projects, including mapping of Ecological Systems for map zones 2 and 7 (as well as forest areas in map zones 8 and 9) for GAP. Primary plot data sources are: (1) Most recent periodic inventories of the Forest Inventory and Analysis (FIA) Program, Pacific Northwest Research Station, USDA Forest Service (nonfederal lands), that are currently contained in the FIA Integrated Database (IDB); (2) all intensification and remeasurement plots of the Current Vegetation Survey (R6-CVS), USDA Forest Service, Pacific Northwest Region (on National Forest lands); (3) full intensification of CVS plots installed by the Bureau of Land Management in western Oregon (BLM-CVS). See Table 4 for a summary of plot data used in RF modeling in this study.

For Ecological Systems that were poorly-represented within our plot database, we collated a variety of supplemental data sources. These supplemental data sources varied by modeling region, and included Natural Heritage element occurrence records for threatened and endangered species, Bureau of Land Management district-scale vegetation maps and surveys, points interpreted from National Agriculture Imagery Program (NAIP) airphotos, and surveys of Willamette Valley oak habitats from The Nature Conservancy (Table 3). In northeastern California, we used Forest inventory plot data collated by LANDFIRE, as well as the FIA annual inventory plots.

Table 3: Supplemental plot data sources, by modeling region.

		Modeling Regions						
Data Source	**Description**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Element Occurrence Records		x	x	x	x	x	x	x
EORS	Element Occurrence Records			x	x	x	x	
ECPTS	East Cascades Element Occurrence Records	x	x					x
EC_EO2	East Cascades Element Occurrence Records	x		x				
SEOR	Southern Element Occurrence Records	x	x					
BLM Vegetation Surveys			x					x
Gerber	BLM, Gerber Unit - Polygon Samples		x					x
Lakeview	BLM, Lakeview District - Polygon Samples		x					
Lakeview2	BLM, Lakeview District - Point Samples		x					x
NAIP Airphotos (everything below)		x	x	x	x			x
Lavapts	Airphoto Points, from Oregon NAIP imagery (EG)	x	x	x				
EC_pts	Airphoto Points, from Oregon NAIP imagery(EG)	x	x	x				x
KS_pts	Airphoto Points, from Oregon NAIP imagery (JK)				x			
MR10_photo	Airphoto Points, from California NAIP imagery(EG)		x					x
Other						x		x
OakPlots	Oak Plots - Willamette Valley					x		
LANDFIRE database	LANDFIRE database (without FIA Annual Plots)							x

Ecological System assignment

We developed classification keys for the plots with detailed vegetation data within each model region, based on plant community composition. The logic behind the keys was developed from the NatureServe descriptions of the Ecological Systems, and expert opinion of ecologists (primarily J. Kagan and E. Grossmann). Plot-keying errors were identified by examining the relationship between Ecological System assignment and species composition within plots, System by System, and also by assessing draft maps built from the results from the draft keys. Classification was based primarily on relative abundances (cover) of species. They were written as a script to run within the R programming environment, version 2.4 (R Core Development Team 2006).

For most of the supplemental data sources (Element Occurrence Records, and BLM vegetation map sources), Ecological Systems were assigned by expert opinion of ecologists (primarily J. Kagan) from descriptive data columns. Airphoto points were placed within under-represented Ecological Systems, and interpreted from the NAIP imagery (E. Grossmann and J. Kagan). Although the LANDFIRE group had already sorted their plot data into Ecological Systems, we applied our own keys to these data to ensure internal consistency. Numbers of plots by Ecological System and modeling region for the random forest models (Table 4: forest models, and Table 5: nonforest models).

A few of the Ecological Systems were included in both the forest, and the nonforest models. These included the parkland and savanna Systems. They were included in both models because they were likely to fall within both the 'forest', and the 'nonforest' parts of our mask. These transitional areas with low tree densities include some of the most problematic areas, largely due to limitations in our forest/nonforest mask.

Table 4: Number of plots by Ecological System (ESLF code) and modeling regions for forest model.

ESLF	Ecological System	4	5	6	7	8	9	10
3177	NP Maritime Coastal Sand Dune and Strand	0	0	0	0	0	10	0
4101	NP Oak Woodland	15	0	10	94	181	10	3
4103	NRM Western Larch Savanna	10	0	10	0	0	0	0
4104	RM Aspen Forest and Woodland	0	10	0	0	0	0	35
4202	Cal Coastal Redwood Forest	0	0	0	13	0	82	0
4204	CP Western Juniper Woodland and Savanna	39	79	5	7	0	0	710
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland	279	0	67	8	10	10	0
4208	KS Lower Montane Serpentine Mixed Conifer Woodland	0	0	9	224	0	10	23
4209	KS Upper Montane Serpentine Mixed Conifer Woodland	0	0	0	65	0	10	6
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland	81	207	363	991	33	77	411
4215	MC Mesic Mixed Conifer Forest and Woodland	54	713	637	465	26	42	829
4216	MC Mixed Oak Woodland	0	0	0	71	10	7	170
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland	0	10	56	797	14	10	539
4218	Cal Montane Jeffrey Pine Woodland	0	0	3	9	0	0	409
4219	MC Red Fir Forest	10	20	91	10	10	16	134
4220	MC Subalpine Woodland	0	9	0	0	0	0	98
4221	MC Mesic Serpentine Woodland and Chaparral	0	0	0	8	0	0	0
4222	NP Dry Douglas-fir Forest and Woodland	61	0	101	402	106	191	6
4223	NP Hypermaritime Sitka Spruce Forest	0	0	0	0	0	238	0
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	10	0	1254	181	303	615	0
4225	NP Maritime Mesic Subalpine Parkland	10	10	20	0	0	0	0
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	10	0	656	138	178	1080	0
4228	NP Mountain Hemlock Forest	10	25	333	8	0	0	0
4229	NP Mesic Western Hemlock-Silver Fir Forest	0	0	52	0	0	0	0
4230	MC Mixed Evergreen Forest	0	10	44	1107	0	248	16
4231	N Cal Mesic Subalpine Woodland	10	11	71	0	0	0	67
4232	NRM Dry-Mesic Montane Mixed Conifer Forest	43	10	0	0	0	0	19
4233	NRM Subalpine Woodland and Parkland	10	25	10	0	0	0	0
4237	RM Lodgepole Pine Forest	10	10	27	0	0	0	19
4240	NRM Ponderosa Pine Woodland and Savanna	426	1527	25	10	0	0	420
4242	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	10	14	25	0	0	0	0
4245	SN Subalpine Lodgepole Pine Forest and Woodland	0	84	21	0	0	0	38
4267	RM Poor-Site Lodgepole Pine Forest	18	650	47	0	0	0	148
4268	Cal Coastal Closed-Cone Conifer Forest and Woodland	0	0	0	0	0	10	0
4269	SI Desert Western White Pine-White Fir Woodland	0	30	10	0	0	0	19
4271	NP Hypermaritime Western Red-cedar-Western Hemlock Forest	0	0	0	0	0	12	0
4272	NP Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	10	10	369	0	7	5	0

4301	EC Oak-Ponderosa Pine Forest and Woodland	126	11	10	36	10	0	37
4302	IMB Aspen-Mixed Conifer Forest and Woodland	0	40	0	0	0	0	34
4303	IMB Mountain Mahogany Woodland and Shrubland	0	51	0	0	0	0	117
4304	NP Broadleaf Landslide Forest and Shrubland	0	0	26	10	18	139	0
4329	NP Wooded Volcanic Flowage	10	10	10	0	0	0	158
4333	NP Lowland Mixed Hardwood Conifer Forest and Woodland	4	0	300	24	315	471	0
5304	Cal Montane Woodland and Chaparral	0	26	10	80	0	7	55
5403	Cal Lower Montane Blue Oak-Foothill Pine Woodland and Savanna	0	0	0	0	0	0	25
5425	KS Xeromorphic Serpentine Savanna and Chaparral	0	0	0	83	0	6	21
9190	NP Hardwood-Conifer Swamp	0	0	9	0	8	0	0

Geographic abbreviations: Cal = California, CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, GB = Great Basin, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, SI = Sierran-Intermontane, TP = Temperate Pacific, WV = Willamette Valley.

Table 5: Number of plots by Ecological System (ESLF code) and modeling region for nonforest models.

ESLF	Ecological System	4	5	6	7	8	9	10
3118	NP Alpine and Subalpine Bedrock and Scree	6	26	189	0	0	0	0
3128	IMB Volcanic Rock and Cinder Land	0	17	0	0	0	0	86
3140	NP Volcanic Rock and Cinder Land	29	47	87	0	0	0	25
3152	IMB Wash	0	18	0	0	0	0	11
3160	IMB Active and Stabilized Dune	0	3	0	0	0	0	0
3165	MC Northern Coastal Dune	0	0	0	0	0	5	0
3167	MC Serpentine Barrens	0	0	0	33	0	0	0
3172	MC Alpine Bedrock and Scree	0	0	0	0	0	0	131
3174	CP Ash and Tuff Badland	0	0	0	0	0	0	22
3177	NP Maritime Coastal Sand Dune and Strand	0	0	0	0	0	34	0
3179	IMB Playa	0	77	0	0	0	0	88
4101	NP Oak Woodland	0	0	26	105	292	19	3
4204	CP Western Juniper Woodland and Savanna	265	225	5	7	0	0	238
4216	MC Mixed Oak Woodland	0	0	0	71	12	7	170
4218	Cal Montane Jeffrey Pine Woodland	0	0	0	0	0	0	413
4220	MC Subalpine Woodland	0	9	0	0	0	0	98
4225	NP Maritime Mesic Subalpine Parkland	10	110	214	0	0	0	0
4231	N Cal Mesic Subalpine Woodland	10	45	10	0	0	0	67
4233	NRM Subalpine Woodland and Parkland	10	47	44	0	0	0	0
4240	NRM Ponderosa Pine Woodland and Savanna	247	1534	16	0	0	0	443
4303	IMB Mountain Mahogany Woodland and Shrubland	0	52	0	0	0	0	117
4304	NP Broadleaf Landslide Forest and Shrubland	0	0	26	10	18	139	0
4329	NP Wooded Volcanic Flowage	18	28	35	0	0	0	158
5202	CP Scabland Shrubland	101	11	3	0	0	0	95
5204	MC Alpine Fell-Field	0	0	0	0	0	0	49
5205	NP Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow	10	17	166	0	0	0	4
5256	GB Xeric Mixed Sagebrush Shrubland	0	23	0	0	0	0	34
5257	IMB Big Sagebrush Shrubland	39	241	3	0	0	0	234
5258	IMB Mixed Salt Desert Scrub	0	84	0	0	0	0	8

ESLF	Ecological System	4	5	6	7	8	9	10
5260	NP Avalanche Chute Shrubland	0	0	10	0	0	0	5
5261	NP Montane Shrubland	0	8	52	3	0	0	8
5304	Cal Montane Woodland and Chaparral	0	83	48	93	0	7	77
5305	Cal Xeric Serpentine Chaparral	0	0	0	17	0	3	18
5311	NC Dry-Mesic Chaparral	0	21	37	97	0	0	127
5404	IMB Juniper Savanna	0	0	0	0	0	0	3
5409	WV Upland Prairie and Savanna	0	0	76	101	116	18	5
5425	KS Xeromorphic Serpentine Savanna and Chaparral	0	0	0	128	0	6	31
5452	CP Steppe and Grassland	112	119	0	0	0	0	446
5453	CP Low Sagebrush Steppe	3	380	0	0	0	0	248
5454	IMB Big Sagebrush Steppe	202	394	4	0	0	0	294
5455	IMB Montane Sagebrush Steppe	66	151	17	0	0	0	110
5456	IMB Semi-Desert Shrub-Steppe	3	33	0	0	0	0	8
5457	N Cal Coastal Scrub	0	0	0	0	0	9	0
7102	Cal Mesic Serpentine Grassland	0	25	0	3	0	0	38
7106	CB Foothill and Canyon Dry Grassland	64	0	0	0	0	0	0
7107	IMB Semi-Desert Grassland	10	6	0	0	0	0	39
7108	MC Alpine Dry Tundra	0	0	3	28	0	0	0
7109	MC Subalpine Meadow	0	17	22	0	0	0	26
7110	NP Montane Grassland	35	56	31	11	0	0	85
7112	NRM Lower Montane, Foothill and Valley Grassland	43	148	0	0	0	0	212
7118	RM Subalpine-Montane Mesic Meadow	0	0	0	0	0	0	27
7157	NP Alpine and Subalpine Dry Grassland	5	34	99	0	0	0	24
7162	NP Herbaceous Bald and Bluff	0	0	17	7	3	23	0
8404	Introduced Upland Vegetation - Annual Grassland	0	50	0	0	0	0	89
9103	IMB Greasewood Flat	0	162	0	0	0	0	68
9173	NP Shrub Swamp	0	7	0	0	0	3	3
9221	WV Wet Prairie	0	0	22	18	101	24	0
9222	North American Arid West Emergent Marsh	0	158	0	0	0	0	126
9260	TP Freshwater Emergent Marsh	0	14	0	0	3	11	14
9265	TP Subalpine-Montane Wet Meadow	10	148	52	0	0	0	46
9281	TP Tidal Salt and Brackish Marsh	0	0	0	0	0	32	0
9297	IMB Alkaline Closed Depression	0	109	0	0	0	0	95
9321	CP Silver Sagebrush Seasonally Flooded Shrub-Steppe	0	39	0	0	0	0	29

Geographic abbreviations: Cal = California, CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, GB = Great Basin, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, SI = Sierran-Intermontane, TP = Temperate Pacific, WV = Willamette Valley.

Spatial Data Used in Modeling

All spatial data used in RF modeling were georegistered, clipped to a rectangle encompassing map zones 2 and 7, and resampled to 30m. All spatial data are ArcGIS grids in a modified national Albers projection, datum NAD 1983, Spheroid GRS 1980. The plot locations were intersected with the spatial data layers in GIS, and values for the explanatory variables were assigned to the plots. Plots were represented using multi-pixel 'footprints' that match the actual plot layout on the ground (typically about 1 hectare) as closely as possible. Spatial variables used in modeling are shown in Table 6 and Table 7.

Mapped Data on Physical Environment

We developed spatial data layers for several measures of climate, topography, and solar radiation (Table 6 and Table 7). All climate variables were derived from DayMet data (*www.daymet.org*). All topographic variables were derived from 10-m-resolution digital elevation models (DEMs) that were resampled to 30-m resolution.

Mapped Data on Disturbance History

Maps of forest disturbance, including timber harvest, were available only for the Oregon portion of map zones 2 and 7. These data were developed by Sanborn Spatial Solutions based on analysis of multi-temporal LANDSAT imagery (Cohen et al. 1998). A similar map was created by the Laboratory for Applications of Remote Sensing in Ecology research group in Corvallis using similar methods, which covered the Modoc Plateau modeling region in California. Maps of forest harvest and fire disturbances were derived from these two sources. Data on cumulative insect- and disease-caused mortality, developed from aerial surveys from 1980-2002, were also used.

Mapped Data on Soil Parent Material

We built binary grids describing soil parent material from two separate data sources: 1) Soil Survey Geographic Database (SSURGO), by Natural Resources Conservation Service, and 2) the Soil Resources Inventory (SRI), by the USFS (National Forest lands only). Polygons from these two maps were merged to create a single coverage, linked to attributes from SSURGO's parent_mat field in their copm table, and SRI's parent material descriptions in an Access database. Polygons were identified as members of a variety of soil parent material types. It was possible for a given polygon to have membership in several classes (e.g., "metamorphic", and "ultramafic"). The polygon coverage was converted to a 30m grid, and then binary grids were created for each parent material type.

Table 6: Environmental and spectral variables used in forest models.

Variable	Description	4	5	6	7	8	9	10
ADR4300	Absolute difference texture measure of R4300	X						
ADR5400	Absolute difference texture measure of R5400		X	X				X
ADR5700	Absolute difference texture measure of R5700			X				
ADTM400	Absolute difference texture measure of TM400			X		X		
ANNFROST	Mean number of days/yr when daily minimum temperature <=0.0 degrees C (scaled * 10 and converted to integer)	X		X	X		X	X
ANNGDD	Annual growing degree days	X		X			X	
ANNHDD	Annual heating degree days	X		X	X	X	X	X
ANNPRE	Annual precipitation (scaled * 100 and converted to integer)		X	X	X		X	X
ANNSWRAD	Annual sum of total daily incident shortwave radiative flux (scaled * 10 and converted to integer)	X		X	X	X	X	X
ANNTMP	Mean annual temperature (scaled * 100 and converted to integer)			X	X		X	
ANNVP	Annual vapor pressure (scaled * 1 and converted to integer)	X	X	X	X	X	X	X
ASPTR	Cosine transformation of aspect (degrees) (Beers et al. 1966), 0.0 (southwest) to 200 (northeast), from 30-m DEM			X		X		
AUGMAXT	Mean August maximum temperature (scaled * 100 and converted to integer)	X	X	X	X	X	X	X
CANOPY	Total tree canopy cover (percent), from NLCD 2001		X	X			X	
CONTPRE	Percentage of annual precipitation falling in June-August (scaled * 100 and converted to integer)	X	X	X			X	X
CVPRE	Coefficient of variation of mean monthly precipitation of December and July (wettest and driest months) (scaled * 100 and converted to integer)	X		X	X	X	X	X
DECMINT	Mean December minimum temperature (scaled * 100 and converted to integer)	X		X	X		X	X
DEM	Elevation	X	X	X	X	X	X	X
DIFTMP	Difference between AUGMAXT and DECMINT (scaled * 100 and converted to integer)	X	X	X	X	X	X	X
DIST26	Binary variable, created from YDIST grid, indicating pixels that were most recently disturbed <X> years ago. Includes both harvest and fire disturbance. <X> values differ between Sanborn's east and west coverages. Data from Sanborn Inc., contracted by ODF, and covering all of Oregon.						X	
FOG	Percent of the hours (tenths of percent) in July with cloud ceiling of marine stratus <91m and visibility <1.6 km (scaled * 100 and converted to integer). From Chris Daly's fog modeling (resolution 795 m) (released Oct. 1999).						X	
IDSURVEY	Cumulative insect and disease mortality density based on aerial detection survey polygons from 1980-2002 by USFS Region 6		X					
MLI	McComb's Landform Index (*http://scholar.lib.vt.edu/theses/available/etd-62897-155656/unrestricted/whole2.pdf*)			X				
MR4300	Median-filtered, ratio of TM band 4 to TM band 3, compiled from Landsat TM images from 1999-2002	X	X	X	X		X	X
MR5400	Median-filtered, ratio of TM band 5 to TM band 4, compiled from Landsat TM images from 1999-2002	X		X	X	X		
MR5700	Median-filtered, ratio of TM band 5 to TM band 7, compiled from Landsat TM images from 1999-2002	X		X	X			X
MTC200	Median-filtered, tasseled-cap transformation axis 2, compiled from Landsat TM images from 1999-2002	X	X	X				X
MTC300	Median-filtered, tasseled-cap transformation axis 3, compiled from Landsat TM images from 1999-2002					X	X	
MTC400	Median-filtered, tasseled-cap transformation axis 4, compiled from Landsat TM images from 1999-2002	X	X		X	X		X

Variable	Description	4	5	6	7	8	9	10
MTC500	Median-filtered, tasseled-cap transformation axis 5, compiled from Landsat TM images from 1999-2002		X	X		X	X	
MTC600	Median-filtered, tasseled-cap transformation axis 6, compiled from Landsat TM images from 1999-2002		X	X				
MTM100	Median-filtered, TM band 1, compiled from Landsat TM images from 1999-2002					X	X	
MTM200	Median-filtered, TM band 2, compiled from Landsat TM images from 1999-2002						X	
MTM300	Median-filtered, TM band 3, compiled from Landsat TM images from 1999-2002				X	X	X	
MTM400	Median-filtered, TM band 4, compiled from Landsat TM images from 1999-2002	X	X					X
MTM500	Median-filtered, TM band 5, compiled from Landsat TM images from 1999-2002						X	
MTM700	Median-filtered, TM band 7, compiled from Landsat TM images from 1999-2002					X		
PRR	Potential relative radiation			X	X			
R4300	Ratio of TM band 4 to TM band 3, compiled from Landsat TM images from 1999-2002	X	X		X			X
R5400	Ratio of TM band 5 to TM band 4, compiled from Landsat TM images from 1999-2002		X	X		X		X
SLPPCT	Slope (percent) (rounded to nearest integer)	X	X	X	X	X		X
SMRPRE	Mean precipitation from May-September (scaled * 1000 and converted to integer)	X	X	X	X	X	X	X
SMRTMP	Mean temperature from May-September (scaled * 100 and converted to integer)	X	X	X			X	X
SMRTP	Growing season moisture stress (ratio of temperature to precipitation from May-September) (scaled * 1000 and converted to integer)	X	X	X		X	X	X
STDTM400	Standard deviation texture measure of TM400		X		X			
STRATUS	Percentage of hours in July with cloud ceiling of marine stratus <1,524 m and visibility <8 m (scaled * 100 and converted to integer). From Chris Daly's fog modeling (resolution 795 m) (released Oct. 1999).			X	X	X	X	
TC100	Tasseled-cap transformation axis 1, compiled from Landsat TM images from 1999-2002						X	
TC200	Tasseled-cap transformation axis 2, compiled from Landsat TM images from 1999-2002	X	X	X				X
TC300	Tasseled-cap transformation axis 3, compiled from Landsat TM images from 1999-2002						X	
TC400	Tasseled-cap transformation axis 4, compiled from Landsat TM images from 1999-2002				X	X		
TC500	Tasseled-cap transformation axis 5, compiled from Landsat TM images from 1999-2002				X	X	X	
TC600	Tasseled-cap transformation axis 6, compiled from Landsat TM images from 1999-2002		X					
TM100	TM band 1, compiled from Landsat TM images from 1999-2002					X	X	
TM200	TM band 2, compiled from Landsat TM images from 1999-2002						X	
TM500	TM band 5, compiled from Landsat TM images from 1999-2002						X	
TPI300	Topographic position index, calculated as difference between cell's elevation and mean elevation of cells within a 300-m-radius window					X		
TPI450	Topographic position index, calculated as difference between cell's elevation and mean elevation of cells within a 450-m-radius window			X				
X	X location (longitude), computed as an index	X	X	X	X		X	X
Y	Y location (latitude), computed as an index	X	X	X	X	X	X	X

Table 7: Environmental and spectral variables used in nonforest models.

