NORTHWEST
FOREST PLAN
THE FIRST 10 YEARS (1994–2003)

Status and Trend of Late-Successional and Old-Growth Forest

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Abstract

Moeur, Melinda; Spies, Thomas A.; Hemstrom, Miles; Martin, Jon R.; Alegria, James; Browning, Julie; Cissel, John; Cohen, Warren B.; Demeo, Thomas E.; Healey, Sean; Warbington, Ralph. 2005. Northwest Forest Plan–The first 10 years (1994-2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

We monitored the status and trend of late-successional and old-growth forest (older forest) on 24 million ac of land managed by the Forest Service, Bureau of Land Management, and National Park Service in the Northwest Forest Plan (the Plan) area between 1994 and 2003. We developed baseline maps from satellite imagery of older forest conditions at the start of the Plan. We used remotely sensed change detection to track losses of older forests on federally managed lands to stand-replacing harvest and wildfire, and we analyzed the amounts and spatial distribution of older forests by using the mapped data. We also performed statistical analysis on inventory plot information collected on Forest Service and Bureau of Land Management lands. These analyses provided statistically rigorous estimates of older forest acres bracketed by confidence intervals. We analyzed remeasured inventory plots to estimate net change in the amount of older forests on federally managed lands.

We estimated the amount of older forest at the start of the Plan corresponding to three different older forest definitions based on average tree size, canopy layering, canopy closure, and life form. The results ranged from 7.87 million ac (± 1.96 million ac) of federally managed lands with average tree size at least 20 in (medium and large older forest), to 7.04 million ac (± 1.93 million ac) using a definition that recognizes variation in regional forest vegetation (older forest with size indexed to potential natural vegetation zone). We found 2.72 million ac (± 0.35 million ac) were in stands with average tree size 30 in and greater, with multistoried canopies (large, multistoried older forest). At least 1.7 million ac of existing “medium and large” older forest were in fire-adapted vegetation types characterized by high fire frequency and low severity in the Eastern Cascades and Klamath provinces. Up to 1 million additional older forest ac occurred in dry mixed-conifer types in the Western Cascades.

Our data from remeasured inventory plots indicated that the annual net rate of increase of “medium and large” older forest was about 1.9 percent, outpacing losses from all sources. The extrapolated gain in older forest 20 in was between 1.25 million ac and 1.5 million ac in the first decade after the Plan. The gain came primarily from increases in the area of forest at the lower end of the diameter range for older forest. The net increase took into account the older forest removed by stand-replacing harvest, 0.2 percent of the total (about 16,900 ac on all federally managed lands), and the amount burned by stand-replacing wildfire, about 1.3 percent (about 102,500 ac on all federally managed lands). The area mapped as logged or burned had an error estimate of between 7 and 12 percent.

The initial amount, distribution, and arrangement of older forest on federally managed land appears to have met or exceeded Northwest Forest Plan expectations. But the large amount of older forest susceptible to catastrophic wildfire may be a concern for managers. Losses to wildfire in the first decade were in line with assumptions for the Plan area, but rates of loss were highly variable among provinces, with the highest rates of loss occurring in the dry provinces. Loss of older forest to harvest was a fraction of the approximately 230,000 ac of older forest expected to have been harvested. Overall gain was about twice the 600,000 ac expected during the first decade of the Plan.

Older forest maps based on remote sensing allowed for a spatial assessment of landscape patterns, but map accuracy was low in some areas, especially the Eastern Cascades. Remotely sensed change detection was highly accurate for assessing older forest losses to catastrophic disturbance (clearcutting and stand-replacing wildfire). But technological improvements are needed to use remotely sensed data for detecting less severe disturbance from partial harvest or less severe burning. Plot data were not of sufficient resolution to allow for spatial analysis or to identify causes of change. But estimates made from plot data were unbiased, accurate, and precise. Future monitoring work will pursue approaches that tie the plot-based and mapped data sets together more closely.

This document, including high-resolution versions of all the map images it contains, is accessible online (http://www.reo.gov/monitoring/).

Keywords: Northwest Forest Plan, effectiveness monitoring, late-successional and old-growth forests, remote sensing, existing vegetation, change detection, Pacific Northwest, Forest Service, Bureau of Land Management, land use allocations, late-successional reserves, physiographic provinces.

Preface

This report is one of a set of reports produced on this 10-year anniversary of the Northwest Forest Plan (the Plan). The collection of reports attempts to answer questions about the effectiveness of the Plan based on new monitoring and research results. The set includes a series of status and trend reports, a synthesis of all regional monitoring and research results, a report on interagency information management, and a summary report.

The status and trend reports focus on establishing baselines of information from 1994, when the Plan was approved, and reporting change over the 10-year period. The status and trend series includes reports on late-successional and old-growth forest, northern spotted owl population and habitat, marbled murrelet population and habitat, watershed condition, government-to-government tribal relationships, socioeconomic conditions, and monitoring of project implementation under Plan standards and guidelines.

The synthesis report addresses questions about the effectiveness of the Plan by using the status and trend results and new research. It focuses on the validity of the Plan assumptions, differences between expectations and what actually happened, the certainty of the findings, and, finally, considerations for the future. The synthesis report is organized in two parts: Part I–introduction, context, synthesis and summary–and Part II–socioeconomic implications, older forests, species conservation, the aquatic conservation strategy, and adaptive management and monitoring.

The report on interagency information management identifies issues and recommends solutions for resolving data and mapping problems encountered during the preparation of the set of monitoring reports. Information management issues inevitably surface during analyses that require data from multiple agencies covering large geographic areas. The goal of that report is to improve the integration and acquisition of interagency data for the next comprehensive report.

Executive Summary

In this assessment we evaluated three older forest definitions. The definitions used average tree size, canopy layering, canopy closure, and life form as defining attributes. “Medium and large older forest” represents forests with a minimum average tree size of 20 in, and having either single-storied or multistoried canopies. “Older forest with size indexed to potential natural vegetation zone” uses an average-tree-size threshold that varies by potential natural forest vegetation zone, and having either single- or multistoried canopies. “Large, multistoried older forest” represents forests with average tree size 30 in and greater and multistoried canopies. Each of the three definitions was applied to create a set of regional and provincial older forest benchmarks. “Medium and large older forest” corresponds closely to the definition of older forests used in the Northwest Forest Plan Record of Decision, and therefore can be used broadly to assess the assumptions upon which the Plan was founded about the amount of remaining older forest. “Older forest with size indexed to potential natural vegetation zone” is a definition that recognizes regional variation in climate, topography, and natural disturbance regimes. “Large, multistoried older forest” retains minimum structural elements of “classic” Douglas-fir old growth (large live, old-growth trees and multiple canopy layers).

We used maps of existing vegetation created from satellite data to estimate the amount and distribution of older forests at the start of the Plan. Older forests assessed by using the “medium and large” older forest definition occupied 34 percent (7.87 ± 1.96 million ac) of the federal forested landscape at the start of the Plan, ranging from 5 percent in the Eastern Cascades of Washington to 47 percent in the California Coast province. There were fewer acres overall of “older forest with size indexed to potential natural vegetation zone” (7.04 ± 1.93 million ac or 30 percent), and the distribution differed from the “medium and large older forest” estimate across physiographic provinces and potential natural vegetation zones. This definition estimated more acres in higher elevation forests and forest types east of the Cascades, and fewer acres in very productive west-side forest types compared with the “medium and large” older forest definition. The “large, multistoried older forest” definition estimated 2.72 ± 0.35 million ac (12 percent), concentrated in forests west of the Cascade divide.

Estimates of older forest compiled from map and plot data were generally consistent. The number of acres of “medium and large” older forest tallied from maps developed from remote sensing data was contained within 90-percent confidence intervals constructed from plot data at the regional level. The map and plot estimates were equivalent in Oregon and Washington, whereas in California the map estimate was higher than the upper 90-percent confidence boundary for the plot estimate. There was even greater difference between map and plot estimates within physiographic provinces. In particular, map estimates were well below plot estimates in the Eastern Cascades of Washington and Oregon where average size was mapped to lower resolution than in the rest of the range. This comparison can help us identify where the mapping technology and related analyses need the greatest effort to improve the accuracy of results.

Our results confirm the older forest amounts reported in the Northwest Forest Plan Record of Decision. The estimate of 7.87 million ac of “medium and large” older forest is within 10 percent of the 8.55 million ac published in the Plan, which used a similar definition. It appears therefore that the Plan was founded upon valid assumptions about the extent of remaining older forest.

Two-tenths of a percent (about 16,900 ac) of "medium and large" older forest on federal land was removed by clearcutting harvests since the Plan was signed. Another 1.3 percent (about 102,500 ac) was burned by stand-replacing wildfires. The area mapped as logged or burned had an error estimate of between 7 and 12 percent. Local variation in wildfire was huge, with 95 percent of acres lost in a few catastrophic fires. Three-quarters of the total was burned in the Oregon and California Klamath provinces during the 2002 Biscuit Fire.

Gains well outpaced losses from all causes between 1994 and 2003. When we analyzed change rates by using remeasured plot data, we projected an increase of 1.01 million ac of "medium and large" older forest in the first decade after the Plan, just on Forest Service Pacific Southwest and Pacific Northwest Regions nonwilderness land. Likely an additional 0.24 to 0.48 million ac were gained on other federally managed lands, assuming that the rate of change was at least half, but no greater than the rate calculated on sampled lands. This was a net increase after taking into account losses from stand-replacing harvest and wildfire.

About three-quarters of existing older forest is in administratively withdrawn, congressionally reserved, and late-successional reserve federal land allocations. Of the older forest on land allocated to matrix, an unknown proportion is in riparian reserves that have not been spatially differentiated from matrix. Therefore our results underestimated the true proportion of older forest in reserved land allocations. The record of decision estimated that matrix accounted for 4.0 million ac, and riparian reserves interspersed with matrix accounted for 2.6 million ac. Applying the same proportions to our results (that is, assuming the combined class is 60 percent matrix and 40 percent riparian reserve), we estimated that riparian reserves accounted for an additional 11 percent of the total older forest (and matrix 11 percent less).

The report focuses attention on the large amount of existing older forest in fire-adapted ecosystems (that is, characterized by high fire frequency and low severity) in dry physiographic provinces. There are 1.7 million ac of "medium and large" older forest in fire-adapted forest types in the Klamath and Eastern Cascades provinces. Up to 1 million additional older forest ac occur in dry mixed-conifer types in the Western Cascades. Twentieth-century fire-suppression policies and resulting accumulation of fuel has increased the susceptibility of these older forests to catastrophic wildfire. Therefore it will be very important to consider wildfire when evaluating management policies aimed at perpetuating a healthy, functioning older forest ecosystem in the Northwest Forest Plan area.

Contents

Introduction

How much late-successional and old-growth forest existed on federal land at the start of the Northwest Forest Plan (the Plan)? How was it arranged on the landscape? How much was lost and gained in the first decade of the Plan? From what causes? How did the amount and pattern of late-successional and old-growth forest (older forest) differ from the expectations under the Plan? These and other related questions are the focus of this report.

This report summarizes the scientific assessment of the status and trend of late-successional and old-growth forest between 1994 and 2003 on the federal lands affected by the Plan (fig. 1).

In the early 1990s, controversy over harvest of old-growth forest led to sweeping changes in management of federal forests in western Washington and Oregon and northwest California. These changes were prompted by a series of lawsuits in the late 1980s and early 1990s, which effectively shut down federal timber harvest in the Pacific Northwest (Tuchmann and others 1996). In response, President Clinton convened a summit in Portland, Oregon, in 1993. At the summit, President Clinton issued a mandate for federal land management and regulatory agencies to work together to develop a plan to resolve the conflict. The President’s guiding principles followed shortly after the summit in his *Forest Plan for a Sustainable Economy and a Sustainable Environment* (Clinton and Gore 1993).

Immediately after the summit, a team of scientists and technical experts were convened to conduct an assessment of options (FEMAT 1993). This assessment provided the scientific basis for the environmental impact statement (USDA and USDI 1994a) and record of decision (USDA and USDI 1994b) to amend Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl (*Strix occidentalis caurina*).

The record of decision, covering 24 million federal ac, put in place a new approach to federal land management. Key components of the record of decision included a new set of land use allocations—late-successional reserves, matrix, riparian reserves, adaptive management areas, and key watersheds. Plan standards and guidelines provided specific management direction regarding how these land use allocations were to be managed (USDA and USDI 1994b). In addition, the Plan put in place a variety of strategies and processes to be implemented. These included adaptive management, an aquatic conservation strategy, late-successional reserve and watershed assessments, a survey and manage program, an interagency organization, social and economic mitigation initiatives, and monitoring.

Monitoring provides a means to address the uncertainty of our predictions and compliance with forest management laws and policy. The record of decision stated that monitoring is essential and is required:

> Monitoring is an essential component of the selected alternative. It ensures that management actions meet the prescribed standards and guidelines and that they comply with applicable laws and policies. Monitoring will provide information to determine if the standards and guidelines are being followed, verify if they are achieving the desired results, and determine if underlying assumptions are sound.

Judge Dwyer reinforced the importance of monitoring in his 1994 decision declaring the Plan legally acceptable (Seattle Audubon Soc. v. Lyons, 871 F.Supp. 1291 [W.D. Wash. 1994]; affirmed Seattle Audubon Soc. v. Moseley, 80 F.3d 1401 [9th Cir. 1996]):

> Monitoring is central to the [Northwest Forest Plan’s] validity. If it is not funded, or done for any reason, the plan will have to be reconsidered.

The record of decision monitoring plan provided a very general framework to begin development of an interagency monitoring program. It identified key areas to monitor, initial sets of questions, types and scope of monitoring, the need for common protocols and quality assurance, and the need to develop a common design framework. In 1995, the effectiveness monitoring program plan (Mulder and others 1995) and initial protocols for implementation monitoring (Alegria and others 1995) were approved by the Regional Interagency Executive Committee. Approval of the effectiveness monitoring plan led to the formation of technical teams to develop the overall program strategy and design

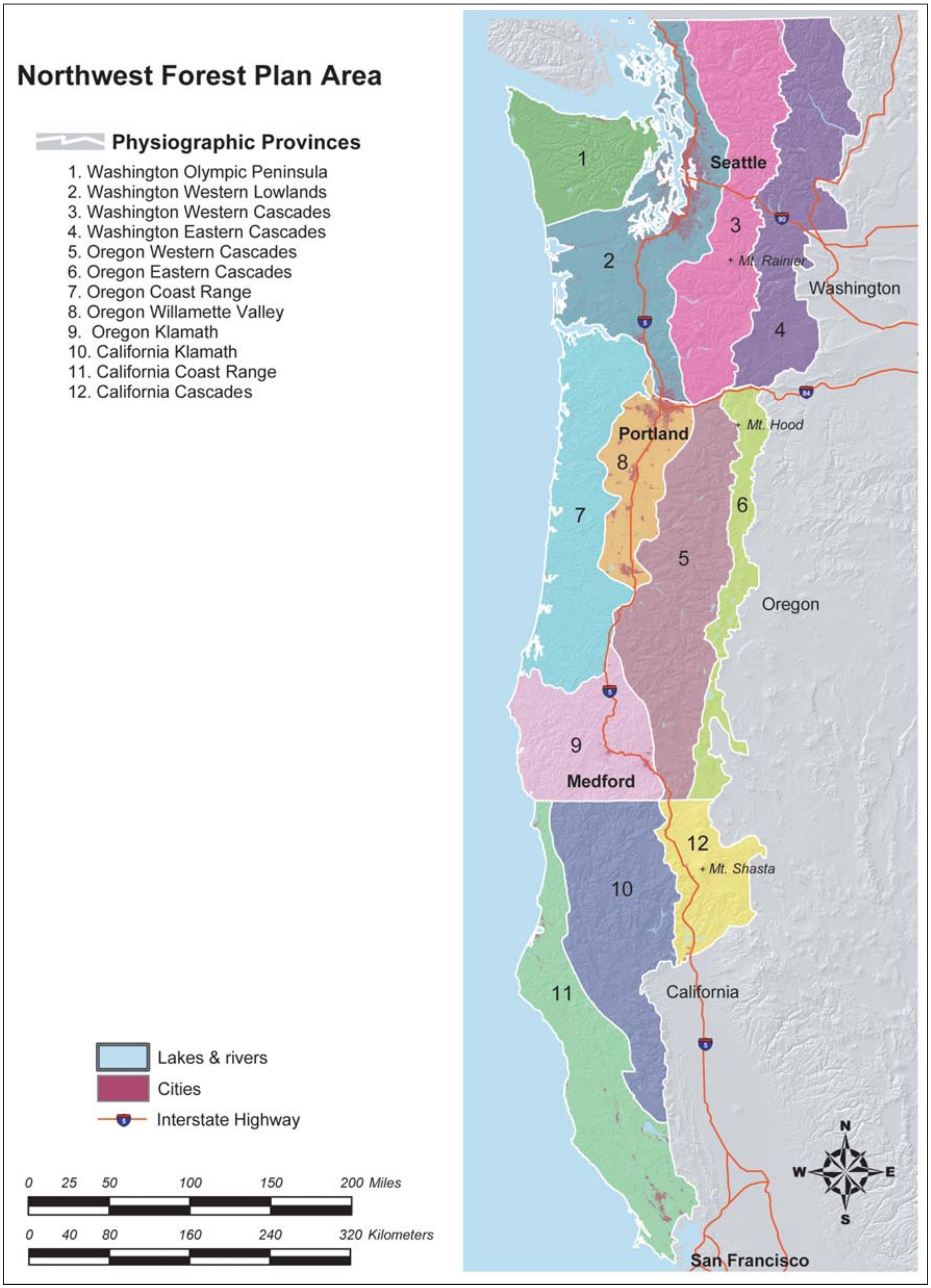

Figure 1—Terrestrial physiographic provinces of the Northwest Forest Plan area (from USDA and USDI 1994a, fig. 3&4-1).

(Mulder and others 1999) and monitoring protocols for late-successional and old-growth forest (Hemstrom and others 1998), northern spotted owls (Lint and others 1999), marbled murrelets (*Brachyramphus marmoratus*) (Madsen and others 1999), tribal concerns (Bown and others 2002), and watershed condition (Reeves and others 2004). Socioeconomic monitoring protocols continue to be tested (Charnley et al., in press).

Periodic analysis and interpretation of monitoring data is essential to completing the monitoring task and critical to completing the adaptive management cycle. This important step was described in the overall monitoring strategy (Mulder and others 1999) and approved by the regional interagency executive committee. This 10-year report is the first comprehensive analysis and interpretation of monitoring data since the record of decision.

The Plan's Expectations

At the very heart of the Northwest Forest Plan was the observation that the amount of older forest on federal land in the Pacific Northwest had declined steeply in the 20th century (see Bolsinger and Waddell 1993), and the assumption was that it would continue to decline unless policies were put in place to halt it. Declining old-growth habitat was also blamed for placing at risk some old-growth-dependent species such as the northern spotted owl and marbled murrelet. The Plan was implemented in hopes of returning older forest to a level more in line with the amount of the historical landscape that was covered by older forest.

The Northwest Forest Plan was developed by expert panel assessments under the direction of the Forest Ecosystem Management Team (FEMAT 1993, USDA and USDI 1994a). Each alternative was evaluated based upon its probable success of achieving historical ranges of older forest abundance and diversity, ecological processes, and landscape arrangement over the life of the Plan. The possible outcomes ranged from high probability of achieving amounts at least as high as the long-term historical average, to the possibility of highly fragmented remnant older forest patches restricted to a few locations and therefore considerably below the low end of the historical range of conditions. The benchmarks were the amounts and variety of plant communities across the range of environments (that is, abundance and ecological diversity), ecological processes such as the balance of successional stages, nutrient and hydrological cycling, and habitat for old-growth-dependent species (that is, processes and functions), and the extent to which the landscape pattern of the ecosystem provides for biological flows that sustain animal and plant populations (that is, landscape patterns and connectivity). Thresholds were set for each of the benchmarks for quantifying the observed outcome relative to the Plan expectation. For example, expert panels estimated there would be a 77-percent likelihood under the Plan of achieving either outcome 1 or 2 (within the historical range of variation) for the abundance and diversity benchmark for moist provinces (and only 63 percent for dry provinces). The actual result could be measured by the total amount of the land base covered by older forest, and the amount covered by large contiguous stands, relative to the stated benchmark amounts.

Comparison of monitoring results with outcomes expected under the Plan gives us a gauge of how well the Plan is working. This concept is covered in much greater detail in subsequent sections. However, it is helpful to note in this introduction some key assumptions of the Plan:

1. The environmental impact statement included an initial estimate of the amount of late-successional and old-growth forest remaining on federal lands at the start of the Plan (8,550,500 ac or 35 percent of the federal landscape—table 3&4-8, USDA and USDI 1994a). Of this amount, about 85 percent was in reserved allocations.
2. The record of decision included estimates of the historical amount of older forest. Under natural disturbance regimes, the long-term average percentage of the regional landscape covered by late-successional and old-growth forest was 60 to 70 percent.
3. The proportion of late-successional and old-growth forest in reserved allocations was expected to increase over time under the Plan, to at least as high as the long-term average in 5 to 10 decades.

Sidebar 1—Plan expectations

Abundance and diversity are the amount and variety of plant communities and environments. **Connectivity** is the extent to which the landscape pattern of the ecosystem provides for biological flows that sustain animal and plant populations. **Processes and functions** are the ecological actions that lead to the development and maintenance of the ecosystem and the values of the ecosystem for species and populations.

Abundance and diversity outcomes and thresholds for late-successional and old-growth forests (LSOG) in the Northwest Forest Plan

Outcome	Land covered by LSOG	Lands in stands of more than 1,000 acres	Provinces meeting both amount and stand size
		Percent	
1	60 to 100	80 to 100	100
2	40 to 60	5 to 80	100
3	5 to 40	1 to 5	50 to 100
4	Less than 5	Less than 1	Less than 50

Outcome 1—Late-successional and old-growth ecosystem abundance and ecological diversity on federal lands are at least as high as the long-term average estimated at 65 percent of the forested landscape prior to logging and extensive fire suppression (FEMAT 1993: 51). Relatively large areas (50,000 to 100,000 ac) would still contain levels of abundance and distribution of late-successional forests that are well below the regional average for long periods. However, within each physiographic province, abundance would be at least as high as province-level long-term averages, which might be higher or lower than the regional long-term average.

Outcome 2—Late-successional and old-growth ecosystem abundance and ecological diversity on federal lands are less than the long-term conditions (prior to logging and extensive fire suppression) but within the typical range of conditions that occurred during previous centuries, assumed to be 40 percent of the forested landscape (FEMAT 1993: 51).

Outcome 3—Late-successional and old-growth abundance and ecological diversity on federal lands are considerably below the typical range of conditions that have occurred during the previous centuries, but in some provinces some older forest (more than 1 percent) would still exist. The ecological diversity (age-class diversity) may be limited to the younger stages of late-successional ecosystems. Late-successional and old-growth communities and ecosystems may be absent from some physiographic provinces and/or occur as scattered remnant patches.

Outcome 4—Late-successional and old-growth ecosystems are very low in abundance and may be restricted to a few physiographic provinces or elevation bands or localities within provinces. Late-successional and old-growth communities and ecosystems are absent from most physiographic provinces or occur only as small remnant patches.

Source: (USDA and USDI 1994a: table 3&4-5).

Connectivity outcomes and thresholds for late-successional and old-growth forest used when ranking land management alternatives considered in the Northwest Forest Plan FSEIS

Outcome	Mean distance between stands of more than 1,000 acres	LSOG cover	LSOG stands less than 1,000 acres	Adjacent provinces connected with large LSOG stands
	– – – *Miles* – – –	– – *Percent* – –		– – – *Percent* – – –
1	Less than 6	60 to 100	Common	100
2	6 to 12	50 to 60	Common	100
3	12 to 24	25 to 50	Present	Less than 100
4	More than 24	Less than 25	Absent to few	Less than 100

Outcome 1—Connectivity is very strong, characterized by relatively short distances (less than 6 mi on average) between late-successional and old-growth areas. Smaller patches of late-successional and old-growth forest frequently occur (riparian buffers, green-tree retention in harvest units, etc.). The proportion of the landscape covered by late-successional and old-growth conditions of all stand sizes exceeds 60 percent, a threshold when many measures of connectivity increase rapidly. At regional scales, physiographic provinces are connected by the presence of landscapes containing areas of late-successional and old-growth forests.

Outcome 2—Connectivity is strong, characterized by moderate distances (less than 12 mi on average) between large late-successional and old-growth areas. Smaller patches of late-successional forest occur as described in outcome 1. At regional scales, physiographic provinces are connected by the presence of landscapes containing areas of late-successional and old-growth forests. The total proportion of landscape in late-successional and old-growth conditions, including smaller patches, is at least 50 percent, so that the late-successional condition is still the dominant cover type.

Outcome 3—Connectivity is moderate, characterized by distance[s] of 12 to 24 mi between large old-growth areas. There is limited occurrence of smaller patches of late-successional forest in the matrix. The late-successional forest is at least 25 percent of the landscape, and the matrix contains some smaller areas for dispersal habitat.

Outcome 4—Connectivity is weak, characterized by wide distances (greater then 24 mi) between old-growth areas. There is a matrix in which late-successional and old-growth conditions occur as scattered remnants or are completely absent.

Source: (USDA and USDI 1994a: table 3&4-7)

Scope and Context of Effectiveness Monitoring for Older Forests

This report covers only older forest effectiveness monitoring. The monitoring is designed to address questions about older forest status and trend such as, "How much older for-est is there? Where is it? How much has it changed and from what causes?" Hemstrom and others (1998) developed specific effectiveness monitoring questions for late-successional and old-growth forest. Of the monitoring questions listed, the first five are within the scope of status and trend monitoring, and are specifically addressed in this report. They deal with amounts, distributions, and spatial patterns of older forests. Monitoring of older forest processes and functions, such as providing habitat or contributing to watershed health, is not explicitly covered in this report beyond the comparison of observed status and trend with the Plan's expectations.

The last two questions are beyond the scope of this report. However, they are addressed explicitly in a synthesis report (Haynes and others, in press), in the context of

Sidebar 2—Status and trend monitoring questions

Older forest status and trend monitoring questions (after Hemstrom and others 1998)

What is the current amount and distribution of older forests in the Northwest Forest Plan?
What is the amount and distribution of older forest classes for the Plan area? Within federal ownerships, physiographic provinces, plant communities, and land use allocations? How accurate are these estimates?

What is the spatial arrangement of older forest classes across the Northwest Forest Plan landscape?
What are the spatial distributions of stand sizes, stand interior areas, edges, and interstand distances?

What are the structural and compositional characteristics of older forest classes?
Large tree diameters, canopy structure, snags, and down woody debris? What is the error associated with these estimates?

How is the amount and distribution of older forest classes changing?
How have they changed during the first decade of the Plan? How much are they likely to change in the near-term and long-term future?

What are the stressors causing change in the amount and distribution of older forest classes?
What are the gains from growth and succession? What are the losses from logging, fire, wind, insects, and disease?

What are the effects of silvicultural treatment and salvage on the development of older forest structure and composition?
This question is outside the scope of the status and trend monitoring report but is addressed by Spies (in press).

Are the relationships of forest structure and composition at stand and landscape scales to ecological processes and biological diversity assumed by the Plan, accurate?
This question is outside the scope of the status and trend monitoring report but is addressed by Spies (in press).

scientific findings external to the monitoring program. In his synthesis report chapter, Spies (in press) includes discussion about possible effects of silvicultural practices for restoring ecological diversity or accelerating old-growth development, as well as a section that reevaluates the validity of the Plan’s assumptions and approaches. Furthermore, the habitat sections of the status and trend reports for northern spotted owls (Lint 2005) and marbled murrelets (Huff, in press) devote discussion on the subject of how well the old-growth forest ecosystem is providing habitat for those species. Habitat for old-growth-dependent species is one (arguably the foremost) of the functions of older forest that the Northwest Forest Plan was designed to address.

We report monitoring results only for the federally administered lands affected by the Plan: USDA Forest Service Pacific Northwest Region (Forest Service-Region 6) and Pacific Southwest Region (Forest Service-Region 5), U.S. Department of the Interior Bureau of Land Management in Oregon (Bureau of Land Management-Oregon) and California (Bureau of Land Management-California), and U.S. Department of the Interior National Park Service in Washington, Oregon, and California (fig. 2). The Plan does not affect lands administered by other federal agencies, such as Fish and Wildlife Service or Department of Defense (USDA and USDI 1994b), nor is it applicable to any nonfederal lands.

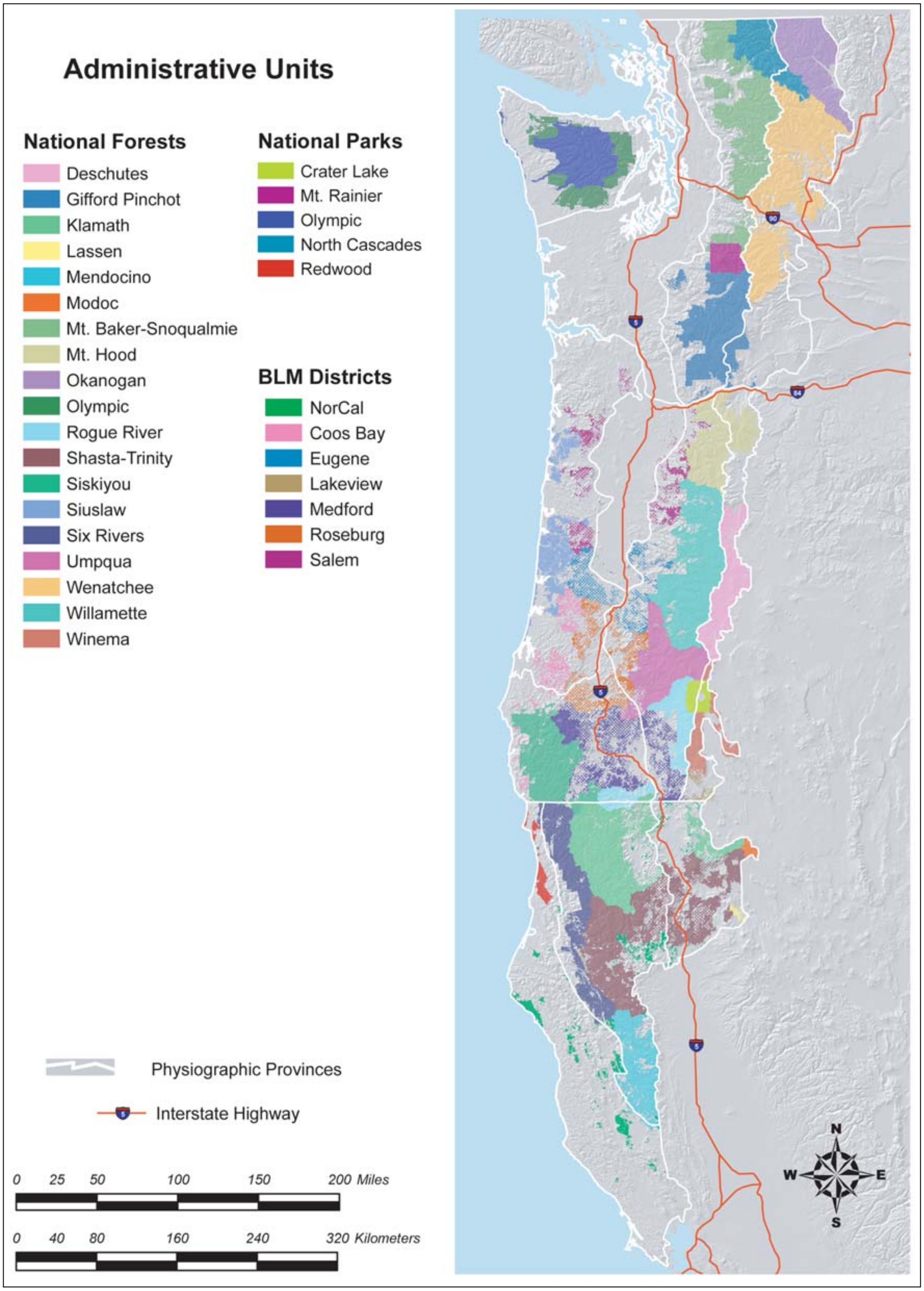

Figure 2–Federal administrative units in the Northwest Forest Plan area.

Status and Trend Monitoring Design for Older Forest

The goal of the monitoring program is to determine the status and trend of older forest, in order to provide information for evaluating the likelihood that the Plan will achieve the stated objectives for maintaining and restoring older forest (Hemstrom and others 1998). The basic monitoring approach is periodic assessment of late-successional and old-growth forest.

This document is the first comprehensive report of the Plan’s effect on older forest status and trend. It presents two main findings. First, it establishes initial older forest conditions by using consistent information to approximate a baseline at the beginning of the Plan in 1994. Second, it reports the observed status and trend in older forest during the first decade after implementation of the Plan by using monitoring information to update baseline estimates. It paints a picture of the cumulative changes from 1994 to 2003 and the resultant current forest conditions in the Plan area. It also discusses aspects of the monitoring design, including strengths and limitations. Finally, it lays some groundwork for major phases of future monitoring activities, such as introducing the concepts of trend analysis using landscape modeling (fig. 3).

Three major types of monitoring information went into this report (fig. 3):

1. A map estimating the amount and extent of older forest at the start of the Plan, developed from remote sensing data, ground observations, and modeling techniques.
2. Estimates of older forest amount at the start of the Plan, developed from statistical analysis of ground-based inventory data.
3. Estimates of the amount of change in older forest during the first decade after the Plan, developed from remotely sensed disturbance maps and from remeasured plot data.

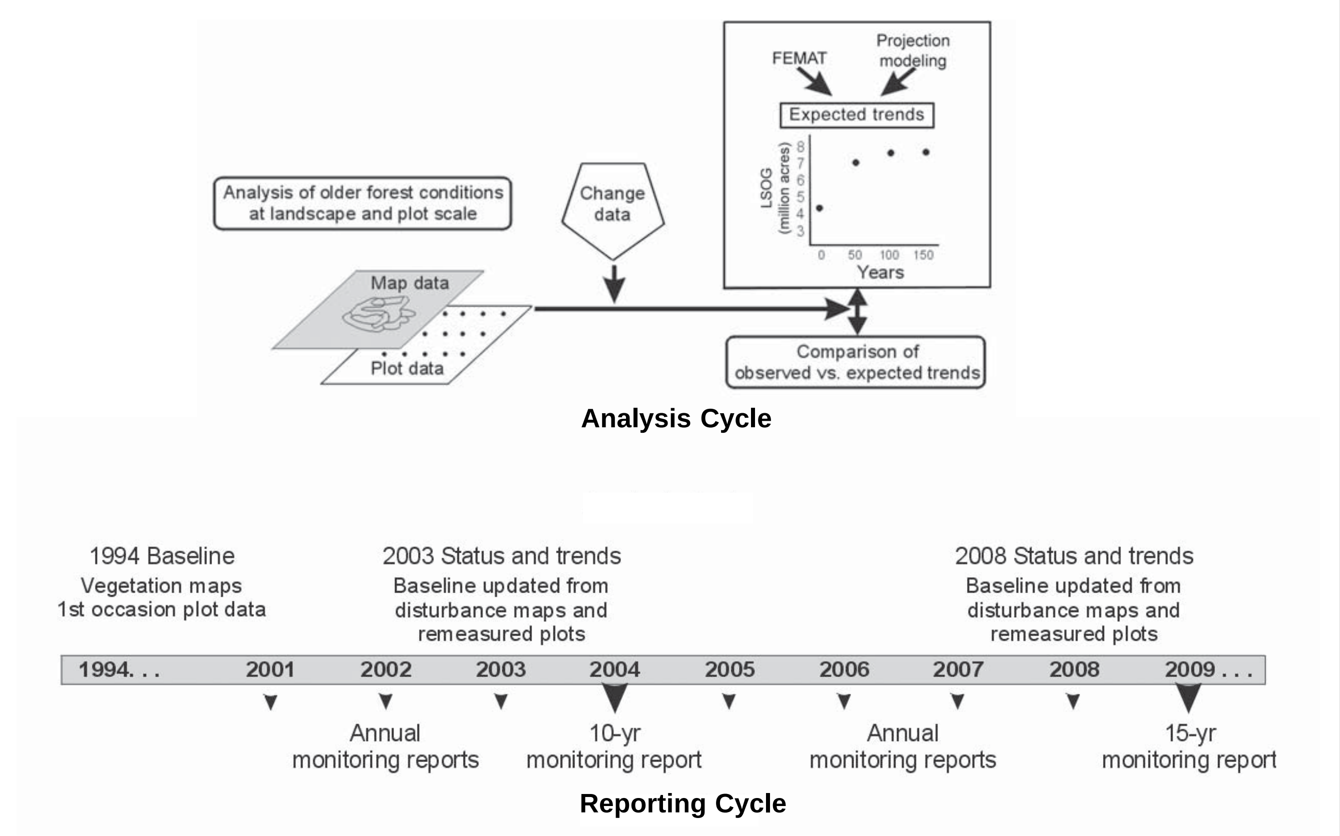

Figure 3—Older forest monitoring activity and reporting cycle.

Older forest maps derived from remote sensing information provide complete and consistent coverage of existing forest vegetation in the Northwest Forest Plan area, at the start of the Plan. Maps are analyzed to evaluate the amount (area) and distribution (size and arrangement) of older forest across the Plan landscape. All lands are mapped, but results on nonfederal lands are not evaluated or discussed in this report. The synthesis report does, however, extend the analysis of map results to nonfederal lands and discusses the contribution of older forest on federal land within the larger regional context (Haynes and others, in press).

Statistical analysis of stand-scale plot data is used to report older forest amounts at provincial and regional scales with a known degree of statistical reliability. Statistical relationships between mapped vegetation attributes and sample-based measurements can be used to describe structural conditions of vegetated landscapes at regional scales by providing information about older forest structural attributes and composition that remote sensing cannot detect.

Monitoring for trend requires establishment of baseline conditions and a subsequent means of tracking changes from the baseline. Change detection tracks losses and gains in forest conditions from a variety of sources—management, natural succession, and disturbances. Remotely sensed change detection is used to track stand-replacing disturbances (clearcut harvest and wildfire). Analysis of stand-scale information on remeasured permanent plots provides a statistical sample reflective of annual changes in forest conditions for the full range of disturbance scales—from stand loss owing to management or natural disturbance, to successional change resulting from growth and mortality.

Organization of This Report

A very large amount of information was analyzed and compiled to write this report. To meet the challenge of presenting the information clearly and effectively, we describe methods and results organized by each major topic: (1) older forest maps developed from remotely sensed data, (2) older forest area estimates from inventory plot information, and (3) analysis of change from remotely sensed data and from remeasured inventory plots. For each topic, we discuss the data sources and methods of analysis in detail, followed by the major findings leading from that topic. When a monitoring approach has been derived from published methodology, we briefly summarize the methods and refer the reader to the original work for additional detail. The discussion section at the report's end synthesizes the findings from the individual topics. Key results and interpretations are reiterated in the conclusions section.

Maps compose much of the information discussed in this report. The key maps are reproduced in this document. In addition, all map images referred to in the report are accessible online as high-resolution graphic images so that the reader may view map detail that cannot be reproduced adequately by the page-size printed maps (http://www.reo.gov/monitoring/).

A Continuum of Older Forest Definitions

Throughout this document we use the term "older forest" interchangeably with the term "late-successional and old-growth forest." Our term is intended to connote greater flexibility inherent to assessing and displaying results based on a variety of definitions.

The concept of "old growth" is laden with social value, and various audiences employ a wide range of language for describing significant unique features of older forest (Marcot and others 1991). Advanced age (or more accurately, time since major disturbance) is an inherent driver leading to ecologically important structural components (such as large trees, snags, down logs, and complex canopy layering) and processes and functions (such as habitat for old-growth-dependent species, carbon storage, hydrologic and nutrient cycling) typically associated with late-successional and old-growth forests (Franklin and others 1981, 1986; Franklin and Spies 1991a, 1991b). Portions of Chapter IV of FEMAT (FEMAT 1993: IV-27-31) and appendix B2 of the environmental impact statement (USDA and USDI 1994a) provide a detailed discussion of older forest elements relevant to the Northwest Forest Plan. They referred specifically to "late-successional conifer forest" as stands dominated by conifer trees that are 21 to 32 in diameter breast height (d.b.h.), characterized by a single canopy layer (also called "medium/large single-storied conifer") and stands dominated by conifer trees that are greater than 32 in d.b.h., and characterized by two or more canopy layers (also called "medium/large multistoried conifer"). Generally speaking, those reports consider late-successional conditions to develop typically between 80 and 140 years, at least in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands west of the Cascade Range. They also refer to the onset of old-growth conditions typically beginning between 150 and 250 years, and persisting for 300 to 600 years depending on local conditions.

Although forest age is an important defining attribute in most old-forest definitions, age is difficult to determine and may be misleading in complex forest conditions. Tree or stand age is difficult or impossible to infer directly from remotely sensed information. In the field, tree age may be difficult or impossible to measure, especially for large trees, and stand age is not readily characterized when trees of very different ages are present. As a result, we rely on more readily measurable attributes as a substitute for stand age. Average large-tree size is a useful attribute because it is easy to measure and well correlated with age, when local site and stand density factors are controlled for. Large trees are also fundamental to old-forest structure, function, and composition and are the precursor to large snags and down logs. In this assessment, we use tree size as the primary attribute for determining older forest status. Other measures provide additional information about older forest status and condition, but they may be less important than size, or less easy to characterize reliably. We include canopy closure and canopy layering as ancillary older forest attributes, as closed canopies and multilayered canopies are common characteristics of very old forests (Franklin and others 1981, Hemstrom and others 1998).

In this assessment, we chose to evaluate and present maps and acreage estimates corresponding to three points along a continuum of older forest definitions. This approach accomplishes several objectives. First, it recognizes that development of older forests is continuous and complex and that multiple definitions help characterize the diversity of forest development. Second, it accommodates a range of acceptable definitions rather than presenting an estimate based upon a single (and arguably, disputable) definition. And finally, it is our hope that reporting results from multiple acceptable definitions may lead to more flexible decisionmaking when different management objectives are presented.

The basis for our older forest definitions lies in the original monitoring plan. Hemstrom and others (1998) discussed a landscape-scale set of classes to describe existing forest vegetation, defined by average tree size, canopy layering, and species composition. Attributes that define the classes are average size of the topstory trees (computed as the quadratic mean diameter of dominant and codominant trees), percentage of canopy closure, canopy layering (single- or multistoried), and life form (percentage of conifer or hardwood tree canopy cover) (table 1). Classes formed from these attributes were based upon a standard set of vegetation attributes established by the Vegetation Strike Team (Askren and others 1995, 1996) (table 2). Two of the older forest definitions we evaluated correspond directly with groups of classes listed in table 1 based on average tree size and canopy layering. The third incorporates variation in average tree size associated with potential natural vegetation zone. We employed these definitions knowing that an estimate of older forest amount depends on which definition is used. Adding more criteria to the definition will reduce the area of forest meeting the definition. Also, we acknowledge that the definitions are simply "rule sets" designed around coarse-filter structural attributes available in our monitoring data. In that sense, they are not truly "ecological" definitions, especially since they cannot encompass important functional features of older forests, or even fine-filter components of structure and composition. Still, they exploit the available monitoring data to describe forests in terms of attributes important in most ecologically-based definitions of older forests—large trees, dense crown closure, and complex canopy layering.

Table 1— Forest vegetation classes based on canopy cover, average tree size, canopy structure, and species composition

	Class attributes				
Class	**Vegetation class**[a]	**Canopy cover**	**Average tree size**	**Canopy structure**	**Species mix**
		Percent	*Inches*		*Present*
1	PF	<10	NA	NA	NA
2	SS-D	≥10	<10	Any	≥80% deciduous
3	SS-M	≥10	<10	Any	20%-79.9% either
4	SS-C	≥10	<10	Any	≥80% conifer
5	SSS-D	≥10	10-19.9	Simple	≥80% deciduous
6	SSS-M	≥10	10-19.9	Simple	20%-79.9% either
7	SSS-C	≥10	10-19.9	Simple	≥80% conifer
8	SMS-D	≥10	10-19.9	Complex	≥80% deciduous
9	SMS-M	≥10	10-19.9	Complex	20%-79.9% either
10	SMS-C	≥10	10-19.9	Complex	≥80% conifer
11	MSS-D	≥10	20-29.9	Simple	≥80% deciduous
12	MSS-M	≥10	20-29.9	Simple	20%-79.9% either
13	MSS-C	≥10	20-29.9	Simple	≥80% conifer
14	MMS-D	≥10	20-29.9	Complex	≥80% deciduous
15	MMS-M	≥10	20-29.9	Complex	20%-79.9% either
16	MMS-C	≥10	20-29.9	Complex	≥80% conifer
17	LSS-D	≥10	≥30	Simple	≥80% deciduous
18	LSS-M	≥10	≥30	Simple	20%-79.9% either
19	LSS-C	≥10	≥30	Simple	≥80% conifer
20	LMS-D	≥10	≥30	Complex	≥80% deciduous
21	LMS-M	≥10	≥30	Complex	20%-79.9% either
22	LMS-C	≥10	≥30	Complex	≥80% conifer

[a] Key to vegetation class names:

	Species composition		
Size and structure class	Deciduous (D)	Mixed (M)	Conifer (C)
Potentially forested but presently nonstocked (PF)			
Seedling and sapling (SS)	SS-D	SS-M	SS-C
Small single-storied (SSS)	SSS-D	SSS-M	SSS-C
Small multistoried (SMS)	SMS-D	SMS-M	SMS-C
Medium and large single-storied (MSS)	MSS-D	MSS-M	MSS-C
Medium and large multistoried (MMS)	MMS-D	MMS-M	MMS-C
Large single-storied (LSS)	LSS-D	LSS-M	LSS-C
Large multistoried (LMS)	LMS-D	LMS-M	LMS-C

Source: Modified from Hemstrom and others 1998.

Table 2—Vegetation Strike Team standards followed during mapping of existing vegetation attributes in the IVMP and CALVEG projects

Element	Existing vegetation standards
Total tree canopy cover	10-percent classes
Forest canopy structure	Single-layered / Multilayered
Tree overstory size class (inches)	0-4.9, 5-9.9, 10-19.9, 20-29.9, 30-49.9, 50+

Source: Askren and others 1995, 1996.

Older Forest With Medium and Large Trees and Single- or Multistoried Canopies (Medium and Large Older Forest)

Our “medium and large” definition of older forest (medium to large trees with single- or multistoried canopies) is the least restrictive of the three definitions we applied. It establishes only a minimum average tree size (quadratic mean diameter of dominant and codominant trees) of 20 in for any forest type, regardless of canopy layering or location in the environment. “Medium and large” older forest is composed of structure and composition classes 11 through 22 in table 1. The “medium and large older forest” definition is similar to the record of decision (USDA and USDI 1994b) definition of late-successional forest, with the exception that the diameter break is set at 20 inches in accordance with the Vegetation Strike Team standards (Askren and others 1995, 1996) rather than at 21 in as specified in the record of decision. The Plan associated this class with combined late-successional and old-growth stages (80+ years). We used the estimated acres of “medium and large older forest” to validate the values stated in the Plan about the amount and distribution of older forest assumed to be present at the start of the Plan. In applying this definition, we recognized that a one-size-fits-all, 20-in average-tree-size minimum criterion, would tend to overestimate older forest amounts in productive forest types, and underestimate it in less productive types. On balance, though, it would provide a reasonable benchmark at the Plan level. Throughout this document, older forest refers to “medium and large older forest” unless it is specified that a different definition is intended.

Older Forest With Large Trees and Multistoried Canopies (Large, Multistoried Older Forest)

Our “large, multistoried older forest” definition (large trees with multistoried canopies) represents forest with a minimum average tree size (quadratic mean diameter of dominant and codominant trees) of at least 30 in, with multistoried canopies, regardless of location in the environment. “Large, multistoried” older forest is composed of structure and composition classes 20 through 22 in table 1, and is therefore a restricted subset of “medium and large” older forest. These particular size and canopy attributes were chosen because they correspond roughly with primary size and canopy structure characteristics representative of old-growth Douglas-fir developing between 175 and 250 years of age (Franklin and others 1981, 1986; Franklin and Spies 1991b). Whereas “medium and large” older forest sets the upper endpoint, “large, multistoried” older forest sets the lower endpoint for establishing the amount of older forest. In fact, the 30-in average-tree-size minimum criterion is inappropriate for many forest community types where older forests simply do not develop trees as large as 30 in. Still, it is a useful definition for identifying the largest, most “classic” old growth.

Older Forest With Medium and Large Trees Defined by Potential Natural Vegetation Zone (Older Forest With Size Indexed to Potential Natural Vegetation Zone)

Neither “medium and large older forest” nor “large, multistoried older forest” definition recognizes the variability in forest conditions across environmental gradients (for example, temperature, moisture, and soils). Instead, they use “one-size-fits-all” average-tree-size rules to screen for older forest. An alternative definition was created to partially account for differences in productivity, size, and structural characteristics that depend on the local environment. The "older forest with size indexed to potential natural vegetation zone" definition uses an average-tree-size (quadratic mean diameter of dominant and codominant trees) threshold that varies by potential natural vegetation zone (table 3). In contrast to the "medium and large" or "large, multistoried" older forest definitions, "older forest with size indexed to potential natural vegetation zone" predicts more area of older forest in community types where trees grow slowly or seldom reach 20 in d.b.h. by imposing a diameter threshold less than 20 in (for example, some pine types east of the Cascade divide, or some high-elevation types). In other zones, by using a diameter threshold greater than 20 in, it predicts fewer acres of older forest where trees quickly reach 20 in, such as in the moist, productive Coast Range. We indexed average-tree-diameter thresholds to potential natural vegetation maps (fig. 4). In Washington and Oregon, we used vegetation zone maps compiled from a model of potential natural vegetation (Henderson, n.d.). In California, we indexed potential natural vegetation zone to potential late-seral condition as classified by Society of American Foresters (SAF) type (Eyre 1980). Diameter thresholds for potential natural vegetation zones were based on local older forest definitions (Forest Service-Region 5 and Region 6 old-growth interim definitions [USDA Forest Service 1992, 1993]). This definition represents the midpoint compared with "medium and large" or "large, multistoried" older forest definitions.

Map Analysis Methods

Hemstrom and others (1998) recommended that older forest monitoring be examined from two perspectives. Broad-scale landscape patterns are best determined from maps of existing vegetation and other spatial information, whereas detailed vegetation surveys are needed to determine older forest characteristics at the stand scale. Because these

Table 3—Average tree-size threshold values used to determine if a map unit or plot data met the definition of "older forest with size indexed to vegetation zone"

Minimum quadratic mean diameter	Vegetation zone
Inches	
40	Redwood
32	Port-Orford-cedar, tanoak, Douglas-fir/tanoak/Pacific madrone
31	Sitka spruce, western redcedar (west[a]), western hemlock (west)
24	Douglas-fir (west), Pacific Douglas-fir (west)
22	Pacific silver fir
21	Grand fir, Douglas-fir (east[b]), interior ponderosa pine, Jeffrey pine, mountain hemlock, Pacific Douglas-fir (east), Pacific ponderosa pine, Pacific ponderosa pine/Douglas-fir, ponderosa pine, red fir, subalpine fir (west), western hemlock (east), western redcedar (east), western white pine, white fir
20	Alpine open, blue oak/grey pine, parkland-mountain hemlock, shrub-steppe, western juniper, hardwood types (Oregon white oak, canyon live oak, California black oak, cottonwood, cottonwood/willow, willow)
13	Subalpine fir (east)
12	Lodgepole pine

[a] West–California Coast Range, California Klamath, Oregon Coast Range, Oregon Klamath, Oregon Willamette Valley, Oregon Western Cascades, Washington Olympic Peninsula, Washington Western Lowlands, and Washington Western Cascades.

[b] East–California Cascades, Oregon Eastern Cascades, and Washington Eastern Cascades.

Source: Modified from Forest Service, Pacific Southwest and Pacific Northwest Regions, old-growth interim guidelines (USDA Forest Service 1992, 1993).

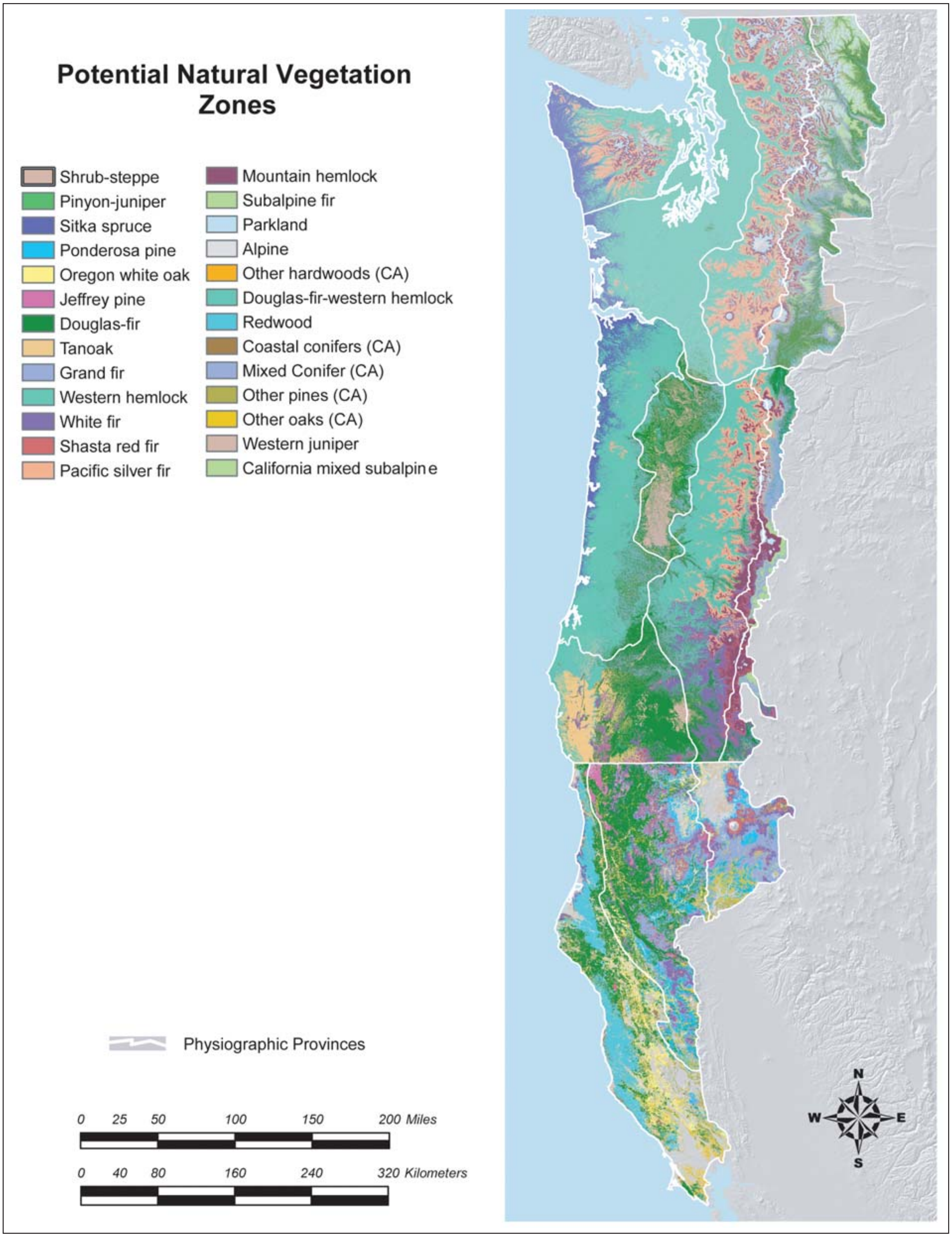

Figure 4—Potential natural vegetation zones for the Northwest Forest Plan area. Vegetation zones in Washington and Oregon are from Henderson (n.d.). In California, vegetation zones are based on Society of American Forester types (Eyre 1980).

perspectives focus on different scales and use different attributes and definitions, analysis of older forest amounts and patterns from vegetation maps and from inventory data are expected to yield different (but complementary) estimates. In this report, vegetation maps primarily were used to examine older forest amounts (percentages of area occupied by older forest) and landscape patterns of older forest elements (their spatial arrangement) relative to other spatial data such as ownerships, land use allocations, and ecological setting. Statistical analysis of inventory plot data primarily was used to estimate the area in acres occupied by older forest, with accompanying confidence intervals, and to estimate net change in older forest amounts by using measurements taken on the same set of plots at two points in time. We summarized the stand-scale characteristics of older forest (density of large trees, snags, and logs, and canopy layering) by using the plot data. We also used the estimates from the plot data, which are considered statistically defensible, to validate the estimates obtained from the map data, whose accuracy and precision are more difficult to quantify.

Federal Lands in the Northwest Forest Plan Area

We mapped existing vegetation on all lands in the Plan area. However, we report results only on federally administered managed lands (see Haynes and others, in press, for results on nonfederal lands). Consequently, we portioned the Plan area into federally managed versus other lands. Other lands include those owned or managed by individuals, corporations, tribes, states, counties, and other agencies (USDA and USDI 1994a). Federal lands include lands managed by the three federal land management agencies represented by the Plan (Forest Service, Bureau of Land Management, and National Park Service), as well as lands managed by other federal agencies (Fish and Wildlife Service and Department of Defense). Although the influences of activities on lands administered by Fish and Wildlife Service and Department of Defense were considered in the Plan's assessment, the record of decision did not adopt new management direction for those lands (USDA and USDI 1994b). We summarize the land area and percentage of area occupied by older forest for lands managed by the Fish and Wildlife Service and Department of Defense but do not include them in subsequent discussions.

The Forest Service, Bureau of Land Management, and National Park Service manage about 24,444,100 ac in the Plan area (table 4). This figure excludes major water bodies and is within one-tenth of a percent of the 24,455,200 ac reported in table 3&4-2 of the environmental impact statement (USDA and USDI 1994a). The discrepancy is accounted for by updates to map boundaries used in 1994 and in 2004, and also by land exchanges in and out of federal ownership since the Plan was signed. All acres reported here were calculated from the Northwest Forest Plan land use allocations 2002 polygon coverage released in April 2004 (www.reo.gov/gis/data/gisdata/index.htm).

Not all federal land is potentially capable of supporting older forest. The permanently nonforest area includes administrative sites such as park headquarters and ranger districts, roads and highways, as well as naturally nonforested land—barrens, rock outcrops, alpine meadows above tree line, etc. We separated the land area managed by the federal agencies into area that is forest-capable versus area that is not capable of growing forest by using thematic data from our remote-sensing mapping projects (discussed in following sections). Of the total federal land area, 23,259,000 ac are forest-capable (or 95 percent of the federal land base), and 1,185,100 ac are not forest-capable (table 4).

Physiographic Provinces

The Northwest Forest Plan area is very diverse in terms of physical, biological, and environmental factors. The environmental impact statement (USDA and USDI 1994a) described the Plan area in terms of 12 terrestrial physiographic provinces (fig. 1). The concept of physiographic provinces is not only useful for describing how topography, soils, and geomorphologic differences shape vegetation, but how vegetation responds to natural disturbance and management. Note that the provinces are arbitrarily cut by state boundaries, so they are not strictly ecological provinces. Nevertheless, we used the 12 individual provinces to stratify the monitoring analysis and for reporting purposes to be consistent with the approach in designing the Plan.

Table 4—Land area in the Northwest Forest Plan area

	Federal land					
Province	Total	Forest capable	Not forest capable	Percentage of forest-capable	Other land	Province total
	– – – – – – – – – – – *Acres* – – – – – – – – – – –			*Percent*	– – – – – *Acres* – – – – –	
California:						
Cascades	1,091,300	999,800	91,500	92	1,379,600	2,470,900
Coast Range	503,600	357,800	145,800	71	5,215,900	5,719,500
Klamath	4,520,200	4,221,400	298,800	93	1,530,000	6,050,200
Total	6,115,100	5,579,000	536,100	91	8,125,500	14,240,600
Oregon:						
Coast Range	1,413,300	1,396,200	17,100	99	4,377,300	5,790,600
Eastern Cascades	1,551,800	1,477,500	74,300	95	741,300	2,293,100
Klamath	2,118,200	2,104,400	13,800	99	1,879,600	3,997,800
Western Cascades	4,476,700	4,398,200	78,500	98	2,135,400	6,612,100
Willamette Valley	21,000	18,500	2,500	88	2,643,900	2,664,900
Total	9,581,000	9,394,800	186,200	98	11,777,500	21,358,500
Washington:						
Eastern Cascades	3,502,400	3,347,600	154,800	96	2,130,100	5,632,500
Olympic Peninsula	1,522,300	1,419,300	103,000	93	1,502,000	3,024,300
Western Cascades	3,721,000	3,516,100	204,900	94	2,404,800	6,125,800
Western Lowlands	2,300	2,200	100	96	6,492,300	6,494,600
Total	8,748,000	8,285,200	462,800	95	12,529,200	21,277,200
Northwest Forest Plan area	24,444,100	23,259,000	1,185,100	95	32,432,200	56,876,300

Note: Federal land includes land administered by the Forest Service, Bureau of Land Management, and National Park Service. Other land includes land administered by Department of Defense and Fish and Wildlife Service, and all nonfederal owners.

Strong climatic, topographic, and social gradients across the Plan area create significant differences in the physiographic provinces in terms of potential natural vegetation and current vegetation, natural disturbance regime, historical land use, and land ownership (USDA and USDI 1994a: 14-24, chapters 3&4). Most of the Plan area is dominated by coniferous forests and mountainous terrain, with the exception of some lowland interior valleys and coastal plains. Of the coastal physiographic provinces, the Washington Olympic Peninsula province is dominated by coniferous rain forest on the western slope of the Olympic Mountains, and drier Douglas-fir forest in the rain shadow on the eastern slope. Fire frequency is very low, resulting in some remnant forest hundreds or even thousands of years old. Current vegetation is a mosaic of late-successional and old-growth forest mixed with early-seral stages resulting from extensive forest management. Federally managed lands occupy the interior half of the province, the core being Olympic National Park girded by the Olympic National Forest (fig. 2, table 4). Moist, productive forests in the Oregon Coast Range province are dominated by Douglas-fir, western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western redcedar (*Thuja plicata* Donn ex D. Donn). The Forest Service and Bureau of Land Management together manage one-quarter of the land in the Oregon Coast Range (fig. 2, table 4). Older forest there is highly fragmented, largely as a result of infrequent but very large wildfires in the 1800s and 1900s, and heavy cutting. Only a small proportion of area (9 percent) in the California Coast Range province is administered by federal agencies (fig. 2, table 4). Some of the last remaining old-growth redwoods (*Sequoia sempervirens* (D. Don) Endl.) are conserved in Redwoods National Park, and the Bureau of Land Management administers holdings of mixed forests of Douglas-fir and hardwoods. Fire frequency is low compared with the adjacent California and Oregon Klamath provinces.

Along the western slope of the Cascade Range (Washington Western Cascades and Oregon Western Cascades), lower elevation forest dominated by Douglas-fir and western hemlock gives way to Pacific silver fir (*Abies amabilis* ex Forbes) in the middle elevations, and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) and subalpine vegetation at higher elevations. In the southern part of the range, moist lowland vegetation yields to drier, mixed conifer-forest. Historical fire frequencies were low or moderate (100+-year fire-return intervals) in the northern part of the range, and high (0-35-year fire-return intervals) in the south, resulting from a north-to-south moisture gradient. About two-thirds of the area is administered by the Forest Service, Bureau of Land Management, and National Park Service (fig. 2, table 4). Although highly fragmented, numerous areas of late-successional and old-growth forest still exist along the western slopes of the Cascade Range.

The provinces along the eastern slopes of the Cascade Range (Washington Eastern Cascades and Oregon Eastern Cascades) are dominated by mixed-conifer forest and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forest at lower-to-mid elevations, and by true fir (*Abies* spp.) and mountain hemlock at higher elevations. Forest productivity is low in places owing to poor soils and high elevations. Historically, fire frequencies were high (0-35-year fire-return intervals) in the Eastern Cascades. Intensive fire suppression practices since the latter half of the 20th century have resulted in areas with significant accumulations of fuel, and shifts in species composition and stand structure. About two-thirds of the area is federally managed (fig. 2, table 4). Older forest is highly fragmented as a result of both natural factors and management history. The California Cascades province includes the very southern end of the Cascade Range. Similarities to the Eastern Cascades provinces of Washington and Oregon include dominance of mixed-conifer and pine forest in fire-adapted community types. Slightly less than half of the province is federally managed (table 4). Older forest is fragmented as a result of fire, harvest activities, and checkerboard ownership patterns of Forest Service land (fig. 2).

The Oregon Klamath province in southwestern Oregon and the California Klamath province in northwestern California are influenced by geologic conditions unique within the Plan area. Serpentine soils formed by the accretion of rocks onto the continent control the native vegetation, which is dominated by mixed-conifer and mixed-conifer/hardwood forest such as Douglas-fir/tanoak (*Lithocarpus densiflorus* (Hook. & Arn. Rehd.) /Pacific madrone (*Arbutus menziesii* Pursh). The Klamath provinces are characterized by historically high fire frequencies (0-35-year fire-return intervals), and fire suppression has resulted in areas with significant accumulations of fuel, shifts in species composition, and changes in stand structure. Older forest is highly fragmented as a result of dry climate, poor soils, and past harvest practices, as well as ownership patterns, especially on lands administered by the Bureau of Land Management. These parcels are typically intermixed with harvested private lands in a checkerboard pattern of alternating 1-mi sections (fig. 2). National forests cover three-quarters of the land area in the California Klamath province, and slightly over half of the Oregon Klamath province is federally managed (table 4).

There is very little federally managed land in either the Washington Western Lowlands province or the Oregon Willamette Valley province (table 4), and only small parcels of these lands are occupied by older forest. Both provinces include extensive urban and agricultural areas. Both are dominated by wide, glaciated valleys, except for the Willapa Hills in the coastal section of the Washington Western Lowlands. Lowland coniferous forest, deciduous forest, and native prairie were the natural dominant vegetation types.

Land Use Allocations

The Northwest Forest Plan record of decision divided federal land into seven land use allocations. These allocations were the foundation for establishing an older forest reserve network category while maintaining lands designated for scheduled timber harvest.

The 2002 land use allocation map (www.reo.gov/gis/data/gisdata/index.htm) combined or further split some existing allocations (fig. 5, table 5). Late-successional reserve has three mapped components: (1) large-block late-successional reserve, (2) activity centers reserved for northern spotted owls, and (3) marbled murrelet reserved areas. These three categories are grouped together in our analysis. A few areas have more than one land allocation; lands with overlapping late-successional reserve and adaptive management area designation are treated as late-successional reserves. We grouped together administratively withdrawn and congressionally reserved lands for analysis purposes. All national park lands are congressionally reserved. Late-successional reserves, when combined with congressionally reserved lands and the smaller, more fragmented administratively withdrawn lands, form the backbone of the large-block older forest reserve network.

Matrix and adaptive management areas are land allocations where scheduled timber harvest activities may take place. For analysis and reporting purposes, we grouped these categories. Lands that are denoted as "not designated" are lands that were acquired after the Plan was implemented and had no allocation in the 1994 land use allocation map. They are treated as matrix in our analysis.

Riparian reserve allocations have never been mapped separately from matrix at the scale of the Northwest Forest Plan, because riparian reserves are a fine-scale delineation intended for mapping at the project scale. At the Plan scale, riparian reserves could not be reliably distinguished from matrix because of a lack of consistency in defining intermittent stream corridors and varying definitions for riparian buffers. The Plan estimated that riparian reserves may constitute 40 percent of the land area within the matrix/riparian reserve class (see sidebar 3), depending on local variation in stream density and topography (USDA and USDI 1994b). For more discussion of this issue, refer to Gallo and others (2005). We had no way to analyze riparian reserve separately from matrix. We acknowledge that including riparian reserve in matrix in the older forest analysis results in an overestimate of the amount of older forest in the nonreserve category, and a conservative estimate of the amount of older forest in the reserve category.

Our reporting level for most analyses is land use allocation groups or reserve categories within each physiographic province (shown in table 5), totals by province, province results totaled within state, and state values totaled across the Plan area.

Classification of Existing Vegetation

Hemstrom and others (1998) determined that a landscape-scale map of existing forest vegetation created from remotely sensed data was needed to provide a baseline estimate of older forest at the beginning of the Plan from which future changes could be benchmarked. The acquisition or development of an accurate, consistent, and continuous map representing older forest conditions at the start of the Plan over the entire Plan area was key to effectiveness monitoring (Hemstrom and others 1998, Mulder and others 1999). The option of using map products already in existence and covering some or all of the Plan area was evaluated and rejected because existing maps have been created originally to meet a variety of objectives not necessarily compatible with regional-scale monitoring needs, and were mapped to a variety of standards and spatial extents. Instead, consistent maps were developed under the direction of the regional monitoring program.

Existing vegetation mapping for Northwest Forest Plan monitoring was carried out by two independent programs—the Interagency Vegetation Mapping Project (IVMP) in Oregon and Washington and the Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) project in California. Both CALVEG and IVMP mapped forest vegetation by using satellite imagery from Landsat Thematic Mapper (TM) and other spatial data to classify primary attributes of forest vegetation—life form,

Sidebar 3—Land Use Allocations

Land Use Allocations Under the Northwest Forest Plan

Excerpted from the Record of Decision (USDA and USDI 1994b)

Congressionally Reserved Areas: (7,320,660 ac, 30 percent of the federal land within the Plan area)
Lands reserved by acts of Congress for specific land uses such as Wilderness Areas, Wild and Scenic Rivers, National Parks, and other lands with congressional designations. The Plan cannot and does not alter these lands.

Late-Successional Reserves: (7,430,800 ac, 30 percent of the federal land within the Plan area)
These reserves, in combination with the other allocations and standards and guidelines, are designed to restore a functional, interactive, late-successional and old-growth forest ecosystem over time. They are designed to serve as habitat for terrestrial and aquatic species that depend on these old-growth characteristics, including the northern spotted owl. Some silvicultural treatment is allowed to enhance development of old-growth conditions.

Managed Late-Successional Areas: (102,200 ac, 1 percent of the federal land within the Plan area)
These lands are either mapped to protect areas where spotted owls are known to exist, or they are unmapped protection buffers. Protection buffers are designed to protect certain rare and endemic species.

Adaptive Management Areas: (1,521,800 ac, 6 percent of the federal land within the Plan area)
Ten areas were identified to develop and test innovative management approaches to integrate and achieve ecological, economic, and other social and community objectives. Each area has a different emphasis, such as maximizing the amount of late-successional forests, improving riparian conditions through silvicultural treatments, or maintaining a predictable flow of harvestable timber and other forest products. Each area considers learning a principle product of their adaptive management activities. A portion of timber harvest will come from this land.

Administratively Withdrawn Areas: (1,477,100 ac, 6 percent of the federal land within the Plan area)
These areas are identified in current Forest and District plans and include recreation and visual areas, back country, and other areas where management emphasis does not include scheduled timber harvest.

Riparian Reserves: (11 percent of the federal land within the Plan area, estimated at 2,627,500 ac interspersed throughout the matrix)
Riparian reserves are areas along all streams, wetlands, ponds, and lakes, and on unstable and potentially unstable lands vital to protecting and enhancing the resources that depend on the unique characteristics of riparian areas. These areas also play a vital role in protecting and enhancing terrestrial species.

Matrix: (3,975,300 ac, 16 percent of the federal land within the Plan area)
The matrix includes all federal lands not falling within one of the other categories. Most of the scheduled timber harvested will be from matrix lands. They include nonforested as well as forested areas that may be technically unsuited for timber production.

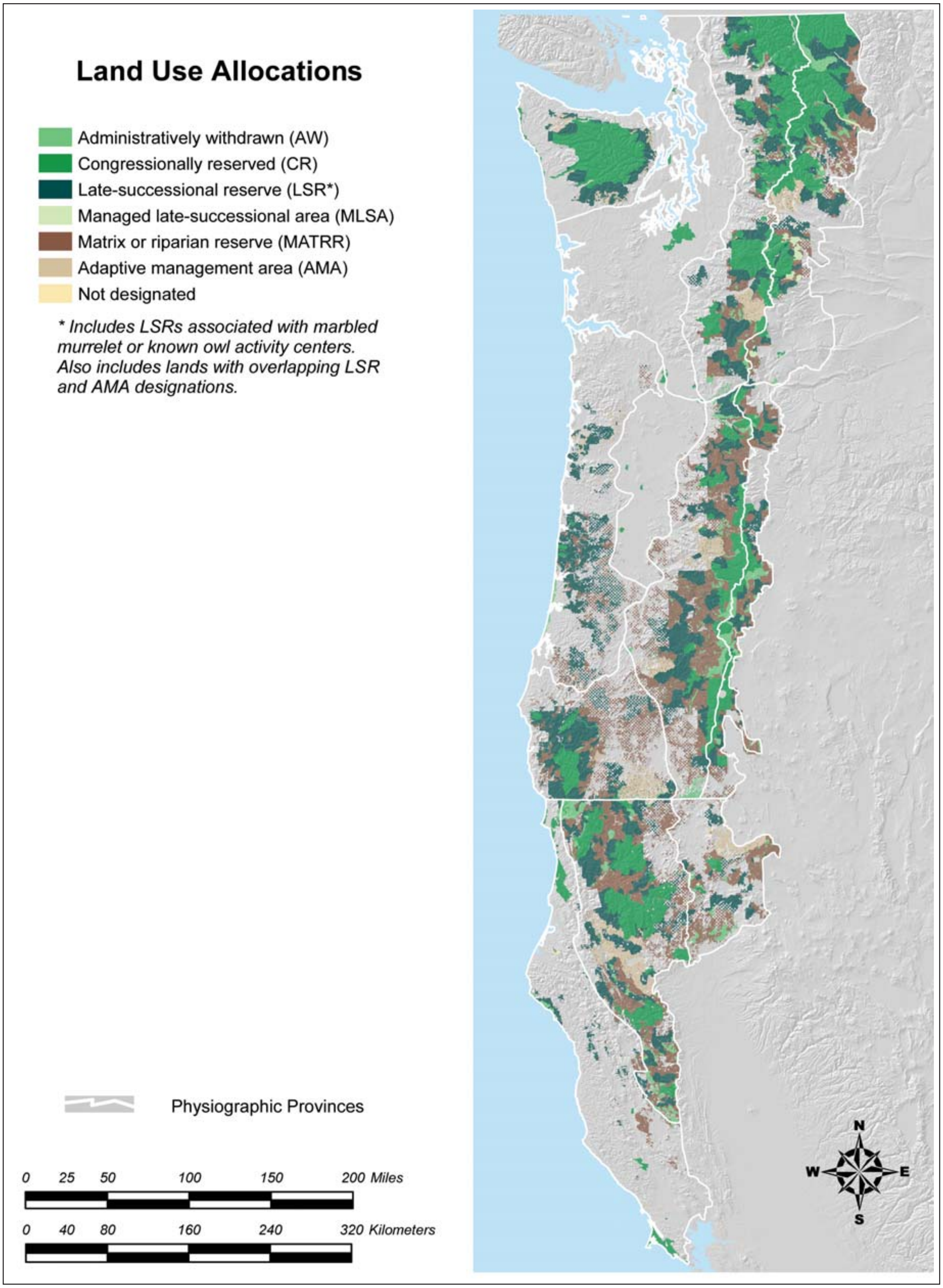

Figure 5—Land use allocations of federally managed lands in the Northwest Forest Plan area. Source: http://www.reo.gov/gis/data/gisdata/index.htm.

Table 5—Mapped land use allocation classes and codes

Land use allocation	Map abbreviation	Land allocation group code	Reserve category
Adaptive management area	AMA	MAT+	Nonreserve
Adaptive management area and late-successional reserve overlapping designation	AMR	LSR+	Reserve
Administratively withdrawn	AW	AW/CR	Reserve
Congressionally reserved	CR	AW/CR	Reserve
Late-successional reserve	LSR	LSR+	Reserve
Marbled murrelet reserve area	LSR3	LSR+	Reserve
Spotted owl activity core reserve	LSR4	LSR+	Reserve
Managed late-successional area	MLSA	LSR+	Reserve
Matrix or riparian reserve (not mapped separately)	MATRR	MAT+	Nonreserve
Not designated	ND	MAT+	Nonreserve

Note: Refer to sidebar 3 for additional description of land allocations.

Source: Northwest Forest Plan Land Use Allocations 2002 http://www.re.gov/gis/data/gisdata/index.htm.

average tree size, canopy density, and canopy layering. Both used inventory plots as reference and validation data to guide the classification. The IVMP and CALVEG together mapped a region of nearly 57 million ac crossing all ownerships in the Plan area, including the approximately 24.4 million ac administered by federal agencies affected by the Plan (table 4).

Although IVMP and CALVEG used different mapping protocols, both projects mapped existing vegetation in compliance with established standards to assure the compatibility of the map products to midscale monitoring (Askren and others 1995, 1996). These standards included average overstory tree size mapped in 10-in classes, with an additional class of 0 to 4.9 in, total tree crown closure mapped in 10-percent classes, and forest canopy layering mapped in two classes (single- and multistoried) (table 2).

Interagency Vegetation Mapping Project—
The IVMP was initiated in 1998 under joint program management and funding by the Bureau of Land Management-Oregon and the Forest Service-Region 6. The project's goal was to provide consistent spatial data for monitoring older forests within the portions of the Plan area in Washington and Oregon. The IVMP mapped existing vegetation in the nine physiographic provinces in Washington (Eastern and Western Cascades, Olympic Peninsula, and Western Lowlands) and Oregon (Eastern and Western Cascades, Coast Range, Willamette Valley, and Klamath Mountains) (fig. 2).

The following description highlights the features of IVMP methods and map products that are most important for understanding their application to Plan monitoring. More detailed discussions are given in Weyermann and Fassnacht (2000) and Fassnacht and others (n.d.). In addition, detailed documentation and metadata accompany the map data for each physiographic province (Browning and others 2002b, 2003e, 2003f, 2003g, 2003h, 2004; O'Neil and others 2001b, 2001d, 2002c). All IVMP map data and supporting documentation are available online at http://www.or.blm.gov/gis/projects/ivmp.asp.

The IVMP modeling approach combined remotely sensed satellite imagery (25-m Landsat TM), digital elevation models, interpreted aerial photos, and inventory information collected on the ground to classify existing vegetation. Landsat scenes used in the IVMP project ranged from fall 1992 through summer 1996. Of the 17 scenes, 2 were acquired in 1992, 1 each in 1994 and 1995, and 13 in 1996 (app. 1). Even though they repre-sented a range of dates around 1994, with most images from 1996, we made the assumption in the monitoring analysis that older forest maps derived from the IVMP data were representative of baseline conditions at or near the start of the Plan. This assumption would be shown to be invalid if it were determined that a large amount of change had occurred between 1994 (that is, the date of the start of the Plan) and the actual date of the imagery. To assess potential difference in the amount of older forest between 1994 and 1996, we examined stand-replacing harvests detected by remote sensing between 1992 and 1996 (see the later section in this report titled, “Trend Analysis: Forest Disturbance Map Methods”). For the portions of the plan area that were mapped by using 1996 imagery, our disturbance map indicates only about 5,300 ac of older forest were regeneration-harvested between 1992 and 1996. Assuming half the harvest occurred prior to 1994 and half between 1994 and 1996, there is a maximum error of only about 2,600 ac (or 0.03 percent) attributable to mapping older forest in 1996 rather than in 1994. We therefore accepted 1996 data as baseline.

Inventory plot data were used as reference information for IVMP model building and accuracy assessment. Almost 10,000 plots were used for model building and testing, and another 2,800 plots were held out for an independent accuracy assessment. These data came primarily from Current Vegetation Survey (CVS) plots maintained by Forest Service-Region 6 and Bureau of Land Management-Oregon on Forest Service and Bureau of Land Management lands in Washington and Oregon, and from Forest Inventory and Analysis (FIA) plots administered by Pacific Northwest Research Station on nonfederal lands. Details of the inventory data are described in a later section.

The IVMP mapped existing vegetation attributes for forest-capable land. The final IVMP products included canopy cover prediction maps by life form, an average-tree-size prediction map, and a canopy layering prediction map. Life form refers to the dominant type of vegetation (conifer, nonconifer, and total vegetation—the sum of conifer and nonconifer). The nonconifer class (also called broadleaf in the IVMP map data) includes hardwood trees, shrubs, grasses, and forbs. Each IVMP layer also included non-forest-capable land-cover classes (water, wetlands, urban, agriculture, prairie, barren, snow, sensor noise, topographic shadow, and smoke, fog, and clouds or cloud shadow), mapped by using a combination of supervised and unsupervised classification methods. Ground plots, local field knowledge, and aerial photographs were used as ground-training data for mapping non-forest-capable land-cover classes.

Average size of trees in the uppermost canopy, percentage of conifer cover, percentage of nonconifer cover, and percentage of total vegetation cover were predicted by following a regression modeling approach developed by Cohen and others (1995, 2001) and Cohen and Spies (1992). Canopy cover is the percentage of ground covered by the vertical projection of the vegetation foliage as measured from aerial photographs. Average topstory tree size is the quadratic mean diameter (inches) of the trees in dominant and codominant crown classes, measured from diameters of trees collected on inventory plots and related to spectral signatures from Landsat TM data, as described by Weyermann and Fassnacht (2000) and Fassnacht and others (n.d.). Canopy cover was mapped by using continuous values from 0 to 100 in 1-percent increments. For 7 of the 9 physiographic provinces, average tree size was mapped in 1-in diameter classes from 0 to 75 in. This continuous format allows maximum flexibility for end users to regroup the data for their specific applications. In two provinces (Eastern Cascades Oregon and Eastern Cascades Washington), sample sizes were insufficient to detect a significant relationship between the remotely sensed variables and tree size. In other words, there was too much variability in the data to fit regression models with acceptable r^2 values. Therefore, average tree size was mapped in wider class intervals for Eastern Cascades Oregon (0-4.9, 5-9.9, 10-19.9, 20-29.9, and 30+ in) and Eastern Cascades Washington (0-4.9, 5-9.9, 10-19.9, and 20+ in), by using a supervised classification approach.

For all provinces mapped by IVMP, a second iteration of modeling was performed for improving classification of the average-tree-size attribute. This was because for all provinces, a proportion (up to 30 percent in some provinces) of the potentially forested land was impossible to map into continuous average-tree-size classes by using the regression modeling approach. In most cases, these difficult cases were in forested areas without an adequate spectral signal of visible tree crowns resulting from one of several common conditions: either they were recently regenerated clearcuts, green-tree retention cuts, or they were naturally open stands with scattered large trees and large confounding soil signature. The last condition was most prevalent in the Eastern Cascades provinces. Predictions for these areas were outside the reasonable range of the model, so the regression results were deemed unacceptable for these areas. A subsequent analysis was performed to reclassify these unknowns into broad average-tree-size classes (0-9.9, 10-19.9, 20-29.9, and 30 in and larger) by using a supervised cluster-busting classification approach. The proportion of potential forest for which average tree size could not be mapped was subsequently reduced to 5 percent or less of the forested area within each province.

Forest canopy layering refers to the vertical stratification of tree heights in a forest stand, classed in our analysis as either single-storied (stands having a tree canopy of uniform height) or multistoried (stands with two or more distinct tree canopies). Canopy layering was modeled following methods outlined in appendix 2. Reference data were the number of canopy layers computed from CVS plot data on Forest Service and Bureau of Land Management lands by using the Forest Vegetation Simulator (Crookston and Stage 1999). Canopy layering could not be mapped for two provinces (Oregon Willamette Valley and Washington Western Lowlands) because of insufficient inventory plots. The methods for modeling canopy layering differed substantially from those used in the cover and tree-size predictions, in that the modeling unit was the vegetation polygon rather than the individual pixel. Vegetation polygons were deemed more appropriate than individual pixels as the base unit for prediction, because canopy layering is naturally a stand-scale rather than pixel-scale phenomenon. Resulting canopy layering predictions for polygons were then resampled at the 25-m (82-ft) pixel scale so that they could be processed in combination with tree-size and cover data from the other IVMP map layers.

Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG)—
Existing vegetation for Northwest Forest Plan monitoring in northwestern California is derived from California's wildland vegetation classification system, known as the Classification and Assessment with Landsat of Visible Ecological Groupings, or CALVEG (USDA Forest Service 1981, 2000a). Remote sensing specialists at Forest Service-Region 5 conducted the CALVEG project in cooperation with the U.S. Fish and Wildlife Service, California Department of Fish and Game, California Department of Forestry and Fire Protection, Bureau of Land Management, National Park Service, California State Parks, and Humboldt State University. Unlike IVMP, CALVEG did not have its origin within the Northwest Forest Plan monitoring program. Instead, the attributes needed for monitoring and meeting the Vegetation Strike team standards for effectiveness monitoring (table 2) (Askren and others 1995, 1996) were derived from the existing CALVEG data (Schwind and others 1999). These standards ensured that the resulting data developed by CALVEG in California would be compatible with IVMP data in Washington and Oregon for planwide analysis. This compatibility was deemed essential to the ability to analyze the map data consistently despite differences in methodologies, mapping approaches, and resolution of map products. Many other attributes besides those listed above were classified for CALVEG map units but were not used in the Northwest Forest Plan monitoring analysis, and therefore are not mentioned here.

The following description highlights the features of CALVEG methods and map products that are most important in the monitoring analysis. Additional details are discussed in Schwind and others (1999). All CALVEG map data and supporting documentation are available online at http://www.fs.fed.us/r5/rsl/projects/mapping/.

Existing vegetation attributes derived from CALVEG for monitoring were average topstory tree size, canopy closure by life form, and canopy layering. CALVEG shares many important similarities in methodology with the IVMP project, as well as important differences. It classified existing vegetation from Landsat TM imagery (image dates were all from 1994—app. 1). The classification accuracies resulting from the 1994 data were checked, and some map labels were adjusted by using 1998 imagery (app. 1). Reference data for training the classification were map notes and aerial resource photos rather than inventory plot data. CALVEG map units differed in spatial resolution from IVMP map units. CALVEG was a stand-based map, with vegetation polygons created through an image segmentation process to a minimum mapping unit of 2.5 ac (1 ha). The resulting vegetation polygons were labeled according to average topstory tree size (0-4.9, 5-11.9, 12-19.9, 20-29.9, and ≥30 in), canopy closure (10-percent classes), and canopy layering (single- or multistoried) by using a combination of modeling, supervised classification, and unsupervised classification methods. Note that there is a minor inconsistency in CALVEG size classes relative to the Vegetation Strike Team classes. CALVEG uses a breakpoint at 12 in instead of 10 in. In our analysis, map units labeled as 5-11.9 in were put in the <10-in class (table 1), and map units labeled 12-19.9 in were put in the 10-19.9-in class (table 1). Because the older forest definitions used in this analysis begin at 20 in, this discrepancy was not considered to be a major problem because it only pertained to classes not considered to be older forest. It should not therefore affect the estimates of older forest amounts. (It would, however, bias the small-diameter classes overestimating amounts in classes 2 through 4, and underestimating amounts in classes 5 through 10 in table 1).

Central to the CALVEG approach was the creation of stand-based polygons systematically derived from Landsat TM imagery (Schwind and others 1999). Vegetation polygons were generated by an image segmentation based on spectral similarity (Ryherd and Woodcock 1990) by using an algorithm by Frew (1990). The result was a layer of uniquely identified stands or regions that corresponded to intuitively recognizable landscape patterns. Classification and modeling of thematic attributes were performed separately and hierarchically for each additional attribute. Canopy closure was modeled by using the Li-Strahler canopy model (Li and Strahler 1985). The Li-Strahler model generates a continuum of values for each stand ranging from 0 to 100 percent. Continuous crown closure values were subsequently collapsed into 10-percent cover classes in the final CALVEG coverage (Schwind and others 1999).

Tree size was classified as a function of modeled crown width by using iterative unsupervised classification of the Landsat TM band data. The relationship between crown size and tree diameter for major forest types in California (Warbington and Levitan 1993) was used to infer stem diameter classes from mapped crown width classes for each tree type. Tree diameter classes were subsequently developed to be consistent with the Vegetation Strike Team class boundaries for average tree size (with the exception of the 12-in class break noted above (Schwind and others 1999). A two-class attribute for canopy layering (single- vs. multistoried) was spatially modeled with vegetation type, tree size, and canopy closure as inputs (Schwind and others 1999).

Accuracy Assessment of Existing Vegetation Maps

Assessment of a map's accuracy is important for informing users of the map's quality and, consequently, its suitability for intended uses. Both CALVEG and IVMP employed a quantitative comparison of predicted values or classes of sites on the map against independent reference observations for the same sites on the ground. The reference values are considered to be "truth" (Congalton and Green 1999).

For each map, three accuracy values are reported. Overall map accuracy is the proportion of correct classifications across all classes. For specific classes, two other types of accuracy are useful for helping the map user understand the quality of the classification. Producer's accuracy is the probability that a reference observation on the ground has been correctly classified on the map (summarizing errors of exclusion), and user's accuracy is the probability that a unit classified on a map actually represents that class on the ground (summarizing errors of inclusion). For further explanation, see app. 3.

IVMP map accuracies—

The IVMP accuracy analysis used a traditional error matrix approach to calculate the proportion of reference plots that were correctly classified on the map. It weighted overall accuracy, user's accuracy, and producer's accuracy by the sampling probabilities of reference plots (app. 3) (Browning and others 2002a, 2003a, 2003b, 2003c, 2003d; Fassnacht and others, n.d.; O'Neil and others 2001a, 2002a, 2002b).

A subset of inventory plots (about 25 percent, or 2,800) was reserved from the plot data used for modeling and classification to provide independent reference data for IVMP map accuracy assessment. Reference plots were systematically located across the area to be mapped by IVMP. Quantitative accuracy assessments were performed for percentage of canopy cover (conifer, nonconifer, and total vegetation), average tree size, and canopy layering.

The accuracy assessment documentation reported IVMP map error for the data collapsed into the following classes: 20-percent classes for cover; 0-4.9, 5-9.9, 10-19.9, 20-29.9, 30-49.9, and 50+ in diameter for average tree size; and two classes of canopy layering (single- or multistoried). In addition, accuracies were reported for wider classes for cover and average tree size. Accuracies reported for a two-class average-tree-size map analysis (0-19.9 vs. 20 in and greater), corresponding to the threshold used to distinguish young forest classes from older forests, are reported in appendix 3. Cover values reported in three classes (0-39, 40-69, and 70-100 percent), are also repeated here (app. 3).

Overall map accuracies for IVMP ranged from about 61 to about 87 percent for average tree size mapped into less than 20 vs. 20 in and larger (app. 3, table 1). These values are within the ranges of 60- to 80-percent classification accuracies commonly reported for mapping forest structure attributes from satellite data (see, for example, Moody and Woodcock 1995, Peterson and others 1999). There is considerable variation in accuracy among individual size classes, and between provinces. Usually, but not always, classification results are better for the <20-in class than for the ≥20-in class. Low user's accuracies were obtained for the ≥20-in class for Washington Eastern Cascades, Oregon Klamath, and Washington Western Lowlands, and low producer's accuracies for Washington Eastern Cascades, and Washington Western Lowlands (app. 3, table 3-1). These values warrant a closer look at the effect of base map errors on conclusions drawn from older forest maps derived from these data. The subject is treated in greater detail in the "Older Forest Map Accuracy Assessment" section and in the "Discussion" section. Overall map accuracies for three canopy cover classes range from about 57 to 79 percent (app. 3, table 3-2). The two-class canopy layering map (single- and multistoried) had overall map accuracies ranging from 50 to 87 percent (app. 3, table 3-3).

CALVEG map accuracies—
An independent subsample of some 1,250 field reference plots was used for CALVEG map accuracy assessment in the Northwest Forest Plan area (app. 3) (Franklin and others 2001, Milliken and others 1998, http://www.fs.fed.us/r5/rsl/projects/mapping/accuracy.shtml). The CALVEG analysis reported quantitative accuracy assessments for life form categories, tree size classes, and tree canopy closure classes. Overall map and class accuracies reported for CALVEG atttributes include both nonfuzzy (strictly correct or incorrect—"Max") and fuzzy rating values. Observations having a fuzzy rating of 3 or better were considered correct ("Right"). Overall map accuracies for CALVEG tree size ranged from 68 to 78 percent when using the fuzzy approach and 42 to 60 percent when using the Max approach (app. 3, table 3-4). For canopy closure, they ranged from 75 to 83 percent correct when using the fuzzy approach and 49 to 68 percent when using the Max approach (app. 3, table 3-5). The IVMP and CALVEG methods evaluated accuracies for different class widths. For example, CALVEG used an error matrix with six classes, rather than the two classes reported by IVMP (<20 in versus ≥20 in). Because CALVEG size classes are narrower, classification errors calculated for them are inherently higher. For this reason, direct comparison between the magnitudes of IVMP and CALVEG accuracy values was not possible. However, given differences in classification and map assessment approaches, resulting accuracies appear comparable for CALVEG and IVMP. Note also that CALVEG map project areas do not correspond directly with physiographic provinces used in Northwest Forest Plan monitoring.

Maps of Older Forests

We recombined the thematic data from IVMP and CALVEG to map all 22 classes shown in table 1. This produced a continuous map for the Plan area showing existing forest vegetation for all lands mapped by average topstory tree size, percentage of canopy cover, canopy layering, and life form (conifer, deciduous, or mixed). Then we produced three older forest maps corresponding to the "medium and large older forest," "large, multistoried older forest," and "older forest with size indexed to potential natural vegetation type" definitions. The "medium and large" older forest map consists of the total amount mapped as classes 11-22 in table 1. The "large, multistoried" older forest map consists of the total amount mapped as classes 20-22 in table 1. The "older forest with size indexed to potential natural vegetation zone" map uses size classes with breaks shown in table 3. Each of the three map rules had a canopy cover threshold of at least 10 percent (Hemstrom and others 1998) to assure the presence of a minimally forested condition. Forest-capable areas with canopy cover less than 10 percent were classified as "potential forest" (that is, capable of being forested, but presently nonstocked), regardless of average tree size.

These maps were essential to the monitoring analysis. They were the basis for estimates of older forest amounts at the start of the Plan (expressed as the percentage of forest-capable area occupied by older forest). They were combined with other spatial data to examine older forest distribution by province, land use allocation, natural vegetation community, and fire regime. We also used these maps to analyze the degree of fragmentation between older forest patches. And finally, other monitoring programs used the IVMP and CALVEG existing vegetation data to create maps of habitat suitability for northern spotted owls (Lint 2005) and marbled murrelets (Huff, in press). The combination of older forest maps and their habitat counterparts presents a much more complete picture of the status of the older forest network and its contribution to habitat maintenance than would be available if no spatial data were available.

Older Forest Map Accuracy Assessment

There is a saying attributed to statistician George Box that, "all models are wrong; some models are more useful than others." Using satellite imagery to model vegetation structure is a common practice for producing maps for the purpose of displaying general patterns and differences in vegetation conditions. In fact, there are few alternatives if a wall-to-wall map is needed. However, it is important to reemphasize that the older forest maps are models that contain prediction error. Given that knowledge, satellite imagery can yield useful results for characterizing forest structure.

We quantified the classification accuracies of the three older forest maps by using an error matrix approach to compare the proportion of map units labeled as older forest compared to reference values, for each of the three definitions. The reference observations were the more than 7,000 Current Vegetation Survey and Forest Inventory and Analysis plots on Forest Service and Bureau of Land Management lands (table 6). We computed the accuracy within each province map and across the combined provinces. Three provinces did not have a sufficient number of reference plots to quantify map accuracy (California Coast Range, Oregon Willamette Valley, and Washington Western Lowlands). To perform the accuracy assessment, we intersected inventory plot locations with the older forest map and compared the class label from the map with the class label derived from the inventory measurements. For each definition, we compared two classes—"older forest," and "not older forest." For a plot on the map to be labeled "older forest," more than half of the 13 pixels composing the 1-ha (2.47-ac) plot had to be in the older forest class; otherwise the entire plot on the map was labeled "not older forest." Reference values for average topstory tree size, percentage of canopy cover, and canopy layering were calculated from attributes of the inventoried tree list. Based on the results, the reference plot was assigned a label of either "older forest" or "not older forest."

The map accuracies are reported in table 6. Map quality, as assessed by overall map accuracy, within-class producer's accuracy (the probability that a reference observation on the ground has been correctly labeled on the map) and within-class user's accuracy (the probability that a unit labeled on a map actually represents that class on the ground) varied greatly by province and by older forest definition.

Overall map accuracy of the "medium and large" older forest map (the proportion correctly labeled by using "older

Table 6—Accuracy assessment of older forest maps

		Older forest class		Not older forest class				Test of H0: *k*=0	
Province	**N**	**Producer's**	**User's**	**Producer's**	**User's**	**Overall**	***k***	**Z**	**Pr > Z**
		– – – – – – – – – – – – – – – – *Percent* – – – – – – – – – – – – – – – –							
Medium and large older forest definition									
California Cascades	130	65.8	39.1	67.5	86.2	67.1	0.27	286.2	< .0001
California Coast Range	3	—	—	—	—	—	—	—	—
California Klamath	527	70.9	51.9	64.4	80.3	66.7	0.33	653.4	< .0001
Oregon Coast Range	751	72.5	80.1	87.6	82.2	81.5	0.61	735.5	< .0001
Oregon Eastern Cascades	640	31.6	35.2	90.9	89.5	82.8	0.23	287.5	< .0001
Oregon Klamath	990	69.2	48.0	74.2	87.5	72.9	0.38	556.7	< .0001
Oregon Western Cascades	1,945	76.2	68.8	73.3	79.9	74.6	0.49	980.4	< .0001
Oregon Willamette Valley	5	—	—	—	—	—	—	—	—
Washington Eastern Cascades	858	11.3	85.3	99.7	87.6	87.5	0.17	412.7	< .0001
Washington Olympic Peninsula	260	77.3	70.4	83.2	87.6	81.2	0.59	423.4	< .0001
Washington Western Cascades	1,068	73.3	62.6	73.7	82.1	73.6	0.45	721.5	< .0001
Washington Western Lowlands	0	—	—	—	—	—	—	—	—
Northwest Forest Plan	7,177	68.6	59.6	78.2	84.1	75.1	0.45	1962.3	< .0001
Older forest with size indexed to vegetation zone									
California Cascades	130	52.0	40.1	58.9	98.8	58.8	0.01	27.0	< .0001
California Coast Range	3	—	—	—	—	—	—	—	—
California Klamath	527	77.2	53.9	54.8	96.1	56.8	0.11	355.1	< .0001
Oregon Coast Range	751	67.1	75.1	87.1	93.0	83.8	0.48	586.7	< .0001
Oregon Eastern Cascades	640	40.2	30.2	85.9	93.2	81.6	0.20	251.2	< .0001
Oregon Klamath	990	55.4	43.0	76.1	96.0	74.7	0.13	252.5	< .0001
Oregon Western Cascades	1,945	69.1	64.8	74.2	88.4	73.0	0.37	769.4	< .0001
Oregon Willamette Valley	5	—	—	—	—	—	—	—	—
Washington Eastern Cascades	858	33.9	81.3	87.4	95.1	84.0	0.14	218.7	< .0001
Washington Olympic Peninsula	260	77.8	65.1	89.4	96.3	87.8	0.56	410.5	< .0001
Washington Western Cascades	1,068	75.8	61.1	74.1	93.3	74.5	0.37	632.7	< .0001
Washington Western Lowlands	0	—	—	—	—	—	—	—	—
Northwest Forest Plan	7,177	67.0	59.6	73.4	93.6	72.6	0.25	1271.8	< .0001

Table 6—Accuracy assessment of older forest maps (continued)

		Older forest class		Not older forest class				Test of H0: *k*=0	
Province	**N**	**Producer’s**	**User’s**	**Producer’s**	**User’s**	**Overall**	***k***	**Z**	**Pr > Z**
		– – – – – – – – – – – – – – – *Percent* – – – – – – – – – – – – – –							
Large multistoried older forest definition									
California Cascades	130	0.0	0.0	96.1	96.7	93.1	-0.04	-35.4	< .0001
California Coast Range	3	—	—	—	—	—	—	—	—
California Klamath	527	25.2	22.6	91.4	92.4	85.4	0.16	306.3	< .0001
Oregon Coast Range	751	56.0	35.1	85.4	93.2	81.7	0.33	411.3	< .0001
Oregon Eastern Cascades	640	20.2	11.1	99.0	99.5	98.5	0.14	174.7	< .0001
Oregon Klamath	990	53.9	18.2	81.8	96.8	83.4	0.20	342.8	< .0001
Oregon Western Cascades	1,945	42.4	30.2	87.5	92.2	82.3	0.25	517.1	< .0001
Oregon Willamette Valley	5	—	—	—	—	—	—	—	—
Washington Eastern Cascades	858	0.0	0.0	99.0	99.6	98.6	-0.01	-8.9	< .0001
Washington Olympic Peninsula	260	43.3	40.0	92.6	93.5	87.6	0.35	247.7	< .0001
Washington Western Cascades	1,068	53.3	29.4	88.0	95.3	85.0	0.30	501.6	< .0001
Washington Western Lowlands	0	—	—	—	—	—	—	—	—
Northwest Forest Plan	7,177	41.3	26.7	90.9	95.1	87.2	0.26	1146.1	< .0001

Note: N = number of reference observations.

Producer’s accuracy is the probability that a reference observation on the ground has been correctly classified on the map, and user’s accuracy is the probability that a unit classified on a map actually represents that class on the ground.

Kappa is a test statistic for verifying that agreement between older forest map and reference values exceeded chance levels.

Medium and large older forest map—minimum 10-percent canopy cover, minimum average tree size 20 in (quadratic mean diameter), single- or multistoried canopies.

Older forest with size indexed to vegetation zone—minimum 10-percent canopy cover, minimum average tree size varies by vegetation zone.

Large, multistoried older forest—minimum 10-percent canopy cover, minimum average tree size 30 in, multistoried canopy.

— = not enough reference plots available (≤5) to calculate accuracies for California Coast Range, Oregon Willamette Valley, or Washington Western Lowlands.

forest" versus "not older forest" classes) was about 75 percent for all provinces combined, and all province maps were at least two-thirds accurate, overall (table 6). Producer's accuracies were above 50 percent for the older forest class for all provinces but two. In the Eastern Cascades provinces of Oregon and Washington, the low producer's accuracy indicated a low probability of correctly mapping the older forest class. Low user's accuracies in the California Cascades, Eastern Cascades of Oregon and Washington, and the Oregon Klamath indicated that many areas mapped as older forest were in fact misclassified on the map. The implication of these classification errors is that the older forest class will tend to be underpredicted compared with reference values in these provinces. The effect of the error depends on the use made of the results. Although the true magnitude of the error is unknown, it can be reasonably approximated with the values from the quantitative accuracy assessment. We did this by bracketing the amounts of older forest obtained from the maps by the magnitude of the inaccuracy in the error matrix. In our subsequent discussion of results, we make every effort to disclose the obvious inaccuracies in results, and what effect they might have on conclusions drawn from those results.

Map accuracy results for the definition known as "older forest with size indexed to potential natural vegetation zone" were similar in pattern to the mapping errors for the "medium and large" older forest map (table 6). Overall accuracies were between 57 and 89 percent (73 percent for the range). In terms of magnitude, producer's and user's accuracies were a little worse than for the "medium and large" older forest map. For the same provinces noted above, there was less than a 50-percent chance that a pixel identified on the map as older forest was actually older forest (user's accuracy). On the other hand, more than two-thirds of older forest reference values were correctly labeled on the map (overall producer's accuracy equaled 67 percent).

The ability to correctly map the older forest class according to the "large, multistoried" older forest definition was lowest of the three definitions (table 6). Overall accuracies were between 82 and 99 percent (87 percent for the range), but the high overall accuracies reflected the predominance of reference values (93 percent) that were "not older forest." In that map, map units labeled as "older forest" were correctly labeled less than half the time in every province.

For any of the definitions, the "not older forest" class was classified correctly more often than the "older forest" class. This result was expected, because the majority of reference values were "not older forest" for each of the definitions (68 percent for "medium and large," 87 percent for "size indexed to potential natural vegetation zone," and 93 percent for "large, multistoried"). In other words, the probability of getting a correct classification strictly by chance is proportional to the presence of the class in the population. To protect against good classification accuracies being due to random chance, we used a kappa statistic for verifying that agreement between older forest map and reference values exceeded chance levels. We did not use kappa for quantifying strength of agreement, a practice that is very controversial. This is because the test of the proportion of times that map and reference values would agree by chance alone is only relevant if the values are independent—which clearly they are not. Therefore, we report only the significance of the test of the null hypothesis that there is no more agreement between the map and reference values than might occur by chance given random guessing, rather than the absolute values of kappa themselves. An excellent primer on appropriate use of the kappa statistic can be found online (http://ourworld.compuserve.com/homepages/jsuebersax/kappa.htm). For all but two combinations of older forest definitions and provinces, the kappa statistic showed that there was better than random agreement between reference and map values (table 6). The exceptions were those provinces with weakest map results noted above—California Cascades and Washington Eastern Cascades for the "large multistoried" map (both had negative kappa values). No reference values labeled as "large multistoried" older forest in these provinces were predicted by the map to be that class. We expected this result, because there were very few reference plots with average tree size 30 in and greater, the cutoff for the "large multistoried" older forest definition.

Only 3 percent of reference plots were classified as "large multistoried" older forest in California Cascades, and less than 1 percent in Washington Eastern Cascades. With such small reference values in the population, the chance of misclassification is very high.

In summary, the "medium and large" older forest classifications were the most accurate maps, and they were most accurate for the coastal provinces and western Cascades provinces. Some improved accuracies were gained by the eastern Cascades provinces and Klamath provinces in the "older forest with size indexed to potential natural vegetation zone" map as compared with the "medium and large" map. As expected, the "large multistoried" map was least accurate in the eastern Cascades provinces, and to some extent the Klamath provinces. Finally, we conducted one final assessment of the maps, by comparing the amounts (total acres) of older forest estimated by the maps, with acres estimated by using the plot data, for the portions of the landscape that had adequate inventory plot samples. This approach and its results are discussed in subsequent sections.

Landscape Patterns

Along with older forest amounts, the importance of landscape patterns of older forests was also recognized in the Plan. Using the older forest maps created from remotely sensed data, we assessed the distribution and degree of fragmentation of older forests within the federal landscape. We used FRAGSTATS (McGarigal and Marks 1995) to determine the size, number, spatial arrangement, and isolation of mapped blocks of older forests.

We evaluated the fragmentation metrics of contiguous blocks of older forest of any size, and all blocks of at least 1,000 ac. The particular metrics we chose were related directly to Plan expectations for connectivity (see sidebar 1):

- Distribution of older-forest blocks smaller than 1,000 ac.
- Distribution of older-forest blocks larger than 1,000 ac.
- Mean edge-to-edge distance between older-forest blocks larger than 1,000 ac.
- Proportion of adjacent physiographic provinces connected with large older-forest blocks.

We mapped the largest blocks, calculated both within individual provinces, and across the entire Plan area. The latter allowed us to examine the arrangement of large older-forest blocks that cross physiographic province boundaries.

The resolution of a map influences the definition of a patch (block). The area defined as a contiguous forest block depends both on the grain size of a map and on the connection rules that determine whether or not adjacent map elements are considered to be contiguous (that is, part of the same block). The influence of these factors on fragmentation measurements has received much attention in the landscape ecology literature, but there has been little agreement on the best approach. Generally, landscape ecologists agree that the scale of analysis should be matched to the scale of the phenomenon of interest (see, for example, Spies and others 1994).

Older forests in Oregon and Washington were mapped from the IVMP data to a pixel size of 25 m (82 ft on a side or 0.15 ac); in California, the minimum polygon resolution mapped from CALVEG was 100 m (328 ft on a side or 2.47 ac). In conducting the block analysis, we converted the California map from polygons into a raster data set of 100-m cells. Then we resampled the Oregon and Washington maps from 25-m cells to 100-m cells to match the California maps by using a majority aggregation rule. We confirmed that although this aggregation reduced the number of small patches of older forests on the landscape in the Oregon and Washington portion, the overall area of older forests and the number of large blocks was nearly identical at the two grain sizes. In addition to allowing direct comparison between the three states, the use of a common 100-m cell size also dramatically reduced computation time.

In combination with cell sizes, we also tested two connection rules for combining adjacent cells. One rule considered a cell that was older forest to be a member of a block if at least one of the eight surrounding cells was also older forest. In the other rule, a neighboring older forest cell had to be connected at one of the four cardinal directions (that is, directly to the north, east, south, or west, and cells on the diagonal were not considered). The more liberal eight-neighbor connection rule resulted in block sizes weighted more heavily toward small size classes and linear map features compared with the more restrictive four-neighbor connection rule. We found that using a combination of a 100-m cell with an eight-neighbor connection rule produced results that were not very different from using a 25-m cell and a four-neighbor connection rule. That is, the use of a larger grain size and more liberal connection rule tended to offset using a smaller grain size and more restrictive connection rule, and the resulting maps appeared very similar. Therefore we conducted the fragmentation analysis by using the eight-neighbor rule.

Plot Analysis Methods

In addition to constructing and analyzing older forest maps, we also conducted a statistical analysis of older forest amount and distribution by using detailed ground inventory data collected in the Northwest Forest Plan area. Mapped data are conducive to characterizing spatial patterns of older forest on the landscape. However, the inherent inaccuracy of vegetation maps derived from remotely sensed data reduces the reliability of acreage estimates made from them. A map accuracy value of two-thirds is considered realistic for maps derived from satellite imagery (although we always strive for higher accuracies). Fortunately, we also had data from a rigorous, statistically robust sample of forests on lands managed by the Forest Service in Oregon, Washington, and California, and Bureau of Land Management in Oregon. We used these data to estimate the acres, and confidence bounds around the acres, of federal land occupied by older forest. Unfortunately, the inventory data available for the monitoring analysis did not sample the complete population of federal lands affected by the Plan. However, for those lands that were sampled, the acreage estimate is both more accurate and more precise than estimates derived from the map data. Thus, on portions of the Plan area containing inventory samples, the plot data gave us another independent means for confirming the map estimates of older forest.