Variable	Description	4	5	6	7	8	9	10
ADR4300	Absolute difference texture measure of R4300	X			X			
ADTC400	Absolute difference texture measure of TC400						X	
ADTM300	Absolute difference texture measure of TM300						X	
ADTM400	Absolute difference texture measure of TM400					X		
ANNFROST	Mean number of days/yr when daily minimum temperature <=0.0 degrees C (scaled * 10 and converted to integer)	X	X		X		X	X
ANNGDD	Annual growing degree days		X	X	X		X	X
ANNHDD	Annual heating degree days	X		X		X	X	X
ANNPRE	Annual precipitation (scaled * 100 and converted to integer)	X	X	X	X		X	X
ANNSWRAD	Annual sum of total daily incident shortwave radiative flux (scaled * 10 and converted to integer)	X		X		X	X	X
ANNTMP	Mean annual temperature (scaled * 100 and converted to integer)			X		X	X	X
ANNVP	Annual vapor pressure (scaled * 1 and converted to integer)	X	X		X	X	X	X
AUGMAXT	Mean August maximum temperature (scaled * 100 and converted to integer)	X	X	X	X		X	X
CANOPY	Total tree canopy cover (percent), from NLCD 2001	X	X	X			X	
CONTPRE	Percentage of annual precipitation falling in June-August (scaled * 100 and converted to integer)	X	X		X		X	X
CVPRE	Coefficient of variation of mean monthly precipitation of December and July (wettest and driest months) (scaled * 100 and converted to integer)	X	X		X		X	X
DECMINT	Mean December minimum temperature (scaled * 100 and converted to integer)			X	X	X	X	X
DEM	Elevation	X	X	X	X		X	X
DIFTMP	Difference between AUGMAXT and DECMINT (scaled * 100 and converted to integer)	X	X	X	X		X	X
FOG	Percent of the hours (tenths of percent) in July with cloud ceiling of marine stratus <91m and visibility <1.6 km (scaled * 100 and converted to integer). From Chris Daly's fog modeling (resolution 795 m) (released Oct. 1999).						X	
IDSURVEY	Cumulative insect and disease mortality density based on aerial detection survey polygons from 1980-2002 by USFS Region 6						X	
MLI	McComb's Landform Index (*http://scholar.lib.vt.edu/theses/available/etd-62897-155656/unrestricted/whole2.pdf*)				X			
MR4300	Median-filtered, ratio of TM band 4 to TM band 3, compiled from Landsat TM images from 1999-2002	X	X	X			X	X
MR5400	Median-filtered, ratio of TM band 5 to TM band 4, compiled from Landsat TM images from 1999-2002	X						X
MR5700	Median-filtered, ratio of TM band 5 to TM band 7, compiled from Landsat TM images from 1999-2002	X	X	X	X	X	X	
MTC200	Median-filtered, tasseled-cap transformation axis 2, compiled from Landsat TM images from 1999-2002		X	X		X		X
MTC300	Median-filtered, tasseled-cap transformation axis 3, compiled from Landsat TM images from 1999-2002	X						
MTC400	Median-filtered, tasseled-cap transformation axis 4, compiled from Landsat TM images from 1999-2002		X			X	X	X
MTC500	Median-filtered, tasseled-cap transformation axis 5, compiled from Landsat TM images from 1999-2002					X		
MTC600	Median-filtered, tasseled-cap transformation axis 6, compiled from Landsat TM images from 1999-2002		X			X		X
MTM100	Median-filtered, TM band 1, compiled from Landsat TM images from 1999-2002	X						
MTM200	Median-filtered, TM band 2, compiled from Landsat TM images from 1999-2002	X	X			X		
MTM300	Median-filtered, TM band 3, compiled from Landsat TM images from 1999-2002		X		X		X	

Variable	Description	4	5	6	7	8	9	10
MTM400	Median-filtered, TM band 4, compiled from Landsat TM images from 1999-2002		X	X				X
MTM500	Median-filtered, TM band 5, compiled from Landsat TM images from 1999-2002	X						
MTM700	Median-filtered, TM band 7, compiled from Landsat TM images from 1999-2002					X		
PRR	Potential relative radiation				X	X		
R4300	Ratio of TM band 4 to TM band 3, compiled from Landsat TM images from 1999-2002	X	X	X	X	X	X	X
R5400	Ratio of TM band 5 to TM band 4, compiled from Landsat TM images from 1999-2002	X				X		
R5700	Ratio of TM band 5 to TM band 7, compiled from Landsat TM images from 1999-2002						X	
SLPPCT	Slope (percent) (rounded to nearest integer)		X	X	X	X	X	X
SMRPRE	Mean precipitation from May-September (scaled * 1000 and converted to integer)	X	X	X			X	X
SMRTMP	Mean temperature from May-September (scaled * 100 and converted to integer)			X	X		X	
SMRTP	Growing season moisture stress (ratio of temperature to precipitation from May-September) (scaled * 1000 and converted to integer)	X	X	X	X	X	X	
STDTC100	Standard deviation texture measure of TC100						X	
STDTM300	Standard deviation texture measure of TM300						X	
STRATUS	Percentage of hours in July with cloud ceiling of marine stratus <1,524 m and visibility <8 m (scaled * 100 and converted to integer). From Chris Daly's fog modeling (resolution 795 m) (released Oct. 1999).						X	
TC200	Tasseled-cap transformation axis 2, compiled from Landsat TM images from 1999-2002	X	X	X	X			X
TC400	Tasseled-cap transformation axis 4, compiled from Landsat TM images from 1999-2002						X	
TC500	Tasseled-cap transformation axis 5, compiled from Landsat TM images from 1999-2002			X	X			
TC600	Tasseled-cap transformation axis 6, compiled from Landsat TM images from 1999-2002		X			X		
TM100	TM band 1, compiled from Landsat TM images from 1999-2002					X		
TM200	TM band 2, compiled from Landsat TM images from 1999-2002					X		
TM300	TM band 3, compiled from Landsat TM images from 1999-2002				X		X	X
TM400	TM band 4, compiled from Landsat TM images from 1999-2002			X	X			
TM500	TM band 5, compiled from Landsat TM images from 1999-2002			X		X		
TM700	TM band 7, compiled from Landsat TM images from 1999-2002					X		
TPI450	Topographic position index, calculated as difference between cell's elevation and mean elevation of cells within a 450-m-radius window			X		X		
ULTRAMAFIC	Soil parent material contains rocks with ultramafic minerals including serpentine: information based on composite map of SSURGO, SRI, and Oregon Geology				X			
X	X location (longitude), computed as an index	X	X	X	X	X	X	X
Y	Y location (latitude), computed as an index	X	X	X	X	X	X	X

Land Cover Map Development: Regions 2 and 7

Random Forest Modeling

Two Random Forest models were built for each modeling region, one for forested Systems, and one for nonforest Systems. Random Forest models are an extension of classification and regression trees, where a large set (500 here) of classification trees are built, each with a random subset of the plot and explanatory data. Random Forest model predictions are an aggregate of the predictions of each tree. Essentially, each tree 'votes' for a particular system when predicting a new point or pixel. The system with the majority of votes from the trees in the forest becomes the aggregate prediction for the forest as a whole.

Variables to be included in the models were selected by stepwise removal, based on the gini index. Using the spatial data layers corresponding to the variables in the final model, we built a map of the model prediction on a pixel-by-pixel basis, using two supplemental programs (RfPy, and mapRF) which were developed by Brendan Ward working with the LANDFIRE group. The mapping process also generated single-system maps that map the votes that each system received.

For those Ecological Systems that were probably under-mapped (based on the Random Forest model's out-of-box error matrix), we performed a bias-correction procedure to expand their coverage. First, using the FIA inventory plots, we estimated the amount of area that should be occupied by each target system in the final map. Second, we used ArcInfo to select areas most likely to contain each target system, by selecting values greater than a certain threshold from the target Systems single-system maps. These thresholds were set to yield maps with the target area estimated by the FIA inventory plots. These selections were then combined into one adjustment layer, placing the system with the greatest area at the bottom of the stack. Finally, the adjustment layer was layered on top of the original random forest prediction map. This modified map is referred to as the "adjusted" map.

The bias correction procedure was only performed for the forest models. We were unable to generate area targets for the nonforest Ecological Systems due to the fact that the systematic portion of our plot sample is focused on sampling the forested portion of the landscape, and a systematic sample of the landscape is necessary for estimating target areas.

Forest/Nonforest masking

In the map assembly process, we use a forest/nonforest mask to constrain our nonforest Ecological Systems map to areas that are not forest. Forests are defined as areas with > 10% canopy closure or with the potential to reach 10% canopy closure in the near future (~ 40 yr). Therefore, clearcuts (assuming that they will regrow in to forests) were included in the 'forest' portion of our forest/nonforest mask. The mask was developed in a two-step process. First, we selected all forested areas from the National Landcover Dataset's (Homer et al 2007) canopy cover grid with >= 10% canopy closure. Then, we added the clearcuts from our disturbance layer to the forested portion of the mask. This grid was not used for modeling, but critical for the layering portion of the map construction process, where multiple map components were combined to create the final composite map (see 'Map Assembly' below).

Special Features (riparian, developed, transitional, cliffs)

Four types of special features were mapped across all modeling regions: 1) riparian; 2) developed; 3) transitional, and; 4) cliffs. Most ecoregions also had supplemental information for mapping wetland and volcanic classes, but those supplemental layers varied more strongly from model region to model region and are thus discussed in conjunction with each model region under "Map Assembly" below.

A map of floodplain and riparian Ecological Systems was developed from USGS's 1:100,000 National Hydrography Dataset (*http://nhd.usgs.gov/index.html*). Data at the subregion scale were downloaded to cover NLCD mapzones 2 & 7. Both the flowline and area maps were used to help delineate potential riparian areas. The flowline coverage was separated in to two parts, streams and rivers with names (detailed observation showed these to be more likely to be large and permanent), and those without. Streams and rivers were also selected from the National Hydrography

Dataset area coverage. Two different buffers were applied to these three maps. The Area coverage, and the named streams were buffered by 45m (radius), while the unnamed streams were buffered by 15m. These 3 buffers were then converted to grids (30m grain), which were snapped to the rest of our spatial data. The grids containing the larger buffers were then constrained to areas with slope < 20%, and to valley bottoms (TPI150 < 4). The grids containing the small stream buffers were constrained to prevent riparian areas on hilltops (TPI150 < 50). The three constrained grids were then combined into one single grid. In the Coast Range modeling region, a better estimate of the valley bottoms was available (described in Miller 2003), and these valley bottoms were added to the base riparian coverage. When the riparian grid was integrated with the layer stack (described below under Map Assembly), it was further constrained by a Gradient Nearest Neighbor (GNN, Ohmann and Gregory 2002) map to areas with either an open canopy (< 50% closure), or a large deciduous component (> 80%). Finally, Ecological Systems were assigned to the riparian map, based on the forest layer in the stack (Table 8). (For a description of the GNN method, see Ohmann and Gregory (2002). GNN maps are available for download from *http://www.fsl.orst.edu/lemma/common/studyAreas.php*.)

Table 8: Riparian system mapping crosswalk.

Riparian System	**Forest System**
CB Foothill Riparian Woodland and Shrubland	EC Oak-Ponderosa Pine Forest and Woodland
	EC Mesic Montane Mixed-Conifer Forest and Woodland
	CP Western Juniper Woodland and Savanna
	CB Foothill Riparian Woodland and Shrubland
GB Foothill and Lower Montane Riparian Woodland and Shrubland	GB Foothill and Lower Montane Riparian Woodland and Shrubland
	GB Pinyon-Juniper Woodland
	IMB Subalpine Limber-Bristlecone Pine Woodland
	IMB Aspen-Mixed Conifer Forest and Woodland
MC Foothill and Lower Montane Riparian Woodland	SN Subalpine Lodgepole Pine Forest and Woodland
	SI Desert Western White Pine-White Fir Woodland
	Cal Montane Woodland and Chaparral
	Cal Central Valley Mixed Oak Woodland and Savanna
	Cal Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
	MC Lower Montane Black Oak-Conifer Forest and Woodland
	MC Mixed Oak Woodland
	MC Mixed Evergreen Forest
	MC Mesic Mixed Conifer Forest and Woodland
	MC Dry-Mesic Mixed Conifer Forest and Woodland
	NC Mesic Subalpine Woodland
	MC Foothill and Lower Montane Riparian Woodland
MC Serpentine Foothill and Lower Montane Riparian	MC Serpentine Foothill and Lower Montane Riparian
	MC Mesic Serpentine Woodland and Chaparral
	KS Xeromorphic Serpentine Savanna and Chaparral
	KS Lower Montane Serpentine Mixed Conifer Woodland
	KS Upper Montane Serpentine Mixed Conifer Woodland
NP Lowland Riparian Forest and Shrubland	NP Hypermaritime Sitka Spruce Forest
	NP Hypermaritime Western Red-cedar-Western Hemlock Forest
	IMB Mountain Mahogany Woodland and Shrubland
	NP Broadleaf Landslide Forest and Shrubland
	NP Dry Douglas-fir Forest and Woodland
	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
	NP Lowland Riparian Forest and Shrubland
	NP Lowland Mixed Hardwood Conifer Forest and Woodland
	NP Hardwood-Conifer Swamp
	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
	NP Wooded Volcanic Flowage

Riparian System	Forest System
	NP Oak Woodland
NP Montane Riparian Woodland and Shrubland	Cal Montane Jeffrey Pine Woodland Cal Coastal Redwood Forest NP Mountain Hemlock Forest NP Mesic Western Hemlock-Silver Fir Forest MC Red Fir Forest NP Maritime Mesic Subalpine Parkland MC Subalpine Woodland NP Maritime Coastal Sand Dune and Strand NP Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest Cal Coastal Closed-Cone Conifer Forest and Woodland NP Montane Riparian Woodland and Shrubland
RM Lower Montane Riparian Woodland and Shrubland	RM Lower Montane Riparian Woodland and Shrubland NRM Dry-Mesic Montane Mixed Conifer Forest RM Poor-Site Lodgepole Pine Forest RM Lodgepole Pine Forest RM Aspen Forest and Woodland NRM Western Larch Savanna NRM Foothill Conifer Wooded Steppe NRM Ponderosa Pine Woodland and Savanna
RM Subalpine-Montane Riparian Woodland	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland RM Subalpine Mesic-Wet Spruce-Fir Forest and Woodland RM Subalpine-Montane Limber-Bristlecone Pine Woodland RM Subalpine-Montane Riparian Woodland NRM Subalpine Woodland and Parkland NRM Mesic Montane Mixed Conifer Forest MRM Montane Douglas-fir Forest and Woodland

Geographic abbreviations: Cal = California, CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, GB = Great Basin, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, SI = Sierran-Intermontane, TP = Temperate Pacific, WV = Willamette Valley.

Developed areas were mapped from the 2001 National Land Cover Dataset (*http://www.mrlc.gov/nlcd.php*). Developed and agricultural layers were simply selected from this coverage, and layered on top of the GAP coverage. Two modifications were applied to this process in the Willamette Valley modeling region (8) only (see Map Assembly section).

Transitional classes (listed in Table 2. ESLF 8501 - 8604), were generated from the disturbance data described above under "Spatial Data". First, areas that were clearcut within the last 26 years were selected. Clearcuts where the GNN model indicated more than one percent canopy coverage were mapped to "Harvested Forest, Tree Regeneration". All other clearcuts were mapped based on a crosswalk from the unmasked map from the nonforest model. A parallel procedure was used to distinguish areas characterized as burned in the disturbance layers into the three mapped burned classes: forest, shrubland and grassland.

Cliff Systems were mapped in areas with steep slopes, but the cutoff varied between the forest and nonforest portions of the map. In forested areas, slopes greater than or equal to 50% were selected. Additionally, in forested areas, only cliffs greater than 60m tall were mapped. In nonforest areas, slopes greater than or equal to 40% were selected. These two maps were then combined, and the resultant areas assigned to Cliff Ecological Systems during the layering process.

Map Assembly

Construction of the final GAP Ecological Systems Landcover map was done on a model region by model region basis, and model region maps were then mosaicked to cover entire map zones. The layering process for each model region was developed independently, but with the goal of maintaining as much consistency as possible among model regions while minimizing logical errors within each region. In general, six standard layers were put together in the following order (from the bottom up, with higher layers obscuring layers below them): 1) Forest model (bias-corrected); 2) Nonforest model, masked to include only nonforested areas; 3) Riparian areas; 4) Transitional classes; 5) Cliffs; and 6) Developed and Agricultural classes from NLCD. The map resulting from this layer-stack is referred to as the 'composite map'. Within each model region, Systems with apparent logical inconsistencies (e.g., wetlands mapped on steep slopes) and other problems were reclassified using ancillary data sources. These model-region-specific modifications are described below.

Northern East Cascades (Model Region 4)

In the Northern East Cascades model region (Figure 1), we performed five reclassification steps aimed at improving the volcanic Systems, and also modified limited areas near its borders to improve edge-matching with the West Cascades and with MRLC mapzones 8 and 9, and corrected natural nonforest systems that were clearly mapped in powerline corridors (mapping them as Harvested Forest – Shrub Regeneration).

There were five reclassification steps involving the two volcanic Systems mapped in this model region. First, areas mapped as North Pacific Montane Grassland, North Pacific Alpine and Subalpine Dry Grassland, and Columbia Plateau Juniper Woodlands that overlapped with areas mapped as recent lava flows by our Oregon Geology Map, were reclassified to NP Volcanic Rock and Cinder Land. Second, pixels classified as North Pacific Volcanic Rock and Cinder Land and North Pacific Wooded Volcanic Flowage with lacustrine sediments as soil parent material in our spatial data were reclassified to Temperate Pacific Subalpine-Montane Wet Meadow. Third, places mapped to any of the lodgepole pine Systems (Rocky Mountain Lodgepole Pine Forest, Rocky Montane Poor-Site Lodgepole Pine Forest, or Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland) in the composite map, and North Pacific Wooded Volcanic Flowage in the unmasked nonforest map were assigned to the lodgepole pine Systems in the final map. Fourth, areas mapped as North Pacific Wooded Volcanic Flowage in the unmasked nonforest map that were not mapped as one of the lodgepole pine forest in the composite map were reclassified to North Pacific Wooded Volcanic Flowage in the final map. Finally, areas mapped as North Pacific Wooded Volcanic Flowage by the unmasked nonforest map, and Rocky Mountain Poor-Site Lodgepole Pine Forest and Woodland the un-adjusted forest map were assigned to poor-site lodgepole pine in the final map.

Southern East Cascades (Model Region 5)

The layering process for the Southern East Cascades model region contained two additional layers of supplemental information, and nine reclassification steps to improve the mapping of selected classes.

The first layer addition was applied directly to the bias-corrected forest map. Places labeled 'deciduous forest' by the NLCD's landcover classification map were labeled Rocky Mountain Aspen Forest and Woodland. These aspen forests comprise most of the limited deciduous forests in the area, and they were poorly mapped by our forest model due to our limited plot sample for the system. The second layer addition (derived from Christy 2008) contained the North Pacific Bog and Fen system. It was applied on top of the transitional layers described in the general process above. The same edge-matching and powerline corrections described above for Model Region 4 were also applied here.

The nine reclassification steps addressed three types of Systems: 1) juniper and ponderosa pine woodlands and savannas (1 step); 2) wetlands (5 steps); and volcanic Systems (3 steps).

First, areas that were mapped in the composite map as Columbia Plateau Low Sage Steppe, Intermountain Basins Big Sage Shrubland and Intermountain Basins Big Sage Shrub-Steppe that had > 4% canopy closure (NLCD's canopy map) were allowed to revert to their values in the adjusted forest map (primarily Columbia Plateau Juniper Woodland, and Northern Rocky Mountain Ponderosa Pine Woodland and Savanna).

The five wetlands classification steps affected a variety of wetlands and non-wetlands Systems. The first reclassification affected the burn-in layer describing fens. Pixels that the forest model assigned to California-affiliated Systems (Table 9, plus the nonforest Systems: Mediterranean California Subalpine Meadow and Mediterranean California Alpine Bedrock and Scree) that were identified as fens in the supplemental layer were assigned to Mediterranean California Montane Fen in the final map. The second and third wetlands-related reclassifications improved the Temperate Pacific Subalpine-Montane Wet Meadow system by limiting it to flat slopes. Wet meadows mapped at elevations (> 1500m) and on slopes (> 5%) were reclassified to North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow, and wet meadow pixels at lower elevations (<= 1500) and steep slopes (> 30%) were reclassified to North Pacific Montane Grasslands. The remaining marsh Systems that were mapped to sloped areas (> 5%) were reclassified to transitional types (see Table 10). The fifth reclassification step addressed Inter Mountain Basins Alkaline Closed Depression mapped to the southwestern quarter of the map. These places were assigned to Harvested Forest, Shrub regeneration, since this Ecological System should only be present near the eastern border of this model region.

Table 9: Forest Ecological Systems with a California affinity.

Ecological System Name
Cal Central Valley Mixed Oak Woodland and Savanna
Cal Coastal Closed-Cone Conifer Forest and Woodland
Cal Coastal Redwood Forest
Cal Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
Cal Montane Jeffrey Pine Woodland
Cal Montane Woodland and Chaparral
GB Foothill and Lower Montane Riparian Woodland and Shrubland
GB Pinyon-Juniper Woodland
KS Lower Montane Serpentine Mixed Conifer Woodland
KS Upper Montane Serpentine Mixed Conifer Woodland
KS Xeromorphic Serpentine Savanna and Chaparral
MC Dry-Mesic Mixed Conifer Forest and Woodland
MC Foothill and Lower Montane Riparian Woodland
MC Lower Montane Black Oak-Conifer Forest and Woodland
MC Mesic Mixed Conifer Forest and Woodland
MC Mesic Serpentine Woodland and Chaparral
MC Mixed Evergreen Forest
MC Mixed Oak Woodland
MC Red Fir Forest
MC Serpentine Foothill and Lower Montane Riparian
MC Subalpine Woodland
NC Mesic Subalpine Woodland
SN Subalpine Lodgepole Pine Forest and Woodland
SI Desert Western White Pine-White Fir Woodland

Geographic abbreviations: Cal = California, GB = Great Basin, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, SN = Sierra Nevada, SI = Sierran-Intermontane.

Table 10: Reclassification of wetlands on slopes for Southern East Cascades model region.

Original System	Reclassified To
CP Silver Sage Seasonal Shrubland	Harvested Forest, Shrub Regeneration
IMB Alkaline Depression	Harvested Forest, Shrub Regeneration
North American Arid Emergent Marsh	Harvested Forest, Grass Regeneration
NP Shrub Swamp	Harvested Forest, Shrub Regeneration
TP Freshwater Emergent Marsh	Harvested Forest, Grass Regeneration
TP Subalpine-Montane Wet Meadow	Harvested Forest, Grass Regeneration

Geographic abbreviations: CP = Columbia Plateau, IMB = Inter-Mountain Basins, NP = North Pacific, TP = Temperate Pacific.

The volcanic classes were modified by three steps. First, we selected pixels mapped as North Pacific Dry Douglas-fir Forest and Woodland and East Cascades Mesic Montane Mixed Conifer Forest in the composite map that were mapped as a volcanic type by the Oregon Geology supplemental layer. These were reclassified to North Pacific Wooded Volcanic Flowage in the final map. Second, pixels that were mapped as North Pacific Montane Grassland, North Pacific Alpine and Subalpine Dry Grassland and Columbia Plateau Western Juniper Woodland and Savanna by the composite map and as a volcanic type in the Oregon Geology map were reclassified to North Pacific Volcanic Rock and Cinder Land. Third, pixels that were mapped as either North Pacific Volcanic Rock and Cinder Land, or North Pacific Wooded Volcanic flowage by the composite map, but falling within areas identified as having lacustrine soil parent material, were reclassified to Temperate Pacific Subalpine-Montane Wet Meadow in the final map.

West Cascades (Model Region 6)

The layering procedure for the West Cascades model region was similar to the generalized procedure described above, with several modifications: First, the transitional classes were applied after the cliffs. Second, a supplemental layer describing fens (Christy 2008) was added just below the layer describing the cliffs. Third, thirteen reclassification steps were also added to further modify: 1) forests (4 steps); 2) wetlands (3 steps); 3) volcanic Systems (4 steps); 4) cliff Systems (1 step); and 5) reclassifications that applied to areas that were clearly within a powerline corridor (reclassified from natural systems to Harvested Forest – Shrub Regeneration).

Four forested Ecological Systems were reclassified. First, All pixels mapped as California Montane Jeffrey Pine Woodland were reclassified as Mediterranean California Mesic Mixed Conifer Forest. Second, all pixels that were assigned to the two serpentine mixed conifer forest Systems (Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Forest and Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Forest) that fell outside of areas identified as having ultramafic soil parent material were reassigned to Mediterranean California Dry-Mesic Mixed Conifer Forest. Third, instances where the un-adjusted forest model mapped North Pacific Dry Douglas-fir Forest and Woodland, North Pacific Maritime Dry-Mesic Douglas-fir – Western Hemlock Forest, or North Pacific Maritime Mesic-Wet Douglas-fir – Western Hemlock Forest, where the composite map mapped Mediterranean California Dry-Mesic Mixed Conifer, the Systems predicted by the un-adjusted model (the Douglas-fir forests) were assigned to the final map. This step improved edge-matching with the Klamath-Siskiyou model region.

Fourth, we modified the adjustment for Northern Rocky Mountain Subalpine Woodland and Parkland in the following manner. First, we removed the adjustment for this system by applying values from the un-adjusted forest map to the adjusted forest map in areas that were mapped as this system. Then, we applied a constrained adjustment. Areas within its single-system map that indicated that it received more than 9% of the 'votes' from the random forest model were selected. Next, this map was constrained to areas that had a reasonable probability of being mapped as parkland (North Pacific Mesic Subalpine Parkland single-system map showed > 10% of the votes). Then, this layer was further constrained to areas that were not mapped as North Pacific Mountain Hemlock Forest by the un-adjusted forest map. The resulting single-system layer was then applied to the forest layer in the stack.

Three wetland Systems were adjusted. First, the North Pacific Hardwood-Conifer Swamp pixels that fell on slopes (> 5%) were reclassified to North Pacific Lowland Mixed Hardwood-Conifer Forest. Second, Temperate Pacific Subalpine Wet Meadow was over-mapped in the nonforest model, and these areas were reassigned in the final map in the following four steps (in sequence): 1) High elevation areas (> 2000m) were assigned to North Pacific Bedrock and Scree; 2) Other high elevation areas (> 1500m) that were sloped (> 5%) were reclassified to North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow; 3) Low elevation areas (< 500m) were reclassified to Willamette Valley Wet Prairie; 4) Areas at < 1700m elevation, with steep slopes (> 30%) were mapped to North Pacific Montane Grassland. Finally, areas that were mapped as North Pacific Bog and Fen in the supplemental layer that overlapped California affiliated forest Systems in the forest model (Table 9) were reclassified to Mediterranean California Montane Fen in the final map.

There were four reclassification steps relating to the volcanic Systems. First, in the forested portion of the map, where the unmasked nonforest map placed North Pacific Wooded Volcanic Flowage, and the un-adjusted forest model did <u>not</u> map lodgepole pine forests (Rocky Mountain Lodgepole Pine Forest, Rocky Mountain Poor-site

Lodgepole Pine Forest and Woodland, or Sierra Nevada Subalpine Lodgepole Pine Forest), these pixels were reassigned to North Pacific Wooded Volcanic Flowage for the final map. Second, areas that were mapped as North Pacific Wooded Volcanic Flowage or North Pacific Rock and Cinder Land in the composite map that fell in areas with lacustrine sediments as their soil parent material were reclassified to Temperate Pacific Subalpine-Montane Wet Meadow. Third, areas that were mapped as North Pacific Wooded Volcanic Flowage within the nonforest portion of the map, but were mapped as one of the three lodgepole pine Systems listed above by the forest layer, were reassigned to their respective lodgepole pine Systems. Finally, areas mapped as North Pacific Wooded Volcanic Flowage by the nonforest model that were mapped as Rocky Mountain Poor-site Lodgepole Pine Forest by the un-adjusted forest model, were assigned to the pine system in the final map.

Finally, the North Pacific Montane Massive Bedrock, Cliff and Talus was reassigned to North Pacific Alpine and Subalpine Bedrock and Scree wherever the unmasked nonforest model had mapped North Pacific Alpine Bedrock and Scree or Temperate Pacific Subalpine-Montane Wet Meadow.

After accuracy assessment was completed, two additional modifications to map were performed in the northern part of the model region. Sixty five ha of Northern California Mesic Subalpine Woodland were reclassified to North Pacific Mountain Hemlock Forest., and 4.2 ha of Northern and Central California Dry Mesic Chaparral were reclassified to North Pacific Montane Shrubland. These changes were very minor, and it is unlikely that they have skewed the results we present in terms of area mapped, and accuracy assessments to a significant degree.

Klamath and Siskiyou Mountains (Model Region 7)

This region followed the general layering procedure with the following modifications: 1) A layer describing fens, modified from John Christy's wetlands map was added in between the cliff, and NLCD layers; 2) A layer describing the Northern California Claypan Vernal Pool system was layered on top of the fens layer, and also above NLCD's agricultural classes; 3) An alternative forest/nonforest mask (developed by Jeff Campbell) was used to mask nonforest Ecological Systems, and; 4) Twelve reclassification steps, which included modifications to: Forested Ecological Systems (5 steps), wetland Systems (3 steps), cliff Systems (1 step), and other nonforest Systems (2 steps).

There were five reclassification steps that modified the forested Ecological Systems. First, for areas mapped as California Coastal Redwood Forest by the adjusted forest model, and North Pacific Dry Douglas Fir Forest and Woodland, North Pacific Maritime Dry-Mesic Douglas-fir – Western Hemlock Forest, or North Pacific Maritime Mesic-Wet Douglas-fir – Western Hemlock Forest by the un-adjusted forest model, the Douglas-fir forests were used in the final map. Second, for those pixels mapped to Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland in the composite map and mapped as Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland in the un-adjusted forest model were mapped as the Black Oak-Conifer system in the final map. Third, those pixels mapped as North Pacific Maritime Mesic-Wet Douglas-fir – Western Hemlock Forest in the final map that were Mediterranean California Dry-Mesic Mixed Conifer Forest by the un-adjusted forest map, were mapped as the mixed conifer system in the final map. Fourth, those pixels mapped in the composite map as California Montane Jeffrey Pine Forest and Woodland in the composite map were reclassified as follows: 1) Low elevation pixels (< 600m) were assigned to Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Forest and Woodland, and; 2) High elevation pixels (>= 600m) were assigned to Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Forest and Woodland. Finally, where forested serpentine Systems (the two mixed conifer forests mentioned above, and Mediterranean California Mesic Serpentine Woodland and Chaparral) were mapped by the composite map to areas without ultramafic soil parent material, they were reassigned to Mediterranean California Mixed Evergreen Forest in the final map.

There were three reclassification steps for refining wetlands Systems. First, pixels identified as 'wet' within our soil data that fell in areas with a low topographic position (TPI450 < 10), and low slope (<15%) were reassigned to Temperate Pacific Subalpine-Montane Wet Meadow. Second, pixels identified as North Pacific Bog and Fen in our supplemental layer, and mapped as California-affiliated Forest Systems (Table 9) by the forest layer were mapped as Mediterranean California Subalpine-Montane Fen in the final map. Finally, areas mapped as North Pacific Bog and Fen in the composite map with ultramafic soil parent material were assigned to Mediterranean California Serpentine Fen in the final map.

The last three reclassification steps targeted the following Systems: 1) Mediterranean California Foothill and Lower Montane Riparian Woodland; 2) Other riparian Systems, and; 3) North Pacific Montane Massive Bedrock, Cliff and Talus, and Klamath-Siskiyou Cliff and Outcrop. First, pixels mapped as Mediterranean California Serpentine Foothill and Lower Montane Riparian in the composite map and did not have ultramafic soil parent material were reassigned to Mediterranean California Foothill and Lower Montane Riparian Woodland. Second, pixels mapped as NLCD agricultural types (Cultivated Crops or Pasture) that were also mapped in riparian layer were assigned to appropriate riparian Systems in the final map. Finally, we reclassified our supplemental cliff layer to either North Pacific Massive Montane Bedrock Cliff and Talus, or Klamath-Siskiyou Cliff and Outcrop, according to the geographic affinity of the forested Systems mapped by the adjusted forest model. Cliff pixels associated with California-affiliated forest Systems (Table 9) were assigned to the Klamath-Siskiyou cliff system, and all other pixels were assigned to the North Pacific cliff system.

Willamette Valley (Model Region 8)

This region followed the general layering procedure with the addition of three supplemental layers, and two reclassification steps and a modification to the nonforest masking process. The layer-additions included: 1) chaparral; 2) wetlands and; 3) fens. Additional agricultural classes were also added in a reclassification step, and the layer describing cliffs was reclassified before adding it to the layer stack. Lastly, a slightly modified mask was used to separate the forests and nonforests.

The chaparral supplemental layer was derived from data obtained from the Oregon Department of Fish and Wildlife, describing the vegetation of the Southern Willamette Valley. Areas that they mapped as chaparral were transferred to the GAP map as Northern and Central California Dry-Mesic Chaparral. This layer was added in between the nonforest and riparian layers in the stack.

A supplemental wetlands layer was developed by crosswalking a map of the wetlands of the Willamette Valley (an unpublished update of Titus et. al., 1996 by John Christy, Murray 2000) to Ecological Systems (crosswalk built by J. Kagan). This layer was applied to the layer stack directly above the cliff Systems. The supplemental layer for fens (North Pacific Bog and Fen) was derived by a different map that was also developed by John Christy, and it was applied to the layer stack directly on top of the other supplemental wetlands layer. Modifications to the 2001 NLCD agricultural classes were, based on a supplemental layer describing landcover of the Willamette Valley in the year 2000 (Brandscomb 2005). Areas mapped as ‘berries and vineyards’, ‘orchard’, or ‘Christmas trees’ in this layer that fell within agricultural classes in the composite map (pasture, and cultivated crops) were reassigned to ‘High Structure Agriculture’ in the final GAP map. The cliffs layer was reclassified as North Pacific Montane Massive Bedrock Cliff and Talus, or Klamath-Siskiyou Cliff and Outcrop according to the forest model. Cliff pixels that were mapped to Klamath-Siskiyou, or California affinities (Table 9) in the forest map were assigned to Klamath-Siskiyou Cliff and Outcrop, while all other cliffs were assigned to North Pacific Montane Massive Bedrock Cliff and Talus.

The original nonforest mask was modified using information from the 2000 Willamette Valley landcover map (Brandscomb 2005). The supplemental layer was used to expand the area of forest in the forest/nonforest mask.

Oregon Coast Range (Model Region 9)

The coast range map followed the standard layering procedure, but had one supplemental layer (fens), and 19 reclassification steps applied. The supplemental layer describing North Pacific Bog and Fen (Christy 2008) was added to the layer stack between the transitional types and the NLCD layer. The reclassifications fell in 6 categories 1) reclassifications related to sandy soils (8 steps); 2) reclassifications related to ultramafic soils (2 steps); 3) herbaceous and grassy (2 steps) and; 4) wetlands and fens (5 steps). The numerous reclassification steps regarding the sandy soils, and the wetlands are due to modeling uncertainties and errors stemming from plot data limitations within these Systems in this model region.

The reclassifications relating to the presence of sandy soil parent material affected: 1) forested Systems (2 steps); 2) wetland and other Systems (2 steps) and; 3) mis-mapped dune Systems (5 steps). Within the areas that were mapped as having sandy soil parent material, areas mapped as California Coastal Redwood Forest, or North Pacific Hypermaritime Sitka Spruce were reclassified to California Coastal Closed Cone Conifer Forest and Woodland. One common problem with the unmodified composite map was that dune Systems (North Pacific Maritime Coastal Sand Dune and Strand and Mediterranean California Sand Dune) were sometimes mapped to areas without sand. These mis-mapped dunes were selected into their own coverage, modified in a series of steps (described below), and re-applied to the final map. First, mis-mapped dunes on slopes (> 15%) were reclassified to North Pacific Broadleaf Landslide Forest and Shrubland. Second, areas on hilltops (TPI 150 > 15), were reclassified to North Pacific Herbaceous Bald and Bluff. Third, mis-mapped Mediterranean California Northern Coastal Dunes were reclassified to Northern California Coastal Grassland. Fourth, mis-mapped dunes at very low elevation (<3m), and close to the ocean (< 10km) were reclassified to Temperate Pacific Tidal Salt and Brackish Marsh. Finally, mis-mapped dunes on hilltops (TPI150 > 15), and less than 1 km from the Pacific Ocean were reclassified to North Pacific Hypermaritime Shrub and Herbaceous Headland. Finally, the remaining unmodified mismapped dunes were reclassified to Willamette Valley Wet Prairie.

In addition to mis-mapped dunes, there were some areas where dunes were apparently under-mapped. In particular, areas mapped as Temperate Pacific Tidal Salt and Brackish Marsh located in sandy areas were reclassified to North Pacific Maritime Coastal Sand Dune and Strand.

Mis-mapped serpentine Systems (i.e., mapped outside of areas known to have ultramafic soils) were reclassified in two steps. First, forested serpentine Systems (Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Forest and Woodland, Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Forest and Woodland, and Mediterranean California Mesic Serpentine Woodland and Chaparral) that fell outside of ultramafic soils were reclassified to Mediterranean California Mixed Evergreen Forest. Second, nonforest Serpentine Systems (Mediterranean California Serpentine Grassland, Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral, and California Xeric Serpentine Chaparral) that fell outside of ultramafic soils were reclassified to Northern and Central California Dry-Mesic Chaparral.

The fixes that related to the presence or absence of sand were followed by two reclassification steps relating to herbaceous headlands, and bald and bluff Systems. First, areas that were mapped as North Pacific Broadleaf Landslide Forest and Shrubland by the nonforest map, and were also located on hilltops (TPI150 > 15), were reclassified to North Pacific Herbaceous Bald and Bluff. Second, areas within 5km of the ocean that were mapped by the nonforest model as North Pacific Broadleaf Landslide Forest and Shrubland, or North Pacific Herbaceous Bald and Bluff and were not in valley bottoms (TPI159 > 0) were reassigned to either Northern California Coastal Scrub, or North Pacific Hypermaritime Shrub and Herbaceous Headland., based on the (already modified) forest map. Northern California Coastal Scrub was mapped in accordance with the presence of California-affiliated forest Systems (Table 9), with the following exception: California Coastal Closed Cone Conifer Forest and Woodlands. All of the remaining pixels identified in this step were assigned to North Pacific Hypermaritime Shrub and Herbaceous Headland.

Errors in mapping the wetlands were addressed in the following four steps. First, areas mapped in the composite map as Temperate Pacific Freshwater Emergent Marsh that fell on slopes (> 15%) were reclassified to North Pacific Broadleaf Landslide Forest and Shrubland. Second, areas mapped in the composite map as Temperate Pacific Tidal Salt and Brackish Marsh that were at > 3m of elevation were reclassified to Temperate Pacific Freshwater Emergent marsh. Third, areas mapped in the composite map as North Pacific Broadleaf Landslide Forest and Shrubland that fell on flatter slopes (<= 10%) and were also in valley bottoms (TPI150 < = 1), were reclassified to Cultivated Crops. Fourth, areas mapped in the composite map as North Pacific Broadleaf Landslide Forest and Shrubland that fell on even flatter slopes (< 5%), and at extremely low elevations (<3m) were reclassified to Temperate Pacific Tidal Salt and Brackish Marsh.

The fens mapped in the final version of the map were modified from the burn-in layer in two ways. First, pixels mapped as fens in the composite map and mapped as a California-affiliated system (Table 9) by the adjusted forest model were assigned to Mediterranean California Subalpine-Montane Fen. Second, pixels mapped as North Pacific Bog and Fen in the composite map that fell within areas known to have ultramafic soil parent material were reassigned to Mediterranean California Serpentine Fen in the final map.

Three additional changes were made after accuracy assessment was completed. First, 2.5 ha of Northern and Central California Dry Mesic Chaparral in the northern part of the model region were reclassified to North Pacific Montane Shrubland. Second and third, East Cascades Oak-Pine Forest and Woodland and East Cascades Mesic Mixed Conifer Forest and Woodland were reclassified to North Pacific Oak Woodland and North Pacific Maritime Dry-Mesic Douglas-fir – Western Hemlock Forest (respectively). Therefore, although these classes are listed in our accuracy assessment tables, and area assessment table, they are not present in the map legend for this model region.

Modoc Plateau (Model Region 10)

Within the Modoc Plateau modeling region, we followed our generalized layering procedure, with only two reclassification steps, aimed at fixing errors related to the volcanic Systems. Places that were mapped as lodgepole pine, or spruce forests (Rocky Mountain Lodgepole Pine Forest, Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland, Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland, and Rocky Mountain Poor-Site Lodgepole Pine Forest and Woodland) in the forest map, but North Pacific Wooded Volcanic Flowage by the nonforest map were assigned to the Systems predicted by the forest model to the final map. Then, areas mapped as North Pacific Wooded Volcanic Flowage by the unmasked nonforest model that were mapped as Rocky Mountain Poor-site Lodgepole Pine Forest and Woodland by the un-adjusted forest model were assigned to the pine system in the final map.

Although our layering procedure for this modeling region followed the standard, the transitional classes layer was derived from a slightly different data source here (the one used in Oregon was unavailable for California). The source for transitional classes in California, although it used a similar multi-date change-detection procedure, was done at a different time, and by a different research group, and thus has a lower density of mapped clearcuts.

Land Cover Map Results:

We are providing the following products. The map is an ArcGIS grid, at 30 m resolution, in national Albers projection.

- Final draft of the integrated grid of Ecological Systems and landcover for map zones 2 and 7.
- Zip file with Excel spreadsheets containing accuracy assessment for each modeling region, for all Ecological Systems, including error matrices, kappa statistics, and fuzzy set assignments.

Table 11 on the following pages summarizes the results of the final mapping process, by model region, and over zones 2 and 7 combined.