Inventory Data Sources

Plot data used in this report came from three agency inventory programs—Current Vegetation Survey administered by the Forest Service in Region 6 (Max and others 1996; USDA Forest Service 1998, 2001), Current Vegetation Survey administered by Oregon Bureau of Land Management (Max and others 1996, USDI Bureau of Land Management 2001), and Forest Inventory and Analysis administered by Forest Service-Region 5 (USDA Forest Service 2000b). Each inventory program maintains a collection of permanent sample plots installed on a systematic grid across the land the agency manages. The three inventory programs have subtle differences in sample design but have significant, common features that make the data very useful for monitoring analysis.

A 3.4-mi grid sample is common to all the inventories, resulting in a sampling intensity of about 1 plot for every 7,400 ac. In Washington and Oregon, the CVS sampling intensity is increased fourfold on nonwilderness lands (one plot every 1,850 ac) (fig. 6). The plots are installed by using a rotating panel system. The sampling design is to remeasure every plot on a 10-year (for Forest Inventory and Analysis plots) or 12-year (for CVS plots) periodic cycle. Remeasurement produces information that can be used to analyze the amount of change in vegetation between measurement cycles.

Each inventory plot samples a 1-ha (2.47-ac) area. Five sample points are installed within each plot with nested concentric subplots that sample different components of vegetation (fig. 7). Sample measurements are recorded for individual trees, snags, and logs on sample points. Each full plot has an area-expansion factor, and each point represents one-fifth of the total area-expansion factor. In the monitoring analysis, we exploited the sampling variability inherent in this 5-point design to compute a nonparametric confidence envelope around each acreage estimate. Confidence intervals were constructed by using a stratified two-stage bootstrapping routine that resamples inventory data from sample points by using a Monte Carlo approach programmed by one of the authors (J. Alegria). Bootstrapping

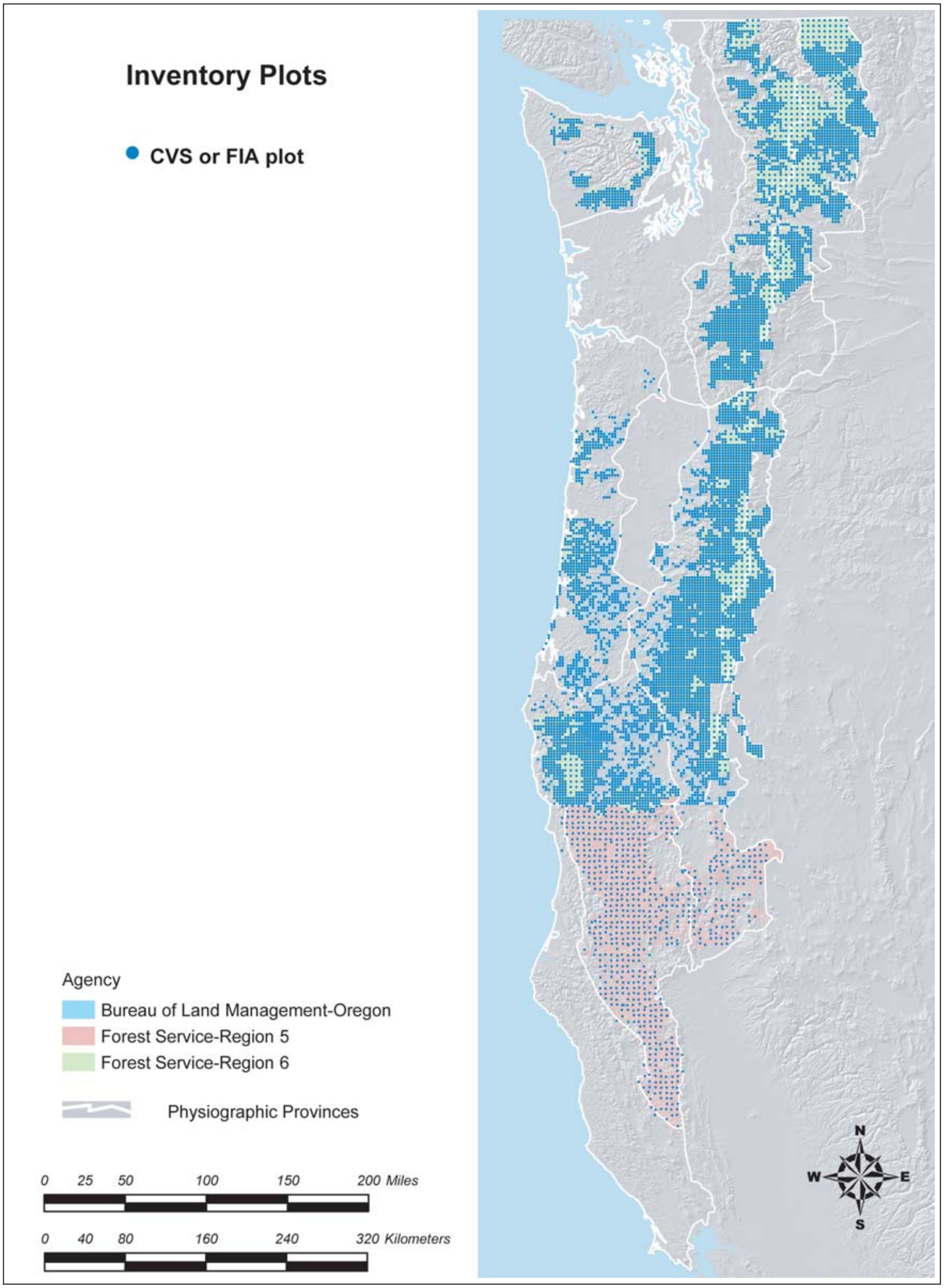

Figure 6—Current Vegetation Survey (CVS) and Forest Inventory and Analysis (FIA) plots. The FIA plots are installed on a 3.4-mi grid on lands administered by Forest Service-Region 5. The CVS Plots are installed on a 3.4-mi grid on wilderness lands administered by Forest Service-Region 6 and Bureau of Land Management-Oregon. On nonwilderness lands in Washington and Oregon, there is one plot every 1.7 mi.

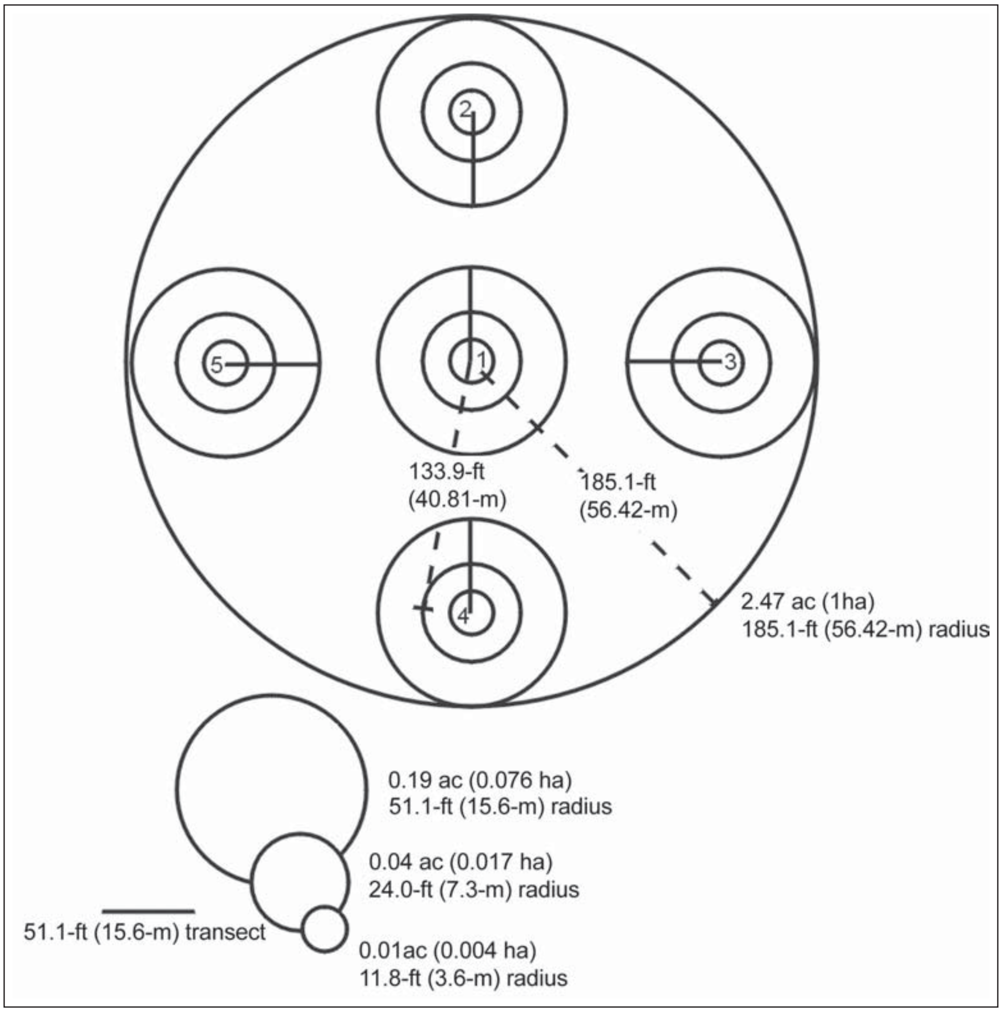

Figure 7—Generalized layout of Current Vegetation Survey (CVS) plot showing five sampling points on a 1-ha full plot (from Max and others 1996).

is a well-accepted statistical approach for exploiting available sampling data to increase precision of estimates (Efron and Tibshirani 1993). In our approach, each first-stage bootstrap sample consisted of n_h randomly selected sample plots with replacement from each of the *h* strata to produce one bootstrap estimate. The strata were land allocation groups, or reserve categories (table 5), within physiographic provinces. This computation was repeated 1,000 times. For each first-stage sample plot, five sample points were randomly selected with replacement from among the possible sample points. The results were adjusted by using the bias-corrected and accelerated method (Bc_a) as detailed in Efron and Tibshirani (1993). Confidence intervals were calculated at the 90-percent value for all acreage estimates.

Data from all plots within the Plan area from the three inventories were combined into a master database. Just as with the map data, the primary attributes compiled from the inventory data used to assess forest condition were average topstory tree size, percentage of canopy closure, canopy layering, and life form, as per table 1. Average tree size was calculated as the quadratic mean diameter of all trees on the sample point having dominant or codominant crowns. Computing the average size for trees only in the upper story produces a size metric that closely parallels the average tree size measure modeled by the existing vegetation maps based on remotely sensed information. Canopy closure and canopy layering were compiled by processing the tree data from each sample point through the Forest Vegetation Simulator (Crookston and Stage 1999, Dixon 2003, Teck and others 1996, Wykoff and others 1982). The Forest Vegetation Simulator reports canopy closure in 1-percent increments from 0 to 100, and canopy layering as the number of canopy layers present (0 = non-stocked, 1 = single-storied, ≥2 = multistoried). Life form was determined by calculating the proportion of total canopy closure accounted for by conifers versus hardwoods: 80 percent or more of total canopy cover in conifers was classified as conifer-dominated, 80 percent or more of total canopy cover in hardwoods was classified as deciduous, otherwise was classified as mixed (table 1).

Once the plot data were compiled, each sample point was assessed for its membership in each of the older forest classes (“medium and large older forest,” “large, multi-storied older forest,” and “older forest with size indexed to potential natural vegetation zone”). All available plots were included, even if they were nonforested. The attributes of nonforested plots resulted in a label of “potentially forested” (table 1). Then the total acres represented by sample points meeting each older forest definition were summed by province and land allocation group. A bootstrap estimate of sampling variance was calculated around each estimate and used to construct 90-percent confidence limits.

The inventory data were also analyzed to address the monitoring question about structural and compositional characteristics of older forests—large-tree diameters, canopy structure, snags, and logs (see sidebar 2). This analysis followed the accuracy assessment of the older forest maps. Samples that were labeled as “older forest” both on the map and on reference plots were assigned to one class. Samples that were labeled as “not older forest” both on the map and on reference plots were assigned to another class. Samples with conflicting plot versus map labels were dropped from the analysis. Then we computed means and confidence intervals for the following attributes by the two classes for each older forest definition:

Average size (quadratic mean diameter) of topstory trees
Average age of topstory trees
Average number of canopy layers
Density of trees (trees per acre) in several size classes (3-9.9, 10-19.9, 29-29.9, and 30+ in)
Snag densities (snags per acre) in 3-9.9, 10-29.9, and 30+ in diameter classes
Tons per acre and cubic foot volume per acre of logs.

A practical discussion of the inventory data— It is important to point out that amounts of older forest, whether determined from map data or from plot data, are **estimates**. They are models of what we can infer about the resource, given the best available information. However, all sources of information have flaws. Some are known, and some are unknown. We know the map data is inherently limited in accuracy owing to the imprecision of the classification of remotely sensed data, and the variation in actual conditions that cannot be captured adequately by map models. The plot data is collected according to a sample design that meets rigorous statistical assumptions, with a sampling intensity intended to capture important variation in the population. Thus sample data yield an unbiased estimate of the population. However, even plot data have limitations that must be disclosed in analyses and results. The major limitation affecting use of plot data for the monitoring analysis is that the data we used did not, at the time, sample the total population of federally managed lands included in the Northwest Forest Plan area. Current Vegetation Survey and Forest Inventory and Analysis plots sampled only lands managed by Forest Service-Region 6,

Forest structure can be characterized by attributes such as tree sizes and canopy layering.

Bureau of Land Management-Oregon, and Forest Service-Region 5. Together these lands accounted for 90 percent of the Plan total federal land area. At the time of the inventory, there were no samples installed on National Park Service lands (Park Service lands accounted for about 9 percent of the total federal land base).[1] Data from Bureau of Land Management-California lands (about 1 percent of the total) were not included either.[2] Thus our statistical estimates excluded Park Service and Bureau of Land Management-California lands. National parks do contribute significantly to the older forest network on federal land, because they make up a large portion of the congressionally withdrawn land allocation (wilderness in national forests is the other significant component of congressionally withdrawn lands). However, the Plan does not and cannot influence management of national parks (USDA and USDI 1994b). Although having missing data is never desirable, our plot analysis does cover all but 1 percent of land (that is, on Bureau of Land Management land in California) where scheduled timber harvest must be considered in the range of management alternatives. All our plot-based results are therefore applicable only to Forest Service-Region 6, Bureau of Land Management-Oregon, and Forest Service-Region 5.

On federal ownerships that were sampled, data were incomplete owing to the fact that some plots could not be measured. For example, where access is hazardous, such as on rock piles, glaciers, or even on the other side of a large river with no bridge crossings, it may have been impossible to install a plot. These uninstallable plots represented a certain number of acres for which no information was known about the conditions on the ground. Of the approximately 22.3 million ac of public land administered by Forest Service-Region 5, Forest Service-Region 6, and Bureau of Land Management-Oregon, 90 percent was represented by a sample (table 7). The remaining 10 percent of land had plots allocated, but not installed, usually because of access issues. A notable exception was in the Washington Eastern Cascades province. On the Wenatchee National Forest in that province, one-quarter of CVS plots were missing from the first measurement occasion because of contractor default (http://www.fs.fed.us/r6/survey).

The unmeasurable areas pose an obvious problem for reporting population estimates of older forest amounts. We made the assumption that most area not sampled because of hazardous access is from a different statistical population, that is, usually permanently nonforested and therefore not capable of supporting older forest. This is a legitimate assumption for most, but not all, conditions where plots were not installed because of access problems. We recognize that we may have slightly underestimated older forest area based on this assumption, but argue that the discrepancy is small enough to be discounted.

The year of installation and initial measurement for the inventory plots used in the monitoring analysis ranged from 1993 to 2001 (table 8). We used all sample plots measured during the initial measurement occasion to represent conditions at or near the start of the plan. More than 90 percent of samples were collected within a 5-yr period around Plan implementation (from 1993 through 1998). In the long term, monitoring results should not be very sensitive to variation caused by sampling information collected over a range of

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[1] There were no inventory plots on national park land at the time of the Northwest Forest Plan implementation. Forest Inventory and Analysis has recently begun sampling all ownerships, including national park land, as a component of their National Strategic Inventory program (http://www.fs.fed.us/pnw/fia/publications/fieldmanuals.shtml). This national annual inventory began in 1999 in California, followed by Oregon in 2000, and Washington in 2001. According to this schedule, the first installation on national park lands in the Plan area will be completed in 2009-11. Thus, most of the inventory information for national parks will be available for analysis in the next monitoring cycle ending in 2009.

[2] On Bureau of Land Management land in California, there were 15 sample plots belonging to the periodic inventory (3 in the California Cascades province, 7 in the Coast Range, and 5 in the Klamath). The periodic inventory became obsolete with the advent of the national annual inventory, and we decided that no periodic data would be used in this monitoring analysis in order to avoid problems associated with differences in sample design and compatibility with the other inventories. Besides, the vast majority of lands sampled by Forest Inventory and Analysis plots at the start of the Plan were in state and private ownerships, and these lands were not a focus of the status and trends monitoring program. As with the Park Service land, data on Bureau of Land Management land in California from the national annual inventory will be included in the next monitoring cycle.

Table 7—Distribution of acres sampled by inventory plots in the Northwest Forest Plan area

Province	Sampled	Not sampled	Total	Percentage sampled
	– – – – – – – – – – – – *Acres* – – – – – – – – – – – –			*Percent*
California Cascades	1,005,900	98,900	1,104,800	91.1
California Coast Range	73,800	6,900	80,700	91.5
California Klamath	3,908,000	470,100	4,378,200	89.3
Oregon Coast Range	1,403,100	84,200	1,487,300	94.3
Oregon Eastern Cascades	1,537,400	93,200	1,630,600	94.3
Oregon Klamath	2,102,700	93,100	2,195,800	95.8
Oregon Western Cascades	4,238,900	220,500	4,459,400	95.1
Oregon Willamette Valley	13,800	0	13,800	100.0
Washington Eastern Cascades	2,600,900	769,000	3,369,900	77.2
Washington Olympic Peninsula	588,300	42,600	631,000	93.2
Washington Western Cascades	2,617,100	347,800	2,964,900	88.3
Washington Western Lowlands	0	0	0	0.0
Northwest Forest Plan	20,090,000	2,226,300	22,316,300	90.0

Note: Includes Current Vegetation Survey plots on Forest Service-Region 6 and Bureau of Land Management-Oregon lands and Forest Inventory and Analysis plots on Forest Service-Region 5 lands.

Table 8—Acres sampled on inventory plots during the first measurement occasion

Year	Area sampled	Percentage of total
	Acres	*Percent*
1993	855,800	4.3
1994	2,644,900	13.2
1995	4,515,300	22.5
1996	6,720,900	33.5
1997	2,198,000	10.9
1998	1,292,000	6.4
1999	281,400	1.4
2000	971,300	4.8
2001	610,400	3.0
Total	20,090,000	100.0

years. Also, use of all occasion-one inventory data to compile the Plan baseline establishes a monitoring approach into the future. Our monitoring protocol calls for remeasured plots to be used for change estimation by assigning them to the correct 5-yr monitoring cycle, disregarding the specific year they were remeasured.

Trend Analysis: Forest Disturbance Map Methods

Assessing changes over time in older forests under the Plan is a two-step process. First, baseline conditions must be established, and second, there must be a means for tracking changes to the baseline. We analyzed changes by using both plot (table 9) and mapped data (table 10). Remote sensing of changes allows examination of substantial changes in forest vegetation over space and time. Related spatial analysis, such as comparison of rates of harvest activity by ownership, or fire occurrence trend by physiographic setting, are possible with this type of spatial information. Information from remeasured inventory plots is a better source of data than are maps for assessing subtle vegetation change (for example, resulting from understory disturbance that does not disturb the canopy, or from forest growth and development).

In this section, we describe how disturbance maps developed from remotely sensed data were used for tracking losses of older forests since the start of the Plan.

Table 9—Distribution of remeasured plot data

Period	Area remeasured	Percentage of area by period
Years	*Acres*	*Percent*
1	623,000	6.7
2	1,080,500	11.6
3	1,252,300	13.4
4	2,371,600	25.4
5	2,981,000	31.9
6	342,600	3.7
7	402,400	4.3
8	284,700	3.0
9	1,500	0.0
Total	9,339,600	100.0

Note: Period is the number of years between initial measurement and remeasurement. The mean remeasurement period, weighted by acres, is 4.08 years.

Table 10—Summary of change cycles in the remote sensing change-detection analysis

Area	Period
California	
CALVEG baseline	1994
Change-detection cycles:	
North Coast project area	1994-1998 1998-2003
Cascade Northeast	1994-1999 1999-2003
Washington and Oregon	
IVMP Baseline:	
2 scenes	1992
1 scene	1994
1 scene	1995
13 scenes	1996
Change-detection cycles:	
Oregon	1995-2000 2000-2002
Washington	1996-2000 2000-2002

Remotely Sensed Change Detection

We used information from broad-scale remote-sensing disturbance-mapping projects to assess loss of older forest in the first decade after the Plan. As was done for mapping existing vegetation attributes from IVMP and CALVEG, data were drawn from two separate projects—one in Washington and Oregon, and another in California. In the approach used in Washington and Oregon, the type of change detection we conducted for monitoring was sensitive to land cover changes resulting from regeneration harvest (that is, clearcutting), land use conversion (e.g., forested land cleared for nonforest use), and wildfire severe enough to remove the forest canopy. It was not sufficiently sensitive to reliably detect less severe disturbances that did not remove the canopy, such as partial harvest, thinnings, or groundfires. Mortality associated with insect and disease damage was not detectable either unless it resulted in full canopy removal. In the California approach, changes were mapped according to magnitude (amount of canopy change) as well as direction (decrease or increase). In other words, the California methodology was sensitive enough to detect partial change. However, for this monitoring assessment, we resorted to the least-common-denominator use of the remotely sensed change-detection data: that is, mapping stand-replacing disturbances, only.

Old-growth ponderosa pine in eastern Oregon

In general terms, the approach used in remotely sensed change detection analyzes spectral differences in paired satellite images captured at multiyear intervals (Cohen and Fiorella 1998; Cohen and others 1998, 2002; Levien and others 1998, 1999). Disturbances severe enough to remove the existing canopy appear as clearly demarcated events in multitemporal imagery, and are easily mapped with a high degree of accuracy (fig. 8). The causes of change are labeled by integrating information from other data sources like aerial photos, agency activity records, and fire perimeters.

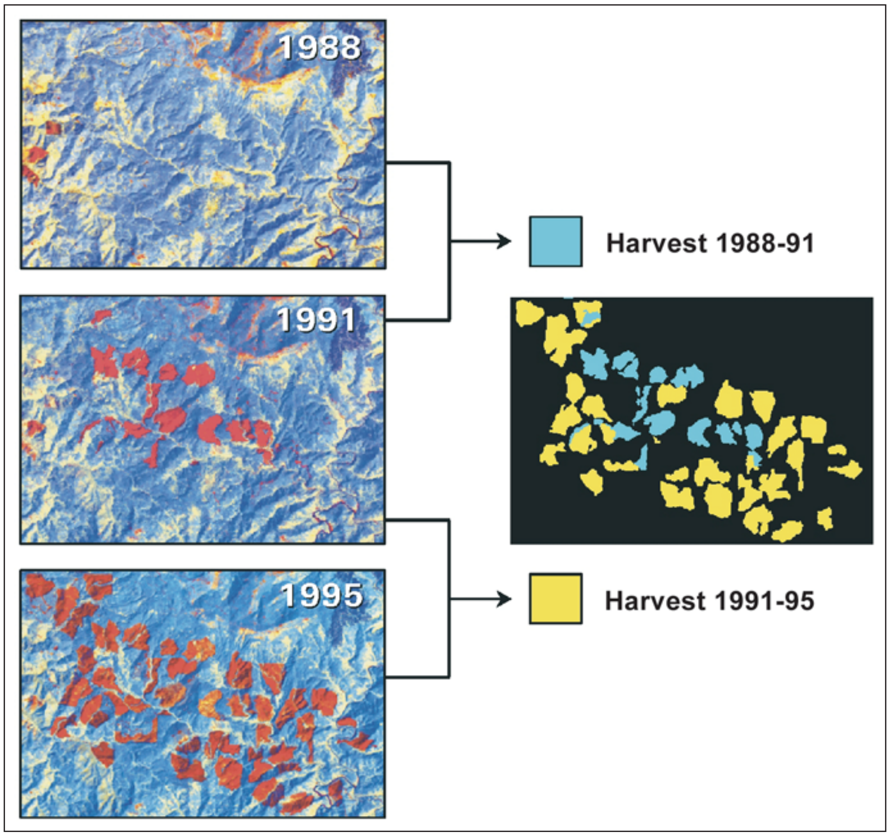


Figure 8—Schematic of remotely sensed change-detection approach using simultaneous image differencing (Cohen and others 2002).

Change detection in Washington and Oregon– In Washington and Oregon, a change-detection project was undertaken to support the late-successional and old-growth forest monitoring analysis. We mapped stand-replacing disturbances resulting from fire and harvest in the Washington and Oregon portion of the Plan area (fig. 9). The analysis built upon earlier research that had mapped disturbances in western Oregon between 1972 and 1995 (Cohen and Fiorella 1998; Cohen and others 1998, 2002). Using this groundwork, we extended the methodology in time (from 1972 through 2002) and in space (encompassing the complete Plan area in Washington and Oregon).

The Oregon and Washington disturbance map resulting from the change-detection project covers a 30-year span, from 1972 through 2002. Although we report results only for the decade after the Plan in this document, other publications in preparation will include a retrospective comparison of rates of change in the decades preceding the Plan and after the Plan on both public and private lands (Haynes and others, in press; Healey and others, n.d.).

The change-detection project in Oregon and Washington used a technique called composite analysis, where imagery from several time steps was georegistered and stacked into a single multitemporal image that was then classified in a way that highlighted forest loss in specific time intervals. Methodological details and results for Western Oregon through 1995 have been published by Cohen and others (2002). We used Landsat TM and Enhanced Thematic Mapper (ETM+) imagery, converted to a single spectral band per year by using the disturbance index transformation (Healey and others 2005). This transformation maximizes the spectral separation of disturbed and undisturbed forest pixels. Change was detected in each Landsat scene by submitting multitemporal disturbance index composites to a maximum likelihood-based supervised classification. Training of this classification was accomplished by using Landsat data transformed with the disturbance index

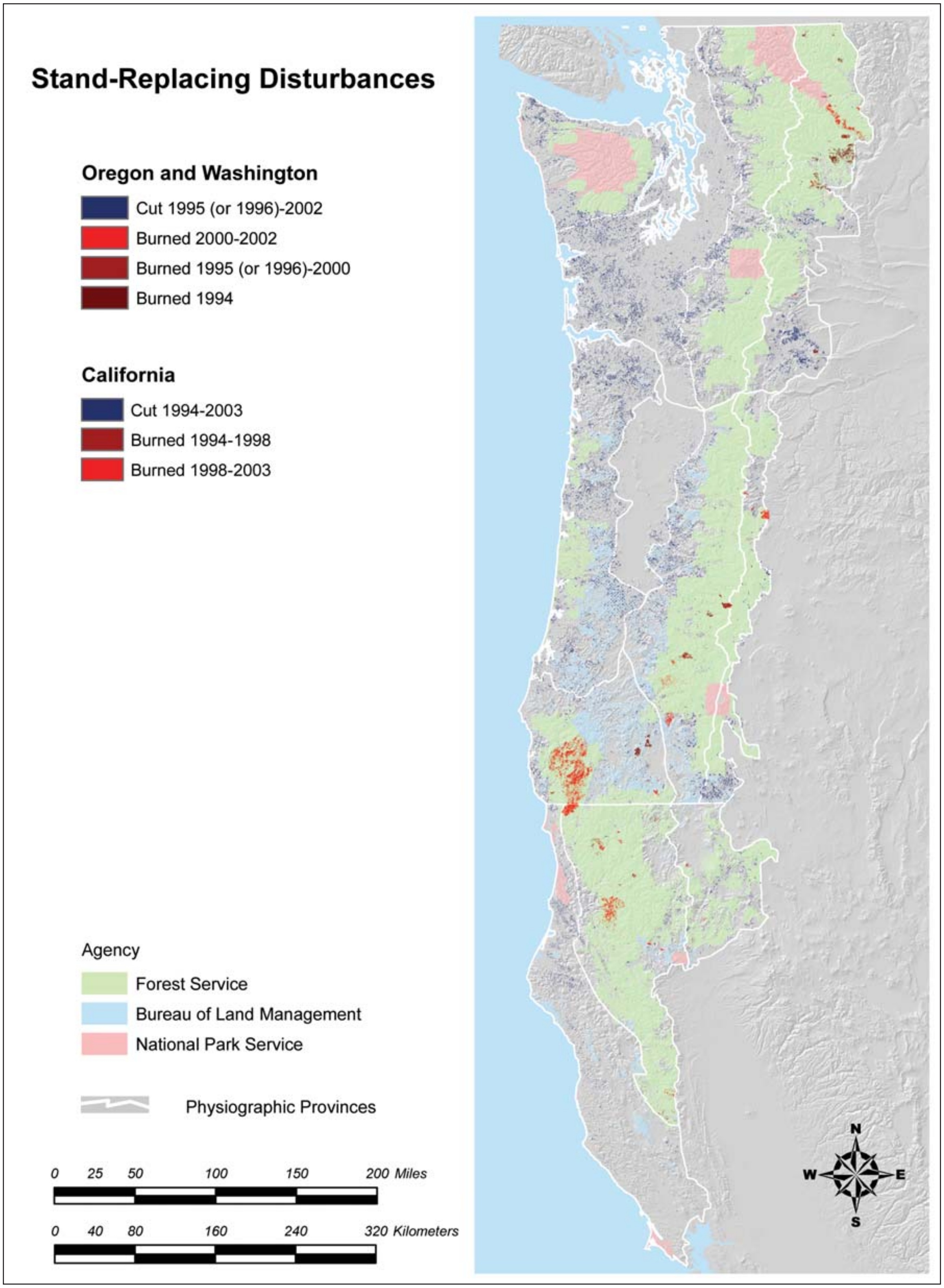


Figure 9—Disturbance map for Northwest Forest Plan monitoring. Washington and Oregon was mapped by Healey and others (n.d.); California was mapped by Levien and others (2003a, 2003b).

Continues

Continue to Part B

Return to Part A

(Healey and others 2005) and tasseled cap transformations (Crist and Cicone 1984, Kauth and Thomas 1976). Cohen and Fiorella (1998) and Cohen and others (1998) found tasseled-cap-transformed data to be nearly equivalent to aerial photography for identifying stand-replacing disturbance. Postprocessing involved passing a majority 3- by 3-pixel filter over the image and automatically eliminating patches of less than 5 ac to remove false change caused by image misregistration. Some manual cleanup was also employed, and disturbances owing to fire were distinguished from those owing to harvest by using rules based on size and shape of disturbance. Other disturbance agents (landslide, rivercourse change) were explicitly excluded from the map by using hand editing.

Change detection in California—
Changes to older forests within the Plan area in California were mapped as part of the California Land Cover Mapping and Monitoring Program (Levien and others 1998, http://frap.cdf.ca.gov/projects/land_cover/index.html). We used information from three portions of this program in our trend analysis. These were the Cascade Northeast project area, mapped between 1994 and 1999 (Levien and others 2003a), the North Coast project area, mapped between 1994 and 1998 (Levien and others, 2003b), and the combination of these project areas mapped through 2003 (table 10). Data from these three projects were combined and clipped to the Plan boundary in California for analysis (fig. 9).

The California change-detection project used Landsat TM imagery to classify vegetation change. Briefly, the methodology followed these main steps: registration of images from times 1 and 2; radiometric correction to remove differences in atmospheric conditions; analysis of tasseled cap differences between the two dates; classifying the magnitude and direction of change into several categories, from large decreases in vegetation to large increases in vegetation; and labeling the cause of change. A more detailed description of the change-detection procedures can be found in Levien and others (1998, 1999, 2003a, 2003b).

In California, vegetation change was mapped in categorical decrease and increase classes. We used only the class labeled as “large decrease” (71 to 100 percent decrease in canopy cover) in our monitoring assessment. This class paralleled the stand-replacing disturbance class mapped in Oregon and Washington project areas (that is, disturbances that result in more or less full removal of the existing tree canopy). In the California change map, we eliminated mapped changed patches less than 5 ac, to be consistent with the mapping resolution in Washington and Oregon.

Disturbance map accuracy assessment—
In California, Forest Inventory and Analysis plots were used as reference values to assess the accuracy of the disturbance maps. Error matrices summarizing absolute and fuzzy accuracies were constructed, similar to the methods described for assessing the CALVEG maps (app. 4). In Washington and Oregon, quality of the disturbance maps was assessed by using visual pixel-level interpretation of the original Landsat imagery, as described in detail by Cohen and others (1998, 2002).

Stand-replacing disturbances are typically large, demarcated events that are readily detected with remote sensing. This is reflected in high overall accuracy values. Accuracies range from about 78 percent to greater than 90 percent in mapping stand-replacing disturbances (Cohen and others 1998, 2002; Healey and others in press; Levien and others 2003a, 2003b). The results are summarized in appendix 5.

Trend Analysis: Remeasured Plot Data Methods

The analysis of older forest change with inventory plots as the data source complemented the analysis of change that used remote-sensing change-detection maps. Remeasured plots were used to assess net change, including vegetation decreases from partial disturbance such as surface fires or thinning harvest, as well as increases resulting from regrowth following stand disturbance and recruitment into older forest classes from younger classes. Change estimates made from plot data have the disadvantage that they are nonspatial data, and thus gain and loss estimates from them cannot be displayed easily on a map. Plots representing approximately 47 percent of inventoried area had been sampled a second time by the time this change analysis was conducted (table 9). The remeasurement period (number of years between the first and second measurements) averaged 4.08 years across the Plan area.

We used the remeasured plot data to estimate rates of change in forest vegetation classes in the following manner. Each remeasured sample was assigned to one of two size classes (<20 in or 20 in) at each measurement occasion. The 20-in class is equivalent to our "medium and large" older forest class. Then a matrix was constructed summarizing transitions between classes. Values in the matrix were acres annualized by dividing by the length of the interval between remeasurements, in years. We calculated the percentage of samples moving between size classes as an annual rate of change, R, weighted by acres sampled, by using the formula,

$$R = 100\left(\frac{\sum_{i=1}^{n}\delta_i\left(\frac{A_i}{P_i}\right)}{\sum_{i=1}^{n}\frac{A_i}{P_i}}\right),$$

where

n is the number of remeasured sample plots,

A_i is the sampling weight in acres for plot *i*,

P_i is the length of the remeasurement period in years for plot *i*,

$$\delta_i\begin{cases} 1 & \text{if } S_{T_1} < 20 \text{ in and } S_{T_2} \geq 20 \text{ in} \\ -1 & \text{if } S_{T_1} \geq 20 \text{ in and } S_{T_2} < 20 \text{ in} \\ 0 & \text{otherwise} \end{cases},$$

S_{T_1} and S_{T_2} are size class at measurement times 1 and 2, respectively.

The net transition rate was then applied to the baseline estimate (that is, at time 1) of "medium and large older forest" and extrapolated to a 10-year basis to estimate the magnitude of acres transitioning into or out of "medium and large older forest" between 1994 and 2003. This approach assumes that average rate of change is constant over the 10-year period. The estimate from the remeasured plot approach represents net change resulting after losses from fire and harvest and gains from growth.

Fire Regime Analysis

We analyzed the older forest baseline amounts against coarse-scale information about fire regimes. In particular, we were interested in the general distribution of older for-ests mapped at the baseline within fire regimes. At one ex-treme, historical fire regimes in the Plan area are characterized by long fire-return intervals and stand-replacing fires (such as in the Washington Olympic Peninsula province). At the other extreme are provinces where historically, fre-quent fires burned with low intensity (such as the Klamath provinces). To analyze the distribution of baseline older forests with respect to fire regimes, we grouped older for-ests into broad climatic areas and fire regime classes based on physiographic province and potential natural vegetation zone. Oregon Coast Range, California Coast Range, Washington Olympic Peninsula, Oregon Willamette Valley, and Washington Western Lowlands were placed in the Coast climatic area, Washington Western Cascades and Oregon Western Cascades in the West Cascades, Washington Eastern Cascades, Oregon Eastern Cascades, and California Cascades in the East Cascades, and Oregon Klamath and California Klamath in the Klamath climatic area. Vegetation zone groups were classed according to the degree to which they represent naturally fire-adapted ecosystems (that is, vegetation types that have evolved in concert with frequent, low-severity fires). Interior Douglas-fir, dry firs, dry/mixed conifers, oaks, pines, and tanoak/Douglas-fir vegetation zone groups were categorized as "fire adapted," and all other vegetation zone groups were categorized as "not fire adapted." Then we calculated fire-adapted acres of older forests by climatic area to broadly assess older forest risk to wildfire.

We also intersected the older forest data with a map showing the relationship between historical and current fire regime (frequency and severity). Fire regimes and condition classes for the Northwest Forest Plan area are displayed in fig. 10 (Hardy and others 2001, Schmidt and others 2002).

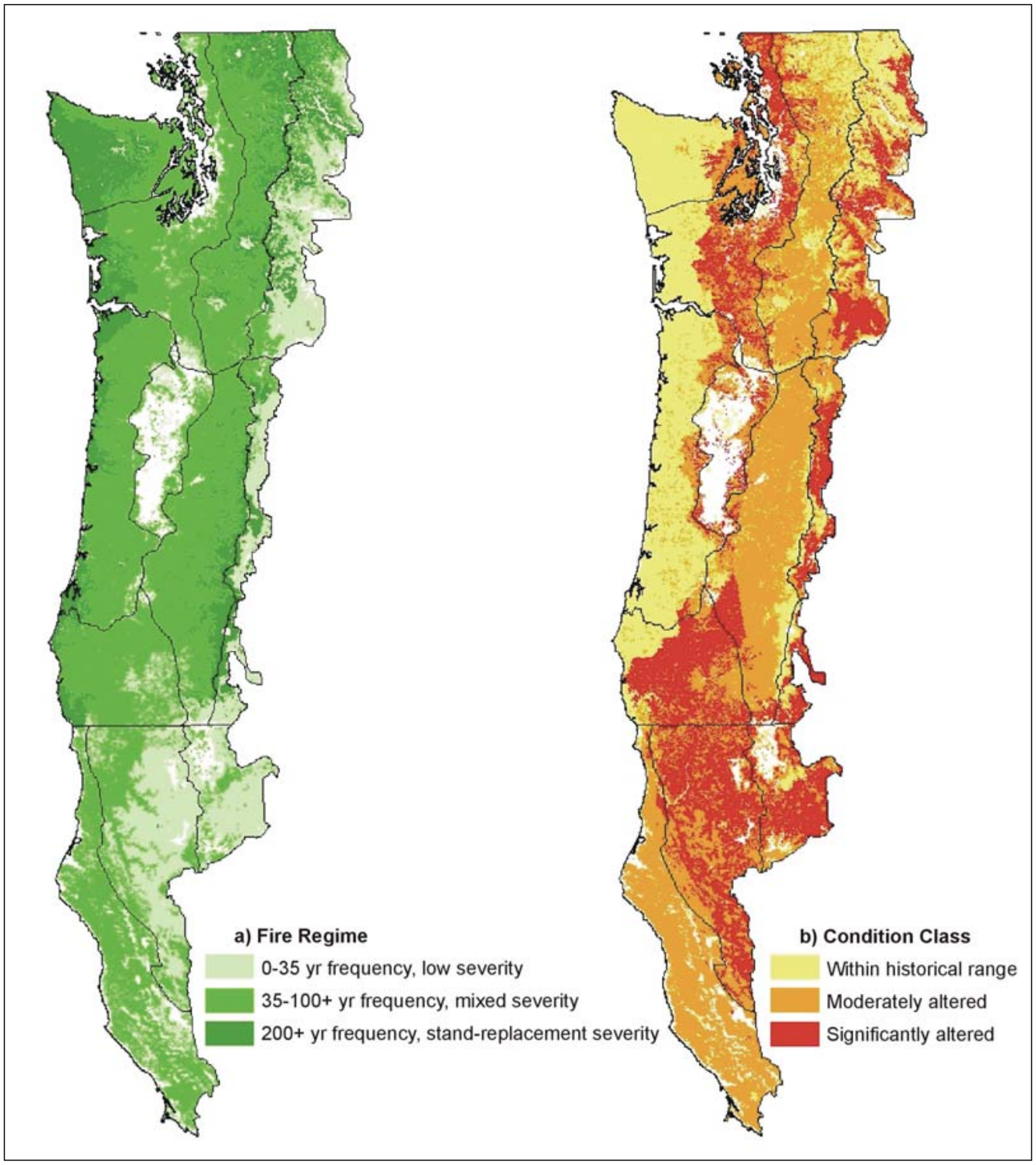


Figure 10—Fire regime and condition class mapped for the Northwest Forest Plan area by Hardy and others (2001) (http://www.fs.fed.us/fire/fuelman). See sidebar 4 for explanation of classes. There is considerable controversy over the appropriateness of using the national classification for forests of the Pacific Northwest. (See text for more discussion.)

The map, developed at the national scale, represents a coarse-level view (1-km^2) (0.386-mi^2) of the degree of departure of current vegetation conditions from an historical fire regime. Fire regime is the characteristic mix of fire frequency and severity for a landscape of interest and is heavily influenced by climate, soils, topography, and vegetation (Schmidt and others 2002). Condition class is a measure of departure from the historical range of seral stages, fire frequency, and fire severity and can be described as both a continuous and categorical variable. For ease of communication, fire regimes and condition class are usually expressed categorically. Condition class 1 areas are functioning within the historical range. Condition class 2 and 3 areas are moderately or significantly altered from the historical range, respectively.

Sidebar 4—Interpreting Fire Regime Condition Classes

Fire regime condition classes measure the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components (from Hardy and others 2001)

Historical Natural Fire Regime–fire frequency and severity

Fire frequency is the average number of years between fires.

Severity is the effect of the fire on the dominant overstory vegetation. Low-severity fires are fires in which >70 percent of the basal area and >90 percent of the canopy cover survives. Mixed-severity: moderate effects on the overstory, mixed mortality. Stand-replacement fires consume or kill >80 percent of basal area or >90 percent of overstory canopy cover.

Code	Description of historical natural fire regime
1	0-35-yr frequency, low severity
2	0-35-yr frequency, stand-replacement severity
3	35-100+ yr frequency, mixed severity
4	35-100+ yr frequency, stand-replacement severity
5	200+ yr frequency, stand-replacement severity

Interpretation:

1: Found in forests that experience frequent, low-severity, nonlethal surface fires.

2: Found primarily in grass and shrublands.

3, 4, 5: Can occur in any vegetation type.

Condition class measures the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components

Code	Description of condition class
1	Fire regimes within or near historical range; risk of losing key ecosystem components is low.
2	Fire regimes moderately altered from historical range; risk of losing key ecosystem components is moderate.
3	Fire regimes significantly altered from historical range; risk of losing key ecosystem components is high.
0	Fire regimes unknown because of 1-km mapping resolution.

Interpretation:

1: Species composition and structure are intact and functioning within historical range. Where appropriate, these areas can be maintained within the historical fire regime by treatments such as fire use.

2: Areas are moderately departed from historical conditions, often having missed at least one fire-return interval (or in some ecosystems, experiencing fires more frequently than occurred historically). Fuels are often accumulating to high levels in these areas. May need moderate levels of restoration treatments to be restored to historical regime.

3: Areas are greatly departed from historical conditions, often having missed two or more fire-return intervals, with associated buildup of fuel. May need high levels of restoration treatments to be restored to historical regime. The amount of effort to restore areas generally increases with condition class; for example, restoring condition class 3 to 2 will be more expensive and time-consuming than restoring from condition class 2 to 1.

The analysis using the national fire regime condition class map should be viewed only as a rough first approximation of the fire situation for older forests at the start of the Plan. The map was based on a 1-km^2 (0.386-mi^2) resolution map prepared for a quick national "snapshot" of conditions in 2000. Perhaps more importantly, this map shows fire regimes influenced by all disturbances (not only fire), including human-caused urban development, logging, and agriculture. Areas with condition class 2 and 3 in western Washington and northwest Oregon often result from patterns of these human-caused disturbances, rather than from fire suppression. Also, the national map is missing a moderate- or mixed-severity fire regime class considered prevalent in parts of the Plan area, especially in the Cascades Range where the fire regimes are a complex mixture of stand-replacing and low-severity fires (Agee 1993, 2003; Spies, in press). A later section in this report touches on work in progress to improve fire regime and condition class maps for the Pacific Northwest.

Results—Older Forests at the Start of the Northwest Forest Plan

We mapped existing vegetation and older forest at the beginning of the Plan from the satellite data. The distribution of forested land mapped by average topstory tree size, canopy layering, and life form classes (table 1) is displayed for the entire Plan area (all ownerships) in figure 11. Three maps corresponding to the "medium and large older forest," "large, multistoried older forest," and "older forest with size indexed to potential natural vegetation zone" definitions are displayed in figure 12. The older forest maps are accessible online for readers wishing to view them with additional resolution (http://www.reo.gov/monitoring/).

Older Forest Distribution

Estimates derived from the older forest maps showed that the proportion of the federally managed land area occupied by older forests at the start of the Plan ranged from 30 per--cent of forest-capable area (7.04 million ac ± 1.93 million ac) by the "older forest with size indexed to potential natural vegetation zone" definition, to 34 percent of forest-capable area (7.87 million ac ± 1.96 million ac) by the "medium and large older forest" definition (table 11). Twelve percent of federal forest-capable land was occupied by "large, multistoried older forest" (2.72 million ac ± 0.35 million ac). The estimates of prediction error placed around the acres for each older forest definition were based on within-province overall map accuracies (table 6) by using the standard formula for the variance of stratified sampling for proportions (Cochran 1977).

Distributions of "medium and large older forest" and "older forest with size indexed to potential natural vegetation zone" were quite different (table 11). In general, applying the "medium and large" definition predicted relatively more area occupied by older forests in the provinces west of the Cascade crest, and relatively less area in the eastern Cascades provinces when compared with predictions made applying the "older forest with size indexed to potential natural vegetation zone" definition. This was because the constant average-tree-size criterion used in the "medium and large older forest" definition (minimum 20 in) tended to predict relatively lower amounts of older forest in potential natural vegetation zones where forest productivity is naturally low (for example, in the dry forests of the eastern Cascades and at higher elevations), and relatively higher amounts in very productive forests (for example, in moist coastal forests). Areas predicted as occupied by "large, multistoried older forest," which is a subset of "medium and large older forest," were concentrated in the Oregon and California Coast Range, Washington Olympic Peninsula, Washington and Oregon Western Cascades, and Oregon and California Klamath provinces.

Of the total amount of older forest in the Plan area, about three-quarters was in the provinces of the Western Cascades (Washington Western Cascades and Oregon Western Cascades) and Klamath Mountains (Oregon Klamath and California Klamath), by any of the definitions (fig. 13). The Coastal provinces (Washington Olympic Peninsula, Oregon Coast Range, and California Coast Range) contained 24 percent of the total "large, multistoried older forest" in the Plan area, 17 percent of total "medium and large older forest," and 14 percent of total "older forest

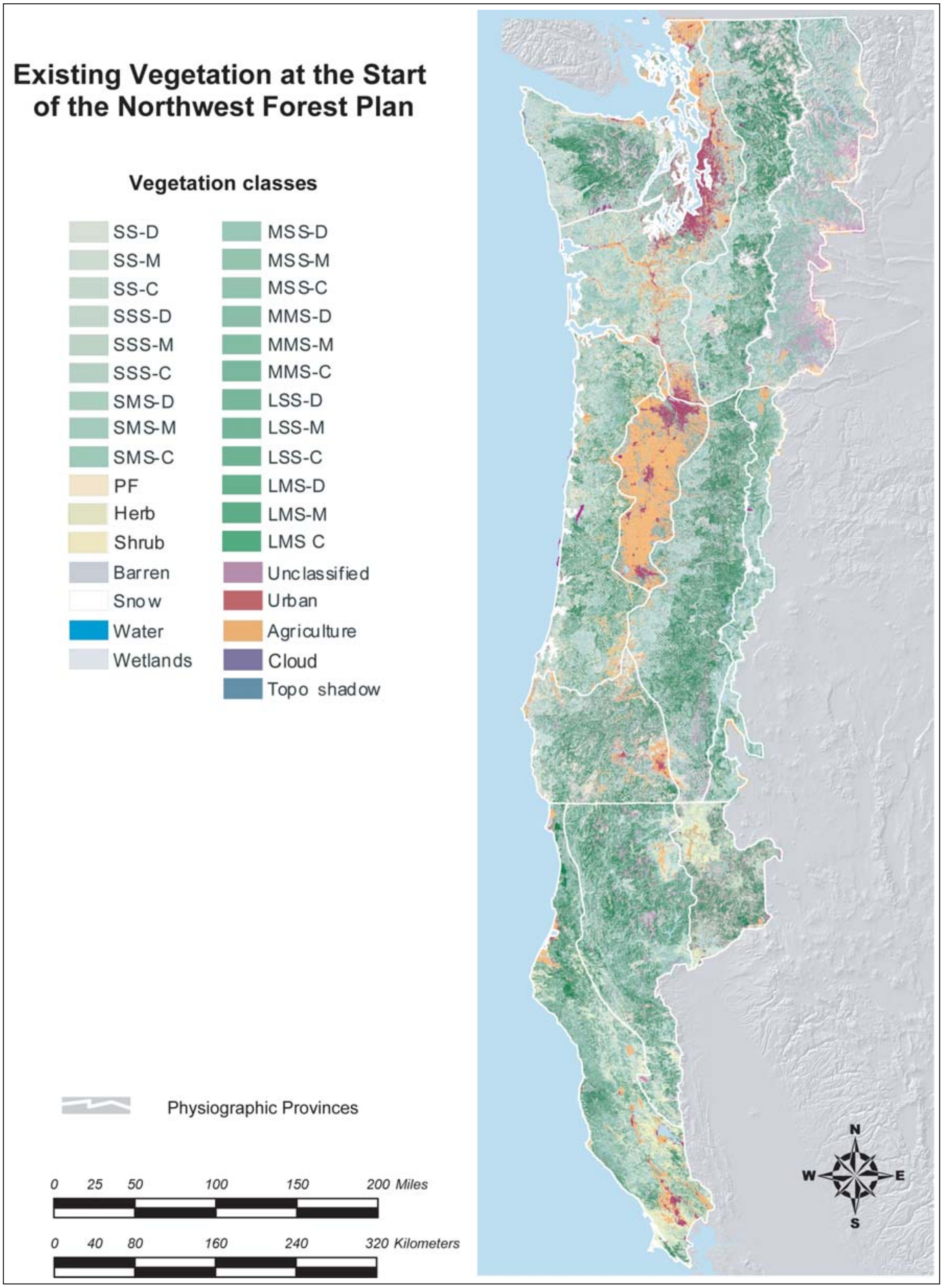


Figure 11—Existing vegetation at the start of the Northwest Forest Plan. Classes are mapped from IVMP and CALVEG based on average tree size, canopy closure, canopy layering, and life form (see table 1 for code definitions).

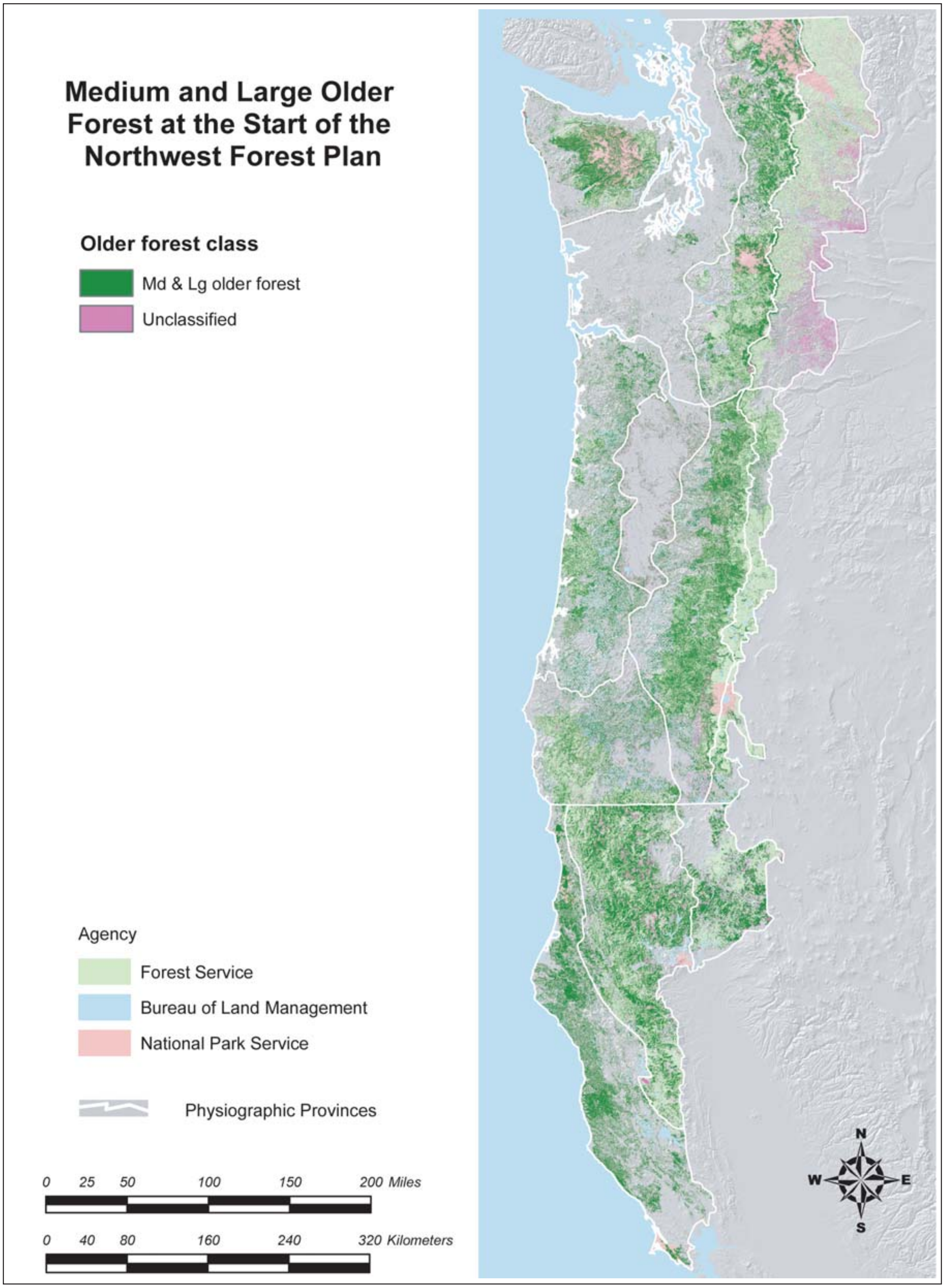


Figure 12a—Older forests at the start of the Northwest Forest Plan mapped in accordance with the "medium and large older forest" definition (minimum 10-percent canopy cover, average tree size ≥20 in, single- or multistoried canopies—classes 11-22 in table 1). Based on IVMP and CALVEG data.