Gradient nearest neighbor maps and associated accuracy assessment products are available for download at: *http://www.fsl.orst.edu/lemma/gnnpac/mapProducts.php.*

Table 11: The land cover types mapped, their area mapped in the region in square kilometers, and the percentage of the region's total area represented by the mapped type. *Note: For model regions 6 and 9, very minor modifications were made to the final map after these statistics were completed. See appropriate Map Assembly sections for a description of these changes.*

ESLF	Ecological System	4	5	6	7	8	9	10	Total	Percent
11	Open Water	110.91	574.53	265.50	44.34	160.56	195.39	649.32	2000.54	1.369
12	Ice-Snow	26.56	0.25	32.59		0.01	0.15	7.97	67.53	0.046
21	Developed, Open Space	183.51	201.11	142.61	507.09	601.58	1201.49	289.54	3126.93	2.140
22	Developed, Low Intensity	98.65	61.24	12.40	160.88	888.09	161.00	73.60	1455.86	0.996
23	Developed, Medium Intensity	23.70	12.60	4.60	63.98	487.40	39.18	13.28	644.74	0.441
24	Developed, High Intensity	3.61	4.33	0.62	23.32	188.08	16.50	1.59	238.05	0.163
81	Pasture/Hay	94.84	593.08	68.00	863.13	3466.21	329.46	1076.89	6491.61	4.442
82	Cultivated Crops	470.70	946.44	60.29	132.28	2212.67	121.87	978.28	4922.52	3.369
88	High Structure Agriculture					368.28			368.28	0.252
3118	NP Alpine and Subalpine Bedrock and Scree	44.05	0.01	129.43					173.48	0.119
3128	IMB Volcanic Rock and Cinder Land		6.44		1.24			225.48	233.15	0.160
3129	RM Cliff, Canyon and Massive Bedrock		1.63						1.63	0.001
3140	NP Volcanic Rock and Cinder Land	171.13	79.81	128.12				17.13	396.18	0.271
3152	IMB Wash		8.34					1.25	9.59	0.007
3155	NP Montane Massive Bedrock, Cliff and Talus	3.51		9.65	0.15	0.01	8.58		21.90	0.015
3158	NP Coastal Cliff and Bluff						2.24		2.24	0.002
3160	IMB Active and Stabilized Dune		0.02						0.02	0.000
3165	MC Northern Coastal Dune						7.01		7.01	0.005
3167	MC Serpentine Barrens				7.37				7.37	0.005
3170	KS Cliff and Outcrop				1.32			4.53	5.85	0.004
3171	SN Cliff and Canyon							5.68	5.68	0.004
3172	MC Alpine Bedrock and Scree							46.63	46.63	0.032
3173	IMB Cliff and Canyon	16.37	1.41					0.23	18.01	0.012
3174	CP Ash and Tuff Badland							4.49	4.49	0.003
3177	NP Maritime Coastal Sand Dune and Strand						145.30		145.30	0.099
3179	IMB Basins Playa		113.98					250.82	364.80	0.250
4101	NP Oak Woodland	42.77		16.68	473.00	1155.85	139.52	34.75	1862.57	1.275
4103	NRM Western Larch Savanna	12.06		1.70					13.76	0.009
4104	RM Aspen Forest and Woodland		17.22					25.29	42.51	0.029
4202	Cal Coastal Redwood Forest				33.64		213.54		247.19	0.169
4204	CP Western Juniper Woodland and Savanna	1289.99	1217.34		20.83			2042.70	4570.85	3.128

ESLF	Ecological System	4	5	6	7	8	9	10	Total	Percent
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland	627.46		295.25	38.94	9.56	31.97		1003.18	0.687
4208	KS Lower Montane Serpentine Mixed Conifer Woodland			0.85	375.52		0.14	19.39	395.90	0.271
4209	KS Upper Montane Serpentine Mixed Conifer Woodland				237.03		0.23	37.48	274.74	0.188
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland	113.73	775.41	1200.34	1990.93	32.97	247.37	1489.77	5850.53	4.004
4215	MC Mesic Mixed Conifer Forest and Woodland	144.61	2409.05	2791.01	1038.05	40.14	72.36	3226.06	9721.28	6.653
4216	MC Mixed Oak Woodland				348.17	7.52	5.03	654.77	1015.48	0.695
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland		13.27	189.14	2243.91	16.27	2.81	2710.53	5175.92	3.542
4218	Cal Montane Jeffrey Pine Woodland							3228.64	3228.64	2.210
4219	MC Red Fir Forest	7.19	41.74	587.62	6.77	15.09	84.79	460.95	1204.15	0.824
4220	MC Subalpine Woodland		14.13					74.89	89.02	0.061
4221	MC Mesic Serpentine Woodland and Chaparral				7.91				7.91	0.005
4222	NP Dry Douglas-fir Forest and Woodland	102.64		337.31	1073.16	196.31	674.82	79.85	2464.09	1.686
4223	NP Hypermaritime Sitka Spruce Forest						1314.84		1314.84	0.900
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	13.58		7016.73	377.81	704.63	2486.43		10599.18	7.253
4225	NP Maritime Mesic Subalpine Parkland	41.70	5.99	339.02					386.71	0.265
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	0.14		2798.91	97.52	166.57	5067.77		8130.90	5.564
4228	NP Mountain Hemlock Forest	3.12	11.77	1966.96	15.35				1997.20	1.367
4229	NP Mesic Western Hemlock-Silver Fir Forest			166.01					166.01	0.114
4230	MC Mixed Evergreen Forest		5.51	178.68	3583.45		804.16	48.15	4619.95	3.162
4231	NC Mesic Subalpine Woodland	13.58	65.20	453.33				151.77	683.87	0.468
4232	NRM Dry-Mesic Montane Mixed Conifer Forest	64.93	3.65					42.21	110.78	0.076
4233	NRM Subalpine Woodland and Parkland	15.25	32.73	20.16					68.13	0.047
4237	RM Lodgepole Pine Forest	5.25	39.47	55.53				26.63	126.88	0.087
4240	NRM Ponderosa Pine Woodland and Savanna	1475.23	7928.74	93.47	0.50			503.27	10001.20	6.844
4242	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4.46	31.70	126.96					163.12	0.112
4245	SN Subalpine Lodgepole Pine Forest and Woodland		241.72	83.20				22.02	346.94	0.237
4267	RM Poor-Site Lodgepole Pine Forest	18.19	1825.19	155.69				27.57	2026.64	1.387
4268	Cal Coastal Closed-Cone Conifer Forest and Woodland						135.69		135.69	0.093
4269	SI Desert Western White Pine-White Fir Woodland		67.18	1.13				65.31	133.63	0.091
4271	NP Hypermaritime Western Red-cedar-Western Hemlock Forest						27.48		27.48	0.019
4272	NP Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	3.41	1.84	2107.73		4.53	25.72		2143.22	1.467

ESLF	Ecological System	4	5	6	7	8	9	10	Total	Percent
4301	EC Oak-Ponderosa Pine Forest and Woodland	492.42	37.55		64.34	9.08		97.50	700.90	0.480
4302	IMB Aspen-Mixed Conifer Forest and Woodland		80.10					31.50	111.60	0.076
4303	INB Mountain Mahogany Woodland and Shrubland		167.62					325.17	492.79	0.337
4304	NP Broadleaf Landslide Forest and Shrubland			206.96	0.94	28.25	1015.82		1251.96	0.857
4329	NP Wooded Volcanic Flowage	123.91	14.82	239.77				605.79	984.28	0.674
4333	NP Lowland Mixed Hardwood Conifer Forest and Woodland	7.71		1137.00	50.77	1449.31	2261.40		4906.17	3.358
5202	CP Scabland Shrubland	640.54	0.31	0.02				123.84	764.71	0.523
5204	MC Alpine Fell-Field							7.33	7.33	0.005
5205	NP Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow	2.55	6.20	56.21				2.48	67.43	0.046
5256	GB Xeric Mixed Sagebrush Shrubland		0.99					239.52	240.51	0.165
5257	IMB Big Sagebrush Shrubland	57.35	256.04	0.04				756.80	1070.23	0.732
5258	IMB Mixed Salt Desert Scrub		68.25					11.99	80.24	0.055
5260	NP Avalanche Chute Shrubland			12.55				1.40	13.94	0.010
5261	NP Montane Shrubland		0.14	70.37				0.56	71.08	0.049
5302	Cal Maritime Chaparral									0.000
5304	Cal Montane Woodland and Chaparral		152.34	52.33	177.92		35.87	173.61	592.07	0.405
5305	Cal Xeric Serpentine Chaparral				0.18			28.12	28.30	0.019
5311	Northern and Central Cal Dry-Mesic Chaparral		11.43	23.26	91.53	39.31	5.18	424.90	595.61	0.408
5312	NRM Montane-Foothill Deciduous Shrubland									0.000
5403	Cal Lower Montane Blue Oak-Foothill Pine Woodland and Savanna							126.03	126.03	0.086
5404	IMB Juniper Savanna							9.04	9.04	0.006
5409	WV Upland Prairie and Savanna			85.67	162.93	144.95	52.05	1.64	447.25	0.306
5425	KS Xeromorphic Serpentine Savanna and Chaparral				97.86		0.11	107.14	205.12	0.140
5452	CP Steppe and Grassland	654.94	34.08					2526.91	3215.92	2.201
5453	CP Low Sagebrush Steppe	5.02	1562.18					1524.18	3091.37	2.116
5454	IMB Big Sagebrush Steppe	450.17	366.80	0.24				1637.59	2454.80	1.680
5455	IMB Montane Sagebrush Steppe	58.94	116.44	15.64				87.21	278.22	0.190
5456	IMB Semi-Desert Shrub-Steppe	0.58	0.26					3.18	4.03	0.003
5457	NC Coastal Scrub						13.51		13.51	0.009
7102	Cal Mesic Serpentine Grassland		6.69		0.11			13.56	20.36	0.014
7103	Cal Northern Coastal Grassland						22.18		22.18	0.015
7106	CB Foothill and Canyon Dry Grassland	328.64							328.64	0.225
7107	IMB Semi-Desert Grassland	5.35	0.55					172.30	178.20	0.122

ESLF	Ecological System	4	5	6	7	8	9	10	Total	Percent
7108	MC Alpine Dry Tundra			0.39	12.05				12.44	0.009
7109	MC Subalpine Meadow		4.24	19.34				11.27	34.85	0.024
7110	NP Montane Grassland	23.08	36.52	101.15	14.91			83.91	259.58	0.178
7112	NRM Lower Montane, Foothill and Valley Grassland	1.60	238.40					293.83	533.83	0.365
7118	RM Subalpine-Montane Mesic Meadow							0.04	0.04	0.000
7157	NP Alpine and Subalpine Dry Grassland	6.40	6.13	84.42				13.36	110.30	0.075
7161	NP Hypermaritime Shrub and Herbaceous Headland						7.87		7.87	0.005
7162	NP Herbaceous Bald and Bluff			37.40	19.22		31.38		88.00	0.060
8404	Introduced Upland Vegetation - Annual Grassland		17.72					77.42	95.14	0.065
8501	Recently burned forest	21.94	60.15	135.79	358.74	50.79	33.08	165.42	825.91	0.565
8502	Recently burned grassland							3.13	3.13	0.002
8503	Recently burned shrubland							16.94	16.94	0.012
8601	Harvested forest-tree regeneration	598.85	2387.01	3708.47	908.25	666.42	4581.56	312.09	13162.65	9.008
8602	Harvested forest-shrub regeneration	4.04	13.30	55.24	3.81	16.77	181.03	0.58	274.75	0.188
8603	Harvested forest-grass regeneration	5.80	6.16	53.93	2.61	10.62	5.88	0.21	85.19	0.058
8604	Harvested forest-herbaceous regeneration			31.47	2.84		19.88		54.19	0.037
9103	IMB Greasewood Flat		406.51					219.50	626.01	0.428
9106	NP Lowland Riparian Forest and Shrubland	14.12	2.06	481.17	145.49	470.62	1429.11	13.72	2556.29	1.749
9108	NP Montane Riparian Woodland and Shrubland	105.58	1.98	166.61	7.78	1.49	9.22	104.46	397.12	0.272
9156	RM Lower Montane Riparian Woodland and Shrubland	73.35	427.40	9.07	0.06			23.75	533.62	0.365
9166	NP Bog and Fen		8.16	1.26		0.14	3.94		13.50	0.009
9168	GB Foothill and Lower Montane Riparian Woodland and Shrubland		12.88					1.15	14.04	0.010
9170	CB Foothill Riparian Woodland and Shrubland	5.88	54.33		0.24			250.31	310.77	0.213
9171	RM Subalpine-Montane Riparian Woodland	0.31	4.73	7.25					12.29	0.008
9173	NP Shrub Swamp		0.12			10.15	0.29		10.56	0.007
9190	NP Hardwood-Conifer Swamp			5.01		20.31			25.31	0.017
9219	TP Freshwater Aquatic Bed					0.19			0.19	0.000
9221	WV Wet Prairie			14.18	20.00	93.23	76.77		204.17	0.140
9222	North American Arid West Emergent Marsh		331.17					75.22	406.39	0.278
9248	MC Subalpine-Montane Fen		0.51	0.40					0.91	0.001
9251	NC Claypan Vernal Pool				31.15				31.15	0.021
9255	MC Serpentine Fen				0.01				0.01	0.000
9260	TP Freshwater Emergent Marsh		36.90			11.85	60.74		109.49	0.075
9262	MC Coastal Interdunal Wetland									0.000

ESLF	Ecological System	4	5	6	7	8	9	10	Total	Percent
9265	TP Subalpine-Montane Wet Meadow	3.44	333.12	47.57	1.38			0.78	386.29	0.264
9281	TP Tidal Salt and Brackish Marsh						94.85		94.85	0.065
9297	IMB Alkaline Closed Depression		89.17					66.46	155.63	0.107
9321	CP Silver Sagebrush Seasonally Flooded Shrub-Steppe		22.73					59.68	82.41	0.056
9325	MC Serpentine Foothill and Lower Montane Riparian			0.17	12.22		0.25	3.17	15.81	0.011
9330	MC Foothill and Lower Montane Riparian Woodland	10.52	96.57	212.62	384.91	3.82	107.74	274.28	1090.47	0.746
	Total:	8949.86	24834.83	28910.19	16339.84	13749.63	23612.55	29728.68	146125.39	100

Geographic abbreviations of System names: Cal = California, CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, GB = Great Basin, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, SI = Sierran-Intermontane, TP = Temperate Pacific, WV = Willamette Valley.

Maps

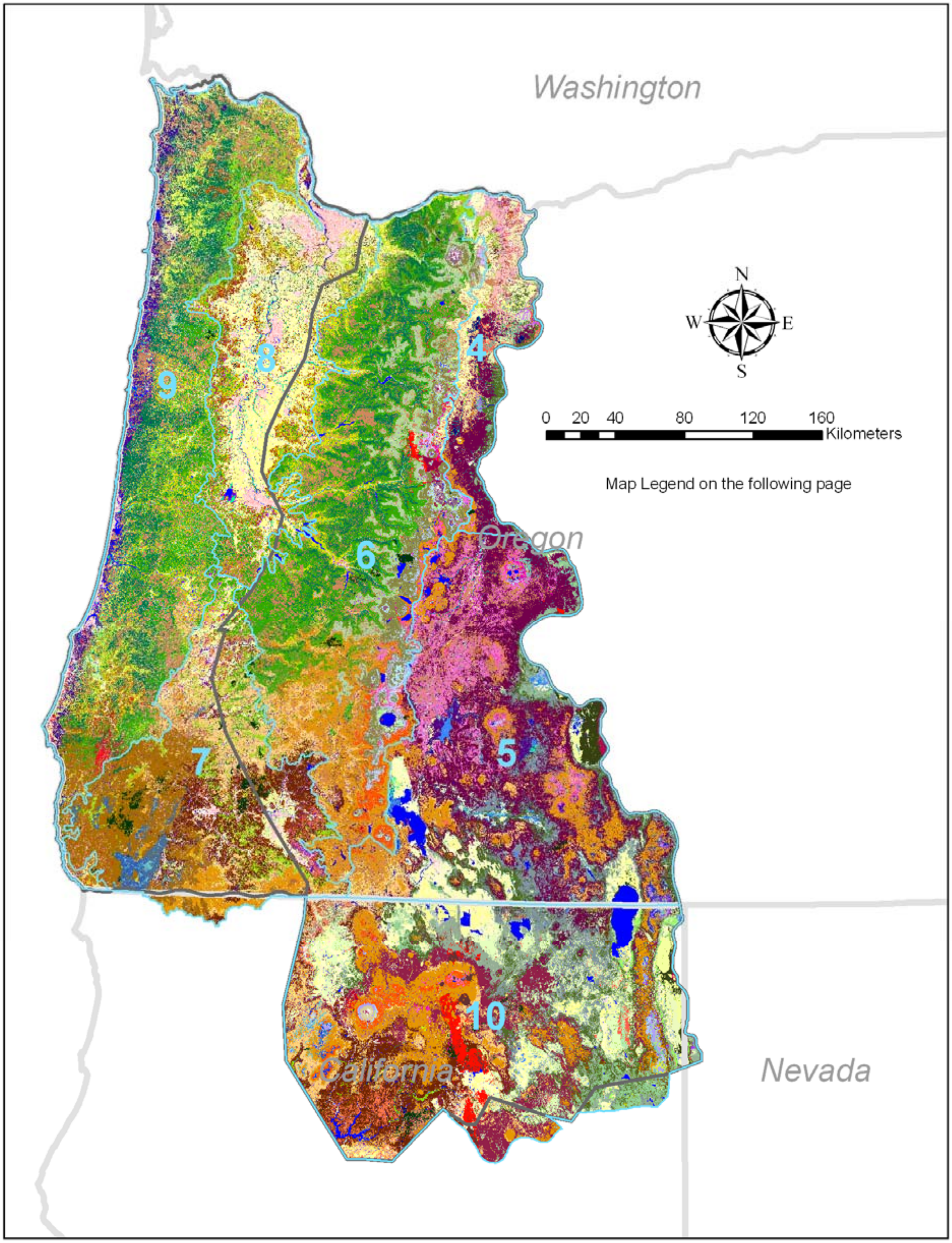

Figure 2: Ecological Systems map for MRLC mapzones 2 and 7.

Legend

- California Coastal Closed-Cone Conifer Forest and Woodland
- California Coastal Redwood Forest
- California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
- California Mesic Serpentine Grassland
- California Montane Jeffrey Pine Woodland
- California Montane Woodland and Chaparral
- California Northern Coastal Grassland
- California Xeric Serpentine Chaparral
- Columbia Basin Foothill and Canyon Dry Grassland
- Columbia Basin Foothill Riparian Woodland and Shrubland
- Columbia Plateau Ash and Tuff Badland
- Columbia Plateau Low Sagebrush Steppe
- Columbia Plateau Scabland Shrubland
- Columbia Plateau Silver Sagebrush Seasonally Flooded Shrub-Steppe
- Columbia Plateau Steppe and Grassland
- Columbia Plateau Western Juniper Woodland and Savanna
- Cultivated Crops
- Developed, High Intensity
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, Open Space
- East Cascades Mesic Montane Mixed-Conifer Forest and Woodland
- East Cascades Oak-Ponderosa Pine Forest and Woodland
- Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland
- Great Basin Xeric Mixed Sagebrush Shrubland
- Harvested forest-grass regeneration
- Harvested forest-herbaceous regeneration
- Harvested forest-shrub regeneration
- Harvested forest-tree regeneration
- High Structure Agriculture
- Ice-Snow
- Inter-Mountain Basins Active and Stabilized Dune
- Inter-Mountain Basins Alkaline Closed Depression
- Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
- Inter-Mountain Basins Big Sagebrush Shrubland
- Inter-Mountain Basins Big Sagebrush Steppe
- Inter-Mountain Basins Cliff and Canyon
- Inter-Mountain Basins Greasewood Flat
- Inter-Mountain Basins Juniper Savanna
- Inter-Mountain Basins Mixed Salt Desert Scrub
- Inter-Mountain Basins Montane Sagebrush Steppe
- Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland
- Inter-Mountain Basins Playa
- Inter-Mountain Basins Semi-Desert Grassland
- Inter-Mountain Basins Semi-Desert Shrub-Steppe
- Inter-Mountain Basins Volcanic Rock and Cinder Land
- Inter-Mountain Basins Wash
- Introduced Upland Vegetation - Annual Grassland
- Klamath-Siskiyou Cliff and Outcrop
- Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland
- Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland
- Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral
- Mediterranean California Alpine Bedrock and Scree
- Mediterranean California Alpine Dry Tundra
- Mediterranean California Alpine Fell-Field
- Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland
- Mediterranean California Foothill and Lower Montane Riparian Woodland
- Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland
- Mediterranean California Mesic Mixed Conifer Forest and Woodland
- Mediterranean California Mesic Serpentine Woodland and Chaparral
- Mediterranean California Mixed Evergreen Forest
- Mediterranean California Mixed Oak Woodland
- Mediterranean California Northern Coastal Dune
- Mediterranean California Red Fir Forest
- Mediterranean California Serpentine Barrens
- Mediterranean California Serpentine Fen
- Mediterranean California Serpentine Foothill and Lower Montane Riparian
- Mediterranean California Subalpine Meadow
- Mediterranean California Subalpine Woodland
- Mediterranean California Subalpine-Montane Fen
- North American Arid West Emergent Marsh
- North Pacific Alpine and Subalpine Bedrock and Scree
- North Pacific Alpine and Subalpine Dry Grassland
- North Pacific Avalanche Chute Shrubland
- North Pacific Bog and Fen
- North Pacific Broadleaf Landslide Forest and Shrubland
- North Pacific Coastal Cliff and Bluff
- North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
- North Pacific Dry Douglas-fir Forest and Woodland
- North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
- North Pacific Hardwood-Conifer Swamp
- North Pacific Herbaceous Bald and Bluff
- North Pacific Hypermaritime Shrub and Herbaceous Headland
- North Pacific Hypermaritime Sitka Spruce Forest
- North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest
- North Pacific Lowland Mixed Hardwood Conifer Forest and Woodland
- North Pacific Lowland Riparian Forest and Shrubland
- North Pacific Maritime Coastal Sand Dune and Strand
- North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
- North Pacific Maritime Mesic Subalpine Parkland
- North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
- North Pacific Mesic Western Hemlock-Silver Fir Forest
- North Pacific Montane Grassland
- North Pacific Montane Massive Bedrock, Cliff and Talus
- North Pacific Montane Riparian Woodland and Shrubland
- North Pacific Montane Shrubland
- North Pacific Mountain Hemlock Forest
- North Pacific Oak Woodland
- North Pacific Shrub Swamp
- North Pacific Volcanic Rock and Cinder Land
- North Pacific Wooded Volcanic Flowage
- Northern and Central California Dry-Mesic Chaparral
- Northern California Claypan Vernal Pool
- Northern California Coastal Scrub
- Northern California Mesic Subalpine Woodland
- Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
- Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
- Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
- Northern Rocky Mountain Subalpine Woodland and Parkland
- Northern Rocky Mountain Western Larch Savanna
- Open Water
- Pasture/Hay
- Recently burned forest
- Recently burned grassland
- Recently burned shrubland
- Rocky Mountain Aspen Forest and Woodland
- Rocky Mountain Cliff, Canyon and Massive Bedrock
- Rocky Mountain Lodgepole Pine Forest
- Rocky Mountain Lower Montane Riparian Woodland and Shrubland
- Rocky Mountain Poor-Site Lodgepole Pine Forest
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
- Rocky Mountain Subalpine-Montane Mesic Meadow
- Rocky Mountain Subalpine-Montane Riparian Woodland
- Sierra Nevada Cliff and Canyon
- Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland
- Sierran-Intermontane Desert Western White Pine-White Fir Woodland
- Temperate Pacific Freshwater Aquatic Bed
- Temperate Pacific Freshwater Emergent Marsh
- Temperate Pacific Subalpine-Montane Wet Meadow
- Temperate Pacific Tidal Salt and Brackish Marsh
- Willamette Valley Upland Prairie and Savanna
- Willamette Valley Wet Prairie

Land Cover Map Validation

Introduction:

Assessing land cover map quality is an important concern for land cover mapping projects. Map quality assessment provides useful information to map users about the reliability of the map product. Various approaches to map quality assessment are recognized (Foody 2002), however, making the assessment helpful to the map user should be of primary importance (Smits et al. 1999). Typically the quality of land cover maps are assessed using a probability based sampling design (Stehman and Czaplewski 1998) with relatively large sample sizes per class (Congalton and Green 1999). These probability based approaches utilize data collected specifically for map quality assessment, and are commonly referred to as "map accuracy assessments."

The process used here, is primarily an internal validation; "validation" in the sense that the purpose is to validate the quality of the map, and "internal" because validation relies on data collected for, and used within, the modeling process (Shtatland et al. 2004). The approach may be viewed as a "split sample" or "hold out" method. This type of validation is not as accurate as a k-fold cross-validation (Goutte 1997) or as robust as an external validation (Shtatland et al. 2004). We developed the best validation sample possible given the time and resources allotted. For the forested Ecological Systems, we withheld some plots from our models, and used them in the validation process. For the nonforested Systems, we decided to use all available data for both modeling and accuracy assessment for two primary reasons. First, the plot data available to us was limited for the nonforest Systems, and withholding data from our model often resulted in large decreases in internal (out-of-box) estimates of the Random Forest model accuracy. Given the time allotted, we did not have time to collect additional points for validation.

Land Cover Map Validation Methods:

Quantitative validation methods were described briefly in the previous section dealing with the mapping process. Here we provide a more detailed explanation about the quantitative validation process, focusing on our use of fuzzy set analysis. We also describe our approach to performing a qualitative assessment of the map product.

Quantitative Assessment using Fuzzy Sets

The Gap Analysis Handbook recommends the use of "fuzzy set" analysis as a means of providing map users additional information about the quality of the map product (Crist and Deitner 2000). Our approach to fuzzy set assessment is based on the work of Gopal and Woodcock (1994) and described by Congalton and Green (1999). Using fuzzy set analysis for map quality assessment has proven useful in various land cover mapping efforts (Falzarano and Thomas 2004, Laba et al. 2002, Woodcock and Gopal 1992, Reiners et al. 2000). The premise behind fuzzy set theory for thematic map assessment is that thematic mapping involves placing a continuum of land cover into (somewhat artificially) discrete land cover classes. This continuum suggests that there can be different magnitudes of error between/among classes. The objective of using fuzzy sets for thematic map assessment is to provide map users with information about the frequency *and* magnitude of map error. In other words, a reference site may have been mapped incorrectly, but how incorrect was it? An answer to this question can be provided by reevaluating the error matrix within the context of recognized similarities among land cover classes. The essence of fuzzy set assessment lies in the construction of a "linguistic measurement scale" to assign degrees of correctness to misclassification errors. Gopal and Woodcock (1994) suggest five levels of linguistic values ranging from "absolutely wrong" to "absolutely right" which experts to use when evaluating a map product relative to the reference sample plots. Determining the appropriate linguistic class, or error type, for any given reference plot is subject to the judgment of the error assessment "expert." Establishing objective criteria for assigning the level of error, therefore, is an important component to a fuzzy set assessment. Criteria for error assignment type may be based on seriousness of the error for its intended application (Reiners et al. 2000) or on some aspect of similarity among land cover classes.

We defined our fuzzy sets based on several factors, including seral relationships among the Systems, similarities in geographic affinity, moisture regimes, elevational limits, species composition, structure, and special restricted soil types. Ecological system pairs that were similar in multiple dimensions were designated as “fuzzy correct” for fuzzy accuracy assessment.

Assessment of Area Representation

We also performed a model-region scale assessment of accuracy, estimating how well each map represented the area of each forested System. We obtained an estimate of the actual area for each forested System within each modeling region using the FIA plots, which are a systematic sample of the landscape. We then calculated the total area of each system within each modeling region. This assessment was only carried out for the forested Ecological Systems because the FIA plots sample only forested areas.

Land Cover Map Validation Results:

Each modeling region was assessed independently because each one was mapped independently. Accuracy assessment statistics are presented in tables 10 through 16. Area Assessments are presented in figures 2 through 8. For the area statistics, “NA” values for user’s or producer’s accuracy result when we either had no plots available for accuracy assessment (class mapped through supplementary sources), or where none of our accuracy assessment plots happened to intersect that particular System. Producer’s accuracy and User’s accuracy illustrate omission errors, and commission errors respectively (See Lillesand and Kiefer 2000 for a more in depth definition).

Table 12: Accuracy assessment statistics for the Northern East Cascades, Model Region 4.

	Accuracy				**Fuzzy Accuracy**			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
3118	57.14	44.44	0.4964	0.0037	57.14	44.44	0.4964	0.0037
3128	0	NA	0	0.0009	0	NA	0	0.0009
3140	100	36.36	0.5308	0.0035	100	36.36	0.5308	0.0035
3173	NA	0	0	0.0009	NA	0	0	0.0009
4101	33.33	100	0.4993	0.0018	76.39	96.49	0.8437	0.0112
4103	35.71	71.43	0.4717	0.0042	35.71	62.5	0.4495	0.0043
4204	80	50	0.6066	0.0068	88.56	89.8	0.801	0.0419
4205	62.59	94.85	0.688	0.0269	80.07	95.54	0.6177	0.0358
4214	79.22	96.83	0.8628	0.0118	81.88	91.36	0.716	0.0422
4215	77.14	67.5	0.7102	0.0082	79.93	96.8	0.6091	0.0345
4219	0	0	-0.0012	0.0016	53.7	67.44	0.5797	0.0095
4222	78.18	86	0.81	0.0100	76.33	85.38	0.744	0.0287
4224	11.76	100	0.208	0.0040	69.3	96.92	0.6743	0.0413
4225	41.67	100	0.5856	0.0038	38.46	100	0.5526	0.0039
4226	0	NA	0	0.0018	58.84	94.61	0.6446	0.0286
4228	0	NA	0	0.0009	26.83	68.75	0.3729	0.0071
4231	66.67	66.67	0.6648	0.0032	69.57	60.38	0.63	0.0096
4232	75.61	96.88	0.8442	0.0081	79.28	98.35	0.4231	0.0250
4233	87.5	77.78	0.8222	0.0038	66.67	73.08	0.6816	0.0102
4237	0	NA	0	0.0018	66.67	93.33	0.7586	0.0137
4240	83.06	87.43	0.7829	0.0348	82.14	96.97	0.5674	0.0293
4242	33.33	100	0.498	0.0032	33.33	100	0.498	0.0032
4245	0	NA	0	0.0009	53.85	77.78	0.6328	0.0043
4267	16.67	100	0.2835	0.0034	55	86.84	0.6591	0.0096
4272	0	0	-0.0024	0.0022	67.78	95.86	0.679	0.0386
4301	76.81	94.64	0.839	0.0110	80.88	98.06	0.5137	0.0273
4303	0	NA	0	0.0013	73.47	81.82	0.7643	0.0093
4329	NA	0	0	0.0036	78.18	65.15	0.6941	0.0108
5202	NA	0	0	0.0027	100	5.26	0.0984	0.0041
5205	75	100	0.8563	0.0034	68.18	60	0.6305	0.0064

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
5257	50	50	0.4991	0.0018	89.29	48.08	0.6122	0.0085
5261	0	NA	0	0.0009	0	NA	0	0.0009
5452	100	10	0.1805	0.0030	90.48	32.2	0.4598	0.0085
5453	NA	NA	NA	0.0000	92.31	46.15	0.6029	0.0084
5454	NA	0	0	0.0026	92.31	42.11	0.5642	0.0087
5455	75	30	0.4256	0.0034	62.5	25	0.3504	0.0049
7106	NA	0	0	0.0020	NA	0	0	0.0022
7110	66.67	37.5	0.4745	0.0046	70.59	54.55	0.6086	0.0058
7112	NA	0	0	0.0009	35.71	38.46	0.3626	0.0048
7157	60	100	0.7491	0.0026	69.23	100	0.8164	0.0043
8501	NA	0	0	0.0013	94.99	99.41	0.5505	0.0117
8601	NA	0	0	0.0110	94.99	99.41	0.5505	0.0117
9106	0	NA	0	0.0016	8.33	100	0.151	0.0047
9108	0	0	-0.0045	0.0029	0	0	-0.0072	0.0036
9156	NA	0	0	0.0016	16.67	40	0.2304	0.0038
9170	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9265	50	100	0.6659	0.0022	50	100	0.6659	0.0022
9330	NA	0	0	0.0024	71.12	94.52	0.7228	0.0356
			Overall Accuracy	70.02%			Overall Accuracy	76.99%
			Overall Kappa	0.6428			Overall Kappa	0.7578
			ASE	0.0164			ASE	0.0491

ESLF	Ecological System Names
3118	NP Alpine and Subalpine Bedrock and Scree
3128	IMB Volcanic Rock and Cinder Land
3140	NP Volcanic Rock and Cinder Land
3173	IMB Cliff and Canyon
4101	NP Oak Woodland
4103	NRM Western Larch Savanna
4204	CP Western Juniper Woodland and Savanna
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland
4219	MC Red Fir Forest
4222	NP Dry Douglas-fir Forest and Woodland
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
4225	NP Maritime Mesic Subalpine Parkland
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
4228	NP Mountain Hemlock Forest
4231	NC Mesic Subalpine Woodland
4232	NRM Dry-Mesic Montane Mixed Conifer Forest
4233	NRM Subalpine Woodland and Parkland
4237	RM Lodgepole Pine Forest
4240	NRM Ponderosa Pine Woodland and Savanna
4242	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
4245	SN Subalpine Lodgepole Pine Forest and Woodland
4267	RM Poor-Site Lodgepole Pine Forest

ESLF	Ecological System Names
4272	NP Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
4301	EC Oak-Ponderosa Pine Forest and Woodland
4303	IMB Mountain Mahogany Woodland and Shrubland
4329	NP Wooded Volcanic Flowage
5202	CP Scabland Shrubland
5205	NP Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
5257	IMB Big Sagebrush Shrubland
5261	NP Montane Shrubland
5452	CP Steppe and Grassland
5453	CP Low Sagebrush Steppe
5454	IMB Big Sagebrush Steppe
5455	IMB Montane Sagebrush Steppe
7106	CB Foothill and Canyon Dry Grassland
7110	NP Montane Grassland
7112	NRM Lower Montane, Foothill and Valley Grassland
7157	NP Alpine and Subalpine Dry Grassland
8501	Recently burned forest
8601	Harvested forest-tree regeneration
9106	NP Lowland Riparian Forest and Shrubland
9108	NP Montane Riparian Woodland and Shrubland
9156	RM Lower Montane Riparian Woodland and Shrubland
9170	CB Foothill Riparian Woodland and Shrubland
9265	TP Subalpine-Montane Wet Meadow
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, IMB = Inter-Mountain Basins, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, TP = Temperate Pacific.

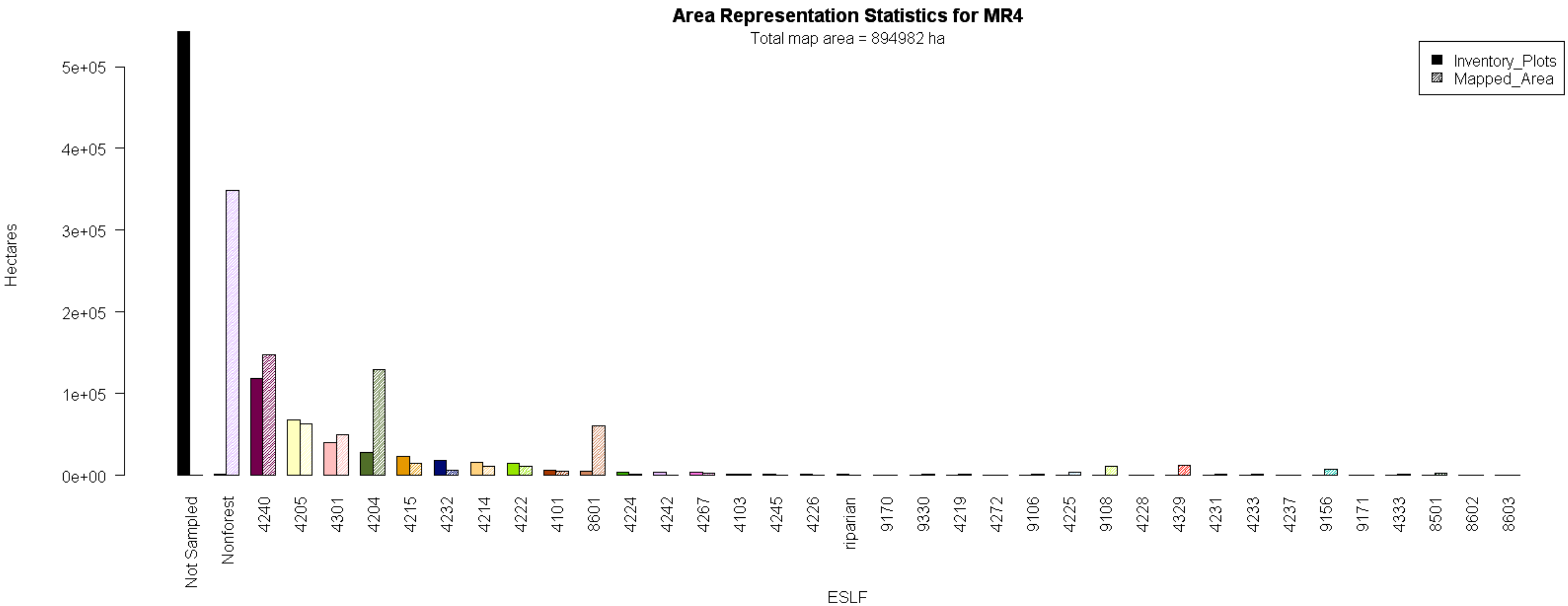

Figure 3: Class Area representation for Northern East Cascades (Model Region 4).

Table 13: Accuracy assessment statistics for the Southern East Cascades, Model Region 5.

	Accuracy				**Fuzzy Accuracy**			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
3128	NA	NA	NA	0.0000	NA	NA	NA	0.0000
3140	38.46	100.00	0.5546	0.0013	38.46	100.00	0.5546	0.0013
3152	NA	NA	NA	0.0000	NA	NA	NA	0.0000
3173	0.00	NA	0.0000	0.0003	0.00	NA	0.0000	0.0003
3179	NA	NA	NA	0.0000	NA	NA	NA	0.0000
4104	22.22	66.67	0.3324	0.0011	56.76	81.97	0.6031	0.0132
4204	64.58	72.09	0.6768	0.0030	86.95	87.38	0.7717	0.0242
4214	84.29	85.64	0.8402	0.0066	89.13	89.09	0.7229	0.0230
4215	81.82	89.81	0.8304	0.0121	89.54	88.76	0.7263	0.0231
4217	44.44	80.00	0.5706	0.0012	82.79	82.41	0.8135	0.0071
4218	0.00	NA	0.0000	0.0004	86.55	92.07	0.8609	0.0160
4219	66.67	33.33	0.4438	0.0009	70.03	87.13	0.6738	0.0203
4220	100.00	72.73	0.8417	0.0014	53.33	76.19	0.6246	0.0022
4225	0.00	0.00	-0.0006	0.0006	40.00	50.00	0.4437	0.0009
4228	33.33	50.00	0.3996	0.0007	58.84	81.15	0.6208	0.0127
4230	100.00	100.00	1.0000	0.0008	84.95	90.10	0.8367	0.0163
4231	62.50	45.45	0.5250	0.0014	82.58	88.08	0.8247	0.0124
4232	70.00	87.50	0.7772	0.0013	85.91	92.97	0.4967	0.0150
4233	27.27	60.00	0.3723	0.0018	82.25	91.25	0.8328	0.0143
4237	70.00	70.00	0.6991	0.0014	65.03	83.91	0.6471	0.0169
4240	87.08	83.41	0.7607	0.0228	88.91	89.32	0.7188	0.0228
4242	37.50	75.00	0.4992	0.0011	50.00	80.00	0.6147	0.0011
4245	71.88	80.70	0.7558	0.0035	73.81	86.11	0.7872	0.0050
4267	57.72	81.90	0.6190	0.0122	60.54	74.32	0.5965	0.0133
4269	83.33	80.65	0.8180	0.0025	73.81	87.74	0.7944	0.0050
4301	36.36	80.00	0.4989	0.0012	87.47	85.44	0.7489	0.0245
4302	42.86	75.00	0.5404	0.0028	44.12	76.92	0.5539	0.0033
4303	89.66	81.25	0.8511	0.0025	58.02	73.44	0.6403	0.0038
4329	NA	NA	NA	0.0000	NA	NA	NA	0.0000
5202	0.00	NA	0.0000	0.0004	20.00	100.00	0.3320	0.0015
5205	14.29	100.00	0.2496	0.0009	20.59	63.64	0.3075	0.0021
5256	NA	NA	NA	0.0000	63.87	77.95	0.6887	0.0055
5257	31.25	71.43	0.4314	0.0021	60.00	73.64	0.6480	0.0051
5258	NA	NA	NA	0.0000	NA	NA	NA	0.0000
5261	0.00	NA	0.0000	0.0008	0.00	NA	0.0000	0.0008
5304	14.29	37.50	0.2040	0.0017	14.29	37.50	0.2040	0.0017
5305	0.00	NA	0.0000	0.0003	0.00	NA	0.0000	0.0003
5311	NA	0.00	0.0000	0.0003	NA	0.00	0.0000	0.0003
5452	23.53	100.00	0.3797	0.0014	52.38	75.86	0.6115	0.0038
5453	69.05	81.69	0.7422	0.0040	65.26	83.22	0.7169	0.0061
5454	50.00	72.73	0.5909	0.0016	65.26	83.22	0.7169	0.0061
5455	30.00	30.00	0.2978	0.0014	63.16	78.26	0.6841	0.0058
5456	NA	NA	NA	0.0000	37.93	62.86	0.4659	0.0030
7102	NA	NA	NA	0.0000	NA	NA	NA	0.0000
7107	NA	NA	NA	0.0000	37.50	72.00	0.4879	0.0027
7109	NA	0.00	0.0000	0.0004	NA	0.00	0.0000	0.0004
7110	33.33	20.00	0.2491	0.0009	20.00	33.33	0.2483	0.0012
7112	34.55	86.36	0.4885	0.0028	34.55	86.36	0.4885	0.0028

	Accuracy				Fuzzy Accuracy			
ESLF	Producer	User	Kappa	ASE	Producer	User	Kappa	ASE
7157	20.83	100.00	0.3431	0.0017	19.35	100.00	0.3222	0.0019
8404	NA	NA	NA	0.0000	NA	NA	NA	0.0000
8501	NA	0.00	0.0000	0.0003	98.88	92.54	0.4843	0.0081
8601	NA	0.00	0.0000	0.0061	98.88	92.54	0.4843	0.0081
8602	NA	NA	NA	0.0000	98.88	92.54	0.4843	0.0081
9103	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9106	NA	NA	NA	0.0000	0.00	NA	0.0000	0.0006
9108	NA	0.00	0.0000	0.0004	NA	0.00	0.0000	0.0004
9156	NA	0.00	0.0000	0.0025	60.07	73.81	0.5954	0.0127
9166	NA	0.00	0.0000	0.0004	NA	0.00	0.0000	0.0004
9168	NA	0.00	0.0000	0.0011	NA	0.00	0.0000	0.0027
9170	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9171	NA	0.00	0.0000	0.0003	50.00	80.00	0.6147	0.0011
9173	0.00	NA	0.0000	0.0006	0.00	NA	0.0000	0.0006
9222	19.23	100.00	0.3208	0.0017	19.23	100.00	0.3208	0.0017
9248	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9260	NA	NA	NA	0.0000	19.23	100.00	0.3208	0.0017
9265	19.12	81.25	0.3039	0.0029	19.12	81.25	0.3039	0.0029
9297	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9321	0.00	NA	0.0000	0.0003	20.00	100.00	0.3320	0.0015
9330	NA	0.00	0.0000	0.0010	86.03	91.15	0.8528	0.0156
			Overall Accuracy	71.67%			Overall Accuracy	76.32%
			Overall Kappa	0.6466			Overall Kappa	0.7619
			ASE	0.0099			ASE	0.0365

ESLF	Ecological System Name
3128	IMB Volcanic Rock and Cinder Land
3140	NP Volcanic Rock and Cinder Land
3152	IMB Wash
3173	IMB Cliff and Canyon
3179	IMB Playa
4104	RM Aspen Forest and Woodland
4204	CP Western Juniper Woodland and Savanna
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland
4218	Cal Montane Jeffrey Pine Woodland
4219	MC Red Fir Forest
4220	MC Subalpine Woodland
4225	NP Maritime Mesic Subalpine Parkland
4228	NP Mountain Hemlock Forest
4230	MC Mixed Evergreen Forest
4231	NC Mesic Subalpine Woodland
4232	NRM Dry-Mesic Montane Mixed Conifer Forest
4233	NRM Subalpine Woodland and Parkland
4237	RM Lodgepole Pine Forest
4240	NRM Ponderosa Pine Woodland and Savanna
4242	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
4245	SN Subalpine Lodgepole Pine Forest and Woodland

ESLF	Ecological System Name
4267	RM Poor-Site Lodgepole Pine Forest
4269	SI Desert Western White Pine-White Fir Woodland
4301	EC Oak-Ponderosa Pine Forest and Woodland
4302	IMB Aspen-Mixed Conifer Forest and Woodland
4303	IMB Mountain Mahogany Woodland and Shrubland
4329	NP Wooded Volcanic Flowage
5202	CP Scabland Shrubland
5205	NP Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
5256	GB Xeric Mixed Sagebrush Shrubland
5257	IMB Big Sagebrush Shrubland
5258	IMB Mixed Salt Desert Scrub
5261	NP Montane Shrubland
5304	Cal Montane Woodland and Chaparral
5305	Cal Xeric Serpentine Chaparral
5311	NC Dry-Mesic Chaparral
5452	CP Steppe and Grassland
5453	CP Low Sagebrush Steppe
5454	IMB Big Sagebrush Steppe
5455	IMB Montane Sagebrush Steppe
5456	IMB Semi-Desert Shrub-Steppe
7102	Cal Mesic Serpentine Grassland
7107	IMB Semi-Desert Grassland
7109	MC Subalpine Meadow
7110	NP Montane Grassland
7112	NRM Lower Montane, Foothill and Valley Grassland
7157	NP Alpine and Subalpine Dry Grassland
8404	Introduced Upland Vegetation - Annual Grassland
8501	Recently burned forest
8601	Harvested forest-tree regeneration
8602	Harvested forest-shrub regeneration
9103	IMB Greasewood Flat
9106	NP Lowland Riparian Forest and Shrubland
9108	NP Montane Riparian Woodland and Shrubland
9156	RM Lower Montane Riparian Woodland and Shrubland
9166	NP Bog and Fen
9168	GB Foothill and Lower Montane Riparian Woodland and Shrubland
9170	CB Foothill Riparian Woodland and Shrubland
9171	RM Subalpine-Montane Riparian Woodland
9173	NP Shrub Swamp
9222	North American Arid West Emergent Marsh
9248	MC Subalpine-Montane Fen
9260	TP Freshwater Emergent Marsh
9265	TP Subalpine-Montane Wet Meadow
9297	IMB Alkaline Closed Depression
9321	CP Silver Sagebrush Seasonally Flooded Shrub-Steppe
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: Cal = California, CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, GB = Great Basin, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, SI = Sierran-Intermontane, TP = Temperate Pacific.