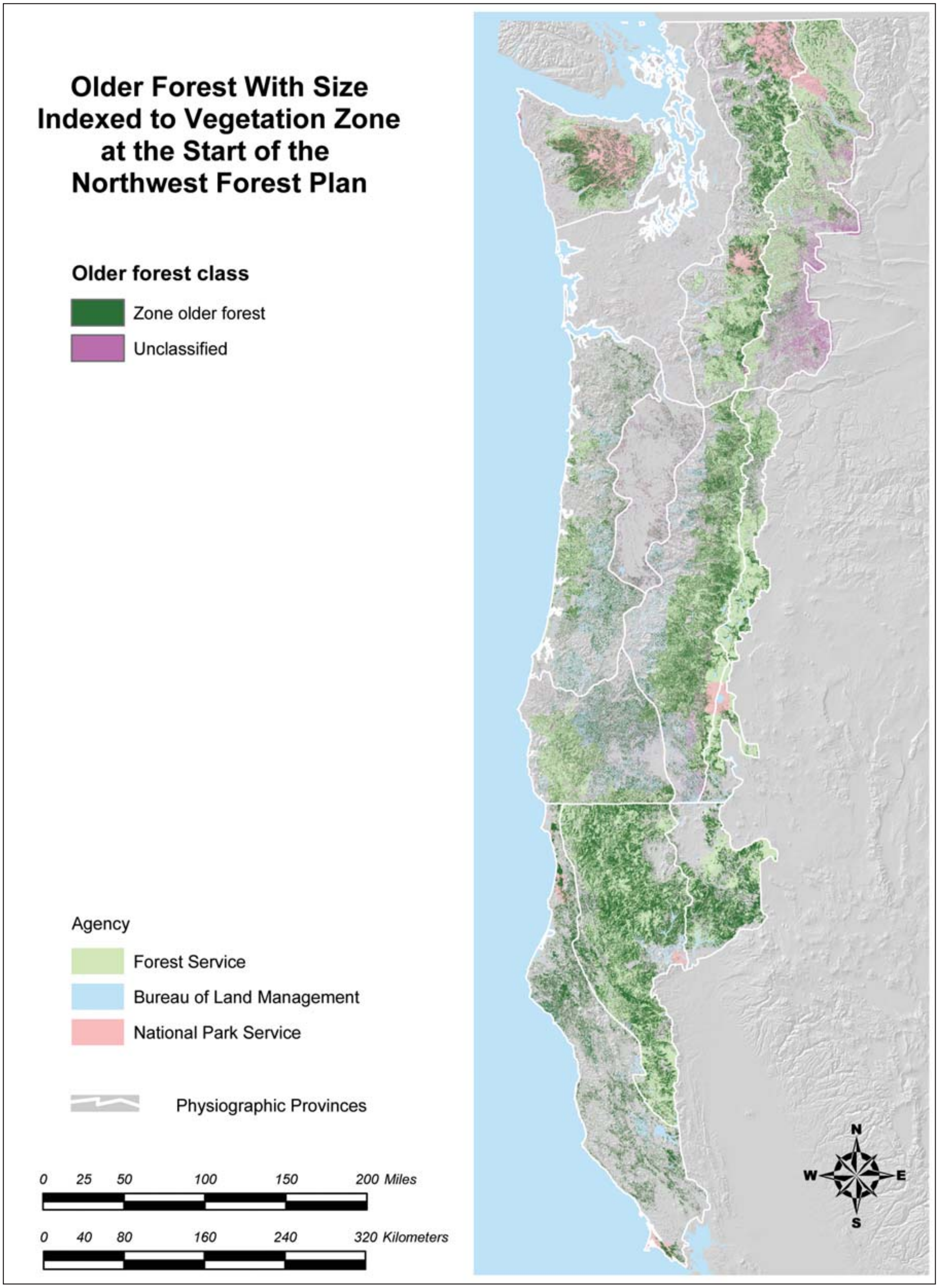


Figure 12b—Older forests at the start of the Northwest Forest Plan mapped in accordance with the "older forest with size indexed to vegetation zone" definition (minimum 10-percent canopy cover, average tree size varies by vegetation zone—see table 3, single- or multistoried canopies). Based on IVMP and CALVEG data.

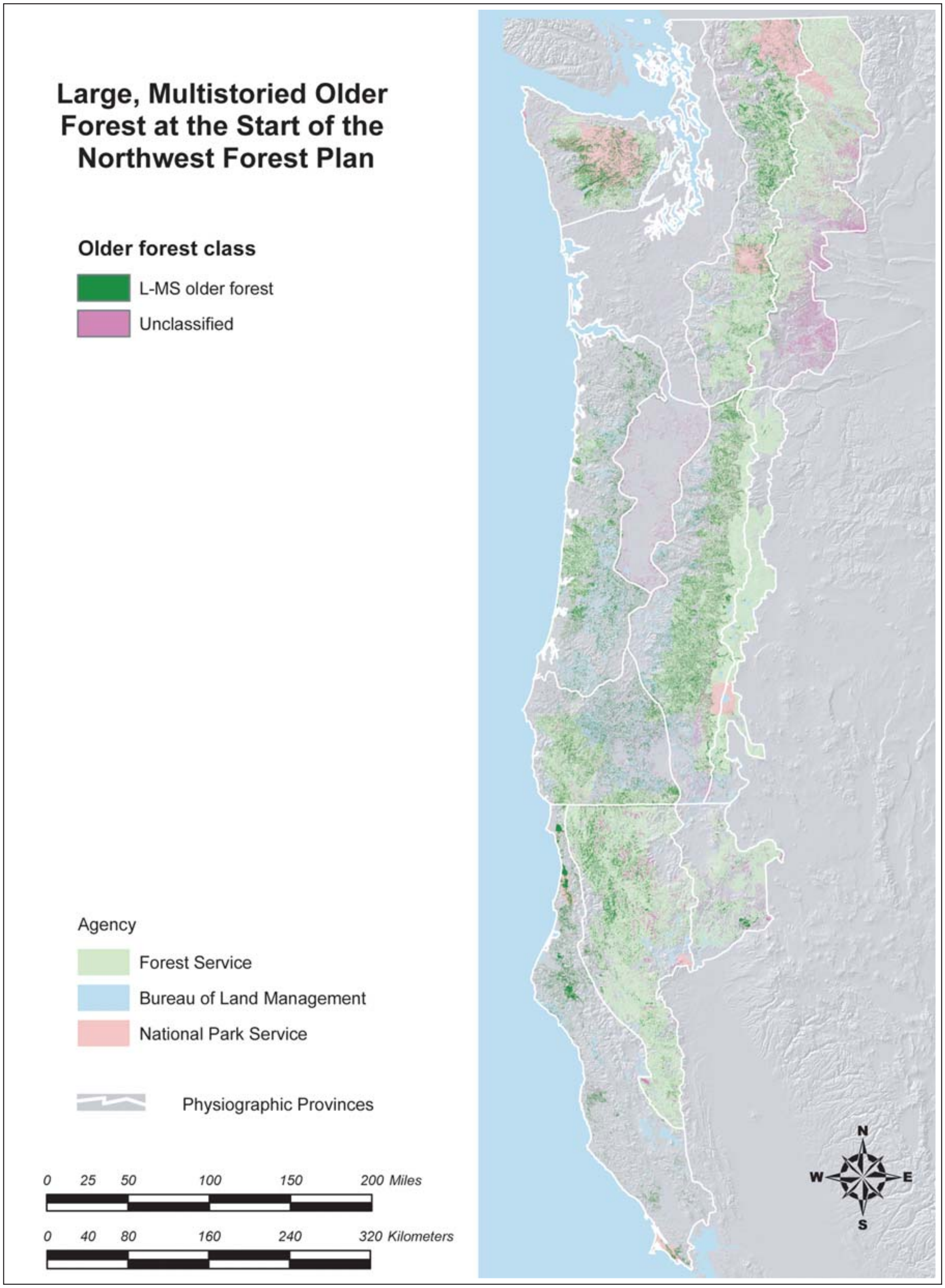


Figure 12c—Older forests at the start of the Northwest Forest Plan mapped in accordance with the "large, multistoried older forest" definition (minimum 10-percent canopy cover, average tree size ≥30 in, multistoried canopy—classes 20-22 in table 1). Based on IVMP and CALVEG data.

Table 11—Percentage of forest-capable areas[a] on federally managed land from map of older forest by definition

	M&L definition		Zone definition		LMS definition	
Province	Total older forest	Blocks >1,000 acres	Total older forest	Blocks >1,000 acres	Total older forest	Blocks >1,000 acres
			Percent			
California						
Cascades	36	23	37	26	2	0
Coast Range	47	29	41	26	21	13
Klamath	43	33	43	34	9	0
Total	42	31	42	32	9	1
Oregon						
Coast Range	37	12	25	4	21	3
Eastern Cascades	15	4	19	9	2	0
Klamath	34	11	26	5	18	1
Western Cascades	44	33	35	24	17	2
Willamette Valley	25	0	15	0	0	0
Total	36	20	29	14	15	1
Washington						
Eastern Cascades	5	0	12	3	0	0
Olympic Peninsula	43	31	33	23	20	6
Western Cascades	38	29	32	23	15	3
Western Lowlands	5	0	1	0	0	0
Total	26	18	24	15	10	2
Northwest Forest Plan	34	22	30	19	12	2
Older forest area	7,867,900 acres		7,038,300 acres		2,722,500 acres	
(± map prediction error)[b]	(5,908,800	9,827,000)	(5,110,300	8,967,600)	(2,374,000	3,070,900)

Note: M& L = medium and large older forest–minimum 10-percent canopy cover, minimum average tree size 20 in (quadratic mean diameter), single- or multistoried canopies.

Zone = older forest with size indexed to vegetation zone–minimum 10-percent canopy cover, minimum average tree size varies by vegetation zone.

L-MS = large, multistoried older forest–minimum 10-percent canopy cover, minimum average tree size 30 in, multistoried canopy.

[a] Total forest-capable acres given in table 4.

[b] Based on map accuracy in table 6.

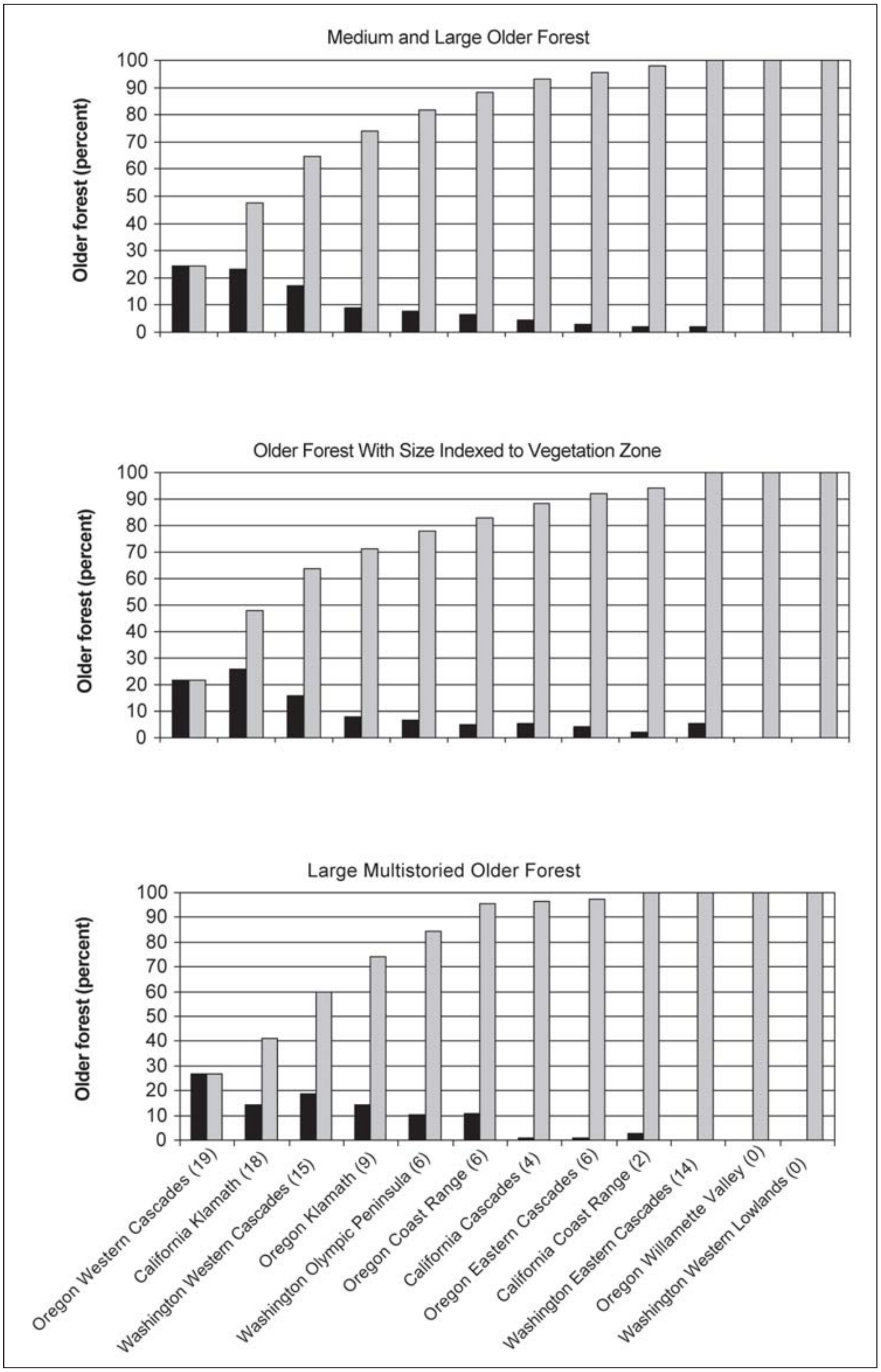


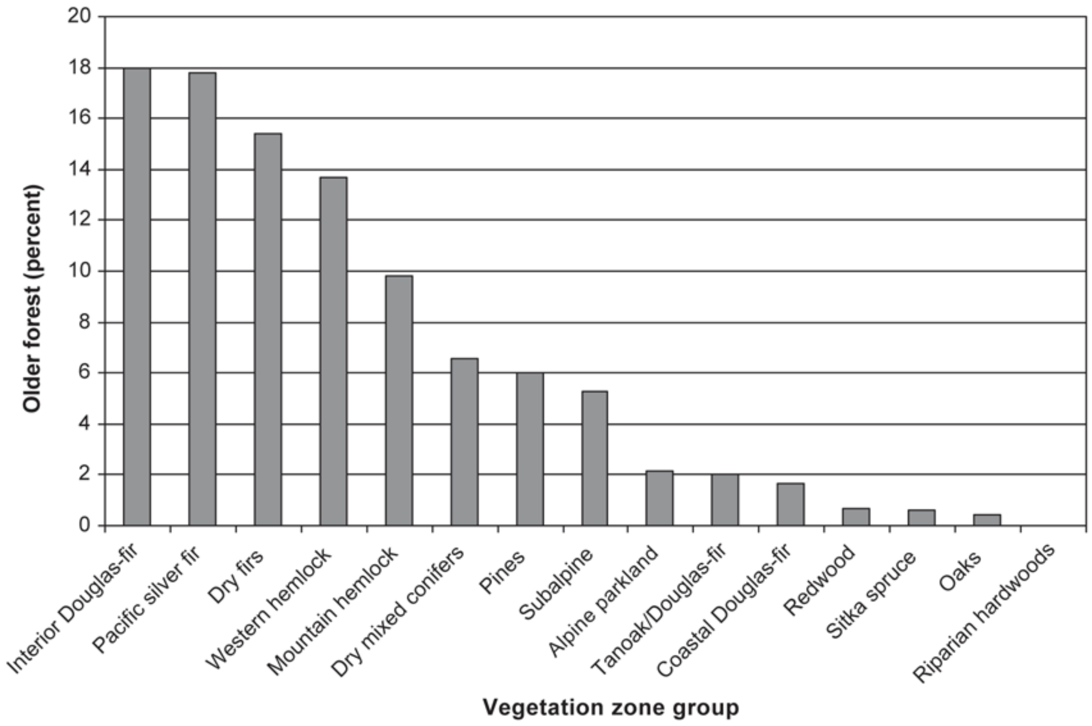
Figure 13—Older forest on federally managed lands at the start of the Northwest Forest Plan. Each chart shows the percentage of total older forest contained within each province (black bars) and cumulative percentage (grey bars). Numbers in parentheses are the percentage of the total federal forest-capable area accounted for by the province. Values were estimated from the map data.

with size indexed to potential natural vegetation zone." The eastern Cascades provinces (Washington Eastern Cascades, Oregon Eastern Cascades, and California Cascades) contained 15 percent of total "older forest with size indexed to potential natural vegetation zone," 9 percent of total "medium and large older forest," and only 2 percent of total "large, multistoried older forest." Of the total older forest acres, there was relatively more "older forest with size indexed to potential natural vegetation zone" than "medium and large older forest" in the Eastern Cascades, and relatively less in the provinces along the Pacific coast and west of the Cascade crest. There was very little federal older forest land in either the Oregon Willamette Valley or ashington Western Lowlands provinces, and thus very little of the total older forest was accounted for in these provinces.

We also examined the distribution across vegetation zone groups (see fig. 4) of total area mapped according to the "older forest with size indexed to potential natural vegetation zone" definition. Interior Douglas-fir and Pacific silver fir zones had the highest proportion of older forests (each with 18 percent of the total) (fig. 14). Older forest in the Douglas-fir zone occurred in every physiographic province but was concentrated in the Klamath provinces, Western Cascades of Oregon, and Coastal California and Oregon (fig. 15). Older forest in the Pacific silver fir zone occurred predominantly in the Western Cascades and Olympic provinces, and to a lesser degree in the Eastern Cascades. The next highest proportions occurred in the dry fir group (grand fir [*Abies grandis* (Dougl. Ex D. Don) Lindl.], white fir [*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.], California red fir [*Abies magnifica* A. Murr.], or Shasta fir [*Abies magnifica* A. Murr. var. *shastensis* Lemm.]), and western hemlock zone, each making up about 15 percent of the total older forest (fig. 14). The western hemlock zone was limited in geographic extent to Washington and Oregon. In those states, older forest occupied large portions of the lowland western hemlock zone in the Oregon Coast and Olympic provinces. Older forest was also extensive in the upland western hemlock zone in the Western Cascades, and in the Eastern Cascades to a smaller extent. Older forest composed a major portion of forest in dry fir types in the Oregon and California Cascades (especially white fir and grand fir) and Klamath (especially white fir and the red firs) provinces. Older forest occupied 10 percent of forests in the mountain hemlock zone, concentrated in the Cascades and Olympic provinces. Older forest occupied less than 10 percent of forest in the remaining vegetation zones.

The relative occurrence of older forest within land use allocation groups (compare table 5) also differed with definition type (fig. 16). There was 29 percent of the total "medium and large older forest" in the matrix group (which, remember, does include an unknown proportion of riparian reserve), and only 24 percent of the total "large, multistoried older forest" in the matrix group. Thus, older forest according to the more restrictive definition ("large, multistoried") occurred in greater proportions in the late-successional reserve land allocations than in the matrix group. There was very little difference between types in the administratively withdrawn/congressionally reserved group. The distribution of older forest with "size indexed to potential natural vegetation zone" was very similar to that for "medium and large" older forest, and is not shown in fig. 16. Planwide, every size and structure class composing "medium and large older forest" occupied a higher proportion of land in reserve allocations than in nonreserve allocations (fig. 17). Conversely, younger forests occupied a greater proportion in nonreserved land than in reserved land allocations.

Within-province older forest map results are summarized in a common set of figures (fig. 18). A key to the format of these figures is included prior to the province results. Each set of charts summarizes the distribution of forest size and structure classes for the province as a whole and by land use allocation group. The four right-hand bars in fig. 18 (labeled M-SS, M-MS, L-SS and L-MS) equate to classes 11-22 in table 1, and the sum of their percentages equals the total percentage of "medium and large" older forest in the province. The rightmost bar (L-MS) equates to classes 20-22 in table 1 and is equivalent to the percentage of "large, multistoried" older forest. Percentage of "older forest with size indexed to potential natural vegetation



Vegetation zone group	Fire-prone	Vegetation zones in group
Interior Douglas-fir	Yes	Douglas-fir (in Klamath and Cascades provinces)
Pacific silver fir	No	Pacific silver fir
Dry firs	Yes	Grand fir, White fir, California red fir, Shasta red fir
Western hemlock	No	Western hemlock
Mountain hemlock	No	Mountain hemlock
Dry mixed conifers	Yes	Shrub-steppe, Mixed conifer, Western juniper
Pines	Yes	Ponderosa pine, Pacific ponderosa pine, interior ponderosa pine, Pacific ponderosa pine/Douglas-fir, Jeffrey pine, lodgepole pine, knobcone pine, western white pine
Subalpine	No	Subalpine fir, California mixed subalpine, whitebark pine
Alpine parkland	No	Parkland-mountain hemlock, parkland-subalpine larch, alpine open
Tanoak/Douglas-fir	Yes	Tanoak, Tanoak/Douglas-fir/Pacific madrone
Coastal Douglas-fir	No	Douglas-fir, Pacific Douglas-fir (in coastal provinces)
Redwood	No	Redwood
Sitka spruce	No	Sitka spruce
Oaks	Yes	California black oak, California coast live oak, canyon live oak, Oregon white oak, gray pine/blue oak
Riparian hardwoods	No	Cottonwood/willow, red alder

Figure 14— Distribution by vegetation zone group of "older forest with size indexed to vegetation zone" on federally managed lands at the start of the Northwest Forest Plan. Values were estimated from the map data.

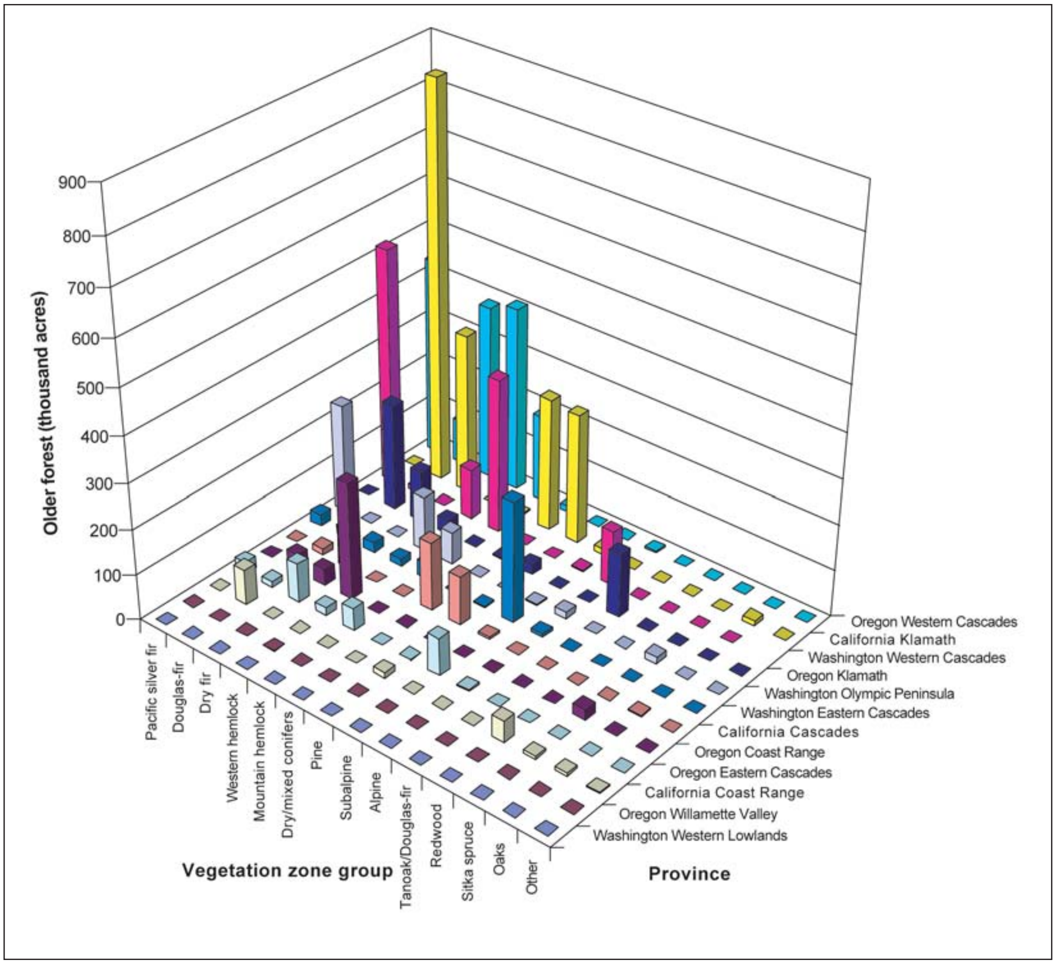


Figure 15—Area of "older forest with size indexed to vegetation zone" at the start of the Northwest Forest Plan. Values were estimated from the map data.

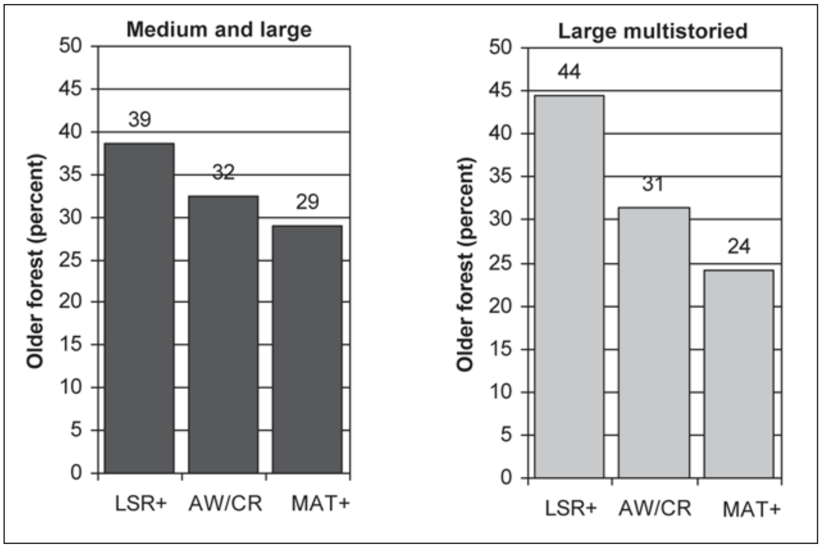


Figure 16—Distribution of total older forest within land allocation groups at the start of the Northwest Forest Plan for "medium and large" and "large, multistoried" older forest. Land allocation group definitions: late-successional reserve group (LSR+); administratively withdrawn/congressionally reserved group (AW/CR), and matrix group (MAT+). See table 5 for individual land use allocations included in groups. Values were estimated from the map data.

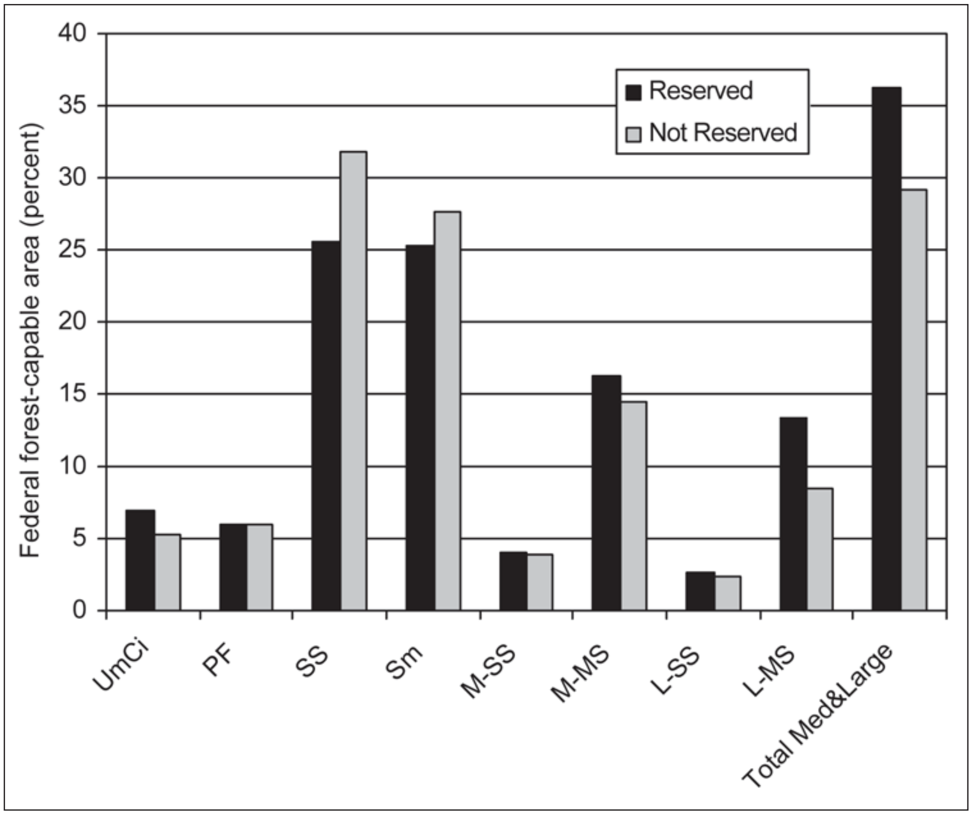


Figure 17—Distribution of federal forest-capable land in the Northwest Forest Plan area by size and structure classes in reserved and nonreserved allocations (table 5). UnCl = unclassified; PF = potential forest (canopy closure <10 percent); SS = seedling/sapling (average tree size <10 in); Sm = small (10≤ average tree size <20 in); M-SS = medium, single-storied (20≤ average tree size <30 in); M-MS = medium, multistoried; L-SS = Large, single-storied (average tree size ≥30 in); L-MS = large, multistoried; Total Med&Large = (M-SS + M-MS + L-SS + L-MS).

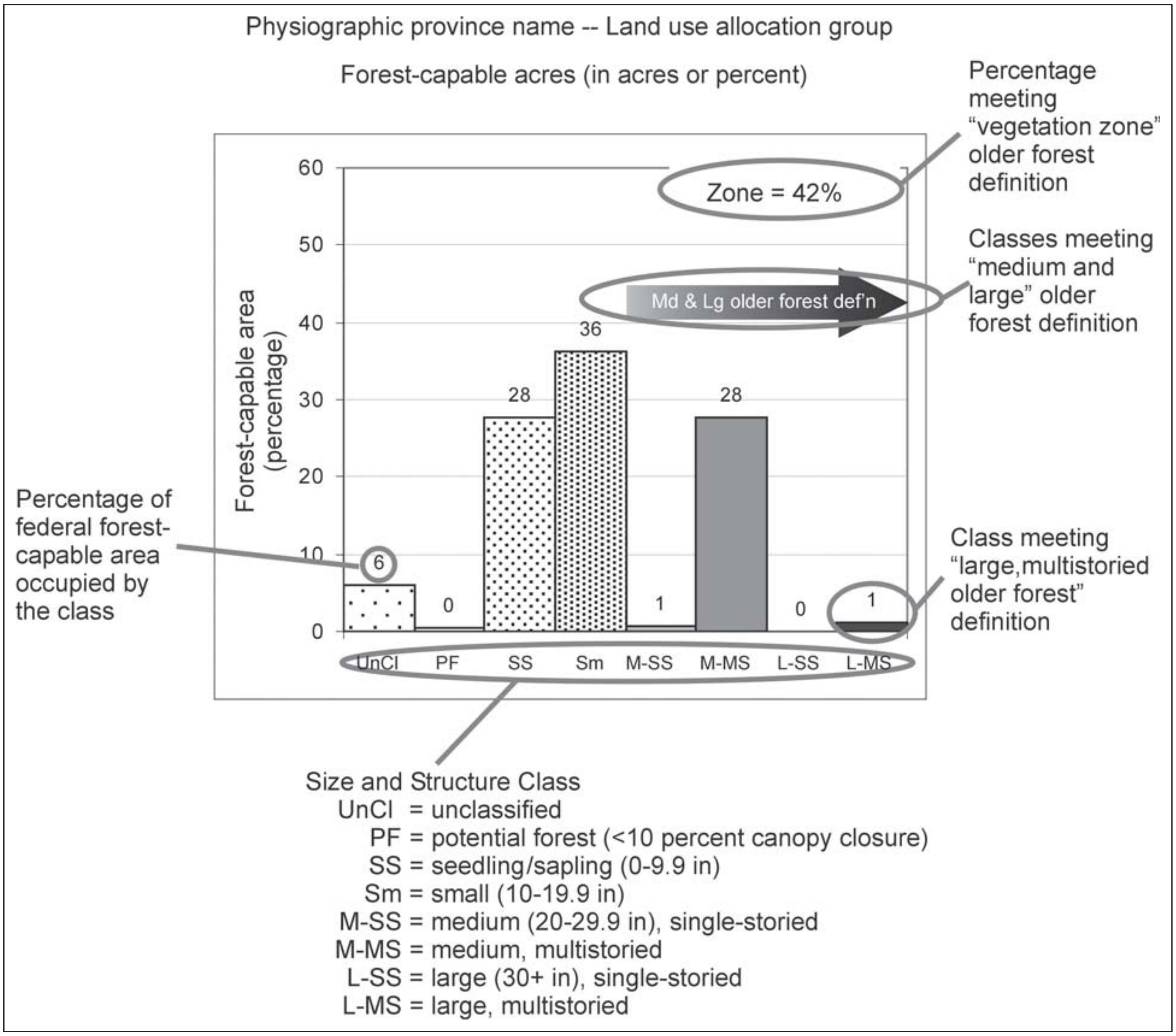


Figure 18a—Key to graphs of percentage of federal forest-capable area occupied by vegetation size and structure classes within physiographic province at the start of the Northwest Forest Plan. Values are estimated from the map data. See table 5 for individual land use allocations included in groups.

California Cascades

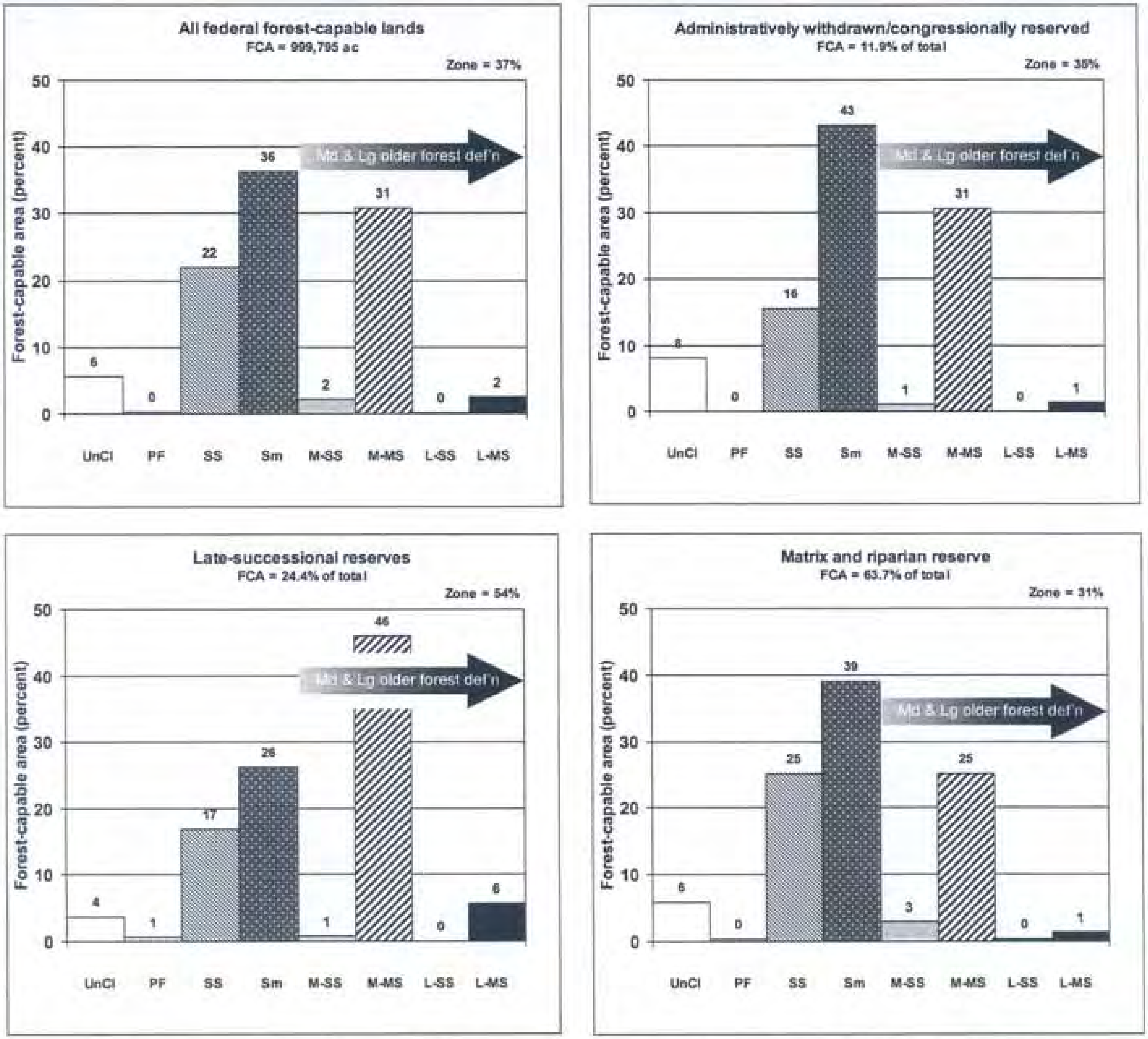


Figure 18b—The percentage of federal forest-capable area occupied by vegetation classes within the California Cascades physiographic province, by land use allocation group. (See fig. 18a for code definitions).

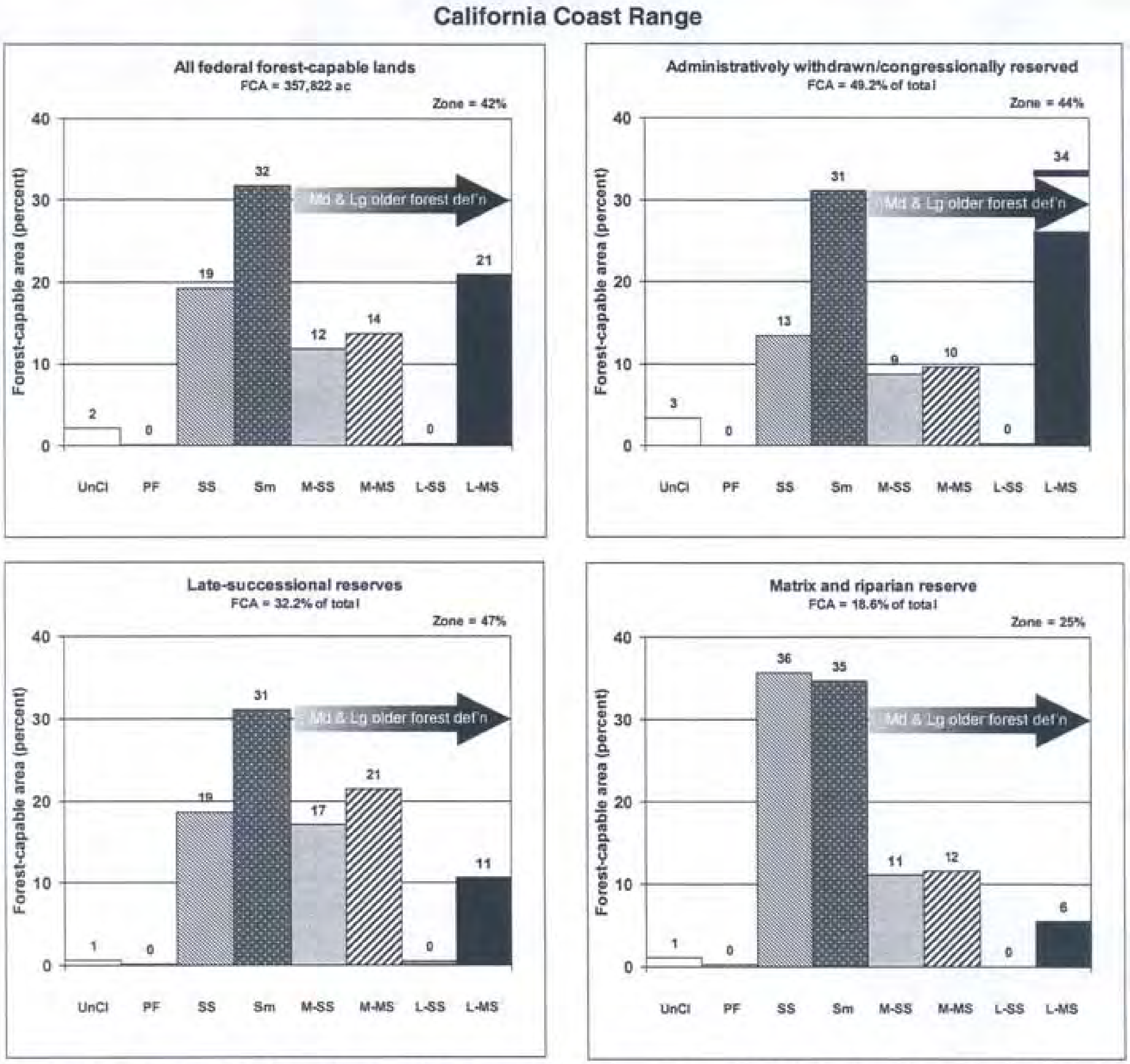


Figure 18c—The percentage of federal forest-capable area occupied by vegetation classes within the California Coast Range physiographic province, by land use allocation group. (See fig. 18a for code definitions).

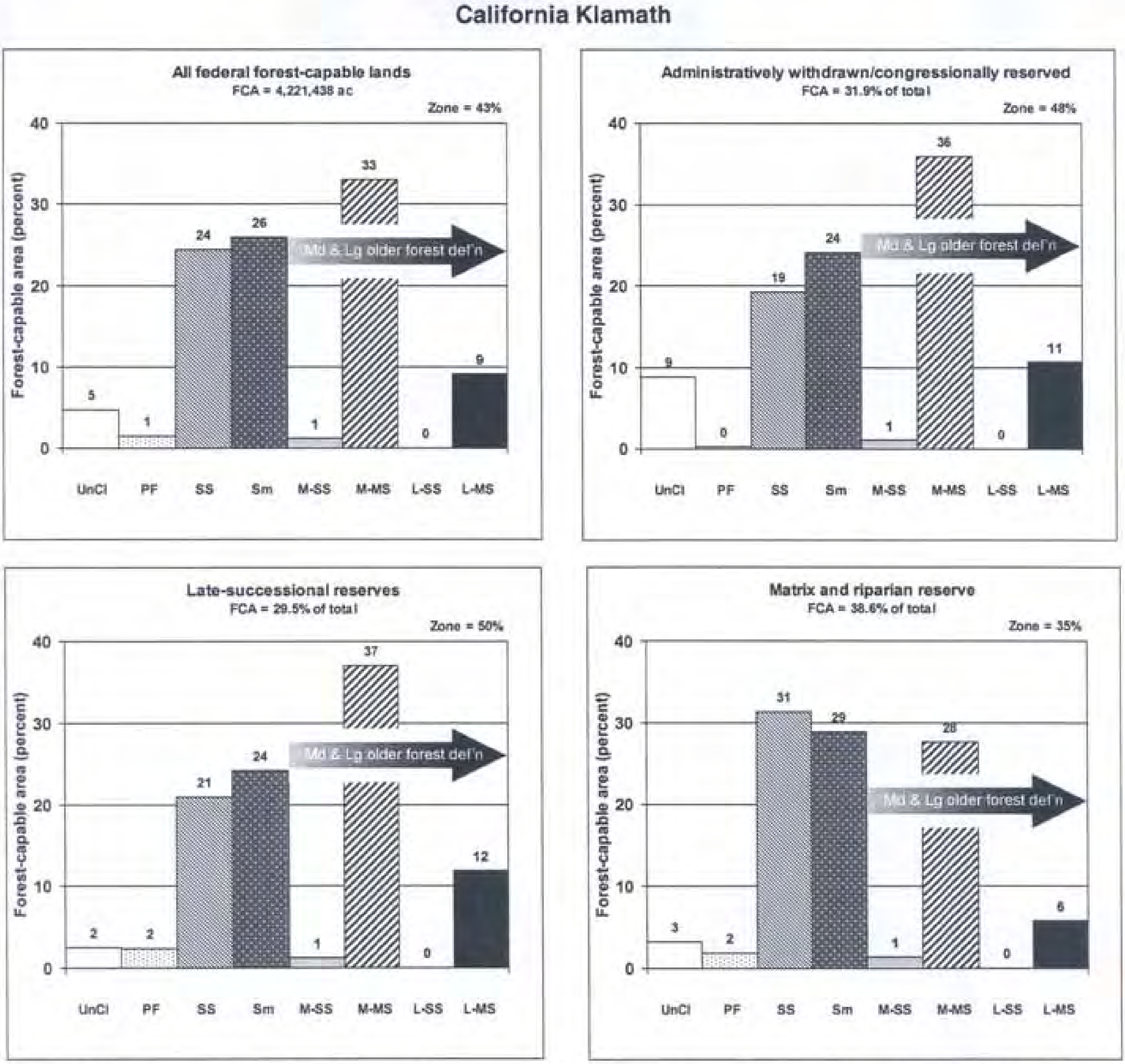


Figure 18d—The percentage of federal forest-capable area occupied by vegetation classes within the California Klamath physiographic province, by land use allocation group. (See fig. 18a for code definitions).

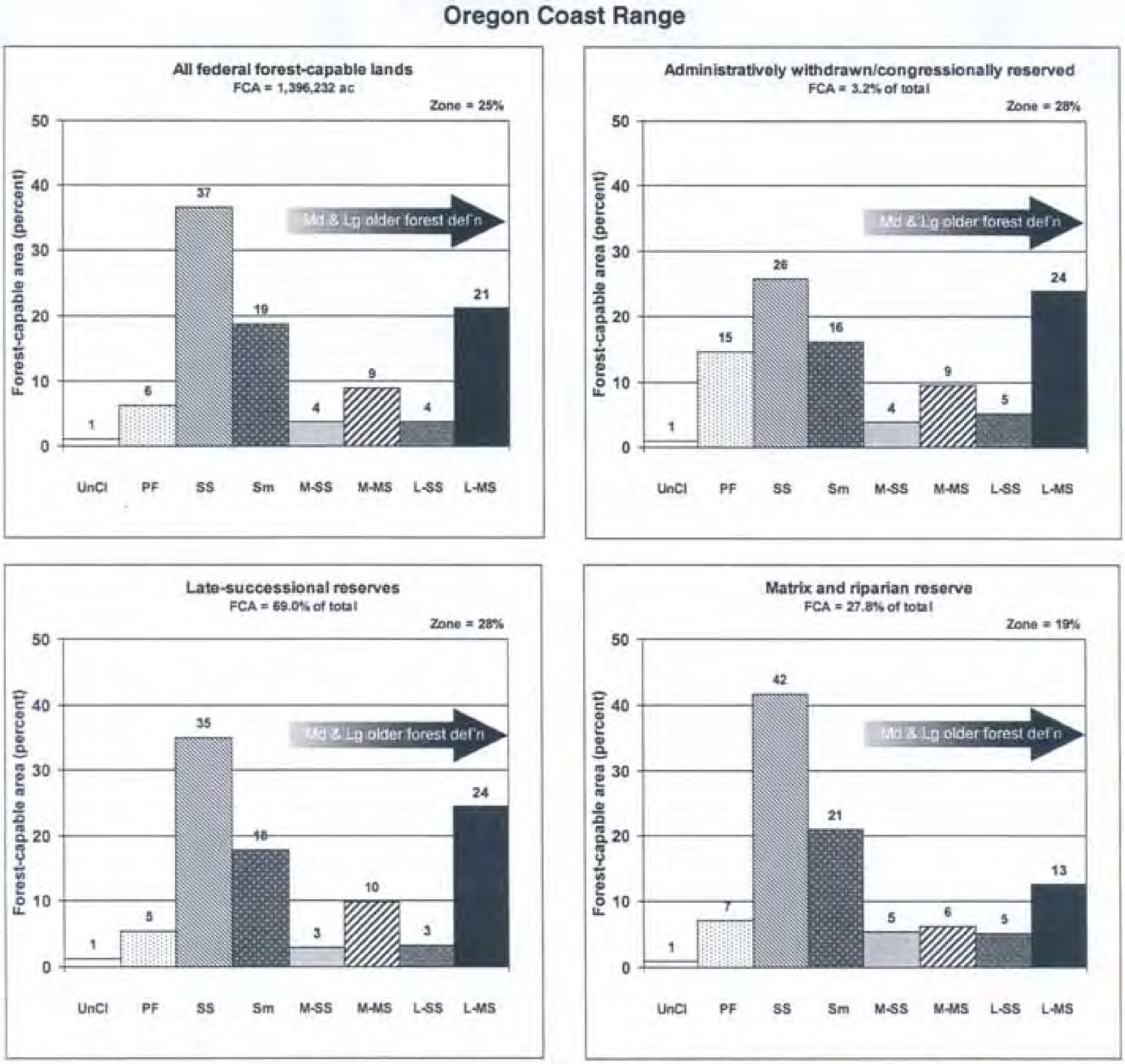
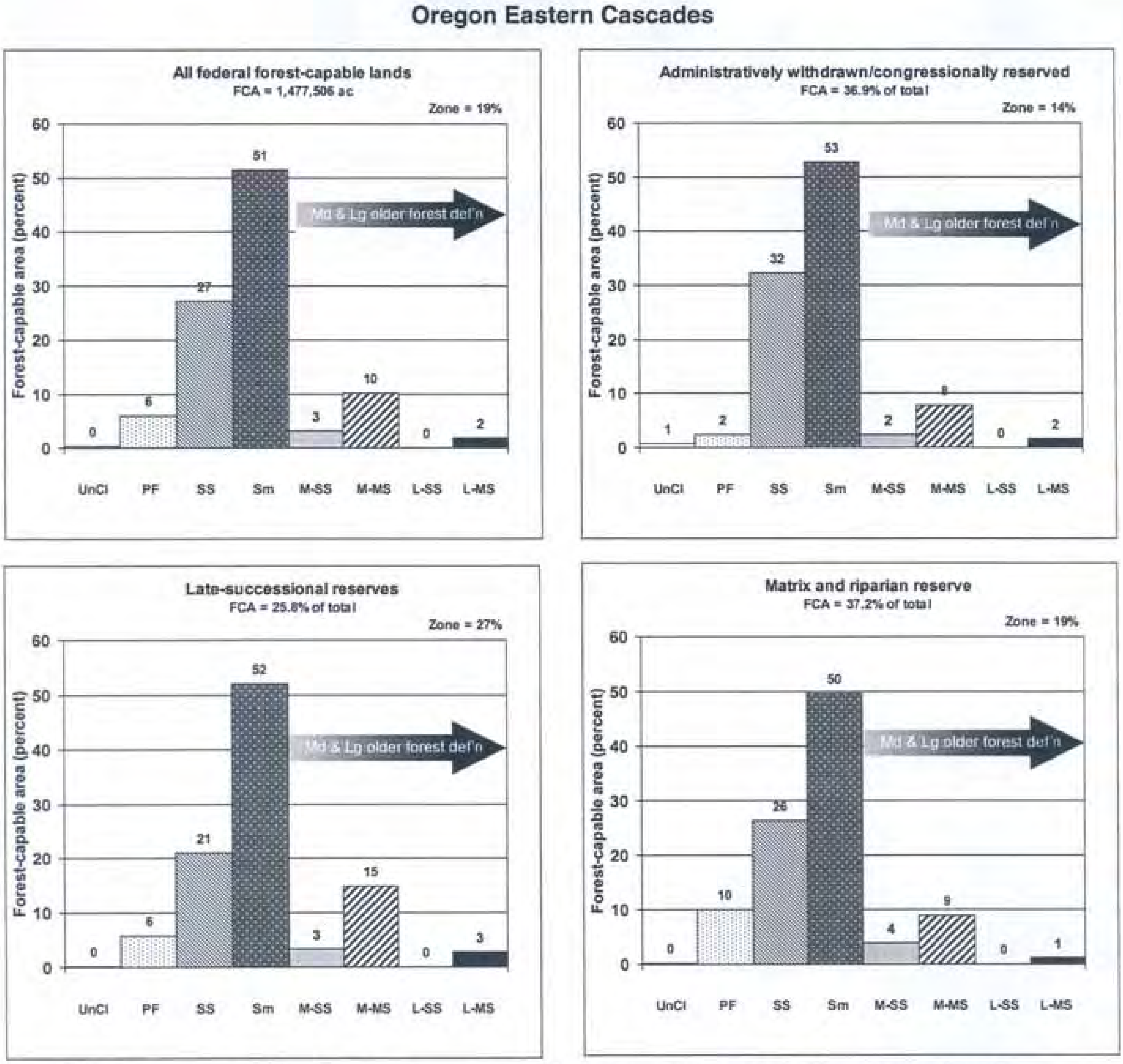


Figure 18e—The percentage of federal forest-capable area occupied by vegetation classes within the Oregon Coast Range physiographic province, by land use allocation group. (See fig. 18a for code definitions).



Oregon Eastern Cascades

All federal forest-capable lands
FCA = 1,477,506 ac
Zone = 19%

Administratively withdrawn/congressionally reserved
FCA = 36.9% of total
Zone = 14%

Late-successional reserves
FCA = 25.8% of total
Zone = 27%

Matrix and riparian reserve
FCA = 37.2% of total
Zone = 19%

Figure 18f—The percentage of federal forest-capable area occupied by vegetation classes within the Oregon Eastern Cascades physiographic province, by land use allocation group. (See fig. 18a for code definitions).