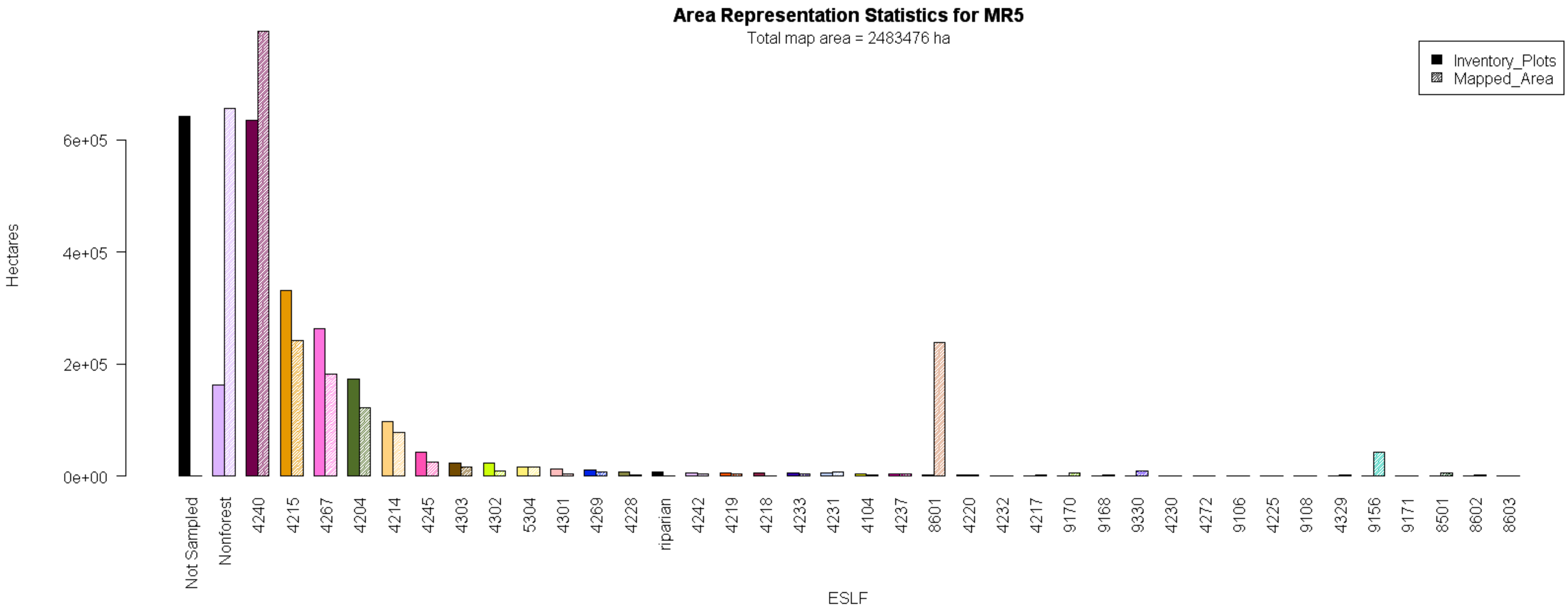

Figure 4: Class Area representation for Southern East Cascades (Model Region 5).

Table 14: Accuracy assessment statistics for the West Cascades, Model Region 6. *Note: minor modifications to classes 4231 and 5311 were made after these statistics were calculated.*

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
3118	28.00	50.00	0.3572	0.0009	28.00	50.00	0.3572	0.0009
3140	50.00	25.00	0.3328	0.0005	50.00	20.00	0.2851	0.0006
3155	NA	0.00	0.0000	0.0002	50.00	20.00	0.2851	0.0006
4101	50.00	50.00	0.4999	0.0003	64.63	81.43	0.7033	0.0046
4103	100.00	100.00	1.0000	0.0005	100.00	100.00	1.0000	0.0005
4104	0.00	NA	0.0000	0.0001	56.10	72.63	0.6270	0.0023
4205	65.96	46.27	0.5401	0.0016	73.74	76.86	0.6813	0.0110
4208	0.00	NA	0.0000	0.0003	47.30	54.69	0.5021	0.0018
4214	66.91	69.23	0.6596	0.0047	79.05	85.53	0.6095	0.0168
4215	74.77	82.53	0.7541	0.0073	80.01	87.66	0.6364	0.0168
4217	67.50	61.36	0.6406	0.0014	70.01	76.08	0.6769	0.0087
4219	65.96	68.89	0.6670	0.0026	74.76	82.44	0.7154	0.0116
4222	63.16	66.67	0.6457	0.0016	73.52	78.51	0.5904	0.0162
4224	68.53	76.38	0.6322	0.0117	85.50	93.96	0.5896	0.0120
4225	15.66	17.81	0.1569	0.0019	71.96	77.55	0.7214	0.0059
4226	70.11	76.41	0.6840	0.0082	81.65	89.94	0.6642	0.0166
4228	66.33	71.59	0.6649	0.0051	80.28	86.70	0.7884	0.0107
4229	86.27	84.62	0.8532	0.0015	71.40	75.84	0.6529	0.0115
4230	49.30	54.69	0.5136	0.0018	78.99	86.62	0.7596	0.0129
4231	62.14	63.37	0.6217	0.0022	73.06	78.53	0.6190	0.0152
4232	0.00	NA	0.0000	0.0003	77.93	85.11	0.5886	0.0167
4233	40.00	75.00	0.5210	0.0007	72.32	82.11	0.7318	0.0079
4237	58.33	77.78	0.6651	0.0012	69.03	75.68	0.6661	0.0089
4240	52.94	60.00	0.5615	0.0009	77.89	82.90	0.7549	0.0100
4242	48.78	68.97	0.5692	0.0013	53.66	70.97	0.6090	0.0013
4245	38.46	55.56	0.4528	0.0010	48.05	69.81	0.5651	0.0017
4267	43.48	83.33	0.5694	0.0013	70.15	78.23	0.7103	0.0064
4272	66.44	69.40	0.6486	0.0057	83.56	90.86	0.4617	0.0113
4301	0.00	NA	0.0000	0.0001	71.75	77.95	0.6245	0.0143
4304	65.22	75.00	0.6967	0.0010	81.77	91.97	0.7495	0.0171
4329	0.00	0.00	-0.0025	0.0012	58.21	37.86	0.4522	0.0020
4333	63.82	83.55	0.7086	0.0043	81.85	91.77	0.7405	0.0172
5205	31.25	45.45	0.3691	0.0008	38.10	48.48	0.4235	0.0013
5257	0.00	NA	0.0000	0.0001	0.00	0.00	-0.0003	0.0003
5260	30.00	75.00	0.4281	0.0006	30.00	75.00	0.4281	0.0006
5261	23.08	30.00	0.2584	0.0010	21.43	30.00	0.2474	0.0010
5304	7.14	33.33	0.1170	0.0006	7.14	33.33	0.1170	0.0006
5311	0.00	NA	0.0000	0.0001	0.00	NA	0.0000	0.0003
5312	0.00	NA	0.0000	0.0002	20.69	26.09	0.2278	0.0011
5409	0.00	0.00	-0.0002	0.0003	30.00	75.00	0.4281	0.0006
5454	0.00	NA	0.0000	0.0001	0.00	0.00	-0.0003	0.0003
5455	NA	0.00	0.0000	0.0002	0.00	0.00	-0.0003	0.0003
7108	NA	NA	NA	0.0000	44.44	50.00	0.4699	0.0006
7109	0.00	0.00	-0.0003	0.0004	0.00	0.00	-0.0003	0.0004
7110	41.18	50.00	0.4503	0.0008	36.36	48.00	0.4113	0.0011

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
7157	44.44	50.00	0.4699	0.0006	36.00	47.37	0.4072	0.0010
7162	37.50	100.00	0.5452	0.0005	30.00	75.00	0.4281	0.0006
8501	NA	0.00	0.0000	0.0005	99.28	98.47	0.3876	0.0024
8601	NA	0.00	0.0000	0.0038	99.28	98.47	0.3876	0.0024
8602	NA	0.00	0.0000	0.0003	99.28	98.47	0.3876	0.0024
8603	NA	0.00	0.0000	0.0001	99.28	98.47	0.3876	0.0024
9106	1.05	1.10	-0.0032	0.0021	81.77	91.97	0.7495	0.0171
9108	0.00	0.00	-0.0054	0.0013	65.46	70.68	0.6474	0.0060
9156	NA	0.00	0.0000	0.0003	43.75	77.78	0.5577	0.0013
9171	NA	0.00	0.0000	0.0002	53.66	70.97	0.6090	0.0013
9190	0.00	0.00	-0.0002	0.0004	0.00	0.00	-0.0002	0.0004
9260	0.00	NA	0.0000	0.0001	0.00	NA	0.0000	0.0001
9265	14.29	37.50	0.2055	0.0008	14.29	37.50	0.2055	0.0008
9330	NA	0.00	0.0000	0.0008	80.77	83.47	0.7680	0.0112
			Overall Accuracy	64.58%			Overall Accuracy	81.92%
			Overall Kappa	0.5981			Overall Kappa	0.8174
			ASE	0.0066			ASE	0.0220

ESLF	**Ecological System Name**
3118	NP Alpine and Subalpine Bedrock and Scree
3140	NP Volcanic Rock and Cinder Land
3155	NP Montane Massive Bedrock, Cliff and Talus
4101	NP Oak Woodland
4103	NRM Western Larch Savanna
4104	RM Aspen Forest and Woodland
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland
4208	KS Lower Montane Serpentine Mixed Conifer Woodland
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland
4219	MC Red Fir Forest
4222	NP Dry Douglas-fir Forest and Woodland
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
4225	NP Maritime Mesic Subalpine Parkland
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
4228	NP Mountain Hemlock Forest
4229	NP Mesic Western Hemlock-Silver Fir Forest
4230	MC Mixed Evergreen Forest
4231	NC Mesic Subalpine Woodland
4232	NRM Dry-Mesic Montane Mixed Conifer Forest
4233	NRM Subalpine Woodland and Parkland
4237	RM Lodgepole Pine Forest
4240	NRM Ponderosa Pine Woodland and Savanna
4242	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
4245	SN Subalpine Lodgepole Pine Forest and Woodland
4267	RM Poor-Site Lodgepole Pine Forest

ESLF	Ecological System Name
4272	NP Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
4301	EC Oak-Ponderosa Pine Forest and Woodland
4304	NP Broadleaf Landslide Forest and Shrubland
4329	NP Wooded Volcanic Flowage
4333	NP Lowland Mixed Hardwood Conifer Forest and Woodland
5205	NP Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
5257	IMB Big Sagebrush Shrubland
5260	NP Avalanche Chute Shrubland
5261	NP Montane Shrubland
5304	Cal Montane Woodland and Chaparral
5311	NC Dry-Mesic Chaparral
5312	NRM Montane-Foothill Deciduous Shrubland
5409	Willamette Valley Upland Prairie and Savanna
5454	IMB Big Sagebrush Steppe
5455	IMB Montane Sagebrush Steppe
7108	MC Alpine Dry Tundra
7109	MC Subalpine Meadow
7110	NP Montane Grassland
7157	NP Alpine and Subalpine Dry Grassland
7162	NP Herbaceous Bald and Bluff
8501	Recently burned forest
8601	Harvested forest-tree regeneration
8602	Harvested forest-shrub regeneration
8603	Harvested forest-grass regeneration
9106	NP Lowland Riparian Forest and Shrubland
9108	NP Montane Riparian Woodland and Shrubland
9156	RM Lower Montane Riparian Woodland and Shrubland
9171	RM Subalpine-Montane Riparian Woodland
9190	NP Hardwood-Conifer Swamp
9260	TP Freshwater Emergent Marsh
9265	TP Subalpine-Montane Wet Meadow
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: Cal = California, EC = Eastern Cascades, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, TP = Temperate Pacific.

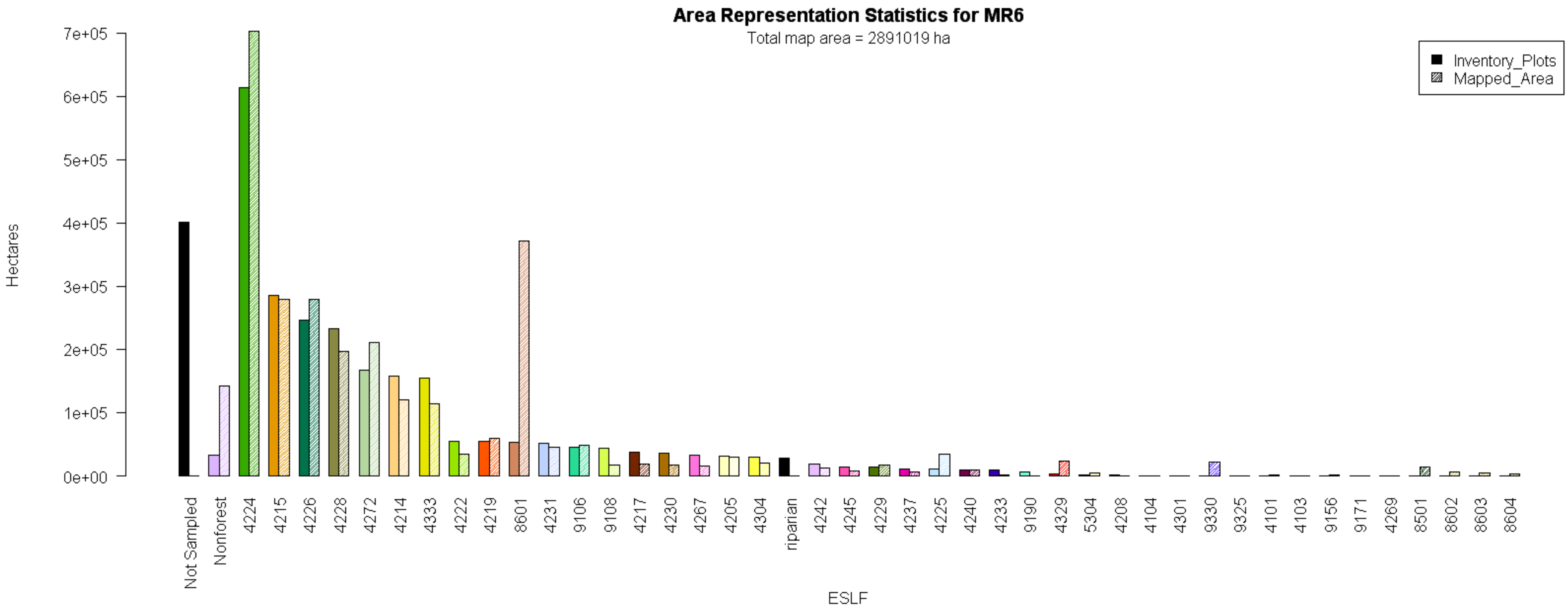

Figure 5: Class Area representation for West Cascades (Model Region 6). *Note: minor modifications to class 4231 were made after these statistics were calculated.*

Table 15: Accuracy assessment statistics for the Klamath and Siskiyou Mountains, Model Region 7.

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
3167	100.00	100.00	1.0000	0.0004	100.00	100.00	1.0000	0.0004
3170	0.00	NA	0.0000	0.0003	0.00	NA	0.0000	0.0003
4101	79.55	66.04	0.7182	0.0025	77.42	82.40	0.7537	0.0122
4202	35.71	62.50	0.4531	0.0012	77.26	85.93	0.7576	0.0146
4204	100.00	83.33	0.9090	0.0008	84.82	85.00	0.7670	0.0196
4205	100.00	70.00	0.8232	0.0010	74.93	77.41	0.7371	0.0078
4208	75.88	82.69	0.7825	0.0048	85.73	87.78	0.8084	0.0180
4209	70.97	89.80	0.7899	0.0027	84.36	86.50	0.7972	0.0168
4214	76.40	83.22	0.7478	0.0128	89.16	94.82	0.6696	0.0151
4215	77.46	84.81	0.7924	0.0073	86.09	91.75	0.7291	0.0212
4216	80.95	80.95	0.8075	0.0023	79.50	85.78	0.7500	0.0177
4217	76.33	82.53	0.7515	0.0116	89.50	93.30	0.6786	0.0162
4218	0.00	NA	0.0000	0.0007	79.28	85.78	0.7521	0.0172
4219	16.67	100.00	0.2842	0.0015	83.79	88.75	0.7100	0.0221
4221	0.00	0.00	-0.0005	0.0005	0.00	0.00	-0.0005	0.0005
4222	83.67	79.68	0.8009	0.0070	85.05	90.96	0.7713	0.0222
4224	65.22	79.79	0.7102	0.0038	79.91	90.64	0.7758	0.0188
4226	65.79	75.76	0.7016	0.0021	54.55	78.43	0.6265	0.0052
4228	87.50	70.00	0.7773	0.0011	35.90	93.33	0.5159	0.0019
4230	84.21	85.40	0.7926	0.0162	89.56	95.55	0.6562	0.0140
4231	0.00	NA	0.0000	0.0003	73.98	77.53	0.7295	0.0083
4240	100.00	100.00	1.0000	0.0008	80.19	87.34	0.7726	0.0168
4301	81.82	94.74	0.8774	0.0016	80.78	86.36	0.7624	0.0178
4304	100.00	100.00	1.0000	0.0005	55.00	80.29	0.6380	0.0049
4333	28.57	40.00	0.3324	0.0009	83.56	88.92	0.7292	0.0222
5257	0.00	NA	0.0000	0.0003	83.33	83.33	0.8331	0.0009
5261	0.00	NA	0.0000	0.0004	0.00	NA	0.0000	0.0004
5302	0.00	NA	0.0000	0.0003	0.00	NA	0.0000	0.0003
5304	51.43	60.00	0.5502	0.0020	51.43	60.00	0.5502	0.0020
5305	0.00	NA	0.0000	0.0008	25.58	91.67	0.3972	0.0019
5311	0.00	0.00	-0.0034	0.0015	0.00	0.00	-0.0034	0.0015
5409	0.00	0.00	-0.0003	0.0004	20.00	33.33	0.2493	0.0007
5425	32.35	91.67	0.4759	0.0017	25.58	91.67	0.3972	0.0019
7102	0.00	NA	0.0000	0.0004	0.00	NA	0.0000	0.0004
7108	0.00	0.00	-0.0004	0.0007	0.00	0.00	-0.0004	0.0007
7110	0.00	NA	0.0000	0.0003	0.00	NA	0.0000	0.0003
7162	25.00	100.00	0.3998	0.0006	20.00	33.33	0.2493	0.0007
8501	NA	0.00	0.0000	0.0019	99.57	98.76	0.1247	0.0022
8601	NA	0.00	0.0000	0.0041	99.57	98.76	0.1247	0.0022
8602	NA	0.00	0.0000	0.0003	99.57	98.76	0.1247	0.0022
8604	NA	0.00	0.0000	0.0003	99.57	98.76	0.1247	0.0022
9106	0.00	0.00	-0.0014	0.0016	55.00	80.29	0.6380	0.0049
9108	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9190	0.00	NA	0.0000	0.0003	0.00	NA	0.0000	0.0003
9221	100.00	100.00	1.0000	0.0004	100.00	100.00	1.0000	0.0004
9265	NA	0.00	0.0000	0.0003	NA	0.00	0.0000	0.0003

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
9325	NA	0.00	0.0000	0.0004	NA	0.00	0.0000	0.0004
9330	4.55	2.70	0.0272	0.0019	88.87	93.66	0.6713	0.0161
			Overall Accuracy	75.27%			Overall Accuracy	86.28%
			Overall Kappa	0.7081			Overall Kappa	0.8525
			ASE	0.0081			ASE	0.0240

ESLF	**Ecological System Name**
3167	MC Serpentine Barrens
3170	KS Cliff and Outcrop
4101	NP Oak Woodland
4202	Cal Coastal Redwood Forest
4204	CP Western Juniper Woodland and Savanna
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland
4208	KS Lower Montane Serpentine Mixed Conifer Woodland
4209	KS Upper Montane Serpentine Mixed Conifer Woodland
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland
4216	MC Mixed Oak Woodland
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland
4218	Cal Montane Jeffrey Pine Woodland
4219	MC Red Fir Forest
4221	MC Mesic Serpentine Woodland and Chaparral
4222	NP Dry Douglas-fir Forest and Woodland
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
4228	NP Mountain Hemlock Forest
4230	MC Mixed Evergreen Forest
4231	NC Mesic Subalpine Woodland
4240	NRM Ponderosa Pine Woodland and Savanna
4301	EC Oak-Ponderosa Pine Forest and Woodland
4304	NP Broadleaf Landslide Forest and Shrubland
4333	NP Lowland Mixed Hardwood Conifer Forest and Woodland
5257	IMB Big Sagebrush Shrubland
5261	NP Montane Shrubland
5302	Cal Maritime Chaparral
5304	Cal Montane Woodland and Chaparral
5305	Cal Xeric Serpentine Chaparral
5311	NC Dry-Mesic Chaparral
5409	Willamette Valley Upland Prairie and Savanna
5425	KS Xeromorphic Serpentine Savanna and Chaparral
7102	Cal Mesic Serpentine Grassland
7108	MC Alpine Dry Tundra
7110	NP Montane Grassland
7162	NP Herbaceous Bald and Bluff
8501	Recently burned forest
8601	Harvested forest-tree regeneration
8602	Harvested forest-shrub regeneration

ESLF	Ecological System Name
8604	Harvested forest-herbaceous regeneration
9106	NP Lowland Riparian Forest and Shrubland
9108	NP Montane Riparian Woodland and Shrubland
9190	NP Hardwood-Conifer Swamp
9221	Willamette Valley Wet Prairie
9265	TP Subalpine-Montane Wet Meadow
9325	MC Serpentine Foothill and Lower Montane Riparian
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: Cal = California, CP = Columbia Plateau, EC = Eastern Cascades, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, TP = Temperate Pacific, WV = Willamette Valley.

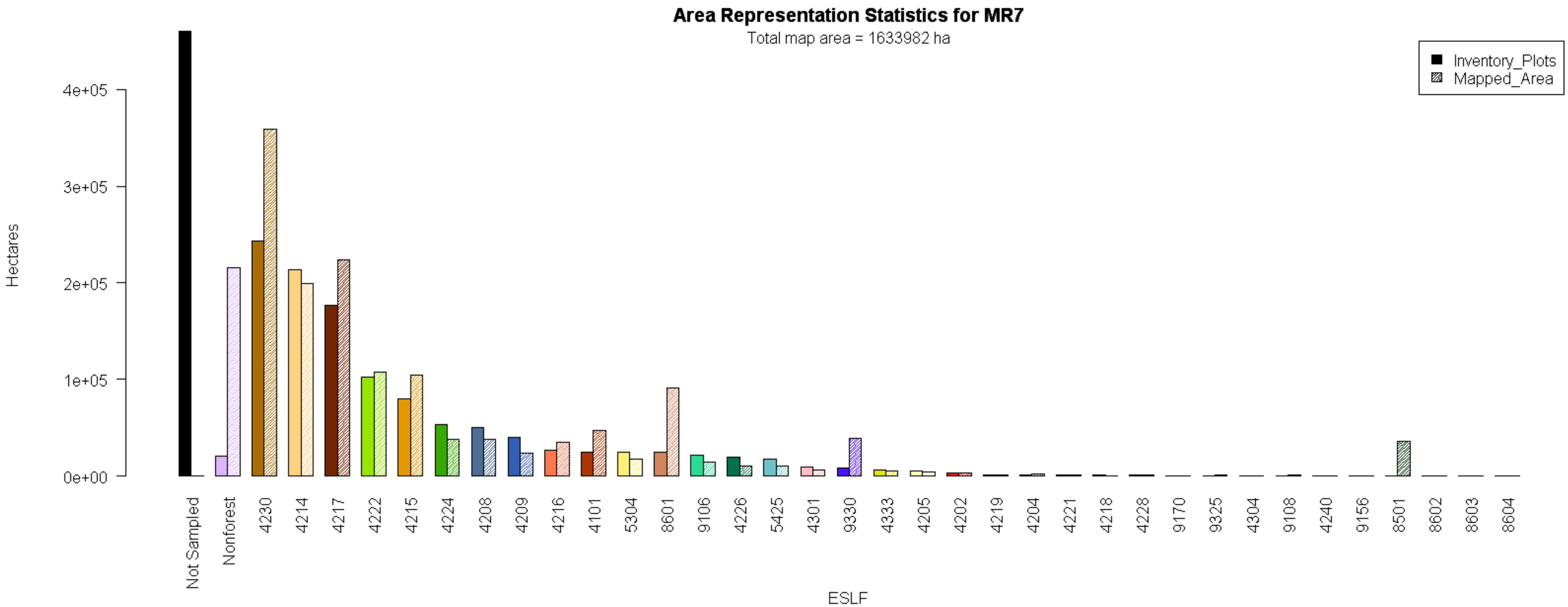

Figure 6: Class Area representation for Klamath – Siskiyou Mountains (Model Region 7).

Table 16: Accuracy assessment statistics for the Willamette Valley, Model Region 8.

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
4101	50.00	52.38	0.4782	0.0213	76.74	83.90	0.6861	0.0690
4205	75.00	100.00	0.8557	0.0080	81.82	94.74	0.8701	0.0209
4214	100.00	100.00	1.0000	0.0106	76.36	89.36	0.7470	0.0614
4215	87.50	100.00	0.9302	0.0175	81.04	91.94	0.6619	0.0728
4216	NA	NA	NA	0.0000	87.50	95.45	0.9066	0.0224
4217	66.67	100.00	0.7986	0.0067	78.05	87.67	0.6767	0.0758
4222	74.19	95.83	0.8220	0.0249	73.60	88.46	0.7028	0.0662
4224	72.29	85.71	0.7211	0.0498	86.45	94.78	0.5696	0.0483
4226	83.33	87.50	0.8333	0.0322	85.95	93.27	0.6569	0.0613
4301	50.00	50.00	0.4970	0.0060	75.00	88.10	0.6803	0.0729
4304	57.14	100.00	0.7231	0.0101	85.71	93.75	0.6534	0.0605
4333	74.51	81.72	0.6892	0.0592	87.41	95.55	0.6214	0.0496
5311	NA	0.00	0.0000	0.0030	NA	0.00	0.0000	0.0030
5409	0.00	0.00	-0.0040	0.0052	0.00	0.00	-0.0040	0.0052
8601	NA	0.00	0.0000	0.0184	98.80	99.70	-0.0048	0.0067
8603	NA	0.00	0.0000	0.0030	98.80	99.70	-0.0048	0.0067
9106	36.36	23.53	0.2561	0.0166	86.12	93.78	0.6593	0.0603
9173	NA	0.00	0.0000	0.0030	36.36	22.22	0.2451	0.0169
9190	0.00	NA	0.0000	0.0067	0.00	NA	0.0000	0.0067
9221	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9330	NA	NA	NA	0.0000	86.21	100.00	0.9195	0.0247
			Overall Accuracy	71.34%			Overall Accuracy	83.58%
			Overall Kappa	0.6562			Overall Kappa	0.8436
			ASE	0.0296			ASE	0.0807

ESLF	Ecological System Name
4101	NP Oak Woodland
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland
4216	MC Mixed Oak Woodland
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland
4222	NP Dry Douglas-fir Forest and Woodland
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
4301	EC Oak-Ponderosa Pine Forest and Woodland
4304	NP Broadleaf Landslide Forest and Shrubland
4333	NP Lowland Mixed Hardwood Conifer Forest and Woodland
5311	NC Dry-Mesic Chaparral
5409	Willamette Valley Upland Prairie and Savanna
8601	Harvested forest-tree regeneration
9106	NP Lowland Riparian Forest and Shrubland
9190	NP Hardwood-Conifer Swamp
9221	WV Wet Prairie
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: EC = Eastern Cascades, MC = Mediterranean California, NC = Northern and Central California, NP = North Pacific, WV = Willamette Valley.

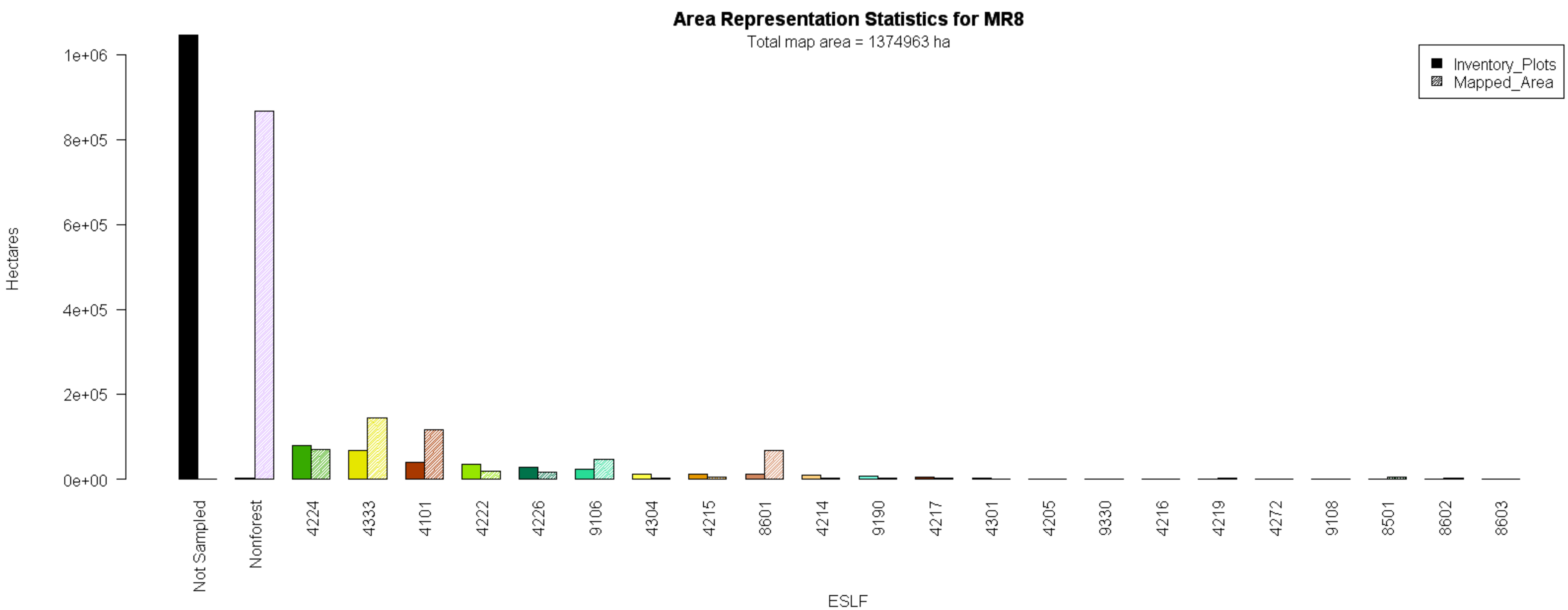

Figure 7: Class Area representation for Willamette Valley (Model Region 8).

Table 17: Accuracy assessment statistics for the Oregon Coast Range, Model Region 9. *Note: After these statistics were calculated, we reclassified those pixels labeled as ESLF 4205 to 4224.*

	Accuracy				**Fuzzy Accuracy**			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
3177	38.46	29.41	0.3303	0.0017	83.33	40.32	0.5378	0.0030
4101	50.00	50.00	0.4997	0.0006	71.29	83.00	0.7369	0.0099
4202	82.26	79.69	0.8058	0.0035	79.53	90.44	0.6401	0.0237
4205	83.33	71.43	0.7688	0.0011	60.98	59.52	0.5973	0.0028
4208	25.00	100.00	0.3997	0.0007	67.39	92.08	0.7700	0.0050
4214	70.15	67.14	0.6794	0.0037	77.13	81.52	0.7175	0.0178
4215	56.67	80.95	0.6641	0.0022	78.66	86.24	0.7205	0.0221
4216	66.67	100.00	0.7999	0.0007	75.00	72.82	0.7305	0.0046
4219	72.22	100.00	0.8380	0.0017	65.93	89.55	0.7476	0.0058
4222	63.43	77.62	0.6828	0.0059	75.15	79.80	0.6987	0.0170
4223	64.06	85.71	0.7120	0.0076	76.19	89.06	0.6715	0.0243
4224	72.90	75.30	0.6843	0.0133	84.79	95.45	0.5941	0.0169
4226	71.92	87.50	0.6749	0.0217	83.53	95.54	0.5433	0.0162
4230	67.16	90.00	0.7608	0.0049	74.05	86.61	0.7526	0.0138
4268	52.94	20.00	0.2849	0.0024	73.95	84.56	0.7684	0.0084
4271	45.45	83.33	0.5873	0.0013	74.91	89.66	0.6684	0.0242
4272	60.00	75.00	0.6662	0.0009	79.56	91.08	0.6537	0.0239
4304	70.87	88.24	0.7783	0.0049	83.15	94.26	0.6153	0.0194
4333	71.39	83.19	0.7387	0.0099	83.77	95.72	0.6007	0.0177
5304	83.33	100.00	0.9089	0.0010	83.33	100.00	0.9089	0.0010
5457	NA	0.00	0.0000	0.0003	NA	0.00	0.0000	0.0003
8601	NA	0.00	0.0000	0.0065	99.91	100.00	0.0000	0.0005
8602	NA	0.00	0.0000	0.0003	99.91	100.00	0.0000	0.0005
9106	3.45	1.41	0.0075	0.0031	83.60	96.44	0.5383	0.0156
9108	NA	0.00	0.0000	0.0004	60.00	50.00	0.5447	0.0010
9190	0.00	NA	0.0000	0.0004	38.46	83.33	0.5251	0.0013
9221	NA	0.00	0.0000	0.0003	NA	0.00	0.0000	0.0004
9260	NA	0.00	0.0000	0.0003	NA	0.00	0.0000	0.0004
9330	NA	0.00	0.0000	0.0010	72.92	83.33	0.7614	0.0072
			Overall Accuracy	69.66%			Overall Accuracy	83.27%
			Overall Kappa	0.6290			Overall Kappa	0.8828
			ASE	0.0098			ASE	0.0266

ESLF	**Ecological System Name**
3177	NP Maritime Coastal Sand Dune and Strand
4101	NP Oak Woodland
4202	Cal Coastal Redwood Forest
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland
4208	KS Lower Montane Serpentine Mixed Conifer Woodland
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland
4216	MC Mixed Oak Woodland
4219	MC Red Fir Forest
4222	NP Dry Douglas-fir Forest and Woodland

ESLF	Ecological System Name
4223	NP Hypermaritime Sitka Spruce Forest
4224	NP Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
4226	NP Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
4230	MC Mixed Evergreen Forest
4268	Cal Coastal Closed-Cone Conifer Forest and Woodland
4271	NP Hypermaritime Western Red-cedar-Western Hemlock Forest
4272	NP Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
4304	NP Broadleaf Landslide Forest and Shrubland
4333	NP Lowland Mixed Hardwood Conifer Forest and Woodland
5304	Cal Montane Woodland and Chaparral
5457	NC Coastal Scrub
8601	Harvested forest-tree regeneration
8602	Harvested forest-shrub regeneration
9106	NP Lowland Riparian Forest and Shrubland
9108	NP Montane Riparian Woodland and Shrubland
9190	NP Hardwood-Conifer Swamp
9221	Willamette Valley Wet Prairie
9260	TP Freshwater Emergent Marsh
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: Cal = California, EC = Eastern Cascades, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NP = North Pacific, TP = Temperate Pacific, WV = Willamette Valley.

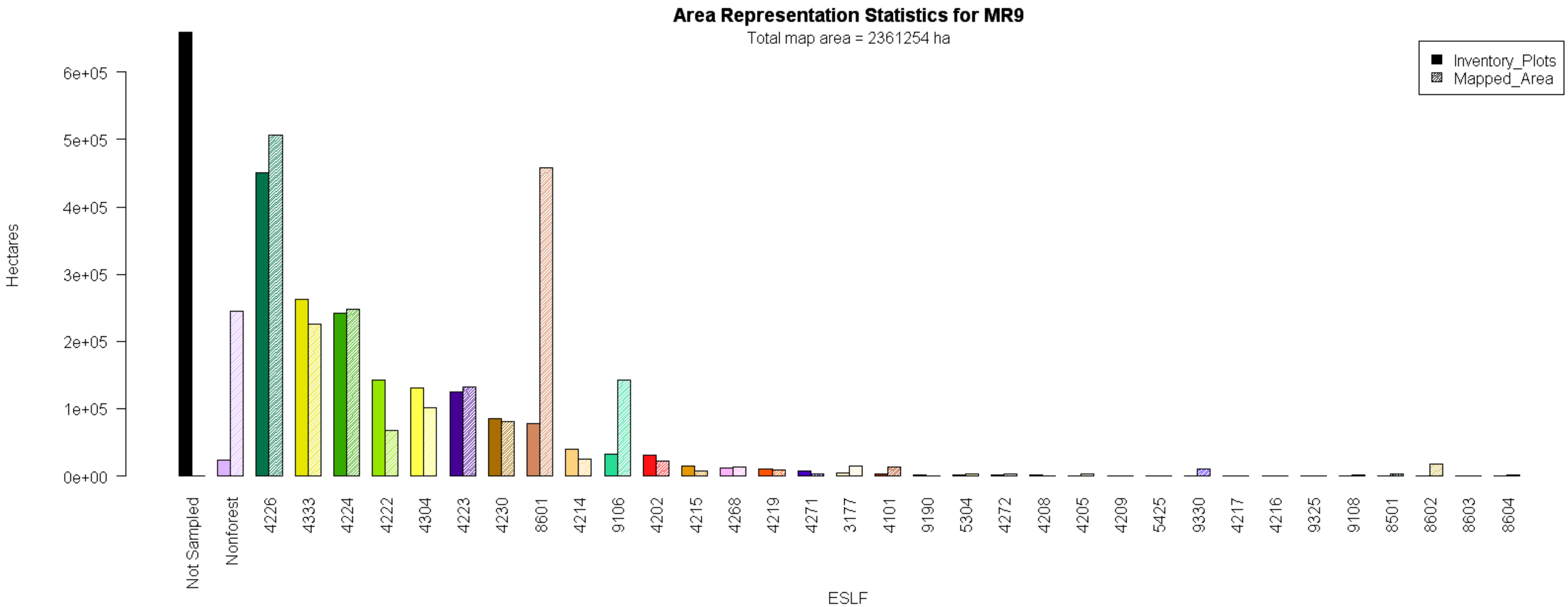

Figure 8: Class Area representation for Oregon Coast Range (Model Region 9). *Note: After these statistics were calculated, we reclassified those pixels labeled as ESLF 4205 to 4224.*

Table 18: Accuracy assessment statistics for the Northern Modoc Plateau, Model Region 10.