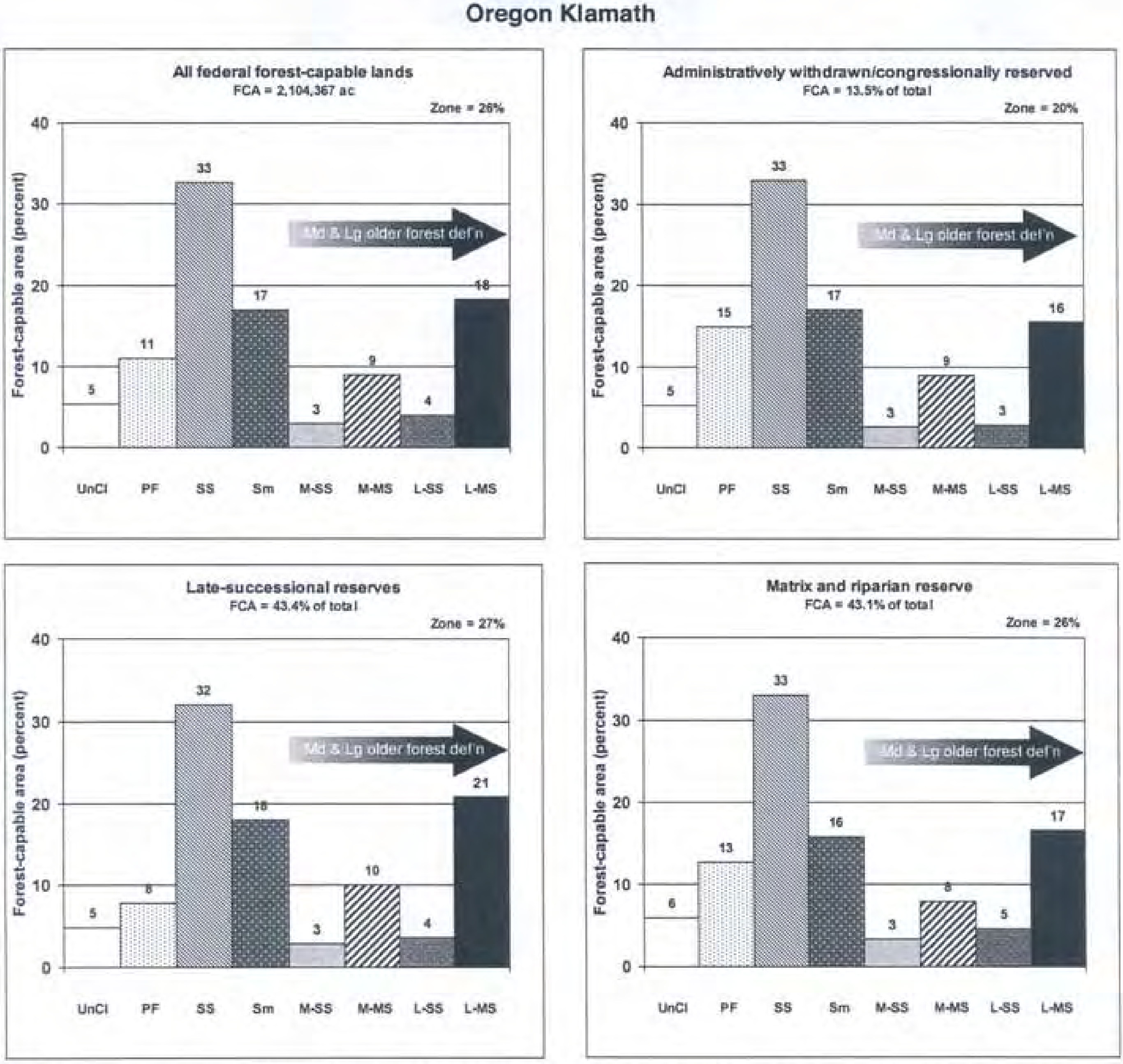


Figure 18g—The percentage of federal forest-capable area occupied by vegetation classes within the Oregon Klamath physiographic province, by land use allocation group. (See fig. 18a for code definitions).

Oregon Western Cascades

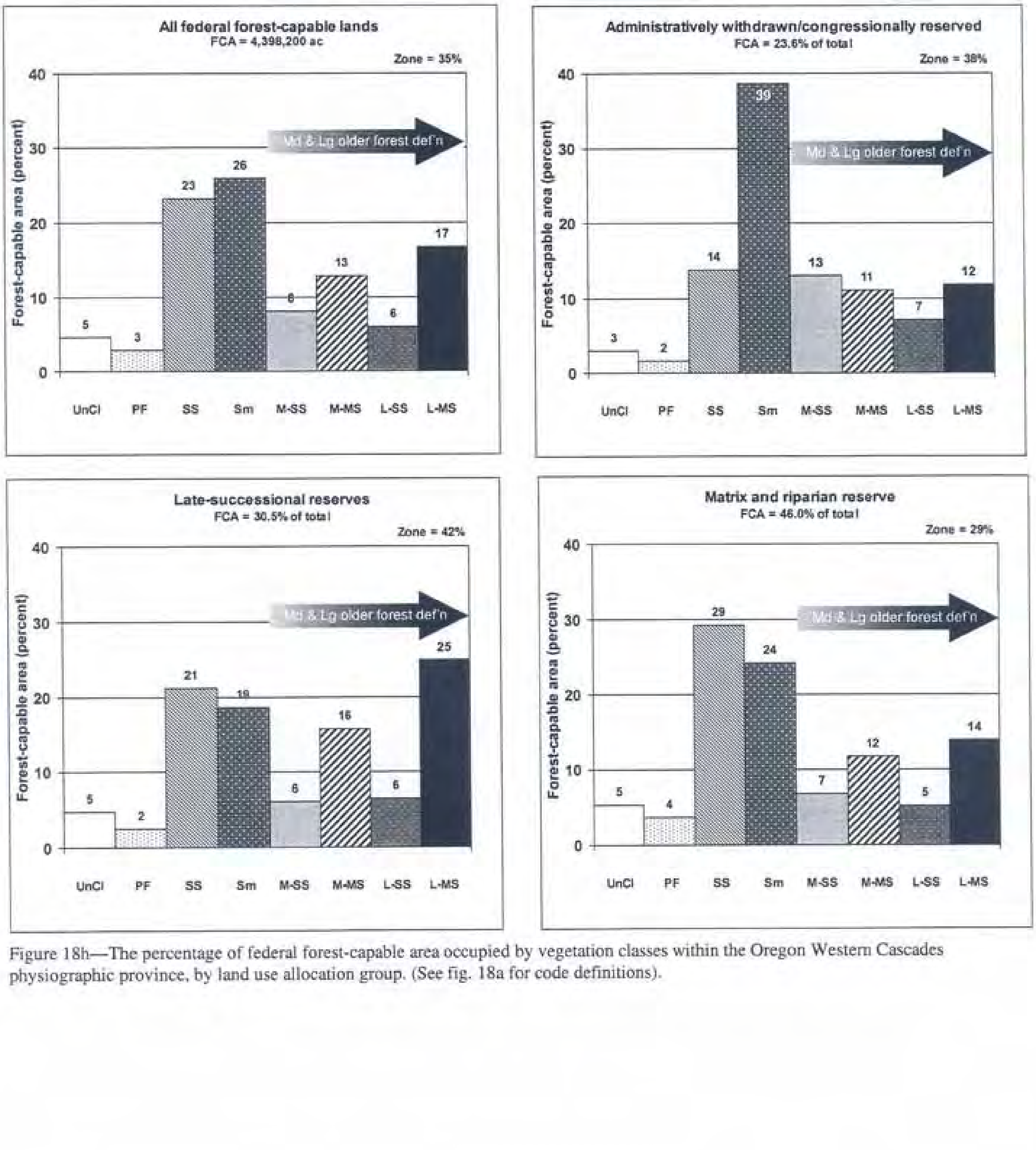


Figure 18h—The percentage of federal forest-capable area occupied by vegetation classes within the Oregon Western Cascades physiographic province, by land use allocation group. (See fig. 18a for code definitions).

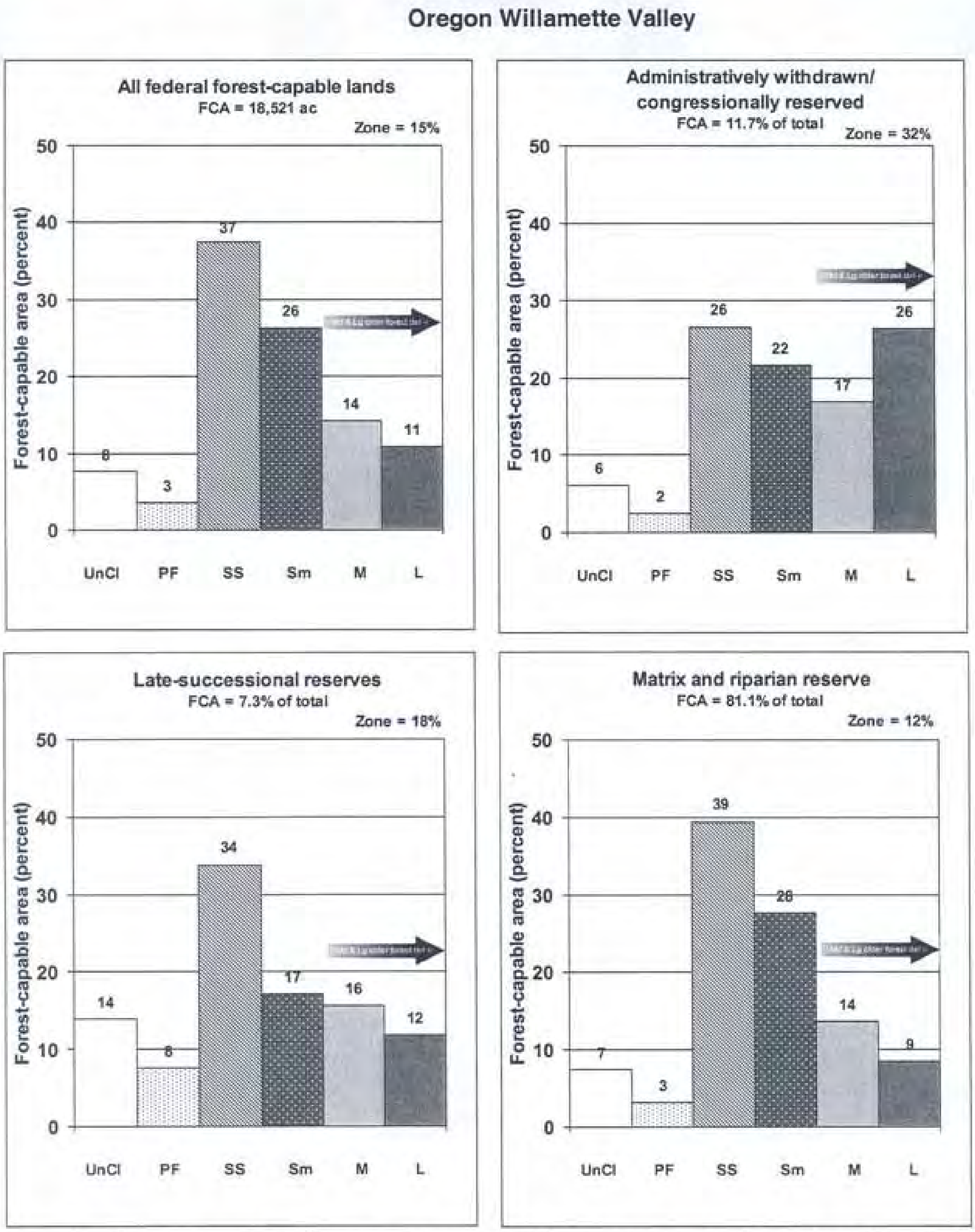


Figure 18i—The percentage of federal forest-capable area occupied by vegetation classes within the Oregon Willamette Valley physiographic province, by land use allocation group. (See fig. 18a for code definitions).

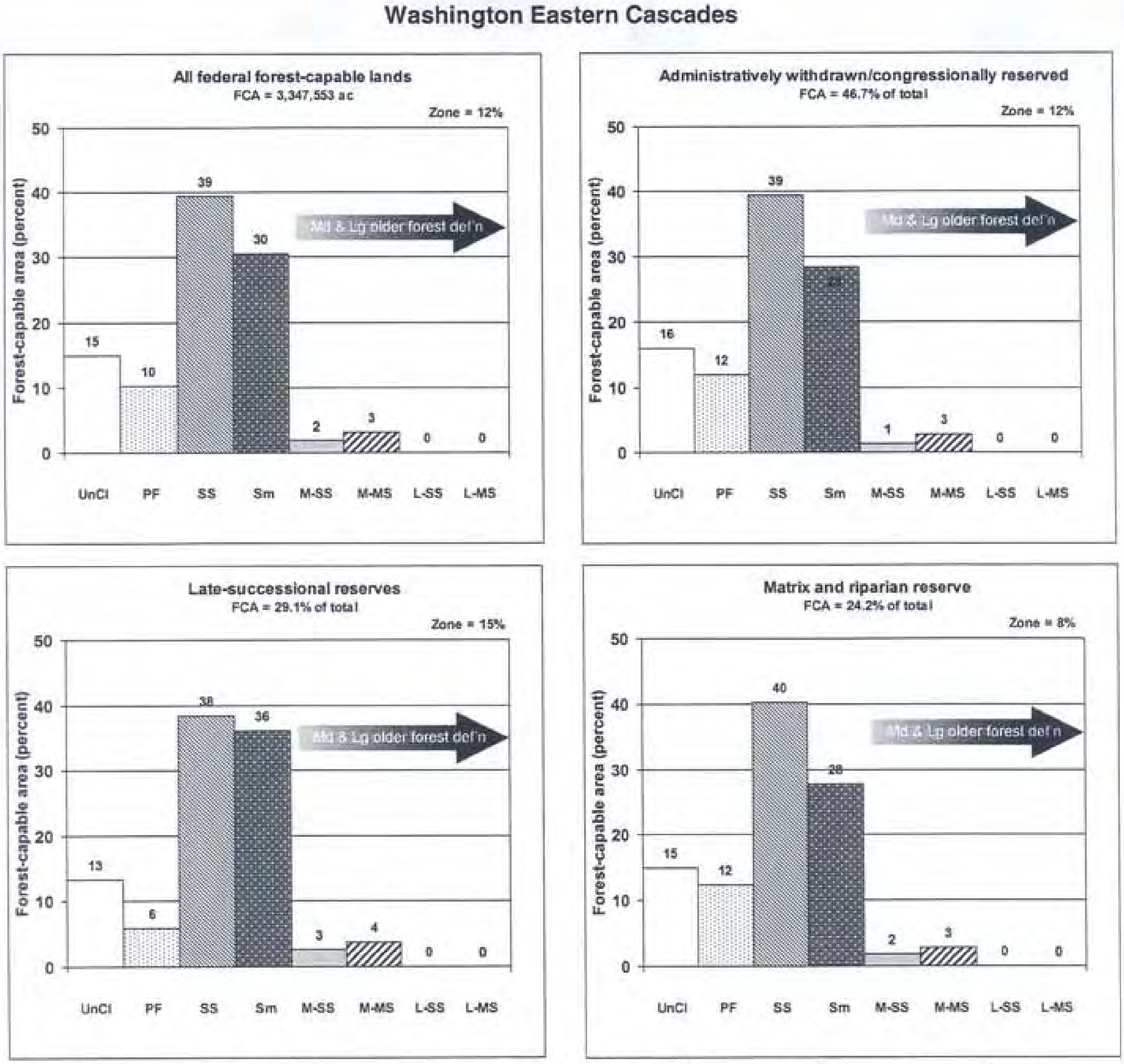


Figure 18j—The percentage of federal forest-capable area occupied by vegetation classes within the Washington Eastern Cascades physiographic province, by land use allocation group. (See fig. 18a for code definitions).

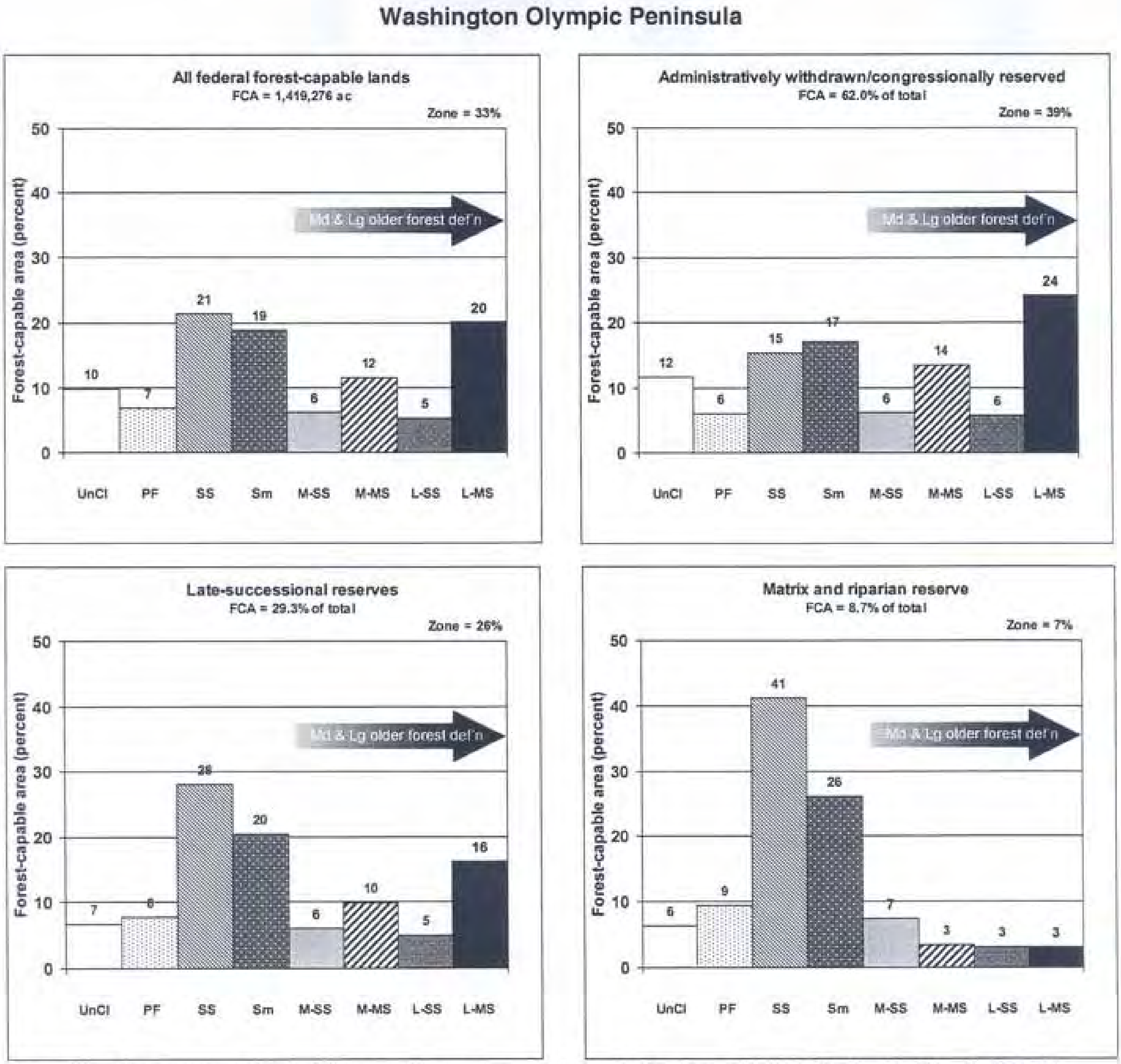
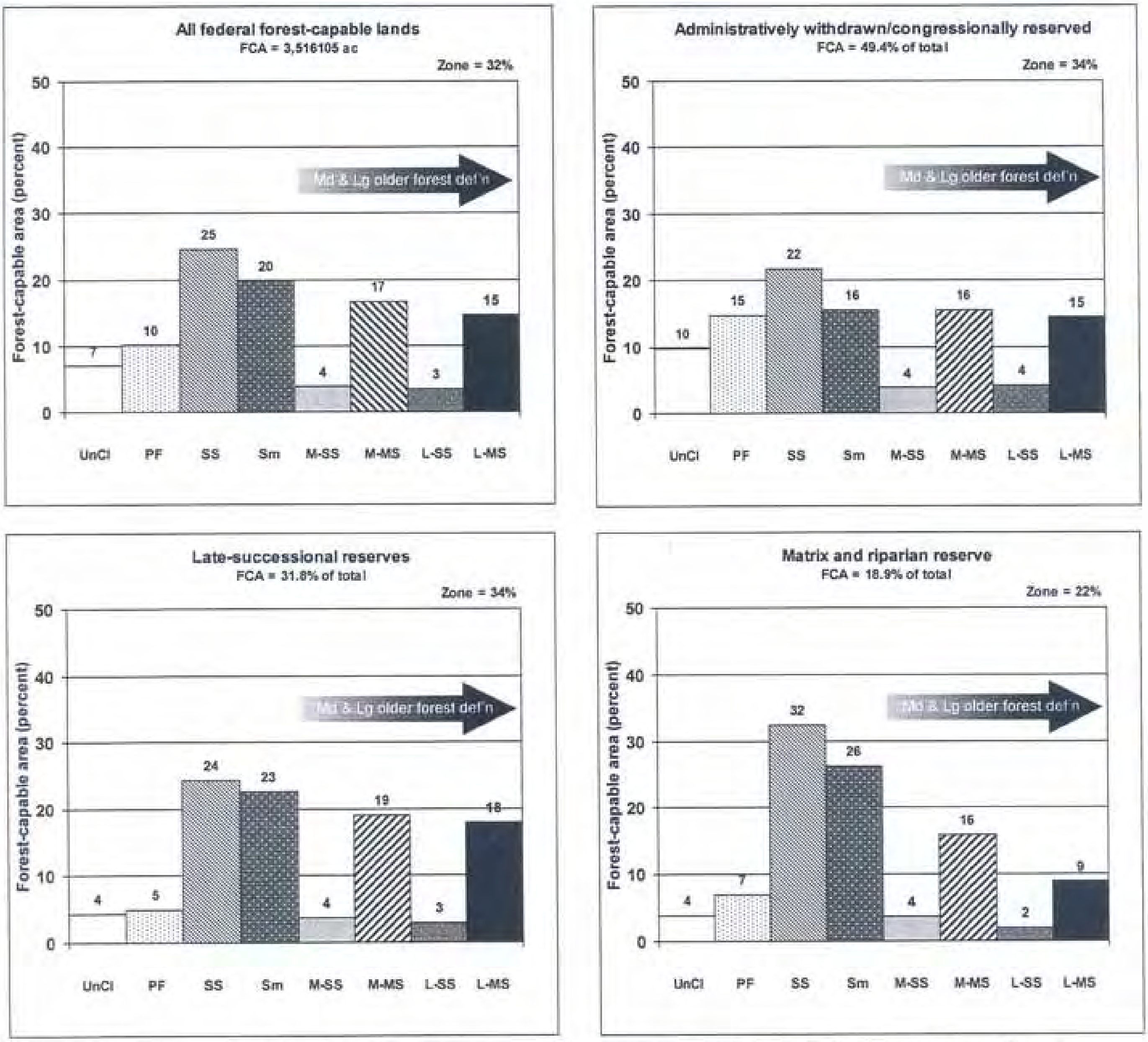


Figure 18k—The percentage of federal forest-capable area occupied by vegetation classes within the Washington Olympic Peninsula physiographic province, by land use allocation group. (See fig. 18a for code definitions).

Washington Western Cascades



All federal forest-capable lands
FCA = 3,516105 ac

Administratively withdrawn/congressionally reserved
FCA = 49.4% of total

Late-successional reserves
FCA = 31.8% of total

Matrix and riparian reserve
FCA = 18.9% of total

Figure 18l—The percentage of federal forest-capable area occupied by vegetation classes within the Washington Western Cascades physiographic province, by land use allocation group. (See fig. 18a for code definitions).

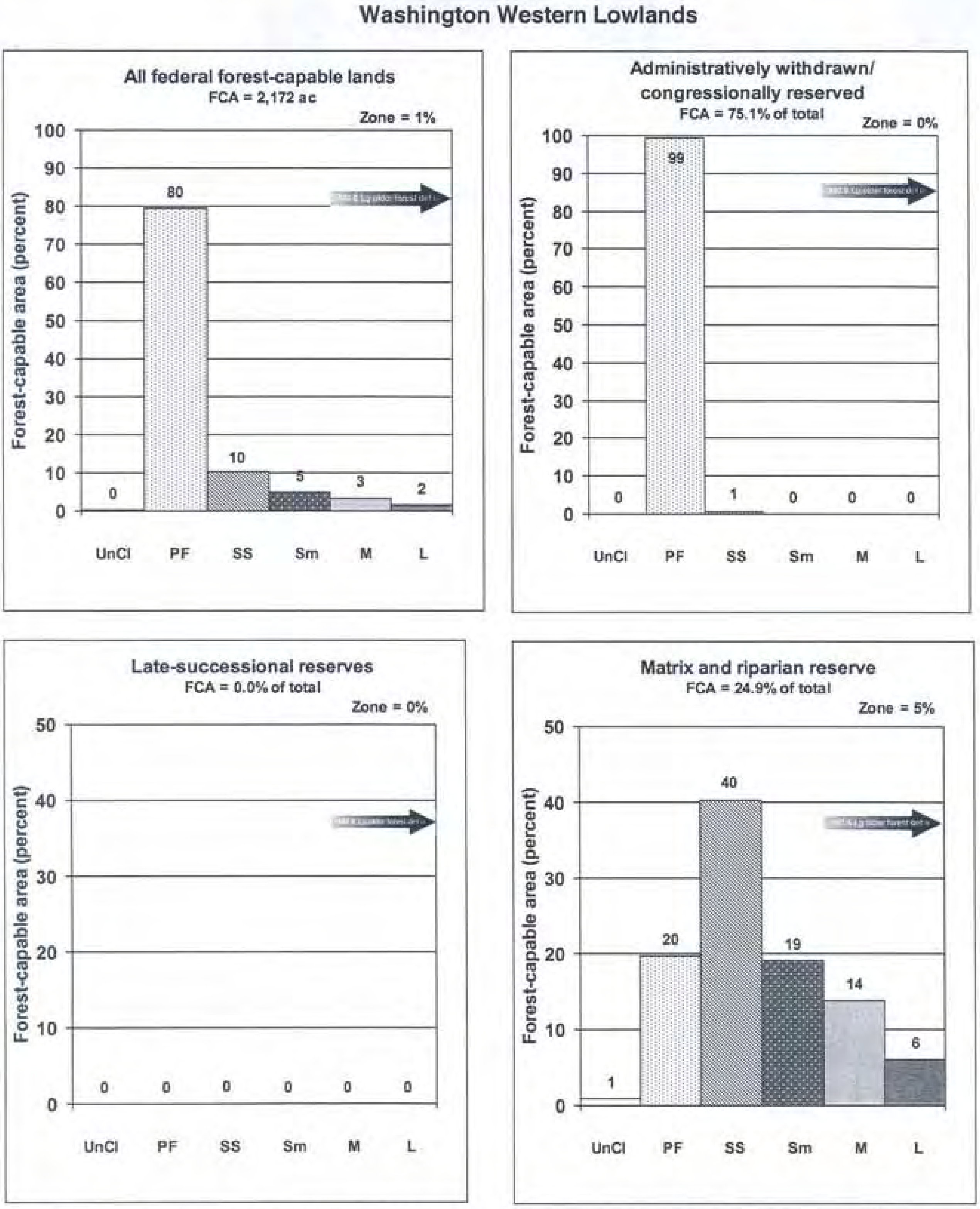


Figure 18m—The percentage of federal forest-capable area occupied by vegetation classes within the Washington Western Lowlands physiographic province, by land use allocation group. (See fig. 18a for code definitions).

zone" is reported in the upper right-hand corner of each chart in figure 18. Note that in each chart, a small proportion of acres are shown as "unclassified." This number represents forest-capable land for which the thematic data required for classification of a map unit was missing, as discussed previously in the section titled, "Classification of Existing Vegetation." For example, there were always a small number of IVMP pixels or CALVEG polygons in which average tree size could not be reliably modeled. As a result, these pixels or polygons could not be assigned to a vegetation size class. The amount ranged from none of the landscape in Oregon Eastern Cascades, to 15 percent of the landscape in Washington Eastern Cascades.

Although generalizing the results across physiographic provinces is somewhat difficult, there are interesting patterns shown in figure 18. For example, multistoried classes (labeled M-MS and L-MS) constituted most of the "medium and large" older forest in most provinces. In the coastal provinces (California Coast Range, Oregon Coast Range, Oregon Klamath, and Washington Olympic Peninsula), the large, multistoried class (L-MS) tended to dominate the older forest classes. With respect to land use allocation groups (see table 5), generally the province charts verified that there was a higher proportion of older forest in reserve group allocations than in nonreserve group allocations in every province. Younger forests (those in seedling/sapling (SS) and small (Sm) classes tended to occupy a larger proportion in the matrix group than in the fragmented administratively withdrawn/congressionally reserved or late-successional reserves groups. Still, "medium and large older forest" occupied nearly one-third of forest-capable area in the matrix group in several provinces. The provinces with the highest proportion of "medium and large older forest" in matrix group lands were Oregon Western Cascades (38 percent), California Klamath (35 percent), Oregon Klamath (33 percent), and Washington Western Cascades (31 percent). California Cascades, California Coast Range, and Oregon Coast Range followed closely, with 29 percent of federal forest-capable area in "medium and large older forest." The eastern Cascades provinces in Washington and Oregon each contained about the same percentage of "medium and large older forest" in the nonreserve allocations as in the reserve allocations. The Olympic province had a much lower percentage of "medium and large older forest" allocated to the nonreserve class (16 percent) than the reserve classes (43 percent).

Table 12 shows the acres of land and percentage of area occupied by "medium and large older forest" on Department of Defense and Fish and Wildlife Service lands within the Plan area. Together, these lands account for less than seven-tenths of a percent of the federal land base, and contain an estimated 30,700 ac of "medium and large older forest." Because these lands are not covered by the Plan, they are not discussed further in this report.

Older Forest Statistical Estimates

Figure 19 displays the acres of older forest estimated from inventory plot data for the three older forest definitions. The values are smaller than the values reported from the map analysis because they reflect only sampled areas on Forest Service-Region 5, Forest Service-Region 6, and Bureau of Land Management-Oregon lands. The estimates do not include older forests on National Park Service or Bureau of Land Management-California lands, because we did not have sample data from these lands.

Relative amounts of older forest estimated from plot data were consistent with relative amounts estimated from the map analyses (compare fig. 20, 'ALL' category, with fig. 13). Differences generally were accounted for by the differences in the populations represented by the two estimates. For example, because Park Service lands (which have a congressionally reserved land use allocation) were not represented in the inventory sample, the plot versus map estimates for the land allocation group labeled, "administratively withdrawn/congressionally reserved," were quite different in provinces with a large proportion of Park Service lands.

For the "medium and large older forest" definition, we compared estimates of older forest amounts made from the plot data versus the map data for the lands represented by

Table 12—Forest-capable area of land managed by Department of Defense and Fish and Wildlife Service and portion that is medium and large older forest

	Department of Defense			Fish & Wildlife Service		
Province	**Total**	**Older forest**		**Total**	**Older forest**	
	Acres	*Acres*	*Percent*	*Acres*	*Acres*	*Percent*
California Coast Range	22,300	1,800	8.1	100	0	0.0
Oregon Coast Range	700	100	14.3	0	0	0
Oregon Western Cascades	0	0	0	100	0	0.0
Oregon Willamette Valley	0	0	0	19,100	1,000	5.2
Washington Eastern Cascades	0	0	0	6,900	200	2.9
Washington Olympic Peninsula	0	0	0	100	0	0.0
Washington Western Cascades	100	0	0.0	600	100	16.7
Washington Western Lowlands	110,300	27,100	24.6	8,100	200	2.5
Northwest Forest Plan	133,400	29,000	21.7	35,000	1,500	4.3

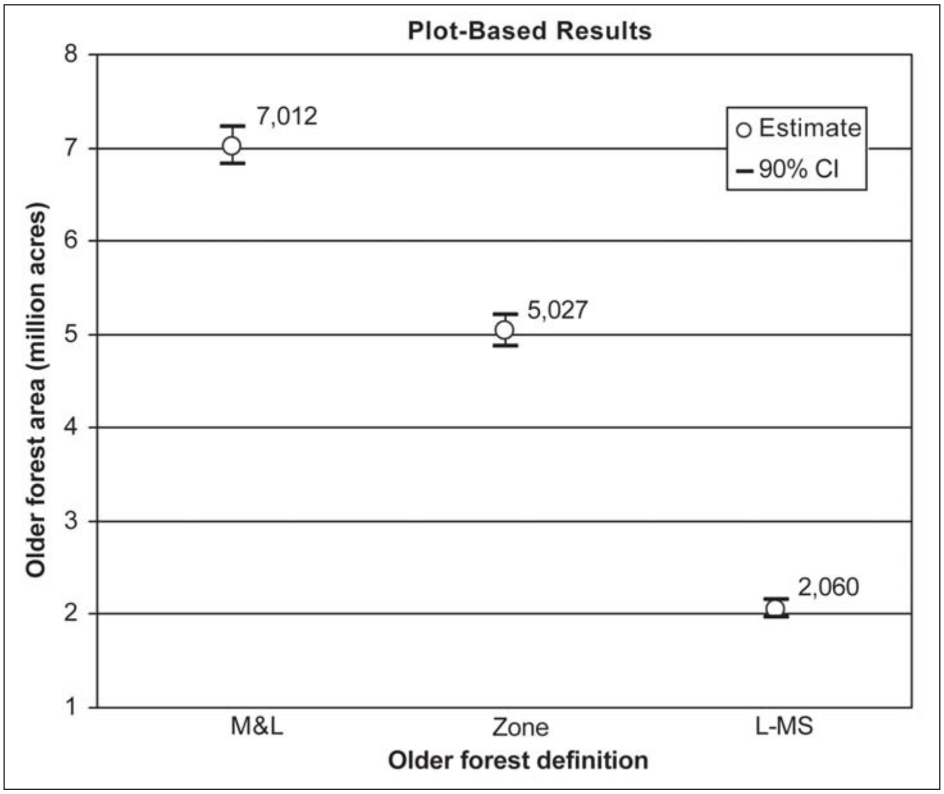


Figure 19—Area of older forest estimated from inventory plot data at the start of the Northwest Forest Plan.The values are smaller than those reported from the map analysis because they reflect only sampled areas of Forest Service-Region 5, Forest Service-Region 6, and Bureau of Land Management-Oregon lands. The estimates do not include National Park Service or Bureau of Land Management-California lands. Bootstrapped confidence intervals were estimated from 40,995 individual sample points. Older forest definitions: M&L = medium and large older forest; Zone = older forest with size indexed to vegetation zone; L-MS = large, multistoried older forest.

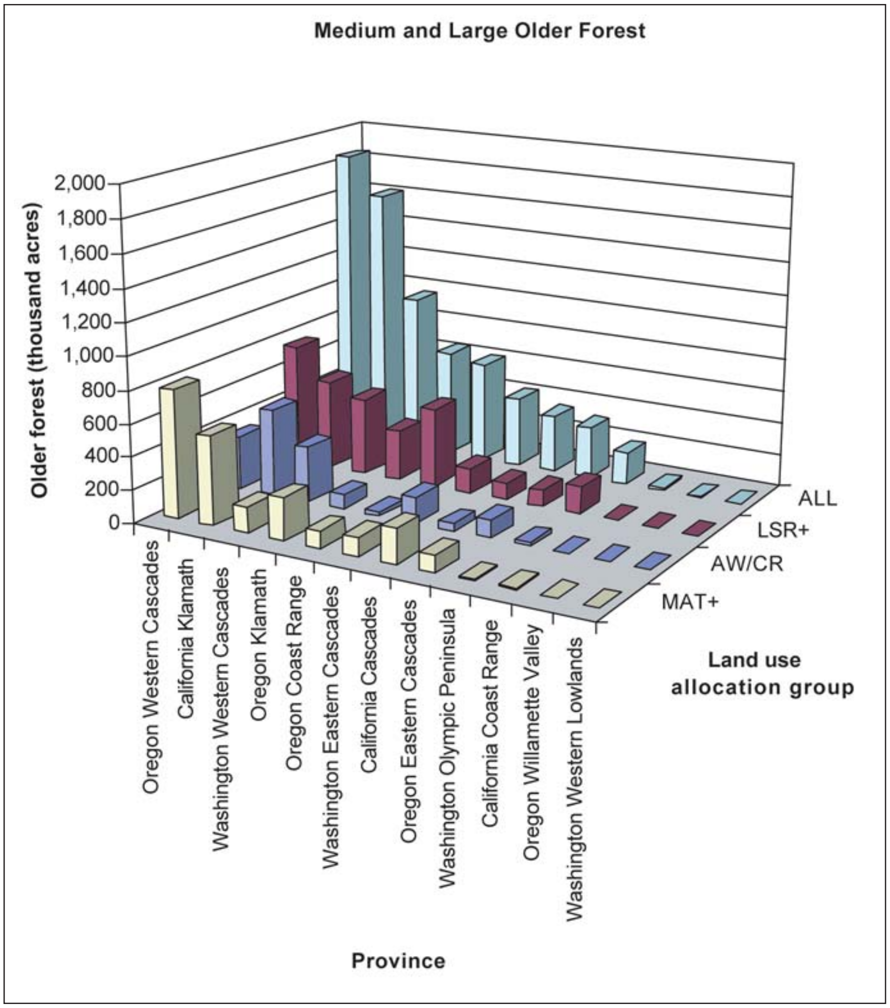


Figure 20a—Area of older forest by province and land allocation group estimated from inventory plot data. Results represent sampled areas only on lands administered by Forest Service-Region 6, Forest Service-Region 5, and Bureau of Land Management-Oregon. LSR+ = late-successional reserve group, AW/CR = administratively withdrawn/congressionally reserved group, MAT+ = matrix group, ALL = all allocations combined. See table 5 for individual land use allocations included in groups.

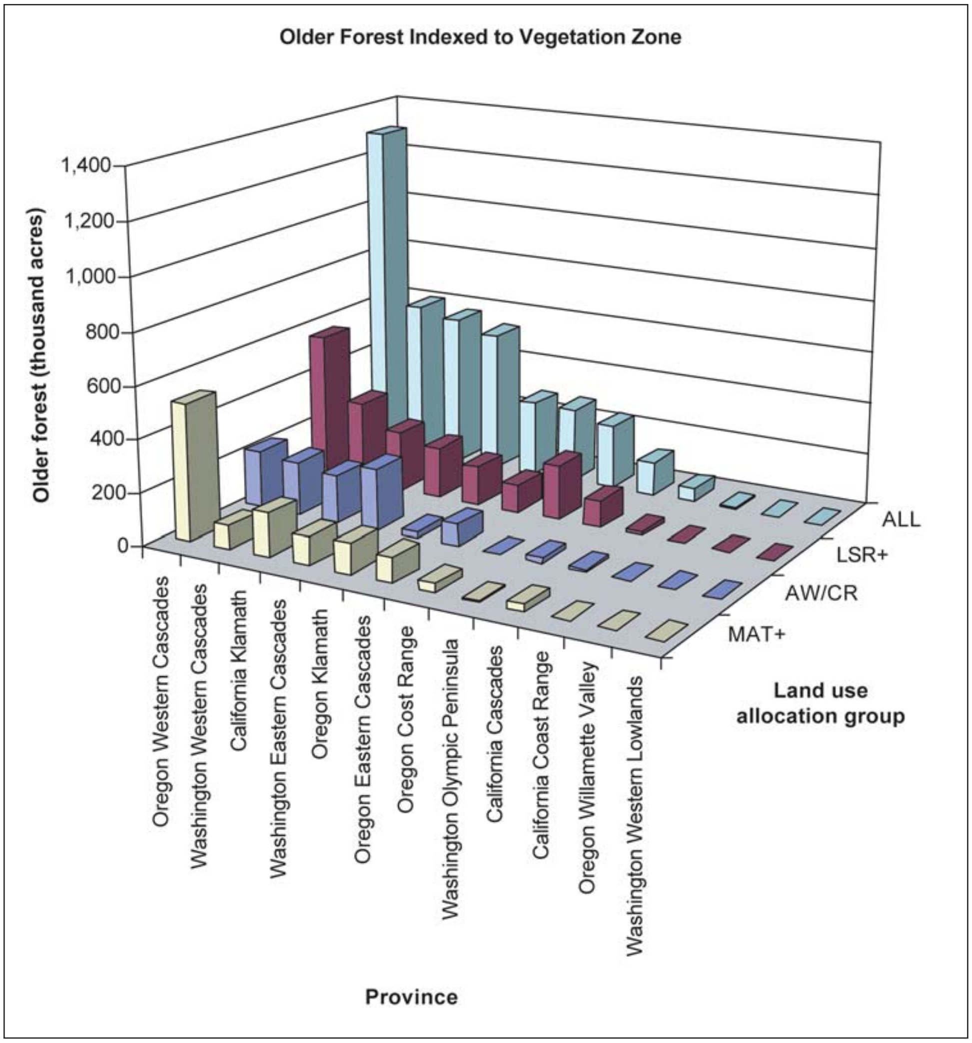


Figure 20b—“Older forest with size indexed to vegetation zone” definition.

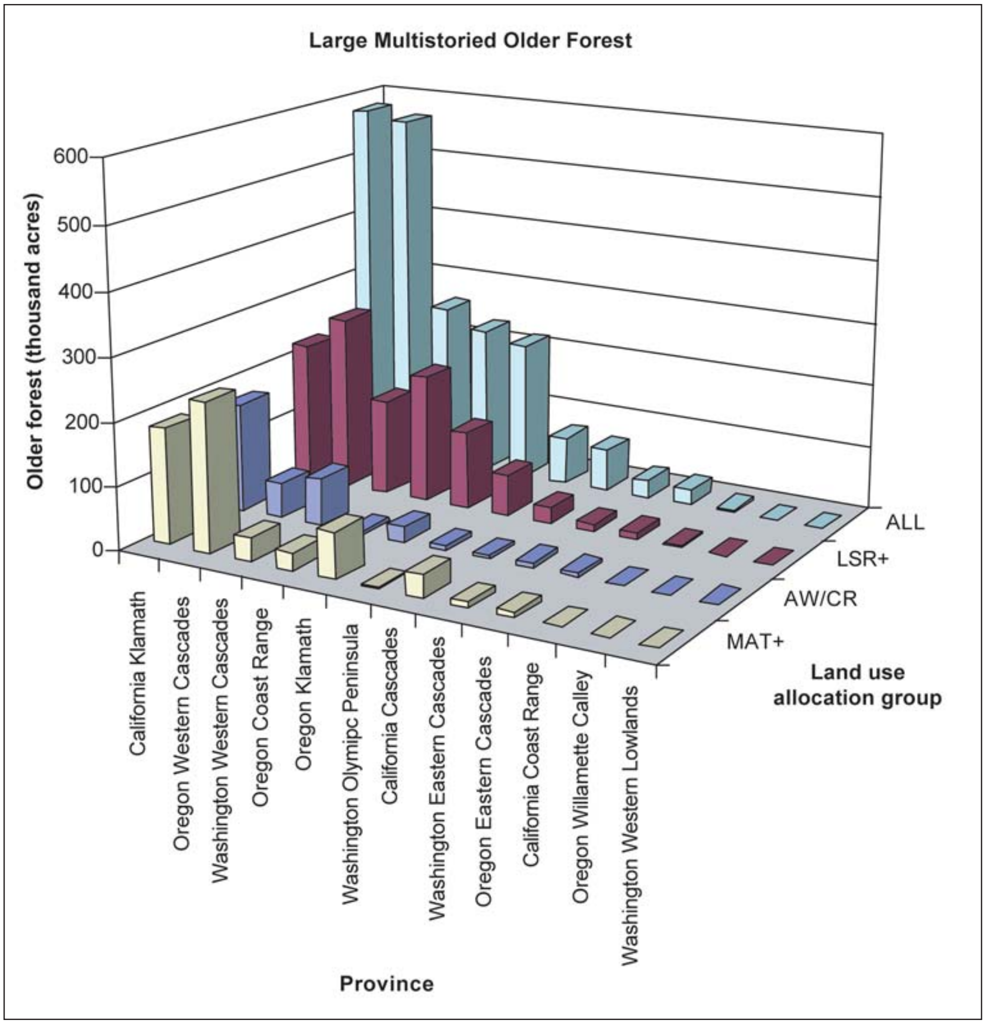


Figure 20c—"Large, multistoried older forest" definition.

inventory plots. Comparison of exact estimates derived from map analysis and plot analysis was a bit of apples and oranges, because the land base in the two estimates was not strictly comparable. The statistical estimates represented an unbiased estimate of acreages for the sampled lands (National Park Service and Bureau of Land Management-California are not included in the statistical estimates). The maps covered all ownerships within the Plan area, but their accuracy was more difficult to quantify. There was good temporal correspondence between the map and plot data. That is, the map was created from satellite imagery collected between 1992 and 1996 (table 10), and the statistical

Large snags and complex canopy layering in an old-growth western hemlock/Douglas-fir forest

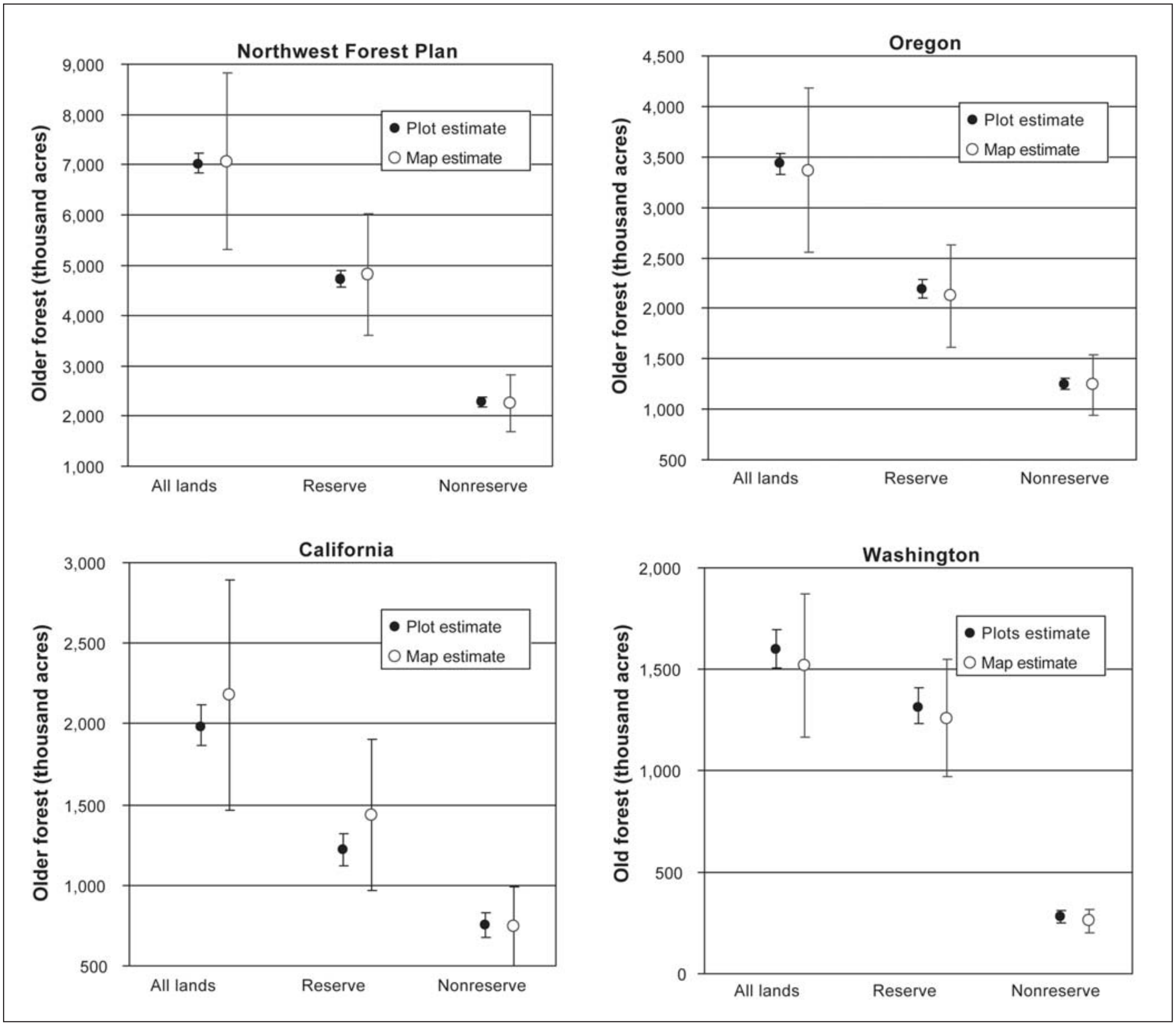


Figure 21a—Comparison of map estimates and statistical estimates from plots for "medium and large older forest" area sampled on lands administered by Forest Service-Region 6, Forest Service-Region 5, and Bureau of Land Management-Oregon. Closed circles = total acres from the plot analysis with 90-percent confidence interval bars computed from a bootstrap variance. Open circles = total acres from the map analysis with map error bars estimated from the map accuracy assessment. See table 5 for individual land use allocations included in reserve and nonreserve categories.

estimate was developed from inventory plots measured between 1993 and 2001 (table 9). Although a formal comparison of the estimates is not statistically valid, a result of consistency between them would lend additional evidence that the older forest maps represent an accurate baseline for the Plan. If the evaluation revealed inconsistencies between the estimates, we would at the least have information about where the maps were weak and be able to assess the effect of the inaccuracies on our interpretations of the results.

We plotted the population estimates and the 90-percent confidence intervals for the amount of older forest estimated from the plot data in figure 21. We plotted the acreage estimates for the same area derived from the maps (with map

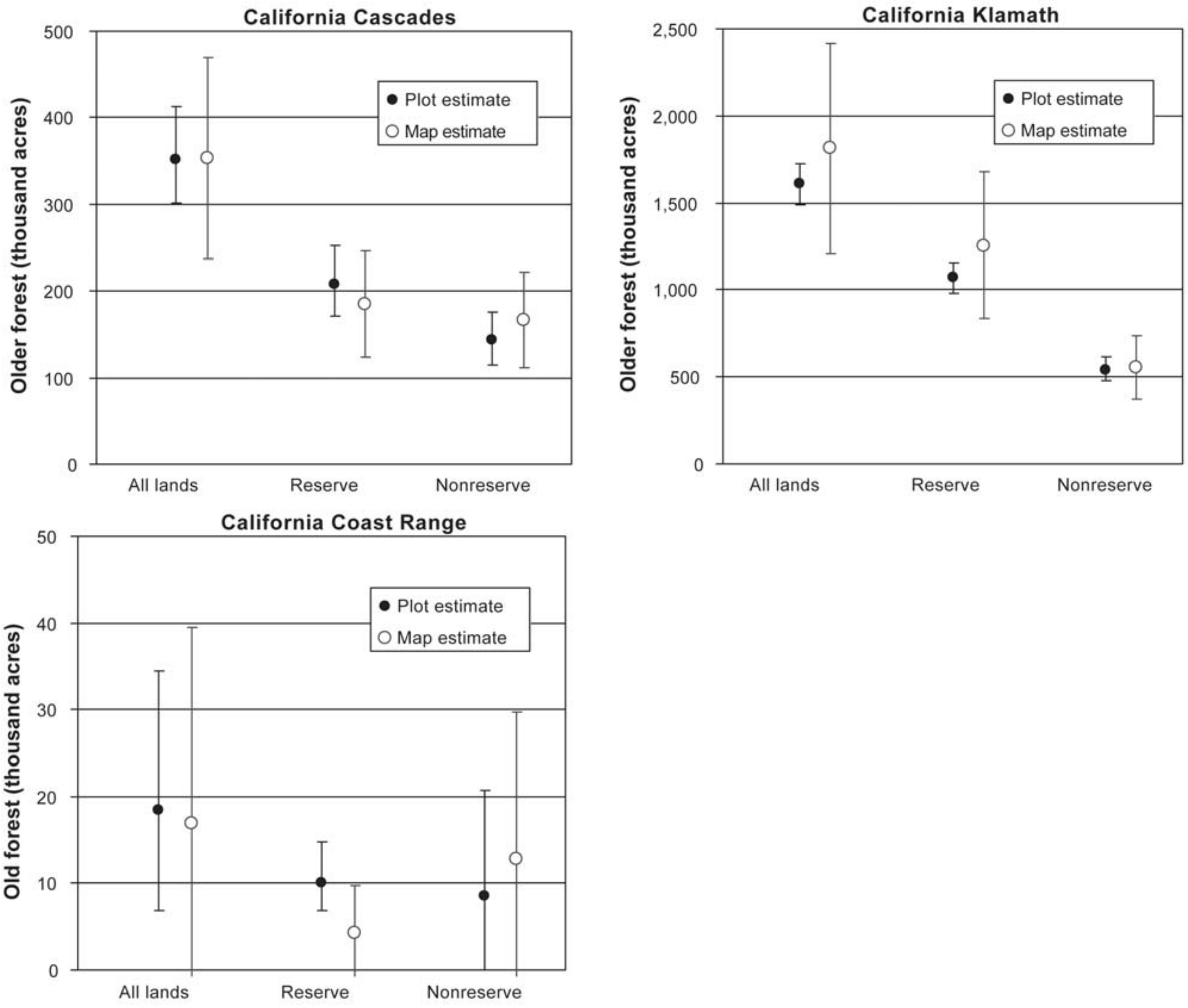
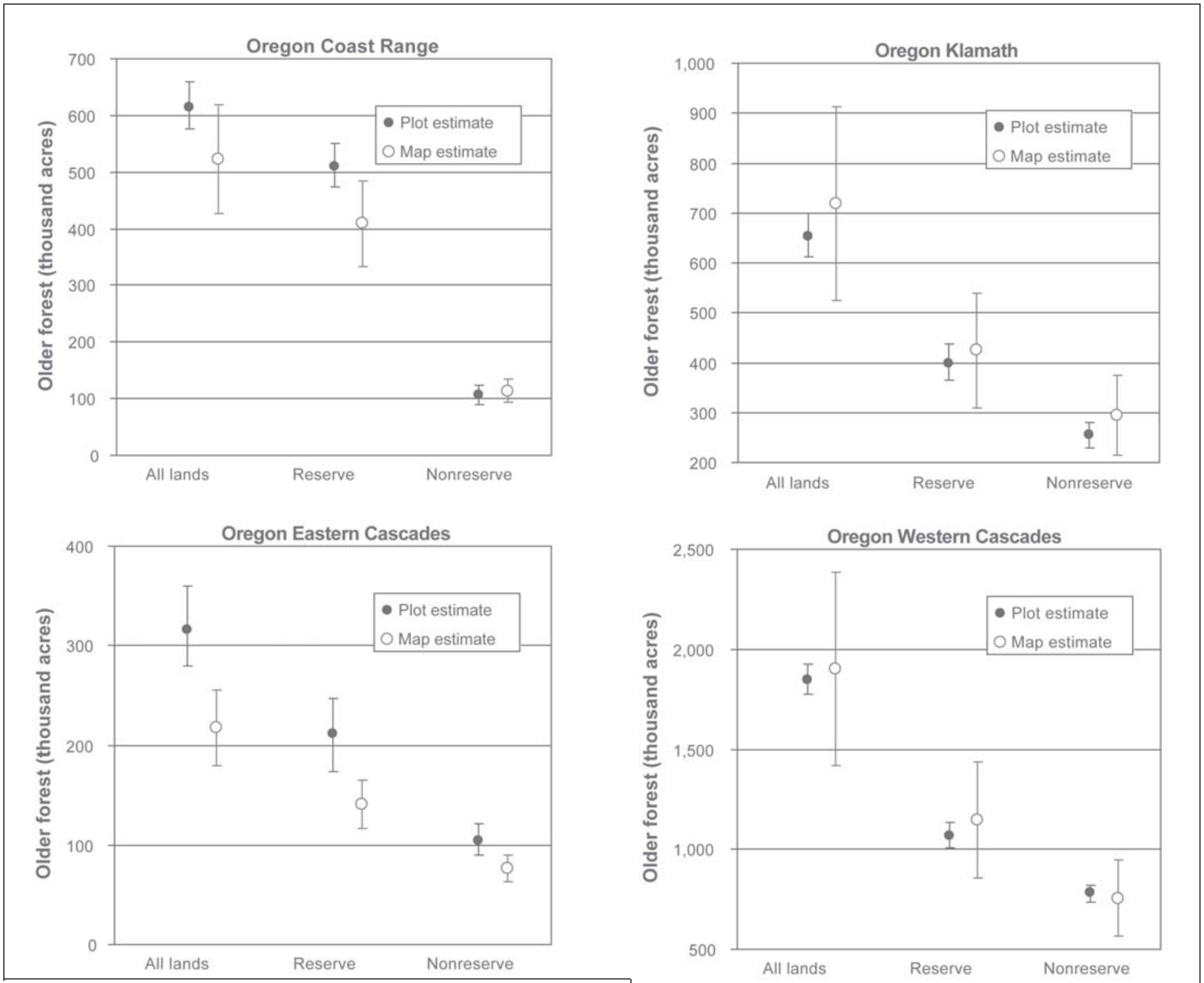
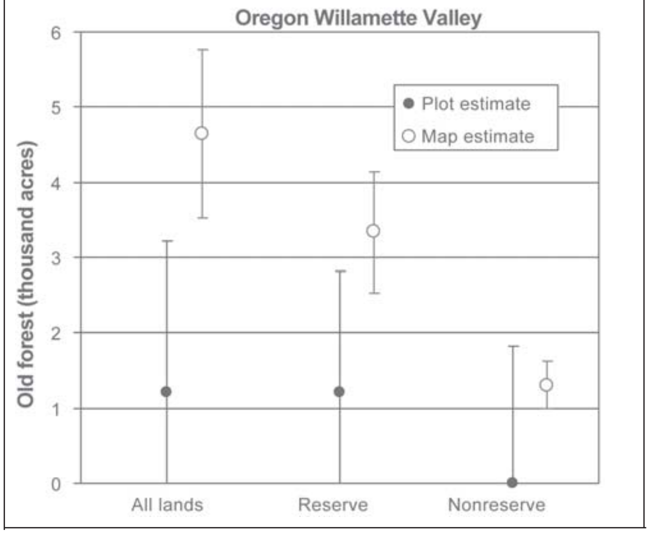


Figure 21b— Comparison of map estimates and statistical estimates from plots for "medium and large older forest," California provinces. Closed circles = total acres from the plot analysis with 90-percent confidence interval bars computed from a bootstrap variance. Open circles = total acres from the map analysis with map error bars estimated from the map accuracy assessment. No reference plots were available in the Coast Range to assess the map's accuracy; confidence bounds shown for the Coast Range reflect accuracies for the state of California.