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
3128	69.23	81.82	0.7449	0.0085	69.23	81.82	0.7449	0.0085
3140	NA	NA	NA	0.0000	NA	NA	NA	0.0000
3152	NA	NA	NA	0.0000	NA	NA	NA	0.0000
3170	NA	NA	NA	0.0000	NA	NA	NA	0.0000
3171	NA	NA	NA	0.0000	NA	NA	NA	0.0000
3172	NA	0.00	0.0000	0.0017	NA	0.00	0.0000	0.0017
3174	NA	NA	NA	0.0000	100.00	100.00	1.0000	0.0024
3179	0.00	NA	0.0000	0.0034	0.00	NA	0.0000	0.0034
4101	100.00	100.00	1.0000	0.0034	92.86	95.59	0.9344	0.0233
4104	NA	NA	NA	0.0000	91.67	95.65	0.9276	0.0236
4204	56.58	81.13	0.6277	0.0222	88.14	95.53	0.8791	0.0471
4208	NA	NA	NA	0.0000	66.67	100.00	0.7992	0.0038
4209	100.00	100.00	1.0000	0.0034	80.00	100.00	0.8881	0.0051
4214	96.00	100.00	0.9778	0.0187	93.33	93.02	0.8624	0.0578
4215	86.67	87.84	0.8543	0.0245	95.36	93.00	0.9024	0.0547
4216	90.00	81.82	0.8546	0.0079	92.89	91.67	0.8754	0.0531
4217	92.65	95.45	0.9327	0.0229	93.62	94.29	0.9208	0.0384
4218	91.67	90.59	0.8966	0.0267	92.69	91.44	0.8740	0.0523
4219	92.31	100.00	0.9591	0.0087	88.96	92.36	0.8719	0.0422
4220	100.00	50.00	0.6659	0.0029	100.00	50.00	0.6659	0.0029
4222	100.00	100.00	1.0000	0.0054	80.82	90.31	0.7749	0.0503
4230	66.67	100.00	0.7992	0.0038	83.97	91.98	0.7742	0.0571
4231	100.00	25.00	0.3984	0.0038	96.05	87.95	0.9057	0.0256
4232	100.00	100.00	1.0000	0.0041	93.75	98.36	0.9553	0.0218
4237	50.00	100.00	0.6659	0.0029	88.24	100.00	0.9358	0.0099
4240	100.00	84.62	0.9150	0.0085	80.19	90.43	0.7747	0.0492
4245	100.00	100.00	1.0000	0.0024	80.00	66.67	0.7248	0.0056
4267	100.00	100.00	1.0000	0.0034	94.12	100.00	0.9688	0.0100
4269	75.00	60.00	0.6642	0.0051	80.00	66.67	0.7248	0.0056
4301	66.67	80.00	0.7248	0.0056	81.25	91.46	0.7842	0.0509
4302	50.00	100.00	0.6659	0.0029	50.00	100.00	0.6659	0.0029
4303	100.00	75.00	0.8538	0.0092	59.09	86.67	0.6838	0.0158
4329	100.00	68.75	0.8107	0.0090	100.00	76.19	0.8606	0.0107
5202	100.00	100.00	1.0000	0.0024	85.00	60.71	0.6964	0.0123
5204	NA	NA	NA	0.0000	NA	0.00	0.0000	0.0017
5205	NA	NA	NA	0.0000	NA	0.00	0.0000	0.0017
5256	NA	0.00	0.0000	0.0017	69.23	55.38	0.5741	0.0208
5257	34.38	84.62	0.4725	0.0119	67.52	94.64	0.7286	0.0371
5258	NA	NA	NA	0.0000	NA	NA	NA	0.0000
5260	NA	NA	NA	0.0000	NA	NA	NA	0.0000
5261	0.00	NA	0.0000	0.0024	0.00	NA	0.0000	0.0024
5304	88.89	80.00	0.8396	0.0075	88.89	80.00	0.8396	0.0075
5305	33.33	100.00	0.4975	0.0048	55.56	83.33	0.6626	0.0066
5311	25.00	14.29	0.1748	0.0056	25.00	14.29	0.1748	0.0056
5403	85.71	85.71	0.8554	0.0064	85.71	85.71	0.8554	0.0064
5404	NA	NA	NA	0.0000	NA	NA	NA	0.0000

	Accuracy				Fuzzy Accuracy			
ESLF	**Producer**	**User**	**Kappa**	**ASE**	**Producer**	**User**	**Kappa**	**ASE**
5409	NA	NA	NA	0.0000	NA	NA	NA	0.0000
5425	100.00	75.00	0.8563	0.0045	55.56	83.33	0.6626	0.0066
5452	81.25	54.17	0.6383	0.0111	73.68	89.09	0.7576	0.0344
5453	75.00	17.14	0.2630	0.0115	82.35	96.18	0.8524	0.0387
5454	56.76	72.41	0.6154	0.0147	81.70	96.15	0.8474	0.0386
5455	NA	NA	NA	0.0000	73.03	69.15	0.6579	0.0280
5456	NA	NA	NA	0.0000	49.28	80.95	0.5754	0.0201
7102	NA	NA	NA	0.0000	NA	NA	NA	0.0000
7107	NA	NA	NA	0.0000	49.28	80.95	0.5754	0.0201
7109	NA	NA	NA	0.0000	NA	NA	NA	0.0000
7110	NA	0.00	0.0000	0.0017	NA	0.00	0.0000	0.0017
7112	75.00	100.00	0.8563	0.0045	75.00	100.00	0.8563	0.0045
7157	NA	NA	NA	0.0000	NA	NA	NA	0.0000
8404	100.00	100.00	1.0000	0.0024	100.00	100.00	1.0000	0.0024
8501	NA	0.00	0.0000	0.0029	92.01	91.81	0.6361	0.0364
8601	NA	0.00	0.0000	0.0024	92.01	91.81	0.6361	0.0364
9103	NA	NA	NA	0.0000	0.00	NA	0.0000	0.0034
9106	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9108	NA	0.00	0.0000	0.0017	NA	0.00	0.0000	0.0017
9156	NA	0.00	0.0000	0.0017	100.00	66.67	0.7992	0.0038
9170	NA	0.00	0.0000	0.0024	NA	0.00	0.0000	0.0024
9222	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9265	0.00	NA	0.0000	0.0024	0.00	NA	0.0000	0.0024
9297	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9321	100.00	100.00	1.0000	0.0041	85.00	60.71	0.6964	0.0123
9325	NA	NA	NA	0.0000	NA	NA	NA	0.0000
9330	NA	0.00	0.0000	0.0038	94.50	93.22	0.8792	0.0578
			Overall Accuracy	78.36%			Overall Accuracy	87.75%
			Overall Kappa	0.7657			Overall Kappa	0.8637
			ASE	0.0183			ASE	0.1375

ESLF	**Ecological System Name**
3128	IMB Volcanic Rock and Cinder Land
3140	NP Volcanic Rock and Cinder Land
3152	IMB Wash
3170	KS Cliff and Outcrop
3171	SN Cliff and Canyon
3172	MC Alpine Bedrock and Scree
3174	CP Ash and Tuff Badland
3179	IMB Playa
4101	NP Oak Woodland
4104	RM Aspen Forest and Woodland
4204	CP Western Juniper Woodland and Savanna
4208	KS Lower Montane Serpentine Mixed Conifer Woodland
4209	KS Upper Montane Serpentine Mixed Conifer Woodland
4214	MC Dry-Mesic Mixed Conifer Forest and Woodland
4215	MC Mesic Mixed Conifer Forest and Woodland

ESLF	Ecological System Name
4216	MC Mixed Oak Woodland
4217	MC Lower Montane Black Oak-Conifer Forest and Woodland
4218	Cal Montane Jeffrey Pine Woodland
4219	MC Red Fir Forest
4220	MC Subalpine Woodland
4222	NP Dry Douglas-fir Forest and Woodland
4230	MC Mixed Evergreen Forest
4231	NC Mesic Subalpine Woodland
4232	NRM Dry-Mesic Montane Mixed Conifer Forest
4237	RM Lodgepole Pine Forest
4240	NRM Ponderosa Pine Woodland and Savanna
4245	SN Subalpine Lodgepole Pine Forest and Woodland
4267	RM Poor-Site Lodgepole Pine Forest
4269	SI Desert Western White Pine-White Fir Woodland
4301	EC Oak-Ponderosa Pine Forest and Woodland
4302	IMB Aspen-Mixed Conifer Forest and Woodland
4303	IMB Mountain Mahogany Woodland and Shrubland
4329	NP Wooded Volcanic Flowage
5202	CP Scabland Shrubland
5204	MC Alpine Fell-Field
5205	NP Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
5256	GB Xeric Mixed Sagebrush Shrubland
5257	IMB Big Sagebrush Shrubland
5258	IMB Mixed Salt Desert Scrub
5260	NP Avalanche Chute Shrubland
5261	NP Montane Shrubland
5304	Cal Montane Woodland and Chaparral
5305	Cal Xeric Serpentine Chaparral
5311	NC Dry-Mesic Chaparral
5403	Cal Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
5404	IMB Juniper Savanna
5409	WV Upland Prairie and Savanna
5425	KS Xeromorphic Serpentine Savanna and Chaparral
5452	CP Steppe and Grassland
5453	CP Low Sagebrush Steppe
5454	IMB Big Sagebrush Steppe
5455	IMB Montane Sagebrush Steppe
5456	IMB Semi-Desert Shrub-Steppe
7102	Cal Mesic Serpentine Grassland
7107	IMB Semi-Desert Grassland
7109	MC Subalpine Meadow
7110	NP Montane Grassland
7112	NRM Lower Montane, Foothill and Valley Grassland
7157	NP Alpine and Subalpine Dry Grassland
8404	Introduced Upland Vegetation - Annual Grassland
8501	Recently burned forest
8601	Harvested forest-tree regeneration
9103	IMB Greasewood Flat
9106	NP Lowland Riparian Forest and Shrubland

ESLF	Ecological System Name
9108	NP Montane Riparian Woodland and Shrubland
9156	RM Lower Montane Riparian Woodland and Shrubland
9170	CB Foothill Riparian Woodland and Shrubland
9222	North American Arid West Emergent Marsh
9265	TP Subalpine-Montane Wet Meadow
9297	IMB Alkaline Closed Depression
9321	CP Silver Sagebrush Seasonally Flooded Shrub-Steppe
9325	MC Serpentine Foothill and Lower Montane Riparian
9330	MC Foothill and Lower Montane Riparian Woodland

Geographic abbreviations: Cal = California, CB = Columbia Basin, CP = Columbia Plateau, EC = Eastern Cascades, GB = Great Basin, IMB = Inter-Mountain Basins, KS = Klamath-Siskiyou, MC = Mediterranean California, NC = Northern and Central California, NRM = Northern Rocky Mountain, NP = North Pacific, Rocky Mountain = RM, SN = Sierra Nevada, SI = Sierran-Intermontane, TP = Temperate Pacific, WV = Willamette Valley.

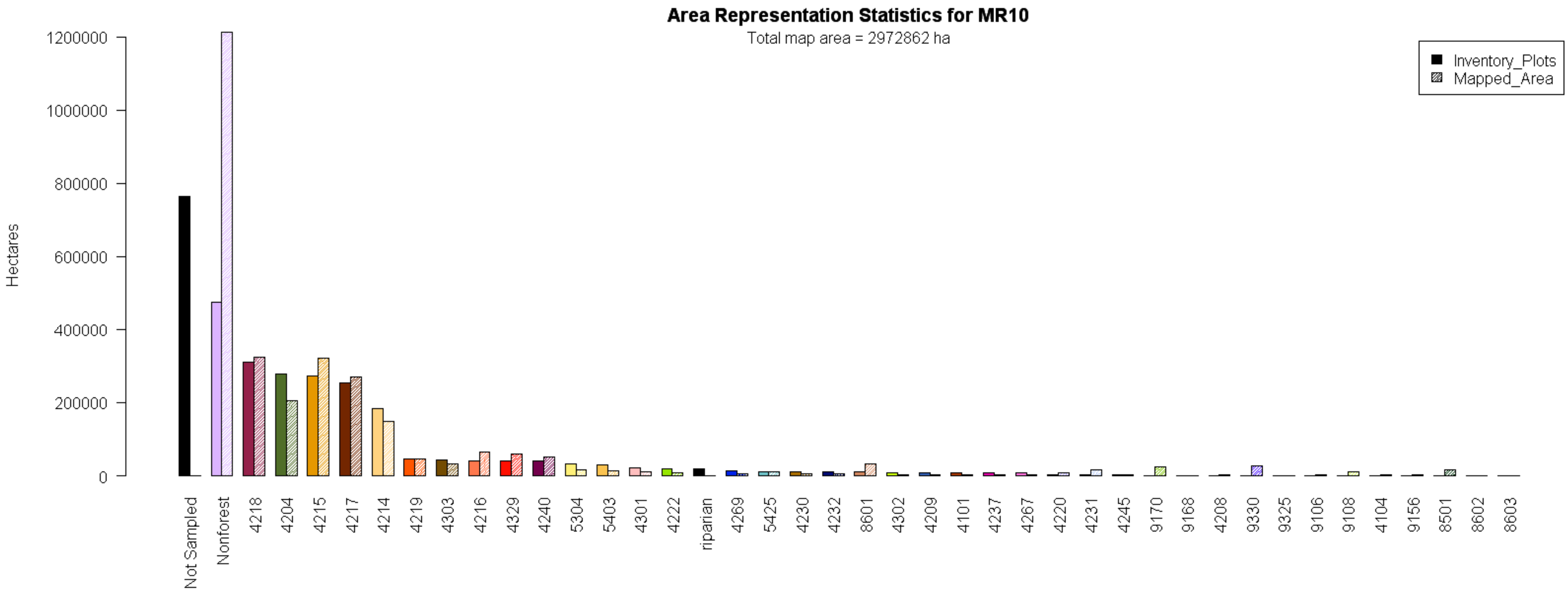

Figure 9: Class Area representation for Modoc Plateau (Model Region 10).

Discussion

Plot Data and Classification

By far the bulk of our time was given to plot classification. We invested our time most heavily towards this phase of the project due to early observations on the strong influence of mis-classified plots. Small changes in plot classification keying can lead to drastically different maps. Keys were developed independently for each ecoregion partly because of logistics. By constraining the number of Ecological Systems in a given key, we were able to write and tune them more efficiently. Also, we were able to more effectively constrain Systems with geographic elements to their definitions. For example, plots dominated by lodgepole pine in the Coast Range were assigned to California Coastal Closed Cone Conifer Forest and Woodland, while plots dominated by lodgepole pine in the Cascades were mapped to the other three lodgepole pine forests.

Keys were developed iteratively, binning plots, checking species composition of the plots binned to each Ecological System, and then adjusting the keys to fix the observed problems. We also built draft maps and models to help identify problems within the keys. Additional refinements were made as we viewed the draft maps together. Inconsistencies along the borders highlighted inconsistent keying among the model regions. Although our plot-binning may not entirely match that from the LANDFIRE sequence tables, we believe that the time we spent refining the plot-binning process will ultimately create a better map.

As mentioned above, for those Ecological Systems that were under-represented in our primary plot database, we often added supplemental plots, either from ancillary data sources, or from creating our own supplementary points via Airphoto interpretation of the 2005 NAIP imagery. Plots from ancillary sources were assigned to Ecological System with expert opinion, as were Airphoto points. After the initial assignment in these cases, points were not fine-tuned. It is also important to note that the image dates of the GAP coverage (2000) and the NAIP (2005) do not match. Although we cannot technically evaluate the impact of the date mismatch on our map accuracy, we have assumed that it is minimal because most of the Ecological Systems represented within these points are nonforest Systems that tend to be relatively temporally stable. The effects of five years of change should be minimal.

Map Quality

Point-level Accuracy

As a rule of thumb, the forested Ecological Systems were better mapped than the nonforest Ecological Systems. This stems partly from the fact that we had larger plot samples with which to model the forests. It is also important to note that our accuracy assessment numbers do come with a few caveats. First, these statistics essentially represent how closely our map corresponds with the Ecological System assignments within the plot data. In order to assert that these statistics resemble on-the-ground map accuracy, we must assume that our original plot-calls were correct. It is also important to note that for some Systems, especially for under sampled non forested types, we needed to model with our entire plot sample due to sample size limitations, making our estimates of accuracy internal (Shtatland et al. 2004). In these cases, our accuracy assessment is based upon the same plots that were used to build the models, a situation that can artificially inflate the accuracy statistics.

For the forests especially, fuzzy accuracy measurements were significantly better than non-fuzzy accuracy measurements. In the non-fuzzy sense, we had significant levels of confusion among many of the mixed conifer forests (e.g., North Pacific Maritime Dry-Mesic Douglas-fir - Western Hemlock Forest, North Pacific Maritime Mesic-Wet Douglas-fir - Western Hemlock Forest, Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland and Mediterranean California Mesic Mixed Conifer Forest and Woodland). However, the strong improvement from the non-fuzzy accuracy assessment to the fuzzy accuracy assessment suggests that a significant portion of our errors were in concentrated in the confusion of relatively similar forest types.

There were some types of Systems that we were simply unable to model well, either due to their structure on the landscape or a lack of plot data, or both. These included the riparian areas, the cliff and canyon Systems, volcanic Systems, and some wetland Systems.

The riparian areas are problematic due to their narrow, linear structure on the landscape, oftentimes narrower than a single pixel. The cliff Systems lacked plots, and also lacked a good strong predictor variable in the RF models. Although we did have plots for many of the wetland Systems, they were not well-restricted in the landscape, possibly because we lacked an appropriate explanatory variable to delineate them. In particular, we often mapped them inappropriately to steep slopes and mountaintops. In the Coast Range, we were unable to effectively model a boundary between the brackish and freshwater marshes as well. We used a wide array of ancillary data sources and logical fixes to solve these types of problems, which are described in detail under the methods section. We mention them here to emphasize that the final map is an aggregation of statistical models, and logical procedures, aimed at generating the best possible map.

One more problematic situation in the map is confusion between pastures and natural grasslands. This is not a new problem to landcover mapping. To the contrary, others (including NLCD and the Willamette Valley Landcover map) have made note of it as well. Without additional information, we unfortunately cannot rectify the confusion any more than others have done so far, and so this particular problem remains in the final map.

Areal Representation

We should also emphasize that we were only able to adjust the forested Ecological Systems to approach their 'correct' areal extent within the maps due to the limitations of our data set. This is important to note because RF models can produce biased output, especially when input sample sizes among the classes are unbalanced (Chen et al. 2004), which is certainly the case in our situation. Nevertheless, we believe that our maps do provide a reasonable starting point or ballpark estimate for the area covered by the nonforest Ecological Systems, partly because the mapping of these classes was constrained to a relatively minor part of the landscape in most model regions, helping to limit the degree that one or two dominant Systems in the nonforest model could effectively dominate the map.

In Figures 3 through 9, we graphically present areal representation statistics for some of the Ecological Systems. In reading these graphs, it is important to note a couple of things. First, a large portion of the area within each model region is not sampled by the inventory plots. Thus, that portion of the landscape is not represented in the system-by-system areal estimates derived from those plots, but is lumped together in the "not sampled" category. The inventory plots were targeted towards the forested portion of the landscape. Therefore, the nonforest Ecological Systems in the map fall primarily into the "Not Sampled" category for the Inventory Plots. This manifests itself in a couple of ways. First, we were unable to develop any areal estimates for most of the nonforest classes (and thus labeled them all "Nonforest" for this analysis). Second, Systems that straddle the boundary of the forest-nonforest definition (e.g., Columbia Plateau Juniper Woodland and Savanna) will likely be under sampled by the inventory plots and thus appear to be overrepresented within the maps.

Second, the Inventory plots represent a small sample portion of the entire landscape. Because of this, estimates of area derived from them encompass some uncertainty, especially for the smaller classes (which will be very poorly sampled at the model-region scale).

Other issues

One additional source of error in our maps is the forest/nonforest mask that we use to constrain where we map from the forest and nonforest models. This mask is derived from the NLCD 2001's canopy coverage estimates, combined with our disturbance layer. Visual inspection shows that it is quite good at differentiating open areas from closed forest, but less effective in areas of low canopy coverage. This can lead to errors in Systems assignments along the margins of the forests, and areas with low density canopies. We minimized thee problems by mapping Savanna and Parkland Systems in both the forest and nonforest models.

Modeling Considerations

Our choice of Random Forest as a modeling technique stemmed from several factors. Recent research has shown it to be more accurate than a variety of other methods (Prasad and Iverson 2006). It can also incorporate both continuous and categorical explanatory data types. Its informational demands for each data point are low as well, requiring just a categorical assignment for each point. This characteristic is what allowed us to incorporate our supplemental data, and airphoto points.

Although Random Forest has known problems with bias from unbalanced samples (Chen et al. 2004), our post-modeling adjustment procedure should help limit the degree to which this is a problem for the forested Systems at least. For the nonforest model, we were not able to measure the bias, and thus were unable to correct it. However, the need to incorporate supplemental points was greater for the nonforest Systems and therefore Random Forest was still the best model choice.

An additional benefit of using RF is its ability to gain in prediction accuracy for the forest Systems when the landsat imagery was incorporated into the model. Other modeling techniques (e.g. GNN, Ohmann and Gregory 2002) can have difficulties using landsat explanatory data to predict species composition. The problems may arise from the scale of variation within the landsat data. Imagery may be informative of species composition at a local scale, but more noisy at the whole model region scale. Regardless, the need for these maps to represent the actual landscape for a single year (2001) lent one more point in favor of choosing RF for modeling as it allowed us to effectively link our models to the imagery data.

Ecological Lessons

In the process of building the Random Forest models, we learned something about which environmental variables were strong predictors of the Systems. While these varied from model region to model region, some general trends did emerge.

First of all, location (especially longitude) was always important. It almost always ranked among the top 5 predictor variables. Latitude was sometimes also important, but not as often as latitude. Various climate variables were near the top of the list in all the different model regions. For the Eastern Cascades (North and South) and the Modoc Plateau, the difference between the maximum August temperature and minimum December temperature was the strongest predictor. In the West Cascades, the percent of annual precipitation falling during the growing season was one of the strongest predictor variables. In the Klamath-Siskiyou mountains, the number of cold days per year was the strongest climate predictor variable. In the Willamette Valley, precipitation variability in December and July was a strong predictor. Finally, the percentage of days in July with high stratus clouds was the most important climate variable in the Oregon Coast Range. After climate, elevation was often a strong predictor within the forest models (except for in the Willamette Valley, which was our only non-mountainous model region). In only 3 models out of 7 did an imagery variable rank among the top five variables for the forest ecological systems.

A different pattern emerges from the nonforest models. Imagery in the nonforest models was often more important here, ranking in the top variables for six out of the seven model regions (and #6 for the other model region). Spatial location was also often an important predictor. Local topography (rather than just elevation) played a stronger role in many of the nonforest models as well (percent slope). Additionally, one soil variable (the presence of ultramafic soil parent material) emerged as a strong predictor in the Klamath-Siskiyou mountains. This was the only instance where a soil variable was strong enough to be retained in the final model.

In summary, for the forests, location, elevation and climate appear to be the strongest correlates of the Systems. For the nonforests, reflectance and local topography appear to be more important than climate. These findings only describe correlations between our explanatory variables and the conceptual definitions of the Systems. However, they also provide useful hints as to what might be driving variables of vegetation, possibly providing a starting point for future ecological work.

Caveats and Cautions

We feel that it is worthwhile to finish with a few caveats and cautions with respect to these maps. First, it is important to remember that they are built from statistical models and thus embody a degree of uncertainty (highlighted by our accuracy assessment figures). Second, these maps are best used to describe and illustrate general patterns at broad scales, such as the ecoregion. Our own research has shown that at local scales, the spatial patterns resulting from different modeling techniques (e.g., GNN) can vary greatly. Caution should certainly be exercised if using these maps as input data for models that depend on local habitat connectivity, patch sizes, and structure.

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