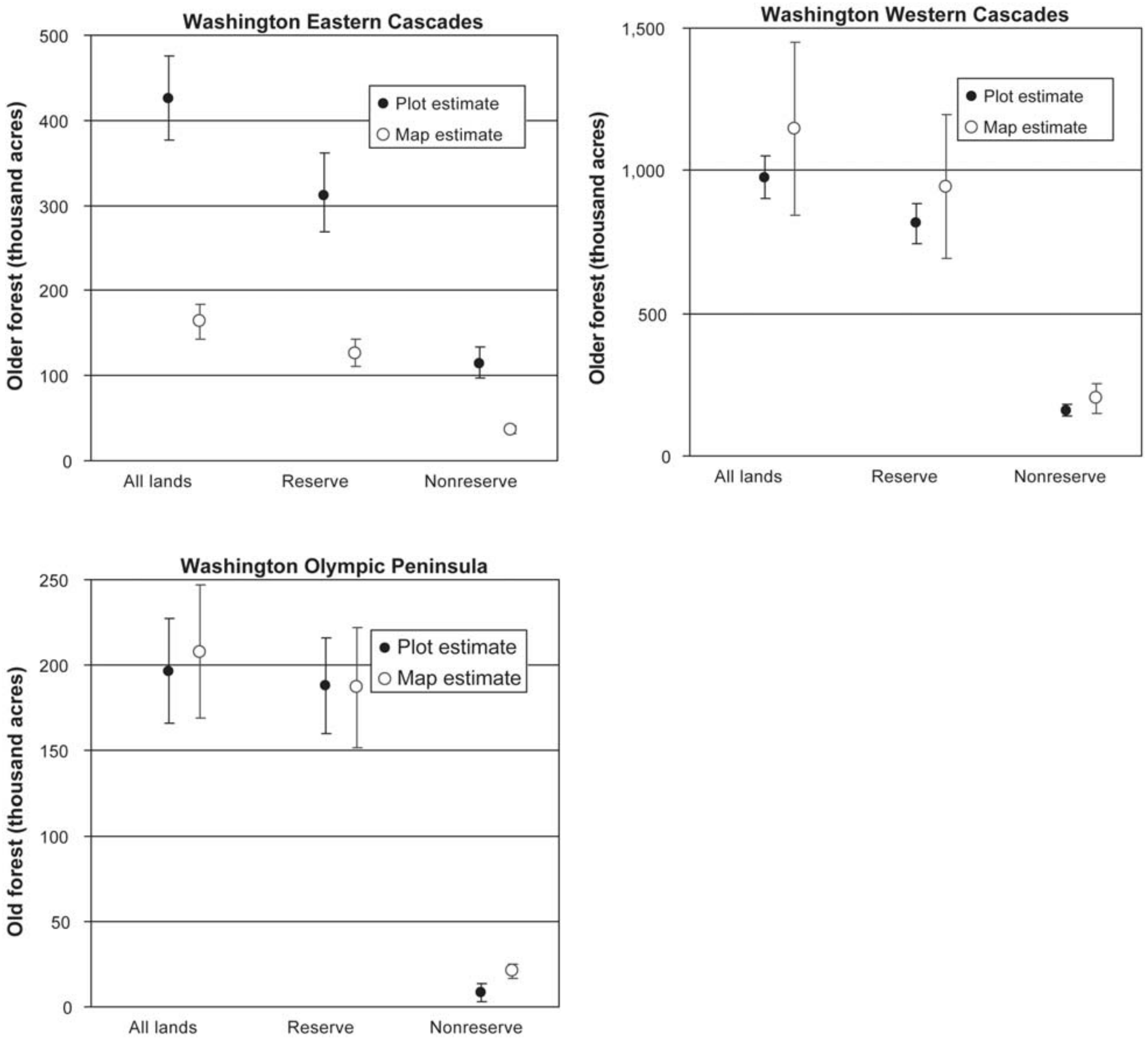
Figure 21c— Comparison of map estimates and statistical estimates from plots for "medium and large older forest," Oregon provinces. Closed





circles = total acres from the plot analysis with 90-percent confidence interval bars computed from a bootstrap variance. Open circles = total acres from the map analysis with map error bars estimated from the map accuracy assessment. A single reference plot was available in the Willamette Valley to assess the map's accuracy; confidence bounds shown for the Willamette Valley reflect accuracies for the state of Oregon.

Figure 21d— Comparison of map estimates and statistical estimates from plots for "medium and large older forest," Washington



provinces. Closed circles = total acres from the plot analysis with 90-percent confidence interval bars computed from a bootstrap variance. Open circles = total acres from the map analysis with map error bars estimated from the map accuracy assessment. There was less than 100 acres in the Washington Western Lowlands province, so the results are not displayed.

Figure 22a—Distribution of older-forest blocks at the start of the Northwest Forest Plan estimated from the map data. M&L = medium and errors estimated from the map accuracy assessment) alongside the plot-based estimates. We called the estimates consistent if the map error bars overlapped the confidence interval from the plot-based estimate.

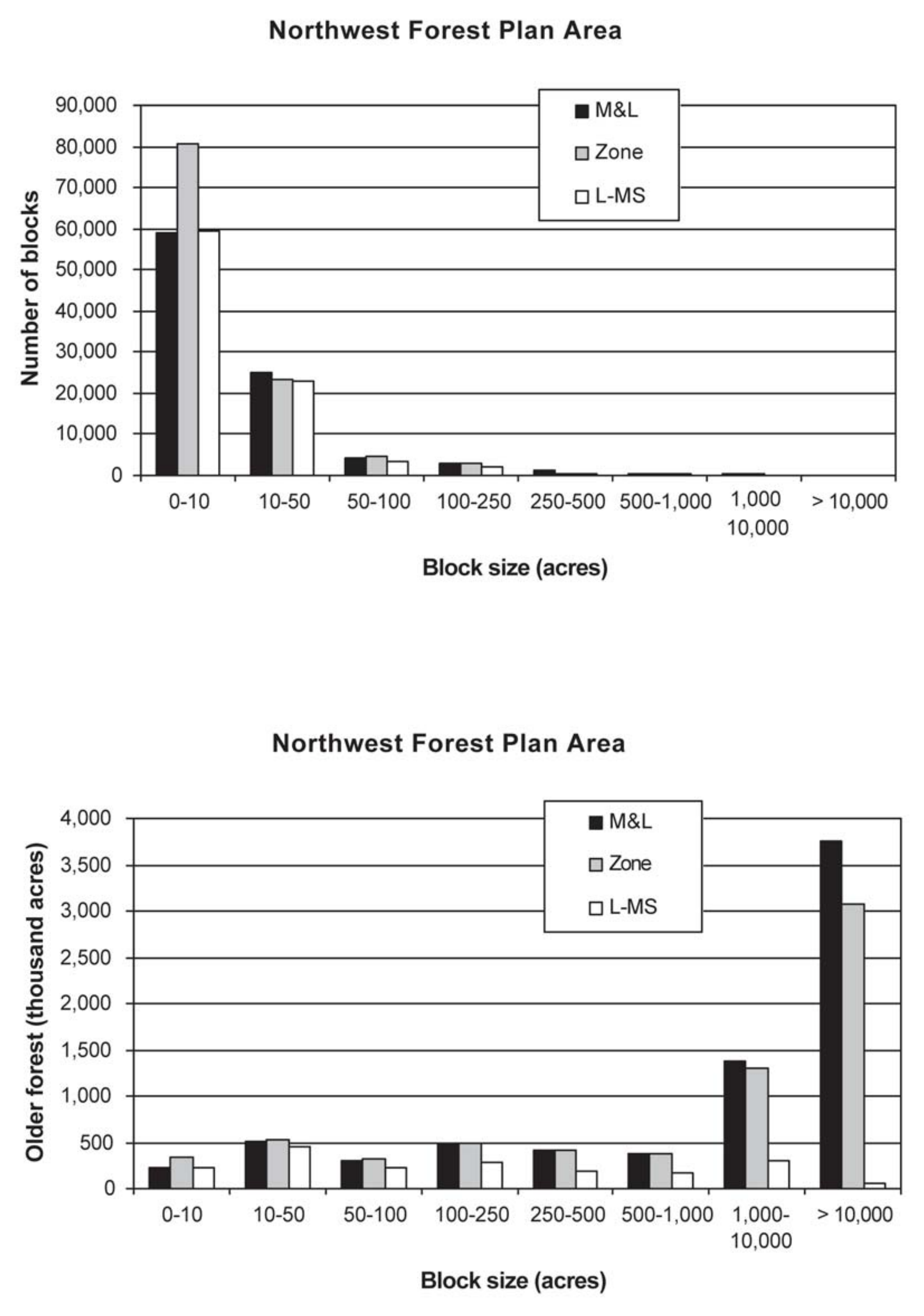
Estimates of “medium and large older forest” acreages developed from statistical analysis of the inventory plot data on Forest Service-Region 5, Forest Service-Region 6, and Bureau of Land Management-Oregon lands were consistent with the amounts estimated by the map analysis at the regional scale, and also at the state level (fig. 21). At the province scale, the map-based and plot-based estimates were consistent, with the following exceptions. Mapped acres derived from the IVMP mapping approach in the eastern Cascades provinces of Oregon and Washington were underestimated compared with plot values (the map error bars were below the 90-percent lower confidence boundary). These two provinces were the map project areas where the relationship between average tree size in the training data, and spectral variables from the satellite data were so weak that the standard modeling protocol was deemed inadequate (see the section on IVMP earlier in this report). Instead of fitting regression models in these provinces, average tree size was mapped by traditional classification methods. Still, there were almost no observations with average size over 20 in on which to base the classification. Thus, the resulting maps predicted very little “medium and large” older forest.

There are different ways of quantifying the magnitude of the underestimate. One is to compute the relative differences between the population estimates. For example, the underestimate appears to be about one-third of the total in the Oregon Eastern Cascades province (that is, the map estimated 217,800 ac, versus the plot estimate of 316,200 ac), or about 98,000 ac total (28,000 ac on nonreserve lands and 70,000 ac on reserve lands). In the Washington Eastern Cascades province, this method leads to an underestimate of about two-thirds (163,500 map-based ac versus 425,300 plot-based ac), for 262,000 ac total (77,000 ac on nonreserve lands and 185,000 ac on reserve lands). An equally valid alternative is to look at the difference between the lower plot confidence limit and the upper map error bar. By this method, the underestimate for the Oregon Eastern Cascades province is about 24,000 ac total, and for the Washington Eastern Cascades, about 193,000 ac total. It is clear that there is a large underestimate of older forest acres in the eastern Cascades provinces (via the mapping method), but the precise value of the underestimate is unknown from our current data—it is likely to be in the 200,000- to 300,000-ac range. However, the implication is clear that relying strictly on the map estimates will probably lead to misinterpretations of amounts and patterns of older forests predicted in the eastern Cascades provinces. In the results that follow, we will continue to provide reminders that the estimates are low in these provinces.

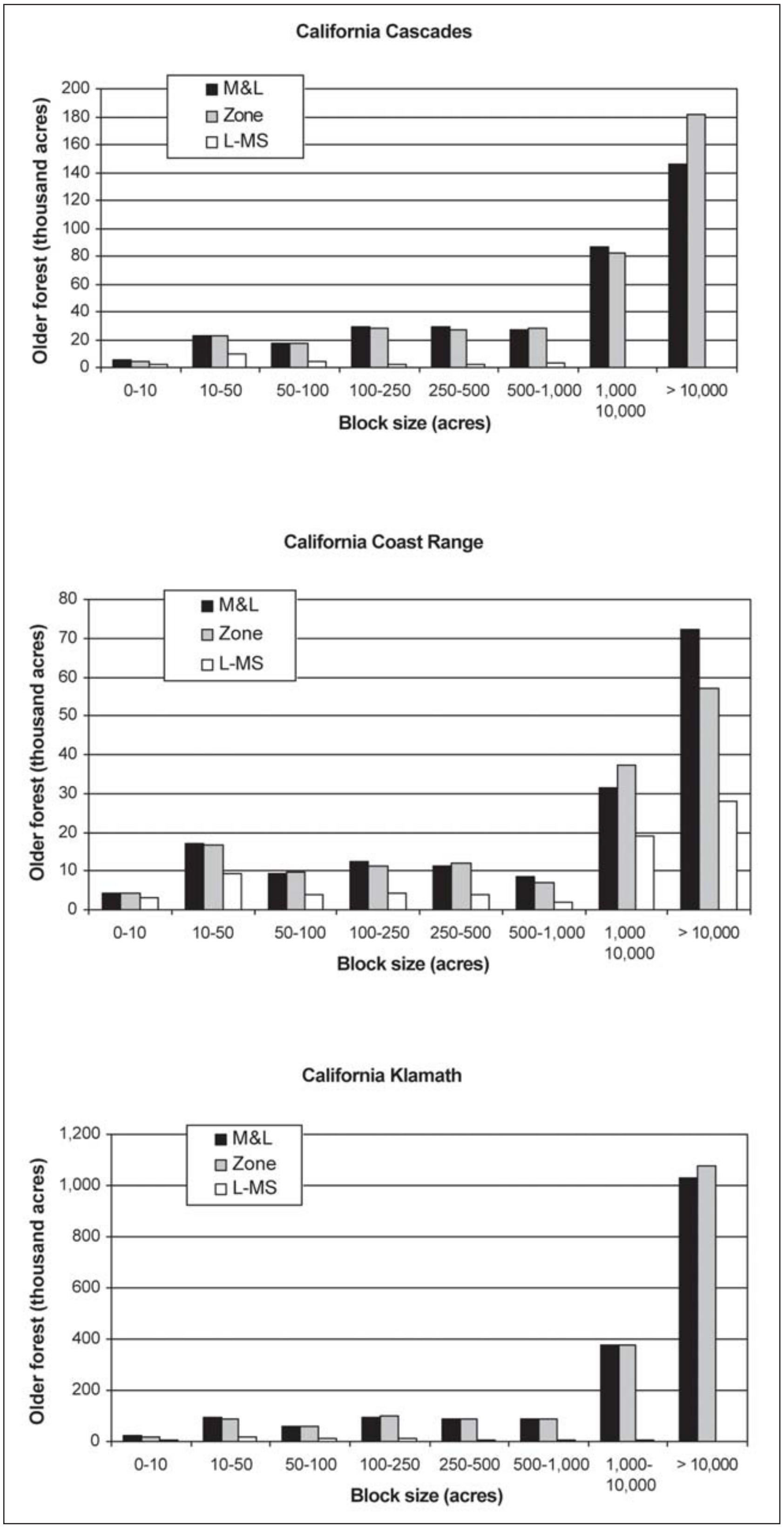
Older Forest Landscape Patterns

The frequency distribution of older-forest block sizes was reverse J-shaped (fig. 22). That is, the vast majority of contiguous older forest patches were in blocks smaller than 1,000 ac, by any of the definitions. However, large blocks (1,000 ac and larger) accounted for the majority of older forest area according to the “medium and large older forest” definition (65 percent of “medium and large” older forest was in blocks >1,000 ac [table 11]) or “older forest with size indexed to potential natural vegetation zone” definition (62 percent). However, blocks >1,000 ac accounted for only 13 percent covered by “large, multistoried” older forest.

Of “medium and large older forest,” very large (at least 10,000 ac) and large (at least 1,000 ac) contiguous older forest blocks were concentrated in the Western Cascades, Klamath, California Cascades, and Olympic Provinces (fig. 22, fig. 23a). Not surprisingly, these provinces had the greatest proportion of land in contiguous federal land ownership. Large blocks were relatively scarce in the Eastern Cascades of Washington and Oregon even though the proportion of federal land was high there. The frequency and acreage of large blocks of older forests in the eastern Cascades provinces is likely higher than shown, because of the underestimate in the map results. In the remaining provinces (Oregon Coast, California Coast), large blocks were scattered, primarily because in those provinces contiguous blocks of federal land are separated by large distances. The relative importance of large older-forest blocks increased in the Eastern Cascades with use of the



large older forest; Zone = older forest with size indexed to vegetation zone; L-MS = large, multistoried older forest.
Figure 22b—Older forest blocks, California provinces.
Figure 22c—Older forest blocks, Oregon provinces.

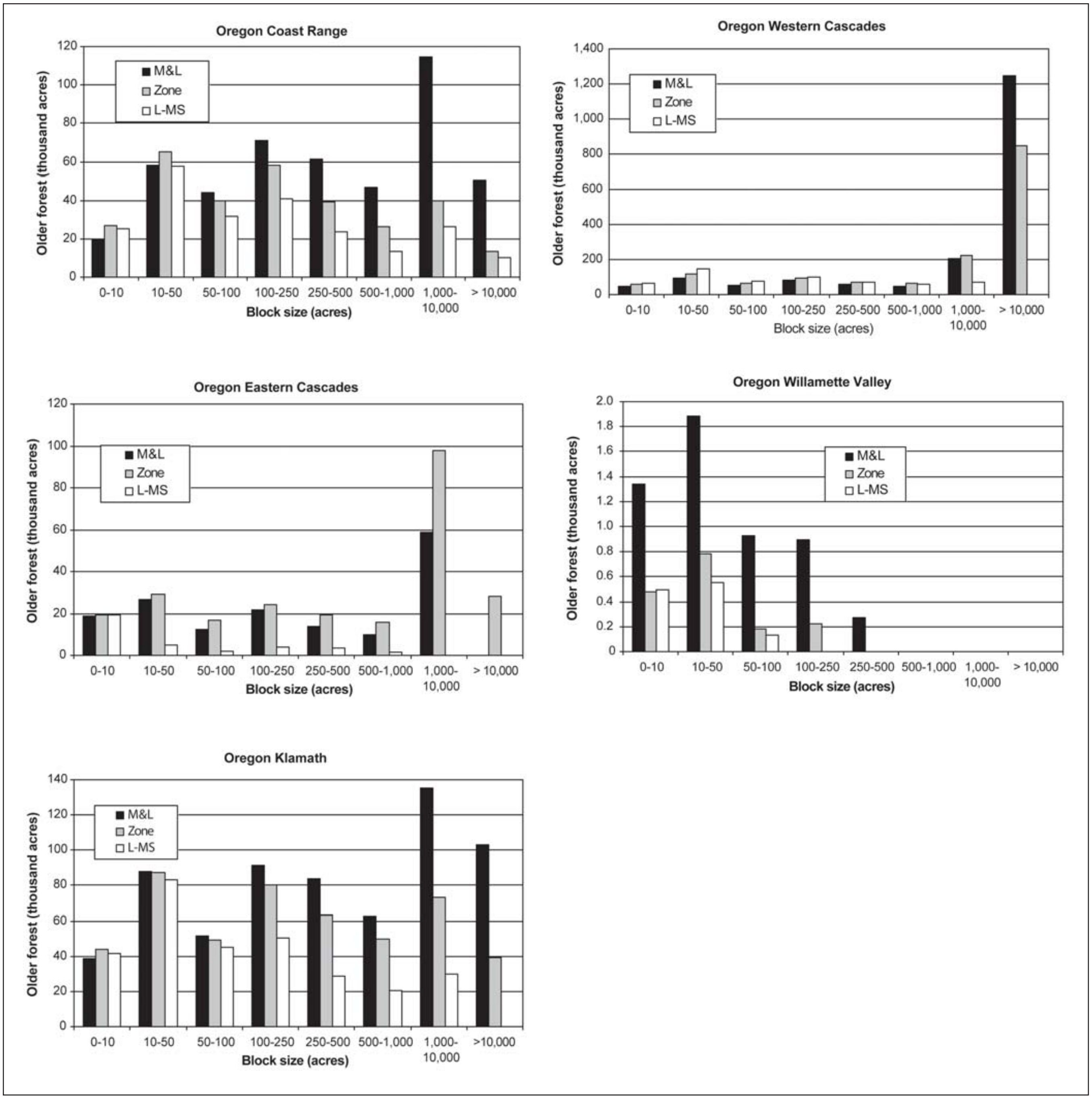


California Cascades

California Coast Range

California Klamath

Figure 22d—Older forest blocks, Washington provinces.



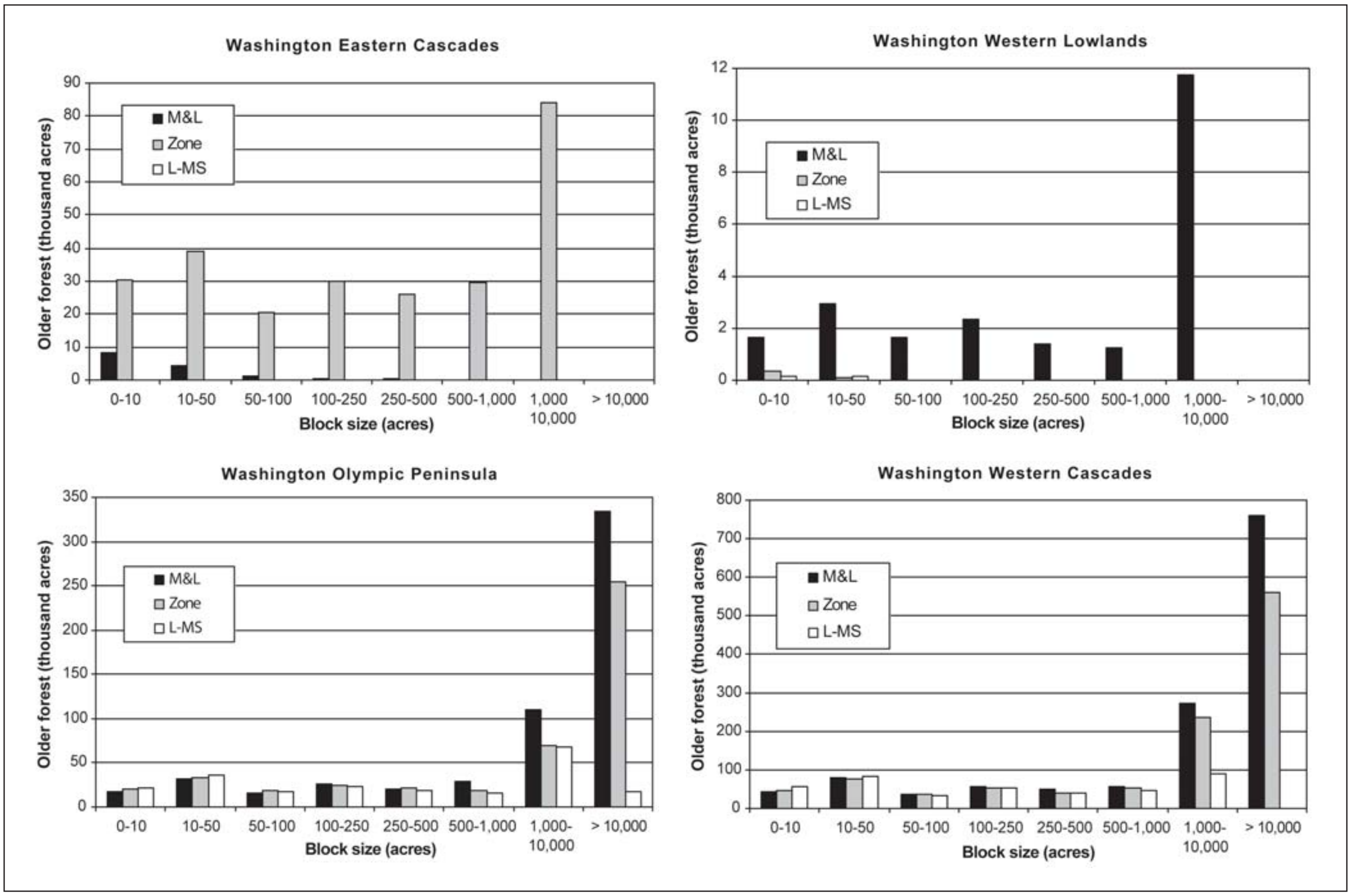
Oregon Coast Range

Oregon Western Cascades

Oregon Eastern Cascades

Oregon Willamette Valley

Oregon Klamath



Continue to Part C

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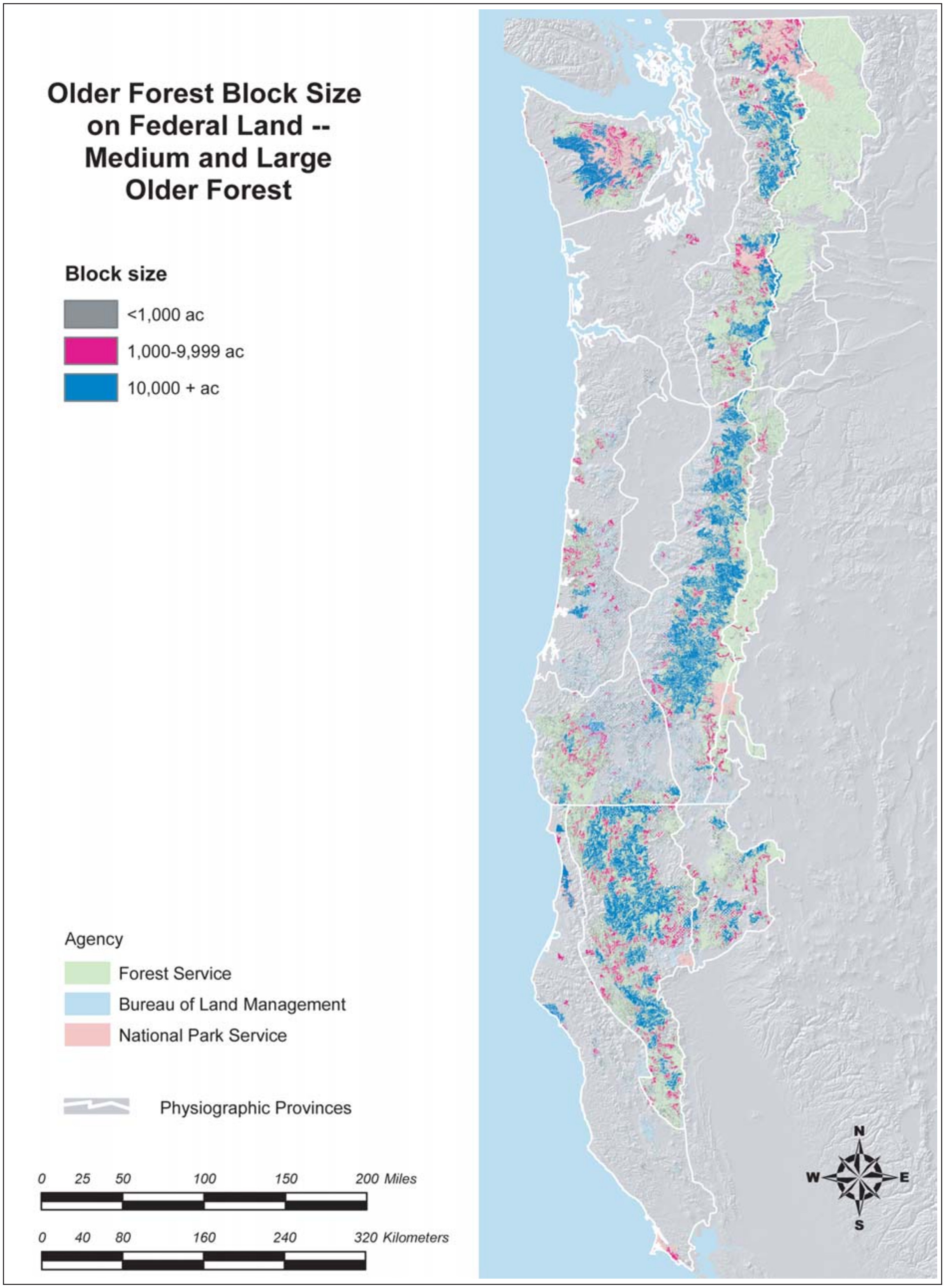

Figure 23a—Older forest blocks mapped according to ”medium and large older forest” definition

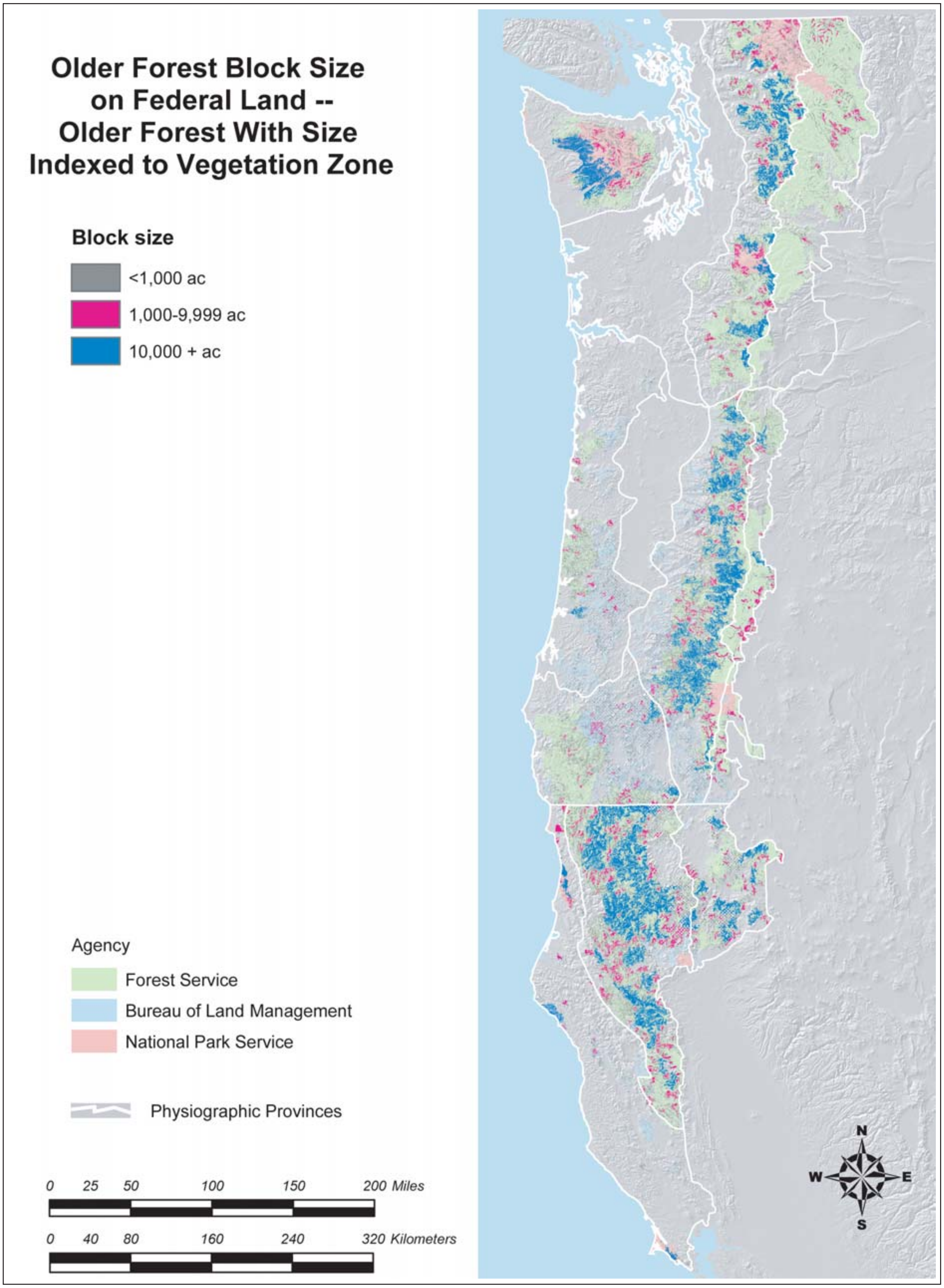

Figure 23b—Older forest blocks mapped according to “older forest with size indexed to vegetation zone” definition.

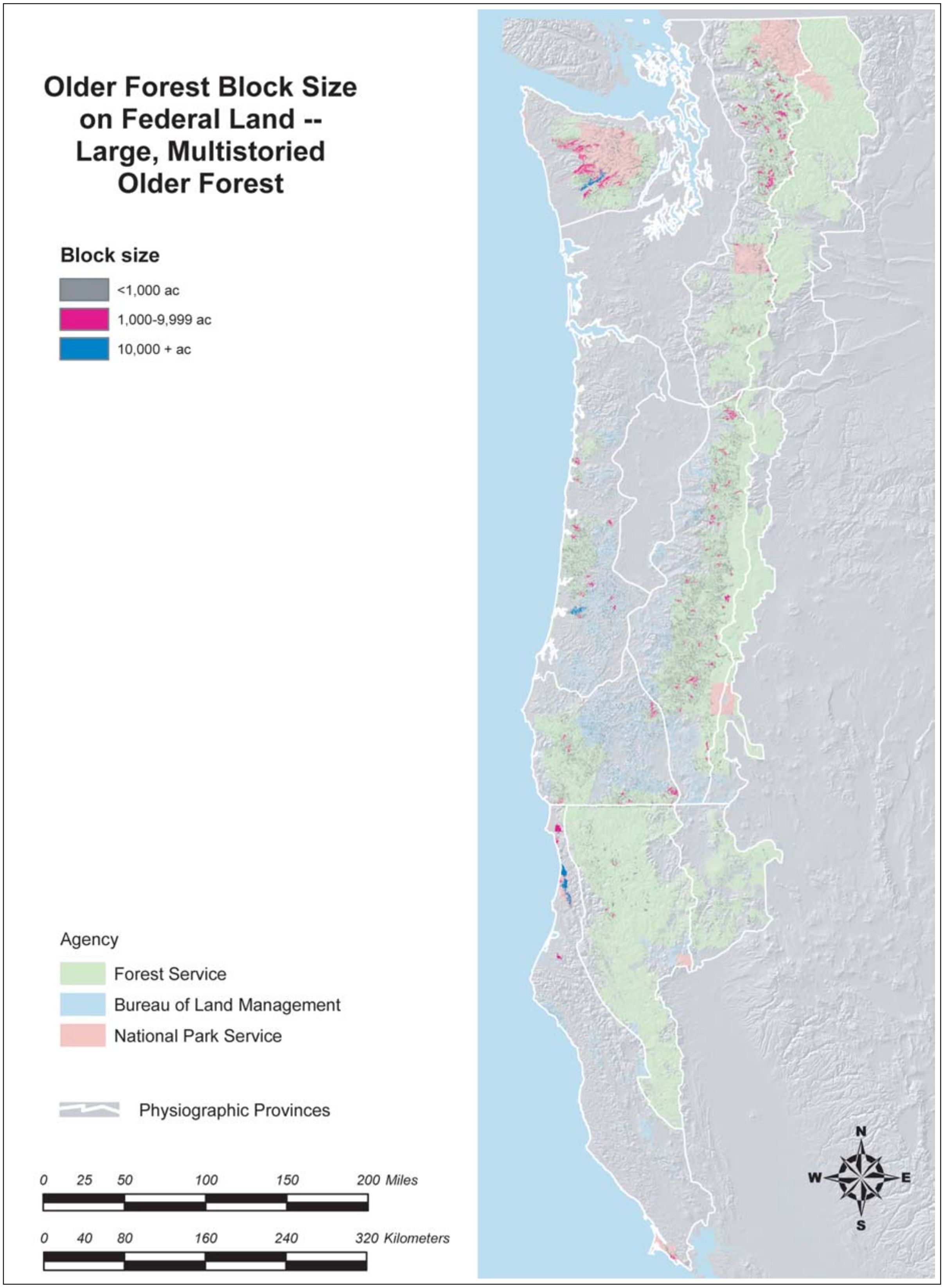

Figure 23c—Older forest blocks mapped according to “large, multistoried older forest” definition.

"older forest with size indexed to potential natural vegetation zone" definition, because this definition tended to predict relatively more older forest acres there (fig. 23b). Large blocks of "large, multistoried older forest" were only mapped west of the Cascade crest (fig. 23c).

The average edge-to-edge distance between older-forest blocks on federal lands regionwide was about 0.2 mi, and older-forest blocks were common in all provinces (table 13). The distribution of large blocks (at least 1,000 ac) varied greatly by province and definition. For the "medium and large" definition, older-forest large blocks were less than about 3 mi apart, on average, in the Washington Olympic Peninsula, California Klamath, Oregon Western Cascades, Washington Western Cascades, Oregon Klamath, Oregon Coast Range, California Cascades, and Oregon Eastern Cascades. In the California Coast Range they were separated by an average of 17 mi. They were nonexistent in the Washington Eastern Cascades province. (Oregon Willamette Valley and Washington Western Lowlands provinces had very little federal ownership, and results there are not discussed.) Patterns for "older forest with size indexed to potential natural vegetation zone" were similar, except in Washington Eastern Cascades. In that province, separation distance for "older forest with size indexed to potential natural vegetation zone" was less than 2 mi, on average. The large block results for "large, multistoried older forest" followed consistent, but more exaggerated patterns (there were larger average distances between blocks). Of the provinces west of the Cascades, large blocks were separated by distances of greater than 10 mi in both the California Klamath and Coast Range. Eastern Cascades provinces had no older-forest blocks >1,000 ac.

Stand-Level Attributes of Older Forests

There were significant differences in the values of several important structure and composition attributes between sample plots labeled as "older forest" and sample plots labeled "not older forests" (fig. 24). Older forest samples had significantly larger average tree sizes, more complex canopies, and older trees in every province for every older forest definition. Differences between "older forests" and "not older forests" were not as pronounced for amounts of coarse woody debris (log biomass and log volume). Generally, older forest samples had greater amounts of logs than "not older forest" samples, with the exception of the Washington Eastern Cascades and California Cascades provinces, where some values were lower for some definitions. Large live trees and large snags (≥30 in) were more numerous on "older forest" samples, and small trees and small snags were more numerous on "not older forest" samples. This quick two-class evaluation of the inventory data holds promise that the variation inherent in important structural characteristics of older forests can be assessed by using the current plot-based approach.

Results—Older Forest Changes in the First Decade of the Northwest Forest Plan

Harvest and Fire Losses (Disturbance Map Analysis)

Using results of the remote-sensing change-detection analysis, we estimated that about two-tenths of one percent of "medium and large older forest" (16,900 ac) was removed by regeneration harvest (that is, clearcutting) in the first decade after the Plan was implemented (table 14). There was a map error rate between about 7 and 12 percent around this estimate (app. 5). About 89 percent of regeneration harvests occurred on land allocated to matrix/riparian reserves or adaptive-management area (seven-tenths of a percent of "medium and large older forest" in the matrix allocation group was harvested). Oregon experienced the most cutting, about 11,900 ac (most from Oregon Western Cascades). California was next, with a third as much as in Oregon (3,900 ac). Washington had the least amount of cutting in older forests (1,100 ac). By province, Oregon Western Cascades accounted for 40 percent of the total cutting of "medium and large" older forest, followed by Oregon Klamath (18 percent) and California Cascades (15 percent). Of the area of "medium and large" older forest harvested, about one-third was "large, multistoried" older forest. Most cutting of "large, multistoried older forest," was in Oregon Western Cascades (43 percent of the

Table 13—Mean distance between older forest blocks by definition, for all older forest blocks, and for blocks of at least 1,000 acres

	Medium and large				**Size indexed to veg. zone**				**Large multistoried**			
	All blocks		**Blocks > 1,000 ac**		**All blocks**		**Blocks > 1,000 ac**		**All blocks**		**Blocks > 1,000 ac**	
Province	**mean**	**(s.d.)**	**mean**	**(s.d.)**	**mean**	**(s.d.)**	**mean**	**(s.d.)**	**mean**	**(s.d.)**	**mean**	**(s.d.)**
							Miles					
California Cascades	0.2	(0.2)	1.0	(1.5)	0.2	(0.2)	1.0	(1.3)	0.4	(0.4)	—	—
California Coast Range	0.3	(0.5)	16.7	(24.8)	0.3	(0.5)	12.5	(22.3)	0.3	(0.4)	33.1	(66.2)
California Klamath	0.2	(0.1)	0.5	(0.8)	0.2	(0.1)	0.5	(0.8)	0.4	(1.1)	10.8	(10.8)
Oregon Coast Range	0.2	(0.3)	2.1	(3.8)	0.2	(0.2)	2.7	(2.4)	0.2	(0.3)	3.7	(4.2)
Oregon Eastern Cascades	0.2	(0.1)	3.1	(5.1)	0.2	(0.1)	1.2	(1.9)	0.3	(0.5)	—	—
Oregon Klamath	0.2	(0.1)	1.3	(2.6)	0.2	(0.1)	1.3	(1.8)	0.2	(0.1)	3.6	(7.4)
Oregon Western Cascades	0.2	(0.1)	0.6	(1.8)	0.2	(0.1)	0.4	(0.7)	0.2	(0.1)	3.6	(2.8)
Oregon Willamette Valley	0.5	(1.1)	—	—	0.8	(1.9)	—	—	0.8	(1.8)	—	—
Washington Eastern Cascades	0.4	(0.5)	—	—	0.2	(0.2)	1.9	(4.2)	0.0	(0.0)	—	—
Washington Olympic Peninsula	0.2	(0.2)	0.4	(0.6)	0.2	(0.1)	0.4	(0.4)	0.2	(0.2)	1.4	(3.3)
Washington Western Cascades	0.2	(0.1)	0.8	(1.8)	0.2	(0.1)	0.7	(1.0)	0.2	(0.1)	3.7	(4.9)
Washington Western Lowlands	0.3	(2.1)	2.0	(3.7)	0.4	(0.5)	—	—	0.8	(0.7)	—	—
Northwest Forest Plan	0.2	(0.2)	1.0	(3.9)	0.2	(0.2)	0.9	(3.7)	0.2	(0.2)	4.9	(17.2)

Note: Mean distance is the average edge-to-edge distance between nearest neighboring older-forest large blocks.

Standard deviation (s.d.) is a measure of block dispersion (small s.d. implies uniform distribution of blocks; large s.d. implies a clumpy distribution of blocks).

— = no older forest blocks >1,000 ac in the province.

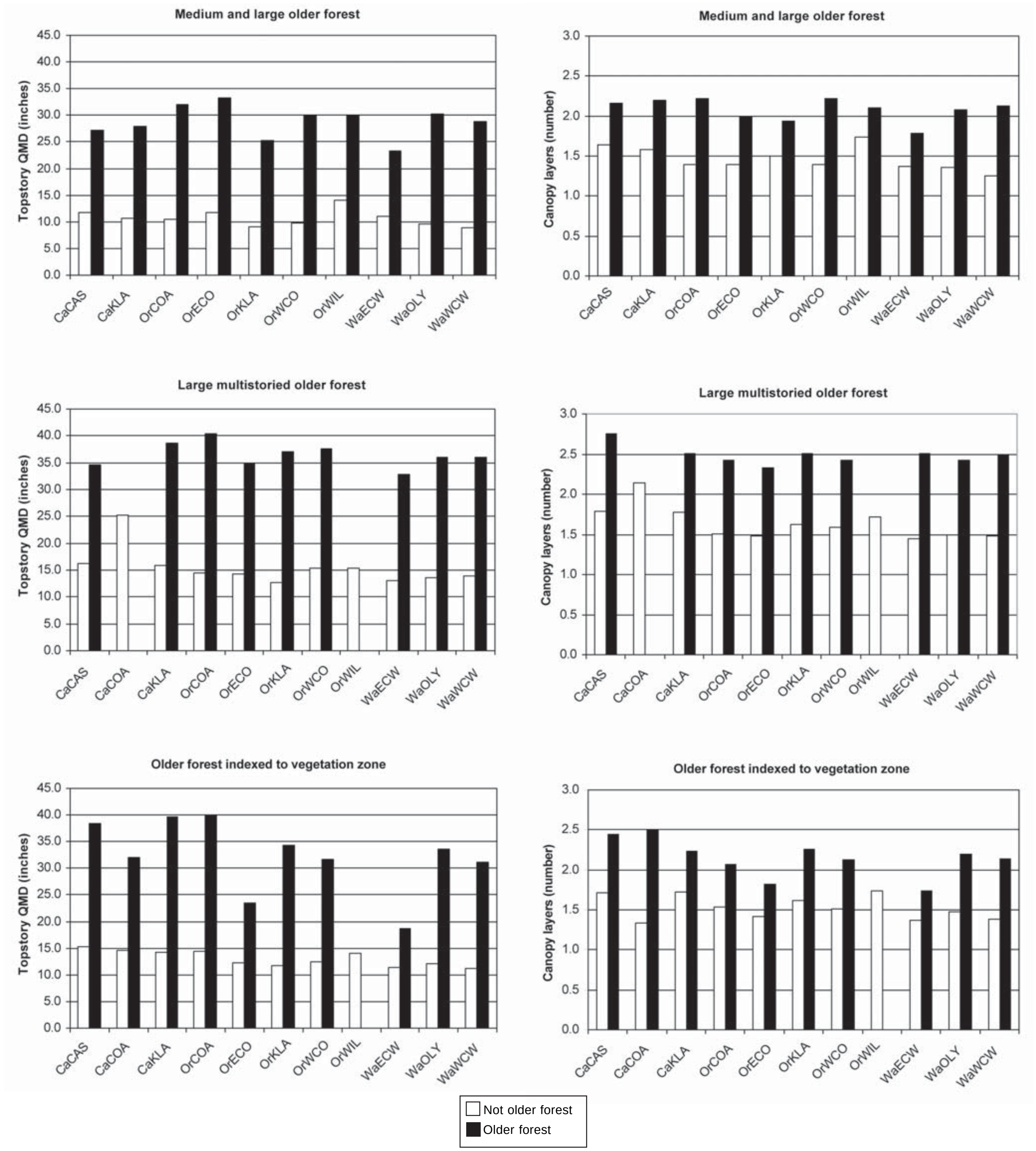

Figure 24a—Within-stand attributes of plots classified as "older forest" (dark bars) versus plots classified as '"not older forest" (light bars). Province codes: CaCAS = California Cascades; CaCOA = California Coast Range; CaKLA = California Klamath; OrCOA = Oregon Coast Range; OrECO = Oregon Eastern Cascades; OrKLA = Oregon Klamath; OrWCO = Oregon Western Cascades; OrWIL = Oregon Willamette Valley; WaECW = Washington Eastern Cascades; WaOLY = Washington Olympic Peninsula; WaWCW = Washington Western Cascades.

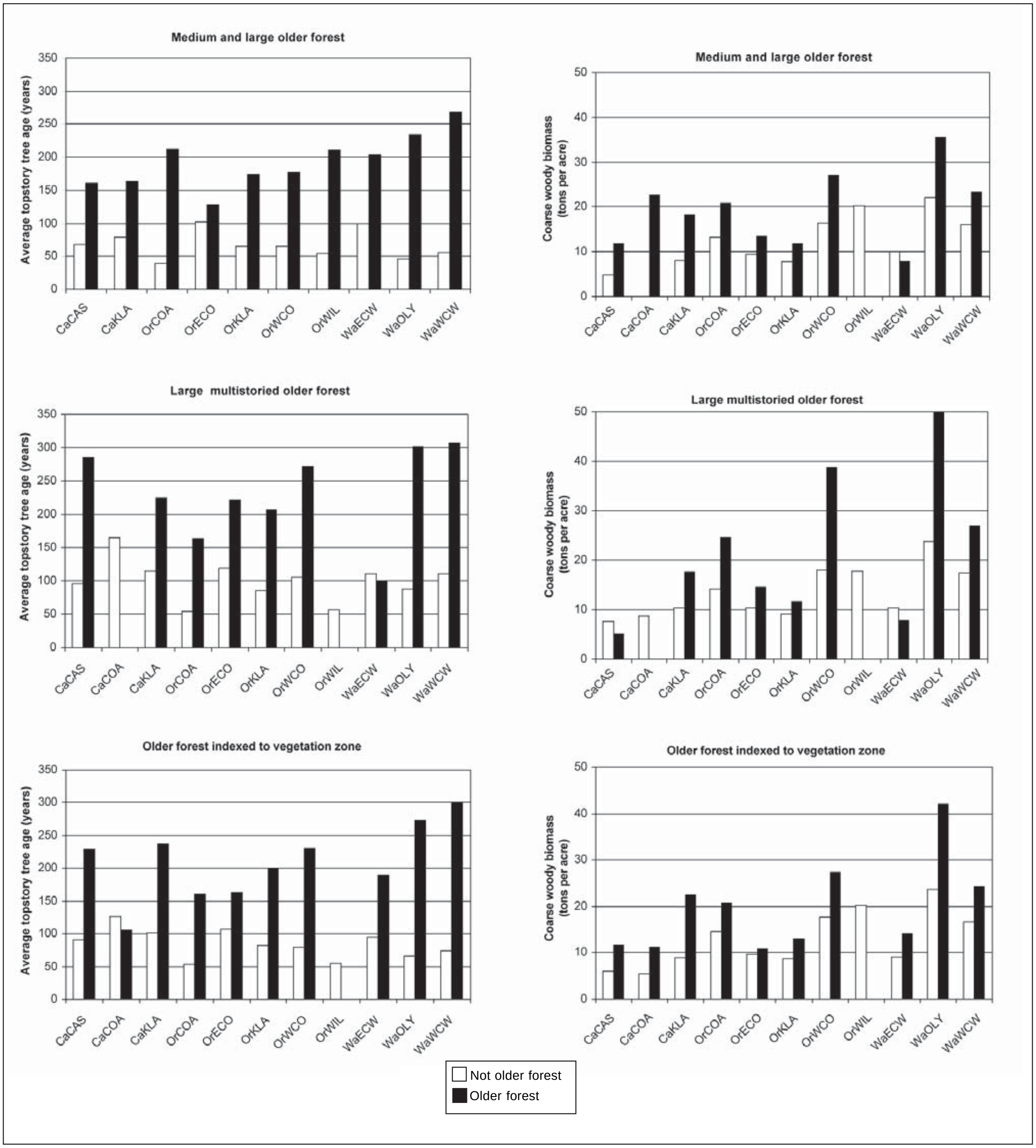

Figure 24b—Within-stand attributes of plots classified as “older forest” (dark bars) versus plots classified as ‘”not older forest” (light bars). See fig. 24a for province codes.

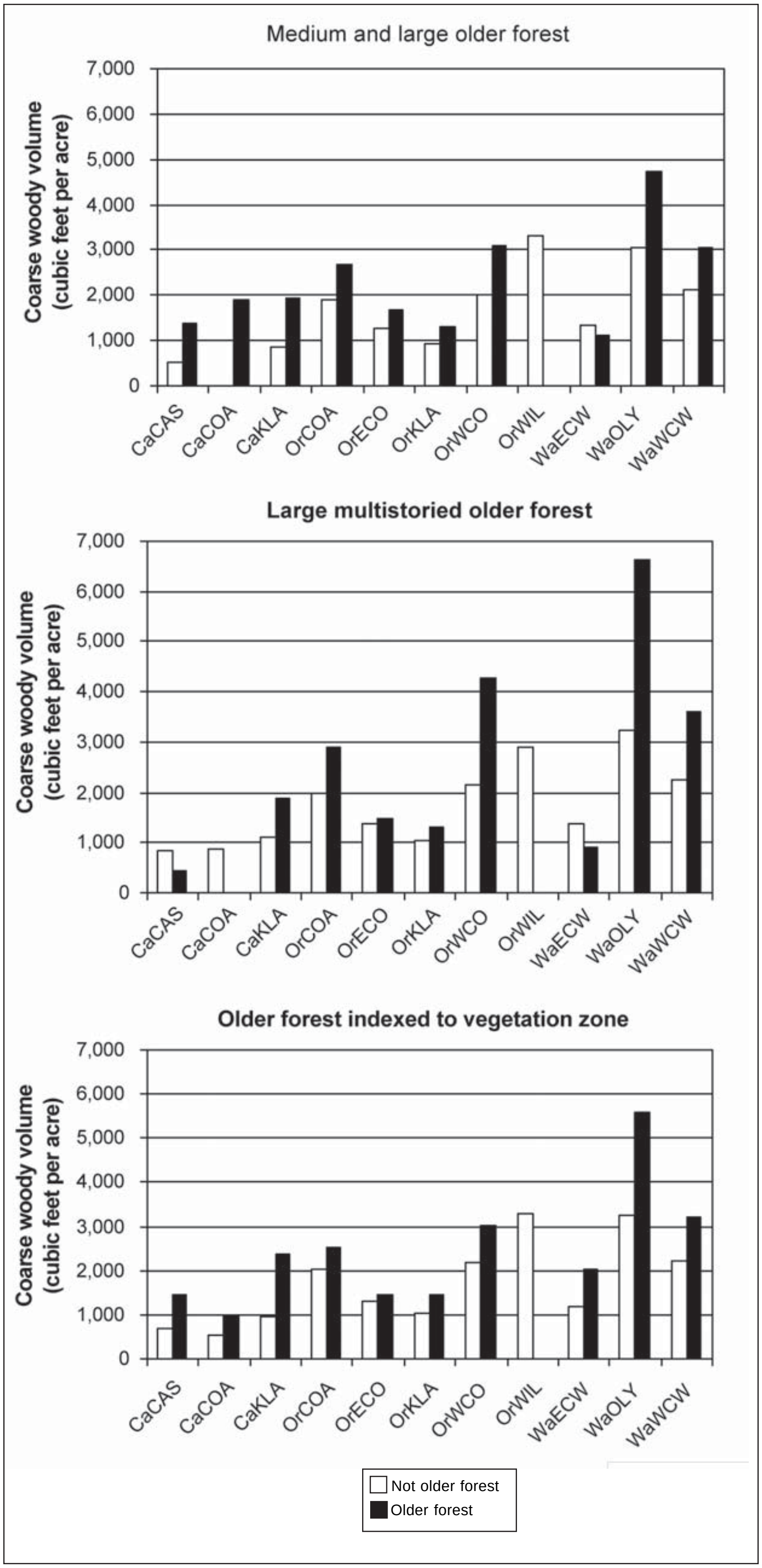

Figure 24c—Within-stand attributes of plots classified as “older forest” (dark bars) versus plots classified as “not older forest” (light bars). See fig. 24a for province codes.

Western hemlock seedling regenerating on rotting log

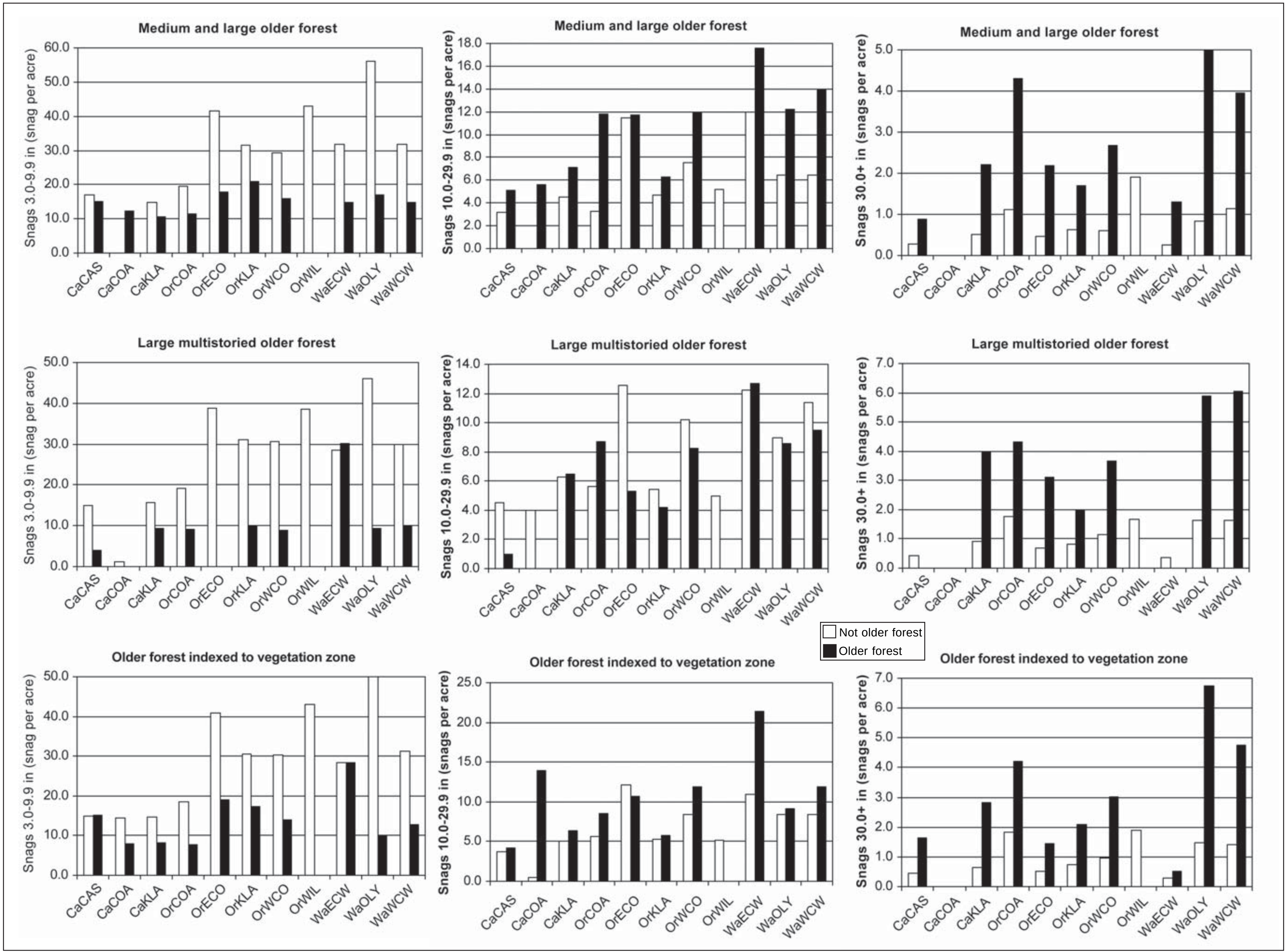

Figure 24d—Within-stand attributes of plots classified as “older forest” (dark bars) versus plots classified as ‘”not older forest” (light bars). See fig. 24a for province codes.

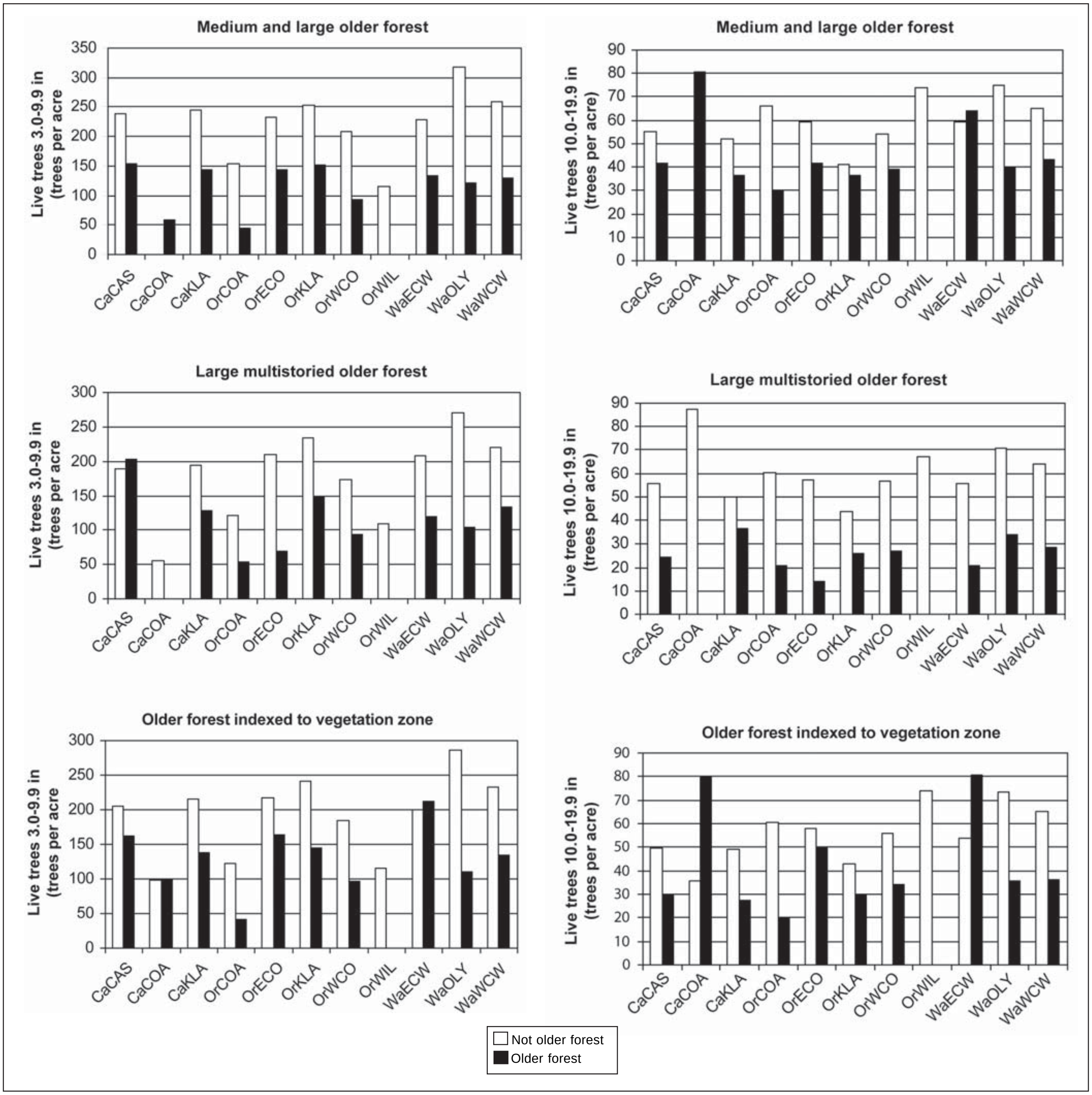

Figure 24e—Within-stand attributes of plots classified as “older forest” (dark bars) versus plots classified as ‘”not older forest” (light bars). See fig. 24a for province codes.

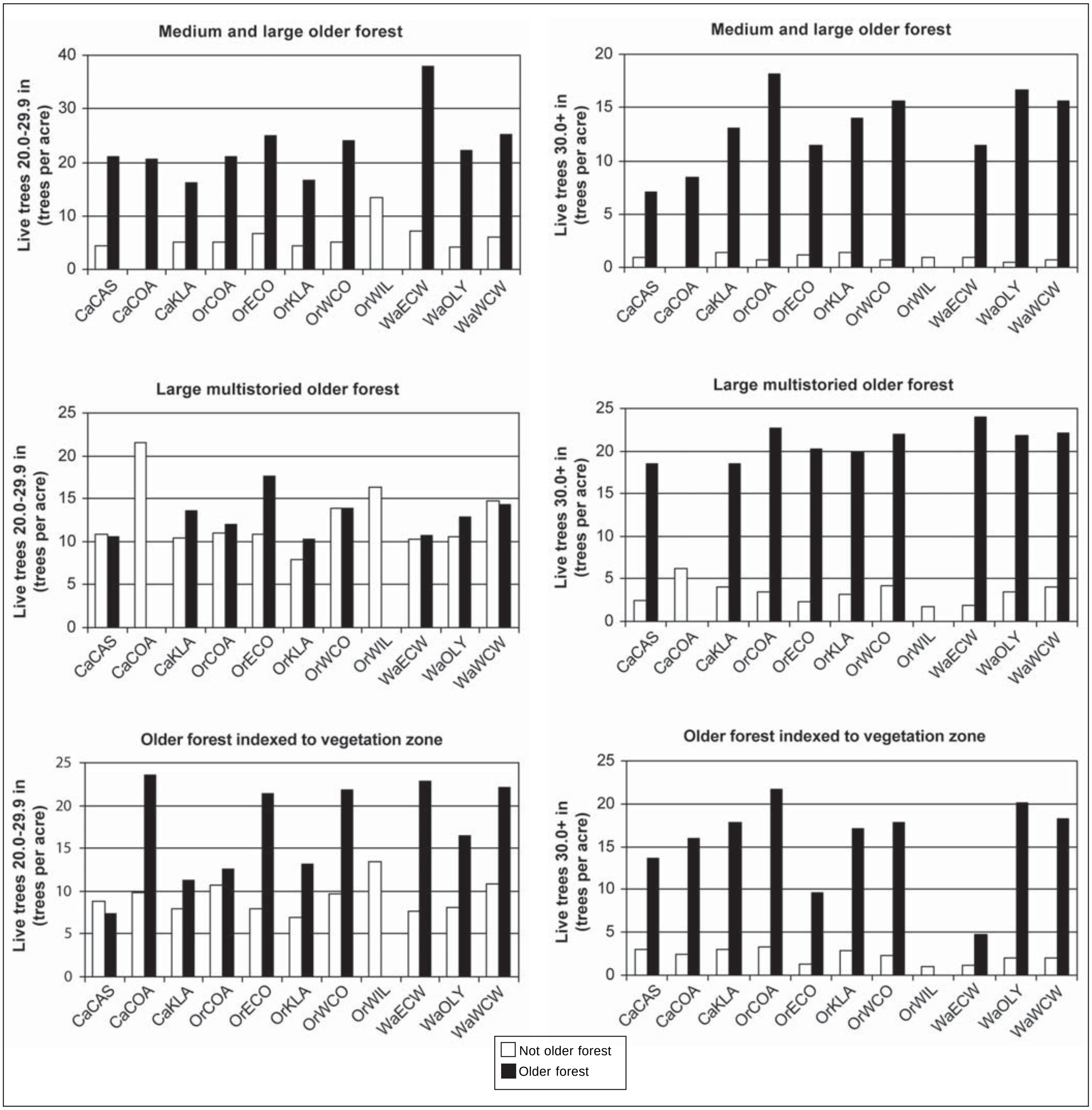

Figure 24e—Continued.

Table 14—Older forest mapped as removed by stand-replacing harvest

Land use allocation group	Medium and large		Size indexed to vegetation zone		Large, multistoried	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
California Cascades:						
Admin. withdrawn/congr. reserved	100	0.25	100	0.24	0	0.00
Late-successional reserve	200	0.16	100	0.08	0	0.00
Matrix	2,200	1.16	1,500	0.75	100	1.11
Total	2,500	0.70	1,700	0.46	100	0.41
California Coast Range:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
California Klamath:						
Admin. withdrawn/congr. reserved	300	0.05	200	0.03	100	0.07
Late-successional reserve	100	0.02	100	0.02	0	0.00
Matrix	1,000	0.18	700	0.12	100	0.11
Total	1,400	0.08	1,000	0.05	200	0.05
California—all provinces:						
Admin. withdrawn/congr. reserved	400	0.05	300	0.04	100	0.05
Late-successional reserve	300	0.04	200	0.02	0	0.00
Matrix	3,200	0.41	2,200	0.28	200	0.19
Total	3,900	0.17	2,700	0.11	300	0.06
Oregon Coast Range:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	300	0.07	200	0.08	200	0.07
Matrix	1,400	1.25	1,000	1.40	800	1.58
Total	1,700	0.33	1,200	0.35	1,000	0.32
Oregon Eastern Cascades:						
Admin. withdrawn/congr. reserved	0	0.01	0	0.00	0	0.00
Late-successional reserve	0	0.01	0	0.01	0	0.00
Matrix	500	0.68	800	0.81	0	0.17
Total	500	0.24	800	0.30	0	0.04
Oregon Klamath:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	500	0.14	300	0.14	300	0.13
Matrix	2,500	0.86	2,000	0.84	1,400	0.93
Total	3,000	0.42	2,300	0.43	1,700	0.43
Oregon Western Cascades:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.01	0	0.01
Late-successional reserve	400	0.05	300	0.06	100	0.04
Matrix	6,300	0.84	4,500	0.78	2,200	0.80
Total	6,700	0.35	4,800	0.32	2,300	0.32

Table 14—Older forest mapped as removed by stand-replacing harvest (continued)

Land use allocation group	Medium and large		Size indexed to vegetation zone		Large, multistoried	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Oregon Willamette Valley:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
Oregon—all provinces:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.01	0	0.01
Late-successional reserve	1,100	0.08	900	0.08	500	0.07
Matrix	10,800	0.87	8,400	0.84	4,400	0.91
Total	11,900	0.35	9,300	0.34	4,900	0.35
Washington Eastern Cascades:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	100	0.09	100	0.05	0	0.00
Matrix	300	0.86	400	0.62	0	0.00
Total	400	0.23	500	0.12	0	0.00
Washington Olympic Peninsula:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.03	0	0.02	0	0.03
Matrix	0	0.17	0	0.08	0	0.05
Total	0	0.01	0	0.01	0	0.01
Washington Western Cascades:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	700	0.33	500	0.32	100	0.15
Total	700	0.05	500	0.04	100	0.02
Washington Western Lowlands:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
Washington—all provinces:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	100	0.01	100	0.02	0	0.01
Matrix	1,000	0.39	900	0.40	100	0.14
Total	1,100	0.05	1,000	0.05	100	0.01
Northwest Forest Plan:						
Admin. withdrawn/congr. reserved	400	0.02	300	0.01	100	0.01
Late-successional reserve	1,500	0.05	1,200	0.05	600	0.05
Matrix	15,000	0.66	11,500	0.58	4,700	0.72
Total	16,900	0.22	13,000	0.18	5,400	0.20

Note: In California, the period represented is 1994 through 2003; In Oregon, the period is 1995 through 2002; and in Washington, the period is 1996 through 2002.

Land use allocation groups are explained in table 5.

total), Oregon Klamath (31 percent), and Oregon Coast Range (19 percent). Cutting patterns within older forest with "size indexed to potential natural vegetation zone" paralleled those for "medium and large" older forest, except that they were about 25 percent lower overall.

Older forest losses to wildfire Planwide were about 1.3 percent (102,500 ac for the "medium and large older forest" definition) (table 15). Variation was high among provinces, concentrated locally around major fire events. More than three-quarters of the total stand-replacing wildfire—about 78,700 ac—was associated with the Biscuit Fire of 2002 in southwestern Oregon and northwestern California (Oregon Klamath and California Klamath provinces) (fig. 25). Ninety percent of all older forest lost to stand-replacing fires was in reserved allocations. The most significant losses of older forest in reserve allocations locally were in the Oregon Klamath (where 21 percent of the administratively withdrawn/congressionally reserved group and 7 percent of the late-successional reserve group burned), California Klamath (3 percent in administratively withdrawn/congressionally reserved group and 1 percent in the late-successional reserve group), Washington Eastern Cascades (3 percent in administratively withdrawn/congressionally reserved group and 2 percent in the late-successional reserve group), and Oregon Western Cascades (2 percent in administratively withdrawn/ congressionally reserved group and 1 percent in the late-successional reserve group) provinces. In the matrix group, the provinces with the largest proportion of "medium and large older forest" lost to wildfire were Oregon Klamath (2 percent) and Washington Eastern Cascades (2 percent). Of the "medium and large" older forest burned, 36 percent was "large, multistoried" older forest, with 81 percent of the total 36,500 ac consumed in the Biscuit Fire. Loss to stand-replacing fire of "older forest with size indexed to potential natural vegetation zone" was the same or lower than loss in "medium and large" older forest in all provinces except the Washington Eastern Cascades. In that province, an additional 4,700 ac of older forest classified as "size indexed to potential natural vegetation zone" burned in the Wenatchee National Forest during 2002. Note that these figures reflect only portions of burned forests resulting in full canopy removal. Even severe wildfires burn existing vegetation in incomplete patterns, resulting in a mosaic of disturbance severities. Not all areas experiencing fire necessarily lose all old forest characteristics.

Net Changes to Older Forests (Remeasured Plot Analysis)

We examined the transition of area into or out of the "medium and large" older forest classes by using data from the remeasured inventory plots (table 16). There was an overall rate of gain into medium and large size classes (≥20 in) of about 1.9 percent per year averaged over the remeasurement cycle. This rate was based only on Forest Service-Region 5 and Forest Service-Region 6 nonwilderness land, where remeasurement data were collected. The between-class annual transition rate was extrapolated to 19 percent on a 10-year basis to approximate a projected increase of older forest, assuming that the rate of change was constant over time. Because this rate was estimated from only a subpopulation of the federal land, it is valid to apply it only to the same subpopulation to estimate net change. Therefore, applying this rate to the 1994 estimate of 5.33 million ac of "medium and large older forest" on Forest Service-Region 5 and Forest Service-Region 6 nonwilderness land resulted in a net projected increase in the first decade of just over 1 million ac (table 17). On land where remeasurement data were not collected, we had no comparable information about rate of change. However, we might assume a comparable rate (1.9 percent per year) for older forest on Bureau of Land Management land because older forest tends to be at low elevations and therefore is comparable, in terms of productivity, to Forest Service land with remeasurement samples. But on Forest Service-Region 6 wilderness land, and also on National Park Service land, both of which tend to have a greater proportion of relatively less productive forests at high elevations, the rate is probably much lower. Overall then, it is probably reasonable to assume that the rate of increase on land not sampled by the remeasurement data was at least half, but no greater than the rate calculated on sampled lands. We therefore calculated a range of net change by using a high estimate of 19 percent per decade, and a low

Table 15—Older forest mapped as lost to stand-replacing fire

Land use allocation group	Medium and large		Size indexed to vegetation zone		Large, multistoried	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
California Cascades:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	200	0.16	200	0.15	0	0.00
Matrix	300	0.16	200	0.10	0	0.00
Total	500	0.14	400	0.11	0	0.00
California Coast Range:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
California Klamath:						
Admin. withdrawn/congr. reserved	20,200	3.15	14,100	2.20	4,900	3.40
Late-successional reserve	8,400	1.34	5,800	0.93	3,100	2.10
Matrix	1,300	0.23	900	0.16	100	0.11
Total	29,900	1.63	20,800	1.14	8,100	2.10
California—all provinces:						
Admin. withdrawn/congr. reserved	20,200	2.61	14,100	1.86	4,900	2.39
Late-successional reserve	8,600	1.06	6,000	0.74	3,100	1.78
Matrix	1,600	0.21	1,100	0.14	100	0.09
Total	30,400	1.29	21,200	0.90	8,100	1.67
Oregon Coast Range:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
Oregon Eastern Cascades:						
Admin. withdrawn/congr. reserved	300	0.42	300	0.37	0	0.17
Late-successional reserve	300	0.38	300	0.34	0	0.01
Matrix	200	0.22	200	0.16	0	0.02
Total	800	0.34	800	0.28	0	0.07
Oregon Klamath:						
Admin. withdrawn/congr. reserved	18,000	21.19	13,000	22.74	7,800	17.74
Late-successional reserve	25,400	7.46	17,500	7.04	11,400	6.02
Matrix	5,400	1.82	4,100	1.73	2,400	1.59
Total	48,800	6.78	34,600	6.36	21,600	5.63
Oregon Western Cascades:						
Admin. withdrawn/congr. reserved	8,200	1.85	7,500	1.89	2,500	2.07
Late-successional reserve	8,600	1.21	6,600	1.17	3,300	1.00
Matrix	1,900	0.25	1,400	0.24	900	0.32
Total	18,700	0.98	15,500	1.01	6,700	0.92

Table 15—Older forest mapped as lost to stand-replacing fire (continued)

Land use allocation group	Medium and large		Size indexed to vegetation zone		Large, multistoried	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Oregon Willamette Valley:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
Oregon—all provinces:						
Admin. withdrawn/congr. reserved	26,500	4.32	20,800	3.83	10,400	5.57
Late-successional reserve	34,200	2.25	24,400	2.07	14,700	1.92
Matrix	7,400	0.60	5,700	0.57	3,300	0.68
Total	68,100	2.02	50,900	1.87	28,400	1.97
Washington Eastern Cascades:						
Admin. withdrawn/congr. reserved	2,000	3.05	4,700	2.53	0	0.00
Late-successional reserve	1,100	1.73	2,800	1.90	0	0.00
Matrix	600	1.53	900	1.43	0	0.00
Total	3,700	2.21	8,400	2.12	0	0.00
Washington Olympic Peninsula:						
Admin. withdrawn/congr. reserved	0	0.01	0	0.01	0	0.01
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.01	0	0.01	0	0.00
Washington Western Cascades:						
Admin. withdrawn/congr. reserved	200	0.04	200	0.04	0	0.01
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	200	0.02	200	0.02	0	0.01
Washington Western Lowlands:						
Admin. withdrawn/congr. reserved	0	0.00	0	0.00	0	0.00
Late-successional reserve	0	0.00	0	0.00	0	0.00
Matrix	0	0.00	0	0.00	0	0.00
Total	0	0.00	0	0.00	0	0.00
Washington—all provinces:						
Admin. withdrawn/congr. reserved	2,300	0.20	5,000	0.45	0	0.01
Late-successional reserve	1,100	0.15	2,800	0.43	0	0.00
Matrix	600	0.22	900	0.43	0	0.00
Total	4,000	0.18	8,700	0.44	0	0.01
Northwest Forest Plan:						
Admin. withdrawn/congr. reserved	49,000	1.92	39,800	1.65	15,300	1.79
Late-successional reserve	43,900	1.45	33,100	1.26	17,800	1.47
Matrix	9,600	0.42	7,700	0.39	3,400	0.52
Total	102,500	1.30	80,600	1.15	36,500	1.34

Note: In California, the period represented is 1994 through 2003; In Oregon, the period is 1995 through 2002; and in Washington, the period is 1996 through 2002.

Land use allocation groups are explained in table 5.

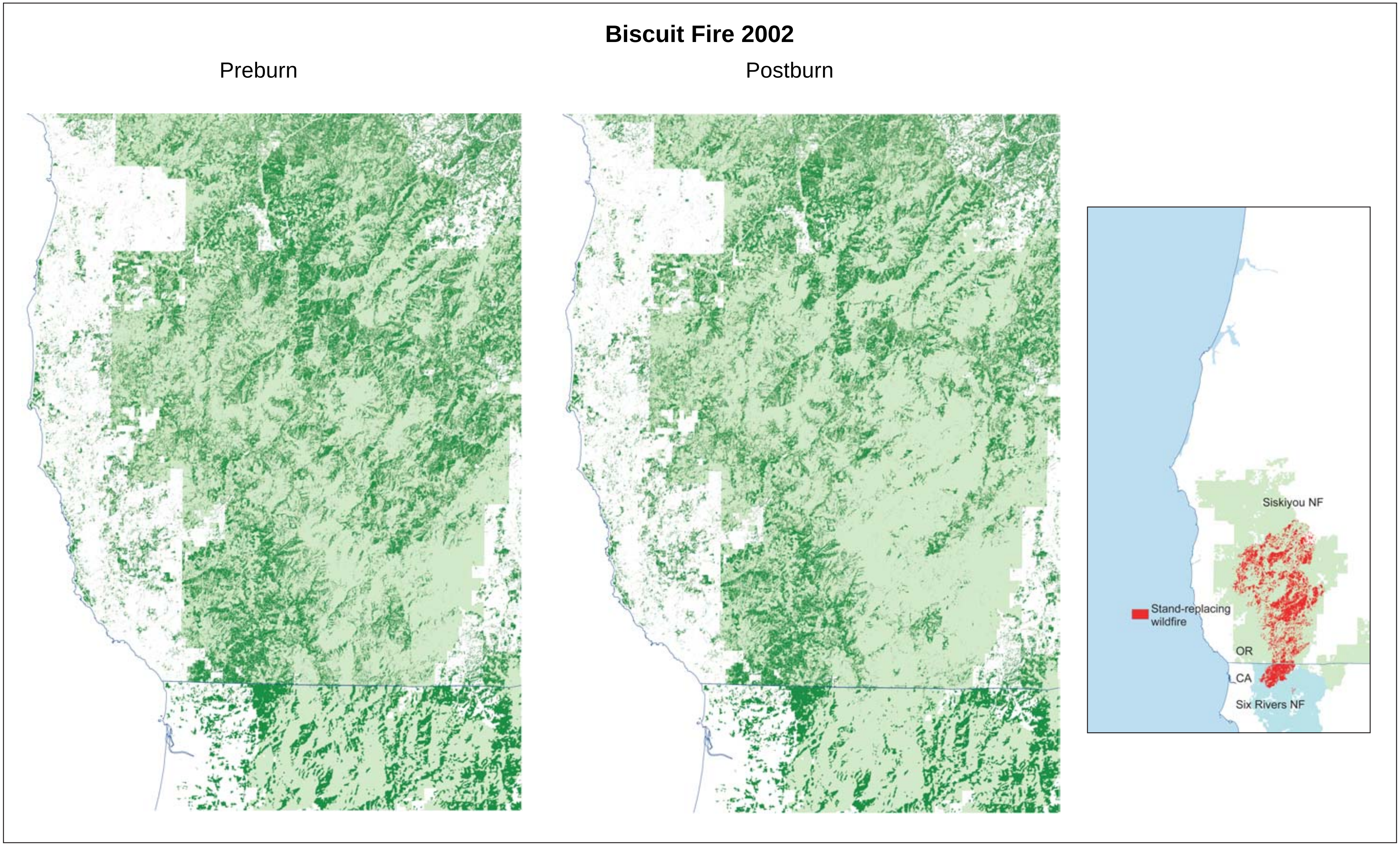

Figure 25—About 78,700 ac of older forest was burned during the 2002 Biscuit fire, Siskiyou National Forest, as detected by remote sensing. Light green = national forest; dark green = medium and large older forest.

Table 16—Acres per year represented by remeasured sample plots, by size class and measurement time

	Time 2		
Size Class	**<20 inches**	**≥20 in**	**Total**
Time 1	– – – – – – *Acres per year* – – – – – – –		
<20 inches	3,036,600	235,400	3,272,000
≥20 inches	136,600	1,789,400	1,926,000
Total	3,173,200	2,024,800	5,198,000

estimate half that rate (9.5 percent per decade) for the 2.53 million ac of older forest mapped in 1994 on Bureau of Land Management, Park Service, and Forest Service-Region 6 wilderness. The additional gain over 10 years ranged from 0.24 million ac to 0.48 million ac (table 17).

The 10-year extrapolation for land on which remeasurement samples were collected was based on a sample of change (both losses and gains) from all causes. In other words, the estimate from the remeasured plot approach represented net change, resulting after subtraction of losses

Table 17—Net change projected in medium and large (≥20 in) older forest over 10 years

		10-year increase with rate of change of:	
Agency	**Mapped area of older forest in 1994**	**19.0 percent**	**9.5 percent**
		Acres	
With remeasurement samples			
Forest Service-Region 5 (all lands) and Forest Service-Region 6, nonwilderness	5,334,300	1,014,000	—
Without remeasurement samples			
Forest Service-Region 6 wilderness, Bureau of Land Management, and National Park Service	2,533,600	481,600[a]	240,800[a]

[a] Hypothetical range of increase on land without measurement samples assuming that the 10-year rate of change was the same (19 percent) or half (9.5 percent) of that calculated on land with remeasurement samples.

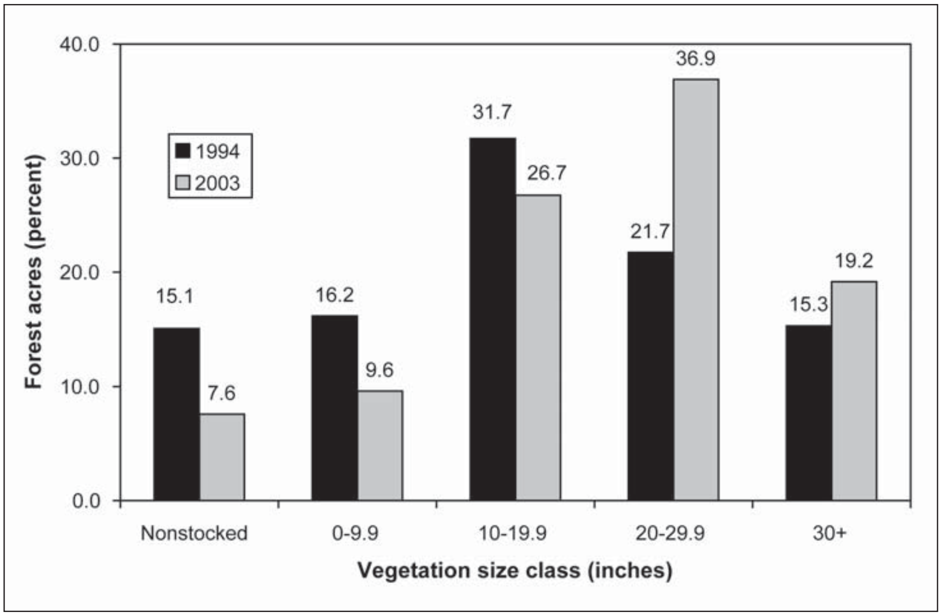

Figure 26—Percentage of forest by diameter class in 1994 and 2003 as estimated from remeasured plot data on Forest Service-Region 5 and Forest Service-Region 6 nonwilderness land. The nonstocked class has canopy closure <10 percent.

from fire and harvest, and addition of gains from ingrowth. We recognize that the assumption of a constant rate of change may be generally valid for growth and possibly for scheduled harvest activities, but for episodic disturbances such as wildfire, the assumption may not be valid. Actual decadal change rates will be influenced greatly by the amount of older forest lost to wildfire.

Most of the projected gain came from increases in the area of forest at the lower end of the diameter range for older forest (fig. 26). In 1994, approximately a third (32 percent) of the area in the remeasurement data was in the 10-19.9-in size class, and was therefore poised to grow into the “medium and large” older forest class during the next decade. The net percentage of acres increased by 10 percent (from 27 to 37) and 4 percent (from 15 to 19) in the medium and large size classes (20-29.9 and ≥30 in) respectively during the decade after the Plan. Net area in the ≥30-in class increased by an estimated 102,000 to 127,000 ac. The percentage of forest land projected to be occupied by the three smaller size classes (potential forest, 0-9.9 in, and 10-19.9 in) decreased over the decade as net acres were recruited into older forest size classes.

Biscuit fire aftermath

Results—Fire Regimes of Older Forests

We analyzed the older forest baseline amounts against information about fire regimes. From a regional point of view, older forest in fire-adapted potential natural vegetation types in the driest provinces (East Cascades and Klamath) accounted for over 1.7 million ac, nearly one-quarter of all older forest (table 18). In the Klamath provinces, nearly all older forest (96 percent) was in fire-adapted ecosystems. In the Western Cascades, an additional 700,000 to 1,000,000 ac (10 percent) was in dry fir, dry mixed-conifer types and interior Douglas-fir. These results were supported by current fire conditions of older forests relative to the national-scale fire regime map (table 19). Three provinces (California Cascades, California Klamath and Oregon Klamath) had the majority of their baseline older

Table 18—Older forests indexed to vegetation zone group as a percentage of forest-capable acres by climatic area

	Coast			West Cascades			East Cascades			Klamath			Northwest Forest Plan	
Vegetation zone group	**Area**	**Percentage of province**	**Plan area**	**Area**	**Percentage of province**	**Plan area**	**Area**	**Percentage of province**	**Plan area**	**Area**	**Percentage of province**	**Plan area**	**Area**	**Percentage of Plan area**
	Thousand acres	*– – – Percent – – –*		*Thousand acres*	*– – – Percent – – –*		*Thousand acres*	*– – – Percent– – –*		*Thousand acres*	*– – – Percent – – –*		*Thousand acres*	*Percent*
Fire adapted:														
Interior Douglas-fir	—	—	—	204	5	2	49	5	1	1,109	47	13	1,362	19
Dry fir	36	4	0	770	18	9	198	19	2	465	20	5	1,469	20
Dry/mixed conifer	1	0	0	28	1	0	152	15	2	296	12	3	477	7
Oak	7	1	0	0	0	0	33	0	0	11	0	0	51	1
Pine	13	1	0	0	0	0	112	11	1	307	13	4	432	6
Tanoak/Douglas-fir	1	0	0	—	—	—	—	—	—	140	6	2	141	2
Total fire adapted	58	6	1	798	20	11	495	48	7	1,219	96	17	3,932	55
Not fire adapted:														
Alpine	17	2	0	128	3	1	10	1	0	—	—	—	155	2
Coastal conifer	1	0	0	—	—	—	—	—	—	—	—	—	1	0
Douglas-fir	116	13	1	—	—	—	—	—	—	—	—	—	116	2
Mountain hemlock	71	8	1	722	17	8	85	8	1	5	0	0	883	12
Pacific silver fir	239	26	3	1,398	33	16	52	5	1	0	0	0	1,689	23
Port Orford-cedar	0	0	0	—	—	—	—	—	—	0	0	0	0	0
Redwood	47	5	1	—	—	—	—	—	—	0	0	0	47	1
Riparian hardwoods	0	0	0	—	—	—	0	0	0	0	0	0	0	0
Sitka spruce	—	—	—	—	—	—	—	—	—	0	0	0	0	0
Subalpine	1	0	0	3	0	0	353	34	4	13	1	0	370	5
Western hemlock	378	41	4	928	22	11	35	3	0	31	1	0	1,372	19
Total not fire-adapted	870	94	12	3,179	80	44	535	52	7	49	4	1	4,633	64
Total	928	100	13	3,977	100	55	1,030	100	14	1,268	100	18	7,203	100

Note: Coast—Oregon Coast Range, California Coast Range, Washington Olympic Peninsula, Oregon Willamette Valley, and Washington Western Lowlands.

West Cascades—Washington Western Cascades and Oregon Western Cascades.

East Cascades—Washington Eastern Cascades, Oregon Eastern Cascades, and California Cascades.

Klamath—Oregon Klamath and California Klamath.

— = no data

Table 19—Percentage of medium and large older forest area falling in national-scale fire-regime condition classes

	Condition class		
Province	**1**	**2**	**3**
		Percent	
Oregon Klamath	11	22	66
California Klamath	0	41	58
California Cascades	7	33	58
Oregon Eastern Cascades	27	33	38
Oregon Willamette Valley	13	54	27
Washington Eastern Cascades	40	36	21
Oregon Western Cascades	10	84	6
Washington Olympic Peninsula	87	7	5
California Coast Range	2	77	3
Washington Western Cascades	38	59	2
Oregon Coast Range	86	12	1
Washington Western Lowlands	1	99	0

Note: Condition class 1 = within historical range; 2 = moderately departed, often having missed at least one fire-return interval; 3 = greatly departed from historical conditions, often having missed two or more fire-return intervals.

forest in fire regime condition class 3, indicating that they were significantly departed from historical conditions (having missed two or more fire-return intervals). Five other provinces had the majority of their older forest in class 2, indicating that they were moderately departed from historical conditions (having missed at least one fire-return interval). Only the northern coastal provinces (Oregon Coast and Washington Olympics) had the majority of their older forest in class 1 (within the range of historical fire conditions).

Discussion

In this publication, we have reported results of a comprehensive assessment of older forest status and trend on federally managed public land in the Northwest Forest Plan area. An incredibly rich data set was assembled and analyzed to support the assessment. There is much to inform us, and there is a huge challenge in reducing the information to meaningful conclusions. In the following discussion, we have two major focuses. One is a focus on results that we think policymakers will need for understanding future management options. Second is a focus on interpreting the ecological evidence in a way that recognizes the limitations of our current knowledge, and helps guide further investigation to increase our understanding of older forest ecosystems in the Pacific Northwest.

An Older Forest Baseline

The two primary types of information we used for monitoring were spatial data (maps created from remotely sensed information) and nonspatial data (inventory plot data). The idea was that we would use different, but complementary, data to answer different types of questions. A corollary was that having redundant, independent sources of information would help inform us about the reliability of our results.

Map-based analysis and plot-based analysis were complementary approaches. Older forest maps developed from remote sensing projects could be used to evaluate forest amount and landscape patterns, and to detect disturbances that resulted in major losses of older forest from the landscape. Inventory data could be used to develop statistical certainty estimates of forest amounts and changes, both gains and losses, from all causes. Statistical confidence intervals could be generated for estimates from plot data, but plots did not sample all ownerships, and sample plots did not give us a map. Maps covered all ownerships, and spatially portrayed important landscape patterns, but their accuracy was more difficult to quantify. Despite these differences, we expected that the estimates developed from the two data sources would lend complementary, consistent evidence of the status and trend of older forests.

The estimates of older forest amounts developed from the map and plot data were consistent with each other at both Planwide and state scales. That is, the same general conclusions would have been reached about the amount and distribution of older forest on federally managed lands in the Plan area regardless of whether we used results from the map-based analysis or from the plot-based analysis. To reiterate the results, depending on whether we applied the “medium and large older forest” or “older forest with size indexed to potential natural vegetation zone” definition, we determined the amount at the start of the Plan to be 7.87 ± 1.96 and 7.04 ± 1.93 million ac, respectively. Using the very restrictive “large, multistoried older forest” definition, we found about 2.72 ± 0.35 million ac (table 11). These estimates had a mapping accuracy of about 75 percent on average (table 6), but this value was higher or lower for individual provinces.

We compared estimates compiled from the maps with statistical estimates compiled from plot data for land sampled by inventory plots—Forest Service-Region 5, Forest Service-Region 6, and Bureau of Land Management-Oregon lands. The fact that the map-based and plot-based estimates for the lands sampled by inventory plots were consistent boosts our confidence that these data sources are sufficient to provide an accurate baseline for older forest Planwide, and in general, at the province scale (fig. 21). Notable exceptions were underestimates of older forest in the Eastern Cascades of Washington and Oregon derived from the map data. There, the plot-based estimates indicated that we may have underestimated the mapped amount of "medium and large" older forests by 200,000 to 300,000 ac.

Our results also showed that a refined baseline estimate established with systematic map or plot information was consistent with the older forest amounts estimated when the Plan was written in 1994. The new baseline using the "medium and large older forest" definition was within 10 percent of the 8.55 million ac reported in the record of decision (USDA and USDI 1994b). (Without the map's underestimate of older forest acres in the Eastern Cascades, our value would have been even closer.) Neither a consistent map of older forest, nor a systematic inventory of federal forest land, existed during initial development of the Plan. Considering the FEMAT team's lack of the vast and systematic data sources available to us today, we conclude that the FEMAT team (FEMAT 1993) did a remarkable job of accurately portraying older forest conditions at the start of the Plan. We further conclude that the evidence supports the idea that the Plan was based on valid assumptions about the amount and distribution of older forests present at the start of the Plan.

An Evolving Ecological Definition of Old Growth

In this report we demonstrated an approach for assessing a variety of older forest definitions representing discrete points along a continuum of older forest definitions. We showed that the systematic map-based and plot-based information used in monitoring can support the assessment of different types of definitions, based on important structural attributes that can be mapped by remote sensing or compiled from inventory plots on the ground.

In this concept, a definition is simply a set of criteria for screening the data to assess whether a given unit on the map or sample on the ground meets or does not meet the minimum threshold to classify it as older forest. The more criteria that are included, the more restrictive the rule set becomes. The simplest definition might have a single criterion, say for average tree size. Inclusion of additional criteria, such as canopy layering, will further restrict the subset of data satisfying the minimum thresholds. Multiple criteria can be reflected in the addition of screening attributes, and also in stratification of the population. An example of the latter was the "older forest with size indexed to potential natural vegetation zone" definition that stratified the data by vegetation zone, assigning different minimum size criteria depending upon natural productivity for the zones.

Also, the type of data used for assessment (that is, map-based or plot-based) imposed additional limitations on the older forest definitions that could be evaluated. The only map attributes that could be developed reliably from the remotely sensed data were average tree size, canopy closure, canopy layering, and life form. (For the eastern Cascades provinces, it was difficult to map average tree size with acceptable accuracy.) Thus, older forest definitions had to be restricted to combinations of attributes that could be obtained from the map data. Because of this restriction, we took the least-common-denominator approach to building older forest rule sets, with the rationale that: (1) these broad characteristics were sufficient to establish a set of refined baseline estimates for older forests from either the map or plot data, (2) we could compare estimates from the two data sources, and (3) we could compare the results to the assumptions upon which the Plan was based.

The definition we called "medium and large older forest" was used as a benchmark for consistency with the definition used in FEMAT (FEMAT 1993) and in the environmental impact statement (USDA and USDI 1994a). It could be used broadly to establish a regional and provincial older forest baseline estimate, and also to assess the assumptions upon which the Plan was founded. In applying this definition, we recognized that a one-size-fits-all, ≥20-in average-tree-size minimum criterion, would tend to overestimate older forest amounts in productive forest types, and underestimate it in less productive types. On balance, though, it would provide a reasonable benchmark at the Plan level.

The "large, multistoried older forest" definition had as its basis important characteristics of "classic" old-growth west-side Douglas-fir forests (Franklin and others 1981, 1986). The aim was to impose a restrictive screen for identifying very large older forests with complex canopy layering. In reality, the usefulness of this definition is limited by the fact that the 30-in average-tree-size minimum criterion is inappropriate for many forest community types. In some potential natural vegetation zones, particularly at higher elevations or east of the Cascade Range crest, older forests simply do not develop trees as large as 30 in. Thus, these forests will seldom or never meet the "large, multistoried older forest" definition, even though they may be old enough and have structure and composition characteristics to be, without doubt, classified as late-successional.

The significant property of the definition we called "older forest with size indexed to potential natural vegetation zone" was that stratifying the size criteria by vegetation zone recognized the regional variation in older forest conditions. It could therefore be "tailored" to potential average sizes developed naturally for forests in different community types. Compared with older forest estimates made by using the "medium and large older forest" definition, the "older forest with size indexed to potential natural vegetation zone" definition estimated additional acres in some pine and subalpine forest communities that were underestimated with the 20-in diameter threshold of the "medium and large older forest" definition. It also estimated fewer acres in some very productive coastal forests.

The "medium and large older forest" definition was useful for establishing baseline values, but it was based upon a one-size-fits-all concept. Alternatively, a definition based upon potential natural vegetation reflects more of the variation inherent in regional older forest ecosystems that could be used as a starting point for an ecologically based older forest definition in future monitoring activities. We can improve upon this basic ecologically based definition as we gain further understanding of older forest structure, composition and function, development pathways, and relationship to past and current disturbance regimes.

As more work is completed to understand the potential for older forest to develop in varying ecosystem types, we will be able to refine the average-tree-size criterion for applying the definition to both map and plot data. An ecologically meaningful definition needs to incorporate structural variation as well as size variation to reflect differences such as stand densities resulting from dry versus wet climatic conditions, or to deal with mixed-structure stands, such as dense young stands with scattered large legacy trees. Definitions can be refined to accommodate important stand-based structural attributes (such as snags and down wood, Franklin and others 1981) and tree ages that can be added to the plot data screens. Researchers are gaining new knowledge all the time that will help us improve the characterization of older forests in the Pacific Northwest (see, for example, Spies 2004). Results of the comparison between sample plots labeled "older forest" and those labeled "not older forest," showed significant differences between important stand-level structure and composition attributes, lending promise that the variation can be assessed from the current plot-based inventories.

Observed Status and Trend Versus Plan Expectations

The Northwest Forest Plan discussed the current state of knowledge of the historical extent of older forest in the Plan area. The Plan objectives with respect to an older forest ecosystem were couched in terms of whether, over several decades, late-successional and old-growth forest could be restored and maintained at or near historical levels.

Many analyses conducted for this report were designed to relate directly to the evaluation of expected outcomes for older forest described in the Plan (sidebar 1, app. 4).

Expected outcomes were quantifiable targets or thresholds that were used to rank Plan alternatives, based upon the likelihood of a given alternative achieving a functioning older forest ecosystem. For the chosen alternative, Option 9, which served as the basis for the Plan, the effectiveness of the Plan could be assessed by comparing results from monitoring of older forest status and trend with the expected outcomes. In other words, assessments at different points in time could help indicate how successful the Plan has been at achieving certain thresholds of older forest amounts, distribution, and functioning. Desired future conditions expressed as expected outcomes served to set a target trajectory for moving present-day older forest amounts and spatial patterns toward historical patterns assumed to be prevalent on the pre-European-settlement landscape. Even so, it was recognized that Option 9 had only a three-quarters likelihood of achieving a functioning older forest ecosystem in moist provinces, and only about a two-thirds likelihood in dry provinces (app. 4, table 4-1).

The expected outcomes of late-successional ecosystems under the Plan were based on the following three attributes that characterize the quantity and quality of components of the ecosystem (app. 4). The late-successional and old-growth monitoring plan (Hemstrom and others 1998) condensed discussion of these from FEMAT (1993: 49-53) and the environmental impact statement (USDA and USDI 1994a: 36-43).

1. Abundance and ecological diversity—the acreage and variety of plant communities and environments.
2. Processes and functions—the ecological actions that lead to the development and maintenance of the ecosystem, and the values of the ecosystem for species and populations.
3. Connectivity—the extent to which the landscape pattern of the ecosystem provides for biological flows that sustain animal and plant populations.

Outcomes for these attributes link to the likelihood of maintaining both the viability of older forest-related species (FEMAT 1993: 28) and the likelihood of maintaining a functional, interacting older forest ecosystem on federal lands (FEMAT 1993: 25; Hemstrom and others 1998). It is therefore enlightening to discuss the baseline results and first-decade trend relative to the Plan expectations. We indexed the older forest status and trend results into the abundance and diversity outcomes and connectivity outcomes that had been stated quantitatively in the Plan (see sidebar 1, app. 4). The process and functions outcomes were not stated in the Plan in quantifiable terms.

To recap the main results, older forest at the start of the Plan occupied between 30 percent (“older forest with size indexed to potential natural vegetation zone” definition) and 34 percent (“medium and large older forest” definition) of forest-capable public lands managed by the Forest Service, Bureau of Land Management, and National Park Service in the range of the northern spotted owl (table 11). “Large, multistoried older forest” occupied about 12 percent of forest-capable public land. Land in blocks of greater than 1,000 ac occupied an estimated 19 to 22 percent of the total older forest according to “older forest with size indexed to potential natural vegetation zone” and “medium and large older forest” definitions, respectively (table 11). In most provinces, the average distance between large older-forest blocks was less than 4 mi (table 13). The exception was the California Coast Range province, where contiguous blocks of federally administered forest lands were separated by large distances. When compared with abundance and ecological diversity thresholds stated in the Plan, baseline amounts and distributions appeared to be consistent with Outcome 3 or Outcome 2 (sidebar 1; app. 4, table 4-2). Although the regional average for percentage of the landscape covered by older forests was lower than the Outcome 2 threshold (40 percent), 4 of 10 provinces contained at least 40 percent “medium and large older forest” (Oregon Willamette Valley and Washington Western Lowlands provinces were not counted because they contain so little federal land) (table 11). These were California Coast Range, California Klamath, Oregon Western Cascades, and Washington Olympic Peninsula. Another four provinces (California Cascades, Oregon Coast Range, Oregon Klamath, and Washington Western Cascades) contained between 34 and 40 percent older forest. Only the eastern Cascades provinces of Washington and Oregon fell well short of the Outcome 2 thresholds, and there we have evidence that the map data underestimated the amounts of older forest. All but one of the 10 provinces—Washington Eastern Cascades—contained at least 5 percent of land in blocks 1,000 ac or larger, meeting the threshold for Outcome 2 for degree of fragmentation (again using the "medium and large older forest" definition). At least 4 of 10 provinces met Outcome 2 for both criteria (percentage of land covered by older forests, and percentage of land in older-forest blocks greater than 1,000 ac).

Considering these results in total, we perceive the condition of older forest abundance, diversity, and connectivity at the start of the Plan to have been generally consistent with Outcome 2, except perhaps for the provinces of the eastern Cascades. The interpretation for this outcome is that the older forest baseline was within the typical range of conditions that occurred during previous centuries, but less than the long-term presettlement average of 65 percent of the landscape (USDA and USDI 1994a). Connectivity was strong, characterized by short distances between large older forest patches. The condition of older forest in the eastern Cascades provinces was more typical of Outcome 3, interpreted as below long-term averages, with relative scarcity in some areas or occurring as scattered remnant patches. Expectations for older forest processes and functions were not assigned quantitative outcomes (app. 4, table 4-3). The outcomes assume that thresholds for processes and functions will be met to the extent that abundance and diversity thresholds are met. In general, Outcome 2 seems appropriate for the baseline condition of older forest, interpreted as natural disturbances and stand development able to occur at some scales, but interrupted at large landscape scales by fire exclusion and fragmentation.

The Plan projected that natural stand development would not achieve the most favorable outcomes for these expectations for at least 100 years; the expectation was that half the thresholds would have been achieved by year 50. This is where short-term, observable trend and long-term, projectable trend become relevant. The observed change was measured against the assumptions of the balance between losses and gains stated in the Plan. The environmental impact statement (USDA and USDI 1994a, 2000) assumed that 0.7 percent of the Plan area would be lost to stand-replacing wildfire per decade, and that 1 percent of the Plan area (or 3 percent of total late-successional forest) would be harvested per decade. It further assumed that ingrowth from younger classes into older forest classes would occur at a rate of 3.5 percent per decade on reserve lands, and 0.7 percent per decade on matrix lands. On balance, older forest was expected to increase by 600,000 ac in the first decade, and by 2.7 million ac after 50 years.

Our monitoring results, albeit based on short-term observed trend, appear to show that certain of the Plan's assumptions were too conservative. Our data show that during the first 10 years of the Plan, projected gains far outpaced losses of older forest, resulting in a net projected increase of between 1.25 and 1.5 million ac of older forest on federally managed land (table 17). The observed rate of gain was about twice the first decadal gain expected under the Plan. It may be that the estimate in the Plan assumed a uniform age-class distribution. According to the remeasured plot data, approximately a third of forested area was in the 10-19.9-in class, poised to transition in the near future into the "medium and large" older forest class (≥20-in) (fig. 26). Many of the stands in the 10-19.9-in class were likely the result of regrowth following large regional fires in the late 19th century through about 1910 (see Agee 1993, chapter 3). Wildfire burned about 1.3 percent (102,500 ac) of older forest (table 15), in line with the amount assumed by the Plan. But harvest levels were much lower compared with Plan assumptions. Our results indicated that about 0.2 percent of older forest (16,000 ac) was harvested (table 14), rather than the approximately 230,000 ac projected to have been harvested at the 3-percent rate.

The Reserve Network

Regardless of which older forest definition is considered, about three-fourths of the total older forest on federally managed lands was in a reserve land allocation at the start of the Plan (fig. 16). "Large, multistoried" older forest occurred in higher proportion in the late-successional reserve group than did "medium and large" older forest.

Thus, the late-successional reserve design apparently did encompass the "best" older forest. These were conservative estimates because they did not include the proportion of older forest in riparian reserves within matrix land. The Plan estimated that riparian reserves accounted for 11 percent of federal land (2.6 million ac). If the average percentage of federal land occupied by older forest were applied to the Plan's estimate of area in riparian reserves, then the underestimate would be in the range of 11 percent (890,000 ac of "medium and large" older forests, 795,000 ac of older forest with "size indexed to potential natural vegetation zone," and 310,000 ac of "large, multistoried" older forest). Slightly more older forest resided in late-successional reserves than in the combination of administratively withdrawn and congressionally reserved allocations. Non-reserve allocations contained a higher proportion of younger stands than did reserve allocations (fig. 17).

It is imperative to view older forest as but one component of a dynamic forest mosaic on the landscape. Over time, varying proportions of older forest will be transitioning back to earlier seral stages through a combination of natural disturbances, scheduled harvest, and turnover caused by natural mortality (see fig. 26). A steady or increasing supply of older forest depends on a perpetual source for replacing it—stands in younger age and size classes. Successful maintenance of older forest requires a balanced near-future and far-future recruitment pool. The mix of early-seral, mid-seral, and older forests resulting from all forces—natural disturbance, silvicultural activities, and stand successional processes—should be evaluated periodically to assess whether the balance between older and younger forest age classes is sufficient to provide a steady or increasing amount of older forest over time. The synthesis report (Haynes and others, in press) treats this topic in much greater detail.

A related theme is that older forest on federally managed land needs to be viewed in the context of the larger regional land base of mixed ownerships. Forest management goals and objectives on private, state, and tribal lands are very distinct from those on federally managed land under the Northwest Forest Plan. For example, the importance of the contribution of older forest from federal land to the overall forest ecosystem in the Plan area will partly depend on whether private industrial forest owners maintain their growing stocks in young plantations managed at short rotations. Again, see Haynes and others (in press) for a more complete discussion.

The Need to Consider Fire

Finally, fire is the most stochastic factor, yet arguably the most important influence on the future condition of the older forest ecosystem in the Plan area, at least in the dry provinces. In the first decade of the Plan, wildfire had a small impact regionally (about 102,500 ac burned, or 1.3 percent of the total), but a potentially huge local impact (more than 90 percent of the total area burned was in several large fires). The region has extremes of natural climatic and fire regimes, varying from moist regions with fire-return intervals in hundreds of years, to dry areas that historically experienced fires on a frequency from 0 to 35 years. Management history (especially fire exclusion and an alteration of naturally occurring species compositions and stand structures) and even climate change, have worked in concert to alter the susceptibility of existing older forest to wildfire, especially in dry provinces and frequent-fire-adapted forest types. In the fire-prone ecosystems most at risk, the possibility of major loss of older forest cannot be ignored. Yet even in moist provinces where fire conditions have been little altered over time, catastrophic loss of older forest to wildfire is always a possibility.

Our results indicated that at least 1.7 million ac of older forest was present in east-side fire-adapted ecosystems (that is, characterized by high fire frequency and low severity) in dry physiographic provinces (East Cascades and Klamath) (table 18). A majority of older forest area there was in current fire condition classes mapped as having missed at least one, and possibly more fire-return intervals, with associated buildup of fuels (table 19). Stands in these conditions are therefore at elevated risk of loss to catastrophic wildfire, depending on ignition under the right conditions. Although this finding is not surprising, it does point out how monitoring information can be useful in identifying ecosystem conditions that would benefit from targeted restoration activities. We used only the coarsest scale of information to arrive at these conclusions. For example, there was no direct consideration of the effects of mortality associated with insect and disease outbreaks in dry provinces where resulting fuel loadings increase the likelihood of catastrophic wildfire. Much more work is needed to refine our understanding of the interactions of fire and management of forest structure and composition in ecosystems characterized by varying degrees of fire-adaptedness.

Emerging Issues

This initial monitoring assessment suggests important future studies to increase our understanding of older forest dynamics. At the stand level, we need better understanding of the relationship between the broad structure-based definitions used in the assessment and additional older forest characteristics, such as composition of down and standing dead wood, age, and understory composition. In the next monitoring cycle, we plan to address this in part by analyzing the inventory plot data that meet the older forest screens for amounts of these attributes. Although we will likely learn much from this data-driven analysis, further incorporation of independent research findings into our results and interpretations is equally important. For example, ongoing studies concerning the historical range of variation of old growth in the Pacific Northwest, development pathways that led to our current older forest, and the relationship of older forest to historical and present disturbance regimes will provide essential information to the monitoring of older forest (Spies 2004). An entire body of empirical research is being developed to study the influence of early stand management on the development of older forest structures and ecosystem functioning (for example, Carey and others 1999, Garman and others 2003, Poage and Tappenier 2001). The results from studies such as these will lead to improved decisionmaking by managers faced with the obligation of maintaining a healthy regional older forest network.

Monitoring Design Considerations

The monitoring strategy established in this paper had two main components. First, a baseline condition for older forest was established through remote sensing classification by using Landsat imagery and an extensive network of reference plots. This baseline was then altered over time in a general way through change rates established by remeasured plots, and in a spatially explicit way by using change detection based on remote sensing. Going forward, this strategy will provide an efficient way to provide timely, regionwide assessments of the status of older forest. The alternative to simply altering a baseline condition by using change detection is to periodically completely remodel the region. Although reevaluation of the baseline will occasionally be desirable to take advantage of new information and methods, the process is too onerous to repeat frequently.

There are known accuracy limitations in classifying forest structural attributes from satellite data. The accuracy of maps of forest attributes classified from remotely sensed data is typically in the range of 60 to 80 percent, with the greatest errors occurring among similar classes (Moody and Woodcock 1995). For many attributes, the accuracy of maps based on satellite imagery is comparable to that of aerial photography and is sufficient for many applications (Peterson and others 1999). Still, for a landscape-level characterization of forest structure, there is no comparable alternative to remote-sensing-based mapping.

Effective change detection is necessary for the timely consideration of the effects of an unusual fire season, for example, or new policies regarding timber sales. One method of monitoring harvest activity is to accelerate the recent move toward a regional federal management activities database. The Bureau of Land Management-Oregon has established a useful model of a unified, spatially explicit database that tracks harvest and forest-health-related management activities. Most national forests in the region have similar records, although considerable efforts will be needed to standardize and integrate these products.

Even having access to such a database will not be sufficient to address every analysis need. For example, there are two possible shortcomings to monitoring harvests when using only spatial management databases. First, there is variation across the region and across agencies in the terminology used in forest management. A shelterwood cut on Bureau of Land Management land in the Oregon Coast province might look very different from a Forest Service shelterwood cut in the east Cascades provinces. There may be very good reasons for such differences relating to different regeneration mechanisms of endemic species or to different optimal stocking densities. However, these differences will create discrepancies in the attribution of polygons in a regional database. The other problem lies at the polygon level. Although harvest-unit polygons are drawn at the stand scale, forest structure and the change in forest structure is rarely uniform within a polygon. Thus, inconsistencies occur at both coarse and fine scales of regional databases based on harvest records.

These problems are diminished with the use of satellite-based change detection. The relatively high resolution and synoptic nature of satellite imagery allows uniform estimates of change at relatively fine scales over large areas. The main shortcoming of current digital change-detection technology, and an area in need of research, is its sensitivity to forest changes less dramatic than the stand-replacing disturbances we monitored. Although different intensities of canopy removal are detectable in the spectra monitored by Landsat, there is currently no protocol for using satellite imagery to monitor stand-thinning disturbances at a regional scale. Detection of more subtle changes would be a large step forward in the monitoring process. Although this report shows very little clearcutting on federal land in the last decade, many national forests have continued to place a strong emphasis on stand improvement through thinning. Tracking partial harvests would add an inventory element currently only available from management records (with the above limitations). Also, the detection of more subtle changes in forest canopy will allow monitoring of completely different disturbance agents. Forest loss owing to insects, fire, and invasive pathogens could be tracked in the same analysis that identifies harvest. The importance of these disturbances will increase as more older forest is added to the age-class mix on federal forests in the region.

Continued remeasurement of inventory plots is an absolute necessity. Plot data are critical both in the establishment of a baseline for forest conditions and in the calibration of existing vegetation classifications and change-detection techniques. Improved techniques for relating plot-based information to vegetation classifications from remote sensing are being developed by researchers (see, for example, Ohmann and Gregory 2002). The baseline-update model established in this report should serve the monitoring needs of the Northwest Forest Plan well as inventory information and remote sensing methods continue to improve.

Conclusions

At the Plan scale, estimates of older forest amounts (between 7.03 and 7.87 million ac, depending on the specific older forest definition used) developed from the map and plot data were consistent with each other. Map estimates had a prediction error of about 25 percent overall, a value typical for characterizing forest structure from remotely sensed data. We interpreted the consistency between map-based and plot-based estimates as evidence that the monitoring data provided an accurate new baseline for older forest in the Plan area. Furthermore, the results supported a conclusion that a new baseline established with systematic map or plot information was consistent with the older forest amounts estimated when the Plan was written in 1993, and therefore the Plan was based upon valid assumptions about the amount and distribution of older forest present at the start of the Plan.

Broken tops of emergent old-growth trees, Olympic National Forest

The net increase in older forest amounts during the first decade of the Plan was projected to be between 1.25 and 1.5 million ac. Gains from movement of younger, smaller size classes into classes meeting older forest criteria outpaced losses from wildfire and harvest combined. We estimated that 16,900 ac of older forest was harvested, regionwide, and about 102,500 ac was burned, most in the fire season of 2002. These values have an error estimate of between 7 and 12 percent.

The initial amount, distribution, and arrangement of older forest on federally managed lands appeared to meet or exceed Northwest Forest Plan expectations. Gains in older forest occurred at a much higher rate than the rate expected under the Plan (600,000 ac). Actual harvest (16,900 ac) was substantially less than the amount projected to be harvested from matrix lands in the first decade (3 percent of late-successional forest, or about 230,000 ac).

An older forest definition based on potential natural vegetation reflected more of the variation inherent in regional older forest ecosystems then a simple “one-size-fits-all” rule like the “medium and large older forest” definition. If used as a starting point for an ecologically based older forest definition in future monitoring activities, a definition based on size indexed to potential natural vegetation type could be continually improved as we gained further understanding of older forest structure, composition, and functioning, development pathways, and relationship to past and current disturbance regimes.

Finally, fire is a potent force on the Plan landscape and an important consideration in perpetuating a healthy, functioning older forest ecosystem in the Northwest Forest Plan area.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.3048	Meters
Acres (ac)	.405	Hectares
Square miles (mi^2)	2.59	Square kilometers
Trees per acre	2.47	Trees per hectare
Tons (ton)	907	Kilograms
Tons per acre	2.24	Megagrams per hectare
Cubic feet per acre (ft^3/ac)	.07	Cubic meters per hectare

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Appendix 1—Path/row and date of Landsat Thematic Mapper imagery

Path/row and date of Landsat Thematic Mapper imagery used in the monitoring analysis for classifying existing vegetation attributes at the start of the Northwest Forest Plan

Path/row	Date
48 / 26	10/9/92
48 / 27	10/9/92
47 / 26	8/12/96
47 / 27	8/12/96
47 / 28	7/11/96
47 / 29	7/11/96
46 / 26	8/21/96
46 / 27	8/21/96
46 / 28	8/21/96
46 / 29	8/21/96
46 / 30	8/3/95
46 / 31	6/18/96
45 / 26	7/13/96
45 / 28	7/13/96
45 / 29	7/13/96
45 / 30	7/13/96
45 / 31	7/8/94
45 / 31	7/8/94
45 / 31	8/4/98
45 / 32	6/22/94
45 / 32	8/4/98
45 / 33	6/22/94
45 / 33	8/4/98
46 / 31	7/15/94
46 / 31	7/26/98
46 / 32	7/15/94
46 / 32	7/26/98

Appendix 2—Forest Canopy Structure Modeling Pilot Study

Craig Ducey and Melinda Moeur

Abstract

The objective of this pilot study was to test the possibility of predicting the Structural Complexity Index (SCI) as a means of modeling forest canopy structure. Image objects created by using the multiresolution segmentation utility available in eCognition version 3.0 (Definiens Imaging 2003) were used as the basic mapping units. Image objects are aggregations of pixels based on a number of user-defined criteria including a scale parameter, color (spectral values), shape, smoothness, and compactness. Image objects were classified as either simple or complex forest canopy structure. The results of this project, in conjunction with other geographic information and remote sensing vegetation classifications, will be used to predict the occurrence of late-successional and old-growth forest throughout western Oregon and Washington for effectiveness monitoring.

Introduction and Methods

The multiresolution segmentation utility in eCognition is a data-driven region-merging method that begins with single pixels. Through subsequent iterations, these pixel-scale image objects are merged together until the smallest increase in heterogeneity exceeds a threshold defined by the user. Image object heterogeneity is determined both spectrally and spatially. Spectral heterogeneity is described by the weighted standard deviations of the spectral values in each layer used during the segmentation. Spatial heterogeneity is determined by both the compactness of image objects and their border smoothness. A mixture of these two heterogeneity criteria results in image objects that may not be as spectrally homogeneous as possible, but have greater contextual meaning.

For this pilot study, the Alsea fourth-field watershed located along the Oregon coast and the north third of the Western Cascades Washington (WCW) physiographic province were selected as study areas. The 1996 Landsat

TM imagery was acquired from both areas and clipped to their respective boundaries. The imagery was processed to produce normalized difference vegetation index (NDVI), band ratios 4:3, 5:4, and 5:7, as well as the three tassled cap transformations. Aspect and slope were calculated for both study areas by using 25-m digital elevation models.

The multiresolution image segmentation utility was applied to both study areas by using the raw and processed imagery. All input image layers were weighted equally (weight = 1.0). For the WCW subset, aspect was also included in the segmentation, and was weighted at 0.5. Aspect was included to help eCognition distinguish between opposing slopes. The resulting segmentations were vectorized, and exported from eCognition as an ArcINFO[1] shapefile. Each image object was attributed with its mean and standard deviation values for all the input image layers.

Current Vegetation Survey (CVS) plot data for both study areas were used as a means of applying calculated SCI values to the image objects. Only those CVS plots determined to be of high quality during a quality control procedure performed for the Interagency Vegetation Mapping Project (IVMP) were used. These plots were checked for registration and photointerpretation information errors, as well as the relative homogeneity of the plot in terms of shadows, ridges, roads, drainages, etc. Twenty percent of the CVS plots from each study area were reserved for accuracy assessment.

Relationships between the image object mean and standard deviation values and SCI were evaluated by using multiple regression (table 2-1). Four of the variables were eliminated based on their r^2 values, residuals, and overall appearance to allow the multiple regression program to run at a reasonable speed. Any significant outliers were removed from the data set. The best potential models containing one to five variables based on their r^2 value were evaluated to determine if each variable significantly contributed to the overall fit of the regression line. If one variable did not, the entire model was eliminated from consideration. The r^2 values of the remaining models were then compared to the model with the highest r^2 value. Any model not within 0.05 of the top r^2 value was eliminated.

Table 2-1—Variables tested in the multiple regression of canopy complexity index (SCI)

Mean	Standard deviation	Description
U_BLUE	SD_BLUE	Landsat TM Band 1 (Blue)
U_GREEN	SD_GREEN	Landsat TM Band 2 (Green)
U_RED	SD_RED	Landsat TM Band 3 (Red)
U_NIR	SD_NIR	Landsat TM Band 4 (Near-Infrared)
U_MIR01	SD_MIR01	Landsat TM Band 5 (Mid-Infrared 01)
U_MIR02	SD_MIR02	Landsat TM Band 7 (Mid-Infrared 02)
U_R01	SD_R01	Band 4/Band 3
U_R02	SD_R02	Band 5/Band 4
U_R03	SD_R03	Band 5/Band 6
U_T01	SD_T01	Tasseled Cap Brightness
U_T02	SD_T02	Tasseled Cap Greenness
U_T03	SD_T03	Tasseled Cap Wetness
U_NDVI	SD_NDVI	Normalized Difference Vegetation Index
U_SAVI	SD_SAVI	Soil Adjusted Vegetation Index
U_SLP	SD_SLP	Slope

Note: U_ = mean and SD_ = standard deviation.

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture for any product or service

Those models surviving the evaluation procedure were applied to the imagery in eCognition. An SCI threshold dividing simple from complex forest canopy structure was determined by comparing the calculated SCI values with their CVS plot's single or multistory canopy attribute. Various SCI threshold candidates were visually judged by juxtaposing the modeled imagery against photointerpreted aerial photography. The model with the best result was then applied to imagery.

Areas with less than 10 percent coniferous cover in the IVMP data yet classified as having complex canopy structure were reclassified as simple canopy structure. The land use and nonvegetated land cover mask created for the IVMP project was applied to the final forest canopy structure map to prevent water, agriculture, urban areas, etc. from having a forest structure assignment.

The accuracy of the SCI models were tested by comparing the predicted and calculated SCI values.

Results

Individual relations between variables and SCI were better overall in the Alsea watershed than in the WCW South study area. Eleven variables in the Alsea watershed and only seven in the WCW South study area had r^2 values greater than 0.25. The SD_NDVI variable exhibited an almost categorical relationship with SCI in both study areas. This was also true for SD_R02 and SD_R03 in the Alsea watershed. Variables SD_BLUE, SD_NDVI, SD_R02, and SD_R03 were left out of the Alsea watershed's regression models. Variables SD_NDVI, SD_R02, U_SLP, and SD_SLP were left out of the WCW South study area's regression models.

The best multiple regression results that passed the evaluation procedure for both study areas are listed below.

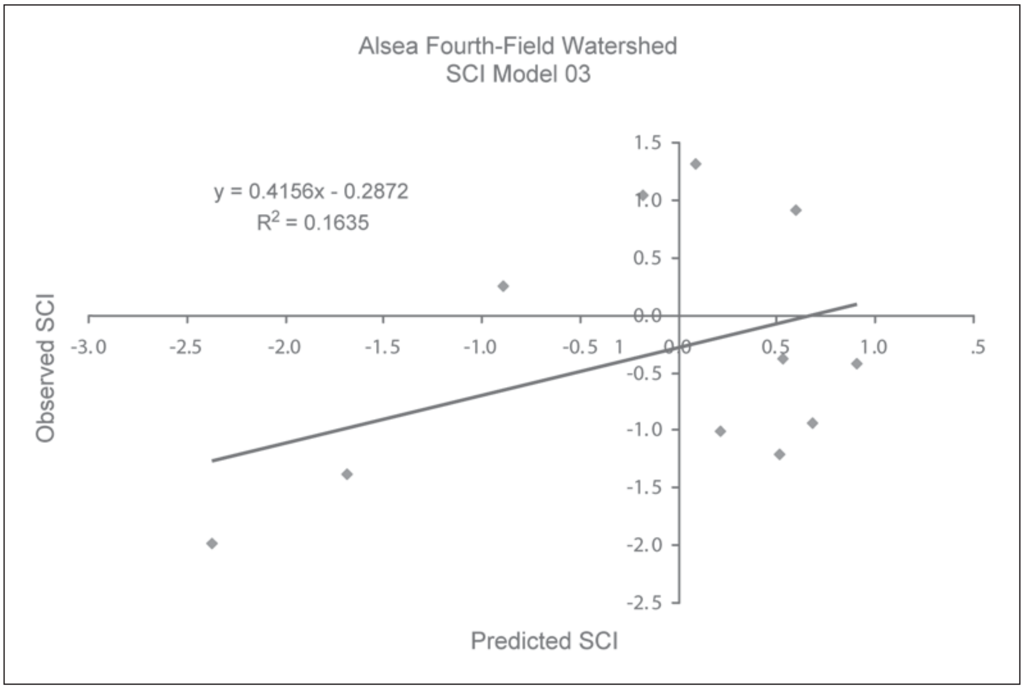
Alsea Fourth-Field Watershed

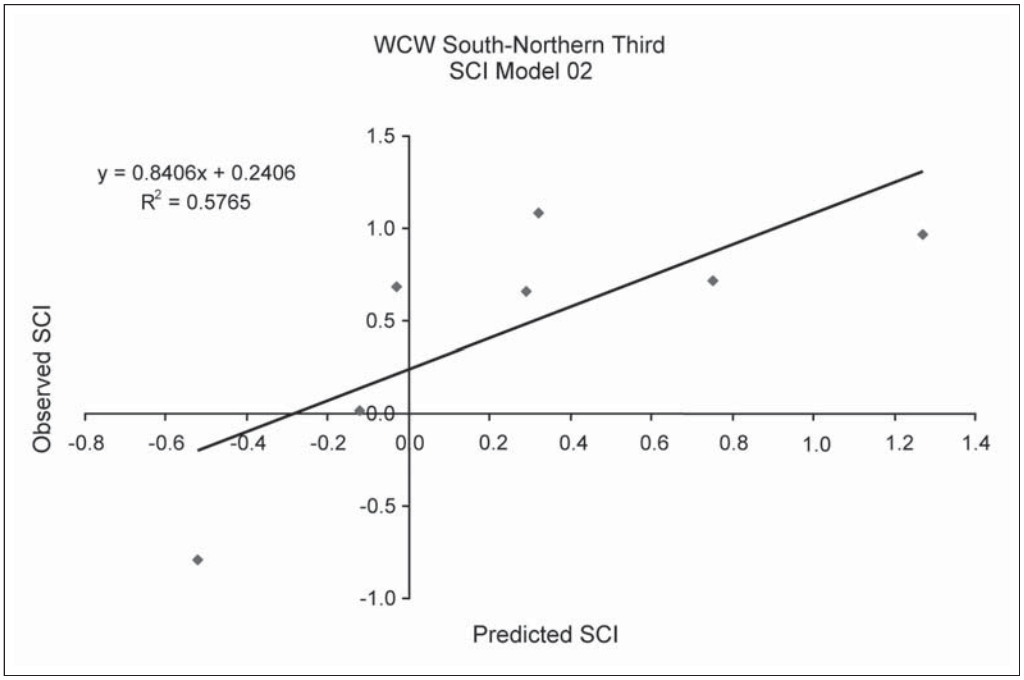
Model	R-Square	Variables in Model
3	0.6582	U_GREEN SD_R01 SD_T01
5	0.7075	U_GREEN SD_GREEN SD_MIR02 SD_T01 SD_T02
5	0.7045	U_GREEN SD_GREEN SD_MIR02 SD_R01 SD_T01
5	0.6966	U_GREEN SD_GREEN SD_NIR SD_MIR02 SD_T01

WCW South–Northern Third

Model	R-Square	Variables in Model
4	0.6684	SD_NIR SD_R03 SD_T01 SD_T02
5	0.7171	SD_GREEN SD_NIR U_R02 SD_T01 SD_T02

Accuracy was assessed by comparing observed SCI versus predicted SCI. Scatter plots showing this relationship for the best models for each study area are shown below. Eleven points were reserved for accuracy assessment for the Alsea watershed, and seven were reserved for the WCW study area.


Alsea Fourth-Field Watershed
SCI Model 03
y = 0.4156x - 0.2872
R2 = 0.1635
Observed SCI
Predicted SCI
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5


WCW South-Northern Third
SCI Model 02
y = 0.8406x + 0.2406
R2 = 0.5765
Observed SCI
Predicted SCI
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
-1.0
-0.5
0.0
0.5
1.0
1.5

Appendix 3—A discussion of map accuracy for Interagency Vegetation Mapping Project (IVMP) and Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG).

In a quantitative assessment of map accuracy, comparison of map values and reference plot values is summarized in an error matrix. The example below shows the frequency of samples classified from the map (rows) relative to their true values in the reference data (columns). Samples along the main diagonal have been mapped correctly, whereas values above or below the diagonal have been incorrectly mapped. Overall accuracy describes how well the total map reflects the reference data and is calculated by dividing the sum of the numbers along the main diagonal by the total number of reference samples (321 / 434 = 74 percent). Two other types of accuracy yield additional information about the performance of the map with respect to specific classes. Producer's accuracy is the probability that a reference observation on the ground has been correctly classified on the map. Producer's accuracy summarizes errors of exclusion. In the example, of 75 sample areas identified as "Deciduous" in the reference data, 65 / 75 = 87 percent were mapped correctly. Ten other reference observations (13 percent) were mistakenly omitted (excluded) from the "Deciduous" class. User's accuracy is the probability that a unit classified on a map actually represents that class on the ground. User's accuracy summarizes errors of inclusion. Of the 115 samples identified on the map as "Deciduous," 65 / 115 = 57 percent were mapped correctly, while 50 reference observations (43 percent) were mistakenly interpreted (included) as belonging to the "Deciduous" class when they really belong to another class.

Example Error Matrix

	Reference plots					
Map	Deciduous	Conifer	Agriculture	Shrub	Row total	User's accuracy (percent)
Deciduous	65	4	22	24	115	57
Conifer	6	81	5	8	100	81
Agriculture	0	11	85	19	115	74
Shrub	4	7	3	90	104	87
Column total	75	103	115	141	434	
Producer's accuracy (percent)	87	79	74	64		74

When reference data are obtained from different inventory sources having unequal sampling probabilities, it is appropriate to weight the contribution of each sample type to the overall accuracy value. For example, plot sizes and sampling intensities differ for Current Vegetation Survey (CVS) inventory plots on U.S. Forest Service (FS), CVS inventory plots on Bureau of Land Management (BLM) lands, and Forest Inventory and Analysis (FIA) inventory plots on state and private lands. The data derived from the three inventories have different area expansion factors, which are used to properly weight the map accuracy values in IVMP. Weighting formulas are included in the IVMP accuracy assessment documentation (Browning and others, 2002a, 2003a, 2003b, 2003c, 2003d; O'Neil and others, 2001a, 2002a, 2002b).

In IVMP, mapped values of percentage of cover are continuous (1 percent increments) for all provinces, and average tree size (quadratic mean diameter—QMD) values are continuous (1-in increments) for 6 of 9 provinces. To create the error matrices, the continuous data were collapsed into classes corresponding to Vegetation Strike Team standards (Askren and others 1995, 1996), that is 20-percent classes for cover, and the following classes for QMD: 0-4.9, 5-9.9, 10-19.9, 20-29.9, 30-49.9, and 50 in and larger. In addition, accuracies are reported for a two-class QMD map (0-19.9 vs. 20 in and greater), which corresponds to the threshold used to distinguish young forest classes from older forests, and a three-class cover map (0-39 percent, 40-69 percent, and 70-100 percent).

Table 3-1—Accuracy matrices for average tree size mapped in 20-in classes by IVMP in Oregon and Washington

Map	Accuracy type	Reference plots		
		0-19.9 inches	**20+ inches**	
Inches		– – – – – – *Percent* – – – – – –		
Oregon Coast Range				
0–19.9	User’s	85.07	14.93	
	Producer’s	80.10	26.02	
20+	User’s	34.23	65.77	
	Producer’s	19.90	73.98	
Overall map accuracy				79.18
Oregon Eastern Cascades				
0–19.9	User’s	86.91	13.09	
	Producer’s	89.46	41.98	
20+	User’s	38.65	61.35	
	Producer’s	10.54	58.02	
Overall map accuracy				81.67
Oregon Klamath				
0–19.9	User’s	82.99	17.01	
	Producer’s	57.62	33.13 B	
20+	User’s	68.61	31.39	
	Producer’s	42.38	66.87 B	
Overall map accuracy				60.77
Oregon Western Cascades				
0–19.9	User’s	86.56	13.44	
	Producer’s	68.19	17.63 B	
20+	User’s	39.13	60.87	
	Producer’s	31.81	82.37 B	
Overall map accuracy				61.99
Oregon Willamette Valley				
(No accuracy assessment performed)				
Washington Eastern Cascades				
0–19.9	User’s	84.43	15.57	
	Producer’s	93.25	100.00	
20+	User’s	100.00	0.00 A	
	Producer’s	6.75	0.00 A	
Overall map accuracy				79.59

Table 3-1—Accuracy matrices for average tree size mapped in 20-in classes by IVMP in Oregon and Washington (continued)

	Accuracy	Reference plots		
Map	type	0-19.9 inches	20+ inches	
Inches		*– – – – – – Percent*	*– – – – – –*	
Washington Olympic Peninsula				
0–19.9	User’s	95.20	4.80 A	
	Producer’s	87.27	14.29 AB	
20+	User’s	55.50	44.50	
	Producer’s	12.73	85.71B	
Overall map accuracy				86.69
Washington Western Cascades				
0–19.9	User’s	80.67	19.33	
	Producer’s	62.98	20.11	
20+	User’s	44.21	55.79	
	Producer’s	37.72	79.89	
Overall map accuracy				72.14
Washington Western Lowlands				
0–19.9	User’s	91.13 B	8.87 B	
	Producer’s	93.39 B	91.67 B	
20+	User’s	88.89 B	11.11 AB	
	Producer’s	6.61 B	8.33 AB	
Overall map accuracy				85.71

Note: User’s, producer’s and overall map accuracy values are shown. Code of (A) in a cell indicates fewer than 5 total observations in the cell; code of (B) indicates one or more of the strata (inventory groups) had no observations.

Table 3-2—Accuracy matrices for percentage of coniferous cover mapped in three classes by IVMP in Oregon and Washington

		Reference plots			
Map	**Accuracy type**	**0–39 percent**	**40–69 percent**	**70–100 percent**	
Percent		– – – – – – – – – – – *Percent* – – – – – – – – – – –			
Oregon Coast Range					
0–39	User’s	65.37	18.16	16.47	
	Producer’s	70.93	21.61	6.05	
40–69	User’s	26.79	32.40	40.81	
	Producer’s	27.71	50.00	21.50	
70–100	User’s	1.59 A	12.04	86.36	
	Producer’s	1.36 A	28.39	72.44	
Overall map accuracy					67.43
Oregon Eastern Cascades					
0–39	User’s	52.17 B	39.13 B	8.70 AB	
	Producer’s	80.00 B	47.37 B	1.43 A	
40–69	User’s	4.06 A	14.22	81.72	
	Producer’s	13.33 AB	36.84 B	28.09	
70–100	User’s	0.93 A	2.79 A	96.29	
	Producer’s	6.67 AB	15.79 AB	70.48	
Overall map accuracy					67.53
Oregon Klamath					
0–39	User’s	67.45	15.82	16.72	
	Producer’s	63.91	28.45	18.09	
40–69	User’s	45.37	17.46	37.17	
	Producer’s	26.87	21.46	21.80	
70–100	User’s	8.13	32.27	59.60	
	Producer’s	9.22	50.09	60.11	
Overall map accuracy					57.04
Oregon Western Cascades					
0–39	User’s	79.20	20.80	0.00	
	Producer’s	55.04	13.14	0.00	
40–69	User’s	30.42	43.36	26.21	
	Producer’s	39.39	51.01	8.44	
70–100	User’s	1.35	9.55	89.10	
	Producer’s	5.57	35.85	60.11	
Overall map accuracy					74.41
Oregon Willamette Valley					
(No accuracy assessment performed)					

Table 3-2—Accuracy matrices for percentage of coniferous cover mapped in three classes by IVMP in Oregon and Washington (continued)

		Reference plots			
Map	**Accuracy type**	**0–39 percent**	**40–69 percent**	**70–100 percent**	
Percent			– – – – – – – – – *Percent* – – – – – – – – –		
Washington Eastern Cascades					
0–39	Users	80.28	13.15	6.57	
	Producer’s	70.99	13.44	2.52	
40–69	User’s	13.38	38.01	48.61	
	Producer’s	21.81	46.64	25.03	
70–100	User’s	2.56	16.47	80.97	
	Producer’s	7.20	39.92	72.45	
Overall map accuracy					66.41
Washington Olympic Peninsula					
0–39	User’s	78.23	19.23	2.54 A	
	Producer’s	63.80	16.60	1.32 A	
40- 69	User’s	26.29	29.34	44.37	
	Producer’s	32.04	41.01	11.84	
70-100	User’s	0.63 A	9.34	90.03	
	Producer’s	4.15 A	42.39	86.84	
Overall map accuracy					79.09
Washington Western Cascades					
0–39	User’s	70.62	17.43	11.96	
	Producer’s	64.60	21.72	3.12	
40–69	User’s	19.57	26.17	54.26	
	Producer’s	20.26	45.92	16.09	
70–100	User’s	4.30	5.19	90.51	
	Producer’s	15.14	32.37	80.79	
Overall map accuracy					74.17
Washington Western Lowlands					
0–39	User’s	59.68 B	25.81 B	14.52 B	
	Producer’s	63.79 B	30.77 B	10.47 B	
40–69	User’s	31.75 B	38.10 B	30.16 B	
	Producer’s	34.48 B	46.15 B	22.09 B	
70–100	User’s	1.41 AB	16.90 B	81.69 B	
	Producer’s	1.72 AB	23.08 B	67.44 B	
Overall map accuracy					60.71

Note: User’s, producer’s and overall map accuracy values are shown. Code of (A) in a cell indicates fewer than 5 total observations in the cell; code of (B) indicates one or more of the strata (inventory groups) had no observations.

Table 3-3—IVMP canopy structure map accuracy

Province/	Canopy	Accuracy value			Number of reference obs[b]	
image subset	structure[a]	Producer's	User's	Overall	aa	mb
		– – – – – – – *Percent* – – – – – – –			– – – *Number* – – –	
Oregon Coast Range						
South	SS	80.0	94.1	87.2	38	91
	MS	94.5	80.2			
North	SS	88.5	88.5	87.5	48	137
	MS	86.4	86.4			
Oregon Eastern Cascades						
Mid	SS	61.9	59.1	63.0	46	140
	MS	64.0	66.7			
North	SS	50.0	50.0	55.6	9	34
	MS	60.0	60.0			
South	SS	78.3	66.7	70.2	47	141
	MS	62.5	75.0			
Oregon Klamath						
North	SS	54.3	76.0	65.2	66	192
	MS	77.4	58.5			
South	SS	79.4	71.1	73.5	68	220
	MS	67.6	76.7			
Oregon Western Cascades						
North	SS	77.8	82.4	73.1	26	51
	MS	62.5	55.6			
Mid-North	SS	73.0	67.5	69.7	76	106
	MS	66.7	72.2			
Mid-Southeast	SS	75.0	72.4	76.6	64	136
	MS	77.8	80.0			
Mid-Southwest	SS	57.1	66.7	75.0	40	153
	MS	84.6	78.6			
South	SS	57.1	57.1	70.0	20	60
	MS	76.9	76.9			
Washington Eastern Cascades						
North	SS	70.0	53.8	55.0	20	58
	MS	40.0	57.1			
Mid	SS	60.0	50.0	50.0	23	63
	MS	40.0	50.0			
South	SS	36.4	80.0	57.9	19	48
	MS	87.5	50.0			
Washington Olympic Peninsula						
East	SS	78.9	78.9	72.4	29	67
	MS	60.0	60.0			
West	SS	83.3	55.6	66.7	15	32
	MS	55.6	83.3			
Washington Western Cascades						
North	SS	61.1	84.6	75.0	36	95
	MS	88.9	69.6			
South	SS	60.5	60.5	62.5	80	239
	MS	64.3	64.3			

[a] SS=single-storied, MS=multistoried

[b] aa=accuracy assessment plots, mb=model building plots

In California, an independent subsample of R5-FIA plots (that is, those plots administered by Pacific Southwest Region [Region 5] on Forest Service lands) and FIA plots (those plots administered by Pacific Northwest Station on non-FS lands) provided reference data for CALVEG map accuracy assessment. Reference plots were systematically located across the area to be mapped by IVMP. Accuracy assessments are reported for tree size classes and tree canopy closure classes.

The CALVEG map error assessment uses error matrix procedures much like those of IVMP. In addition, map accuracies reported for CALVEG attributes include estimates based on fuzzy set ratings. Fuzzy set theory goes a step beyond strictly evaluating whether an observation is correctly or incorrectly classified relative to ground truth data. Instead, the classification is rated on a relative scale from “absolutely right” to “absolutely wrong.” For example, a pure red fir stand, classified as “hardwood” may be rated absolutely wrong, but a classification of “mixed conifer-fir” might be considered sufficiently accurate and thus acceptable for many decisionmaking purposes.

The logic that determines the assignment of fuzzy ratings for each reference/map label combination is based on deviation from the class parameters defined in the classification keys. Fuzzy ratings are ultimately used to determine what percentage of each map class is acceptable and the magnitude of the errors within each map class. The example below illustrates fuzzy ratings assigned to crown closure and tree size based on the deviation from a defined class measured as a percentage of class width.

Example fuzzy rating matrix for CALVEG attributes

	Fuzzy rating				
	5	**4**	**3**	**2**	**1**
			Percent		
Crown closure	7	10	15	18	>18
Tree size	10	30	60	120	>120

The fuzzy rating scale used for Region 5 accuracy assessments is as follows:

5: Absolutely right. Perfect match.

4: Good. Would be happy to find this label on the map.

3: Acceptable. Maybe not the best possible map label but it is acceptable.

2: Understandable but wrong. Not an acceptable map label. There is something about the site that makes the label understandable, but there is clearly a better one.

1: Absolutely wrong. The label is absolutely unacceptable.

Overall map and class accuracies reported for CALVEG atttributes include both nonfuzzy and fuzzy rating values. Observations having a fuzzy rating of 3 or better are considered correct. These operators are useful in identifying more subtle confusion between map classes (for details see Milliken and others 1998 and Franklin and others 2001). The nonfuzzy (MAX operator) corresponds most closely to the IVMP error matrix method. Note that CALVEG uses more classes, and narrower classes for reporting both size and cover. Therefore, we expect calculated classification errors to be inherently higher than for fewer, wider classes reported for IVMP data. In this report, both the MAX operator and fuzzy rating (RIGHT operator) values based on the error matrix are discussed in presenting CALVEG map accuracy results.

The CALVEG classes for average tree size are 0-1, 1-4.9, 5-11.9, 12-23.9, 24-39.9, and 40+ in. No two-class accuracy was evaluated that would correspond with the IVMP classes—0-19.9 and 20+ in. Cover accuracy was assessed for four classes: 0-19, 20-39, 40-69, and 70-100 percent. The CALVEG map project areas do not correspond directly with physiographic provinces used in Northwest Forest Plan monitoring. Tables are reproduced from http://www.fs.fed.us/r5/rsl/projects/mapping/accuracy.shtml.

Table 3-4—Accuracy matrices for average tree size mapped by CALVEG in California

Map Label	Sites	Max		Right	
Inches	*Number*	*Number*	*Percent*	*Number*	*Percent*
Sierran Forest-Alpine Meadows Province Section M261A—Klamath Mountains Section (CALVEG North Coast and Montane—Zone 1)					
0-1	0	0	0	0	0
1-4.9	5	0	0	0	0
5-11.9	65	31	47.69	49	75.38
12-23.9	182	99	54.40	144	79.12
24-39.9	257	87	33.85	167	64.98
40+	10	4	40.00	7	70.00
Total	519	221	42.58	367	70.71
Weighted			41.82		69.00
Sierran Forest-Alpine Meadows Province Section M261B—Northern California Coast Ranges (CALVEG North Coast and Montane—Zone 1)					
0-10	0	0	0	0	0
1-4.9	0	0	0	0	0
5-11.9	41	22	53.66	32	78.05
12-23.9	66	31	46.97	50	75.76
24-39.9	70	24	34.29	42	60.00
40+	1	0	0	1	100.00
Total	178	77	43.26	125	70.22
Weighted			41.70		67.52

Table 3-4—Accuracy matrices for average tree size mapped by CALVEG in California (continued)

Map Label	Sites	Max		Right	
Inches	*Number*	*Number*	*Percent*	*Number*	*Percent*
Sierran Forest-Alpine Meadows Province Section M261D—Southern Cascades Section (CALVEG North Interior—Zone 2)					
0-1	2	0	0	0	0
1-4.9	3	1	33.33	2	66.67
5-11.9	53	25	47.17	45	84.91
12-23.9	226	121	53.54	196	86.73
24-39.9	50	18	36.00	34	68.00
40+	0	0	0	0	0
Total	334	165	49.40	277	82.93
Weighted			48.97		82.69
California Coastal Steppe-Mixed Forest-Redwood Forest Province Section 263A—Northern California Coast Section (CALVEG North Coast and Montane—Zone 1)					
0-1	0	0	0	0	0
1-4.9	6	2	33.33	3	50.00
5-11.9	27	10	37.04	21	77.78
12-23.9	125	67	53.60	94	75.20
24-39.9	51	15	29.41	33	64.71
40+	7	1	14.29	1	14.29
Total	216	95	43.98	152	70.37
Weighted			43.09		69.16

Table 3-5—Accuracy matrices for conifer cover mapped by CALVEG in California

Map label	Sites	Max		Right	
Percent	*Number*	*Number*	*Percent*	*Number*	*Percent*
Sierran Forest-Alpine Meadows Province					
Section M261A—Klamath Mountains Section					
(CALVEG North Coast and Montane—Zone 1)					
10-20	18	10	55.56	11	61.11
20-40	39	29	74.36	34	87.18
40-70	149	100	67.11	122	81.88
70-100	361	224	62.05	259	71.75
Total	567	363	64.02	426	75.13
Weighted			64.14		75.24
Sierran Forest-Alpine Meadows Province					
Section M261B—Northern California Coast Ranges					
(CALVEG North Coast and Montane—Zone 1)					
10-20	8	2	25.00	5	62.50
20-40	21	7	33.33	14	66.67
40-70	81	50	61.73	62	76.54
70-100	151	99	65.56	123	81.46
Total	261	158	60.54	204	78.16
Weighted			57.45		76.58
Sierran Forest-Alpine Meadows Province					
Section M261D—Southern Cascades Section					
(CALVEG North Interior—Zone 2)					
10-20	12	4	33.33	6	50.00
20-40	74	46	62.16	63	85.14
40-70	162	112	69.14	139	85.80
70-100	86	42	48.84	55	63.95
Total	334	204	61.08	263	78.74
Weighted			60.26		78.14
California Coastal Steppe-Mixed Forest-Redwood Forest Province					
Section 263A—Northern California Coast Section					
(CALVEG North Coast and Montane—Zone 1)					
10-20	0	0	0	0	0
20-40	16	5	31.25	6	37.50
40-70	39	18	46.15	25	64.10
70-100	244	185	75.82	200	81.97
Total	299	208	69.57	231	77.26
Weighted			68.15		75.94

Appendix 4—Northwest Forest Plan Expectations

Excerpted from USDA and USDI (1994a: 36-43) and Hemstrom and others (1998)

Expected outcomes are quantifiable targets or thresholds that can be assessed directly by using collective monitoring information. Most Northwest Forest Plan expectations have both short-term and long-term outcomes. Two examples are (1) "At the end of the first decade, the amount of LSOG will have increased by ½ million acres," and (2) "At least 60 percent of the federal landscape will be covered by late-successional and old-growth forest within 200 years as a result of the Northwest Forest Plan." The short-term expected outcome can be addressed by comparing the change in observed amounts of older forest at the beginning of the Plan and at year 10; the long-term expected outcome can be addressed by continued monitoring, and also through trend analysis—projecting current conditions forward and comparing the outcome with expected or desired trajectories.

Comparison of monitoring results with expected outcomes provides a direct link to decisionmaking. For example, observed outcomes that depart significantly from projected trends (say, falling significantly below) could be an early warning that might trigger a variety of actions, ranging from review of refined trend estimates and mapping methods, to examination of the Northwest Forest Plan and its implementation.

Ecosystem Attributes, Thresholds, and Outcomes

The expected outcomes of late-successional ecosystems under the Northwest Forest Plan are based on three attributes that characterize the quantity and quality of components of the ecosystem (USDA and USDI 1994a). These are **abundance and ecological diversity, processes and functions,** and **connectivity**.

Table 4-1—Likelihood of achieving a functional, interacting late-successional and old-growth forest ecosystem on federal lands for Option 9

Moist provinces				Dry provinces			
A[a]	P[a]	C[a]	Average	A	P	C	Average
			Percent				
76	75	80[b]	77	69	53	66	63

[a] Attributes: A = abundance and ecological diversity; P = process and function; C = connectivity.

[b] Numbers of at least 80 percent represent the likelihood that the alternative will meet minimum requirements for these attributes.

Source: Hemstrom and others 1998, table 2.

Abundance and Ecological Diversity

Abundance and ecological diversity is the amount and variety of plant communities and environments (USDA and USDI 1994a: 35). Plan expectations are that, in the short term (at year 10), and in the long term (at years 50, 100, and 200) the proportion of older forest will increase relative to the amount present at the start of the Plan. The environmental impact statement (USDA and USDI 1994a: table 3&4-5) set quantifiable abundance and diversity thresholds relative to long-term expected averages. The Plan does not project achieving thresholds for at least 100 years because current conditions are substantially below these amounts and stand development takes considerable time. It is expected that half the thresholds will have been achieved by year 50.

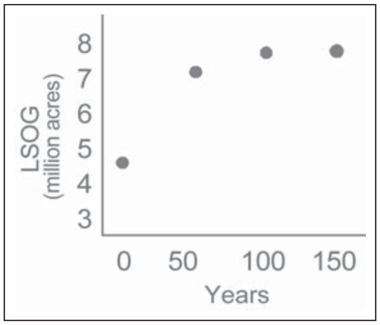


Figure 4-1—Expected trend in amount of late-successional and old-growth forest (LSOG) after implementing the Northwest Forest Plan for the next 150 years (Hemstrom and others 1998).

Table 4-2—Abundance and diversity outcomes and thresholds for late-successional and old-growth (LSOG) forests used in ranking alternative land management strategies considered in the Northwest Forest Plan

Outcome	Land covered by LSOG	Lands in stands of more than 1,000 acres	Provinces meeting both amount and stand size
		Percent	
1	60 to 100	80 to 100	100
2	40 to 60	5 to 80	100
3	5 to 40	1 to 5	50 to 100
4	Less than 5	Less than 1	Less than 50

Source: USDA and USDI 1994a: table 3&4-5.

Outcome 1—Late-successional and old-growth ecosystem abundance and ecological diversity on federal lands are at least as high as the long-term average...prior to logging and extensive fire suppression....Relatively large areas (50,000 to 100,000 ac) would still contain levels of abundance and distribution of late-successional forests that are well below the regional average for long periods. However, within each physiographic province, abundance would be at least as high as province-level long-term averages, which might be higher or lower than the regional long-term average.

Outcome 1 scenario: The long-term average proportion of late-successional and old-growth forest for the entire Forest Plan area was estimated at 65 percent in FEMAT (1993: 51). Because this criterion is the same as older forest cover in connectivity (below), the same number (60 percent) was used for outcome for both abundance and connectivity. Most (more than 80 percent) of the older forest in the long-term average was assumed to have occurred in large blocks (more than 1,000 ac).

Outcome 2—Late-successional and old-growth ecosystem abundance and ecological diversity on federal lands are less than the long-term conditions (prior to logging and extensive fire suppression) but within the typical range of conditions that occurred during previous centuries.

Outcome 2 scenario: Late-successional and old-growth forest is present in all provinces and at all elevations but with larger gaps in distribution than in outcome 1. The average of the low end of the range for older forest amount in the long-term average was assumed to be 40 percent in FEMAT (1993: 51). The range in amounts under outcome 2 is between 40 and 65 percent. Less than 80 percent of the LSOG would be in stands of more than 1,000 ac.

Outcome 3—Late-successional and old-growth abundance and ecological diversity on federal lands are considerably below the typical range of conditions that have occurred during the previous centuries, but some provinces are within the range of variability....The ecological diversity (age-class diversity) may be limited to the younger stages of late-successional ecosystems. Late-successional and old-growth communities and ecosystems may be absent from some physiographic provinces or occur as scattered remnant patches within provinces.

Outcome 3 scenario: Amounts of older forest would be less than the average century lows from the long term (40 percent; FEMAT 1993: 51), but some older forest would still exist (for example, more than 1 percent of the federal land area). Less than 80 percent of the older forest would be in stands of more than 1,000 ac. Older forest may be absent from some physiographic provinces or elevations within provinces and occur as scattered remnant stands within provinces.

Outcome 4—Late-successional and old-growth ecosystems are very low in abundance and may be restricted to a few physiographic provinces or elevation bands or localities within provinces. Late-successional and old-growth communities and ecosystems are absent from most physiographic provinces or occur only as small remnant patches.

Outcome 4 scenario: Late-successional and old-growth forest ecosystems cover less than 1 percent of federal land. Less than 80 percent of the older forest is in stands of more than 1,000 ac. Older forest is absent from most provinces or occurs only as small remnant forest stands.

Processes and Functions

Processes and functions are the ecological actions that lead to the development and maintenance of the ecosystem and the values of the ecosystem for species and populations (USDA and USDI 1994a: 35). No quantitative criteria are provided in the Plan for process and function thresholds. In the near term, process and function thresholds will be assumed to be provided to the extent that ecological abundance and diversity thresholds are met (USDA and USDI 1994a: 3&4: 38).

Table 4-3—Process and function outcomes for late-successional and old-growth forests used in ranking alternative land management strategies considered in the Northwest Forest Plan

Outcome 1—The full range of natural disturbance and vegetative development processes and ecological functions are present at all spatial scales from microsite to large landscapes.

Outcome 2—Natural disturbance and vegetative development processes and ecological functions occur across a moderately wide range of scales but are limited at large landscape scales through fire suppression and limitation of areas where late-successional ecosystems can develop.

Outcome 3—Natural disturbance and vegetative development processes are limited in occurrence to stand and microsite scales. Many stands may be too small or not well developed enough to sustain the full range of ecological processes and functions associated with LSOG ecosystems.

Outcome 4—Natural disturbance and vegetative development processes associated with LSOG ecosystems are extremely restricted or absent from most stands and large landscapes. Most stands of older forest are too small or not well enough developed to sustain the full range of processes and ecological functions associated with late-successional and old-growth ecosystems.

Source: USDA and USDI 1994a: table 3&4-5.

Connectivity

Connectivity is the extent to which the landscape pattern of the ecosystem provides for biological flows that sustain animal and plant populations (USDA and USDI 1994a: 35). Table 3&4-7 (USDA and USDI 1994a) set quantifiable connectivity thresholds relative to long-term expected averages. The Plan does not project achieving thresholds for at least 100 years because current conditions are substantially below these amounts and stand development takes considerable time. It is expected that half the thresholds will have been achieved by year 50.

Outcome 1—Connectivity is very strong, characterized by relatively short distances (less than 6 miles on average) between late-successional and old-growth areas. Smaller patches of late-successional and old-growth forest frequently occur....The proportion of the landscape covered by late-successional and old-growth conditions of all stand sizes exceeds 60 percent, a threshold where many measures of connectivity increase rapidly. At regional scales, physiographic provinces are connected by the presence of landscapes containing areas of late-successional and old-growth forests.

Table 4-4—Connectivity thresholds for late-successional and old-growth (LSOG) forest used when ranking land management alternatives considered in the Northwest Forest Plan

Outcome	Mean distance between stands of more than 1,000 acres	LSOG cover	LSOG stands less than 1,000 acres	Adjacent provinces connected with large LSOG stands
	Miles	*Percent*		*Percent*
1	Less than 6	60 to 100	Common	100
2	6 to 12	50 to 60	Common	100
3	12 to 24	25 to 50	Present	Less than 100
4	More than 24	Less than 25	Absent to few	Less than 100

Source: USDA and USDI 1994a: table 3&4-7.

Outcome 1 scenario: Mean distances of less than 6 miles between older forest stands of 1,000 acres or larger and older forest cover of greater than 60 percent indicate outcome 1. Small stands of older forest (riparian buffers, green-tree retention in harvest units, etc.) are common, as indicated by cumulative frequency distributions of older forest stand sizes. Large older forest stands connect between adjacent provinces.

Outcome 2—Connectivity is strong, characterized by moderate distances (less than 12 mi on average) between large late-successional and old-growth areas. Smaller patches of late-successional forest occur as described in outcome 1. At regional scales, physiographic provinces are connected by the presence of landscapes containing areas of late-successional and old-growth forests. The total proportion of landscape in late-successional and old-growth conditions, including smaller patches, is at least 5[0] percent, so that the late-successional condition is still the dominant cover type.

Outcome 2 scenario: Mean distances of 6 to 12 mi between older forest stands of 1,000 ac or larger and older forest cover of greater than 50 percent indicate outcome 2 (table 4). Small stands of older forest (riparian buffers, green-tree retention in harvest units, etc.) are common as indicated by cumulative frequency distributions of older forest stand sizes. Large older forests stands connect between adjacent provinces.

Outcome 3—Connectivity is moderate, characterized by distance[s] of 12 to 24 mi between large old-growth areas. There is limited occurrence of smaller patches of late-successional forest in the matrix. The late-successional forest is at least 25 percent of the landscape, and the matrix contains some smaller areas for dispersal habitat.

Outcome 3 scenario: Mean distances of 12 to 24 mi between older forest stands of 1,000 ac or larger and older forest cover of greater than 25 percent indicate outcome 3 (table 4). Small stands of older forest occur in matrix lands.

Outcome 4—Connectivity is weak, characterized by wide distances (greater then 24 mi) between old-growth areas. There is a matrix in which late-successional and old-growth conditions occur as scattered remnants or are completely absent.

Outcome 4 scenario: Mean distances of over 24 mi between older forest stands of 1,000 ac or larger and older forest cover of less than 25 percent indicate outcome 4 (table 4). Older forest occurs as small remnant stands or is absent in matrix lands.

Appendix 5—Disturbance Map Accuracy

Table 5-1—Map accuracy results for change-detection maps in Oregon and Washington

		Reference plot class (disturbance year)															
Map class	**No change**	**Cut 72-77**	**Cut 77-84**	**Cut 84-88**	**Cut 88-91**	**Cut 91-95**	**Cut 95-00**	**Cut 00-02**	**Fire 72-77**	**Fire 77-84**	**Fire 84-88**	**Fire 88-91**	**Fire 92-95**	**Fire 95-00**	**Fire 00-02**	**Total**	**User's accuracy**
	Number of plots																*Percent*
Eastern Oregon[a]																	
No change	135	2	10	1	4	3	3	1								159	0.849
Cut 72-77	2	8		1												11	0.727
Cut 77-84	5	1	16													22	0.727
Cut 84-88	8			12			1	1								22	0.545
Cut 88-91	2				8	1	1									12	0.667
Cut 91-95	1					7										8	0.875
Cut 95-00	4	1				1	12									18	0.667
Cut 00-02	2						1	6								9	0.667
Fire 72-77																0	
Fire 77-84																0	
Fire 84-88																0	
Fire 88-91																0	
Fire 92-95																0	
Fire 95-00	1													2		3	0.667
Fire 00-02	1															1	0.000
Total	161	12	26	14	12	12	18	8	0	0	0	0	0	2	0	265	
Producer's accuracy (percent)	0.839	0.667	0.615	0.857	0.667	0.583	0.667	0.750						1.000			0.777
Western Oregon[b]																	
No Change	483	11	11	9	5	1	3			1	1		2	2		529	0.913
Cut 72-77	2	38	3						2							45	0.844
Cut 77-84	2	3	71	3						1						80	0.888
Cut 84-88	5	1	1	62	1											70	0.886
Cut 88-91	2	2	1		40							1				46	0.870
Cut 91-95	10					51										61	0.836
Cut 95-00	12						47	1								60	0.783
Cut 00-02	2						1	33								36	0.917
Fire 72-77																0	
Fire 77-84										11						11	1.000
Fire 84-88	2										10					12	0.833
Fire 88-91												10				10	1.000
Fire 92-95	1												9			10	0.900
Fire 95-00	5													9		14	0.643
Fire 00-02	3														9	12	0.750
Total	529	55	87	74	46	52	51	34	2	13	11	11	11	11	9	996	
Producer's accuracy (percent)	0.913	0.691	0.816	0.838	0.870	0.981	0.922	0.971	0.000	0.846	0.909	0.909	0.818	0.818	1.000		0.887

Table 5-1—Map accuracy results for change-detection maps in Oregon and Washington (continued)

Map class	Reference plot class (disturbance year) No change	Cut 84-88	Cut 88-92	Cut 92-96	Cut 96-00	Cut 00-02	Fire 84-88	Fire 88-92	Fire 92-96	Fire 96-00	Fire 00-02	Total	User's accuracy
	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – –	*Number of plots*	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – –	*Percent*
Eastern Washington[c]													
No change	160	4	2		3		1	1	1	1	2	175	0.914
Cut 84-88	2	9										11	0.818
Cut 88-92	1		16	1								18	0.889
Cut 92-96				5								5	1.000
Cut 96-00	1				15							16	0.938
Cut 00-02						7						7	1.000
Fire 84-88							2					2	1.000
Fire 88-92								2				2	1.000
Fire 92-96	1								9			10	0.900
Fire 96-00										8		8	1.000
Fire 00-02	1	1									11	13	0.846
Total	166	14	18	6	18	7	3	3	10	9	13	267	
Producer's accuracy (percent)	0.964	0.643	0.889	0.833	0.833	1.000	0.667	0.667	0.900	0.889	0.846		0.914
Western Washington[d]													
No change	417	9	5	1	6	1						439	0.950
Cut 84-88	7	83	1	1								92	0.902
Cut 88-92	6	3	71	1	1							82	0.866
Cut 92-96	1		1	44	3							49	0.898
Cut 96-00	2				39							41	0.951
Cut 00-02	2				2	24						28	0.857
Total	435	95	78	47	51	25						731	
Producer's accuracy (percent)	0.959	0.874	0.910	0.936	0.765	0.960							0.927

Note: Only the change cycles from 1995 (Oregon) or 1996 (Washington) through 2002 were used in the monitoring report.

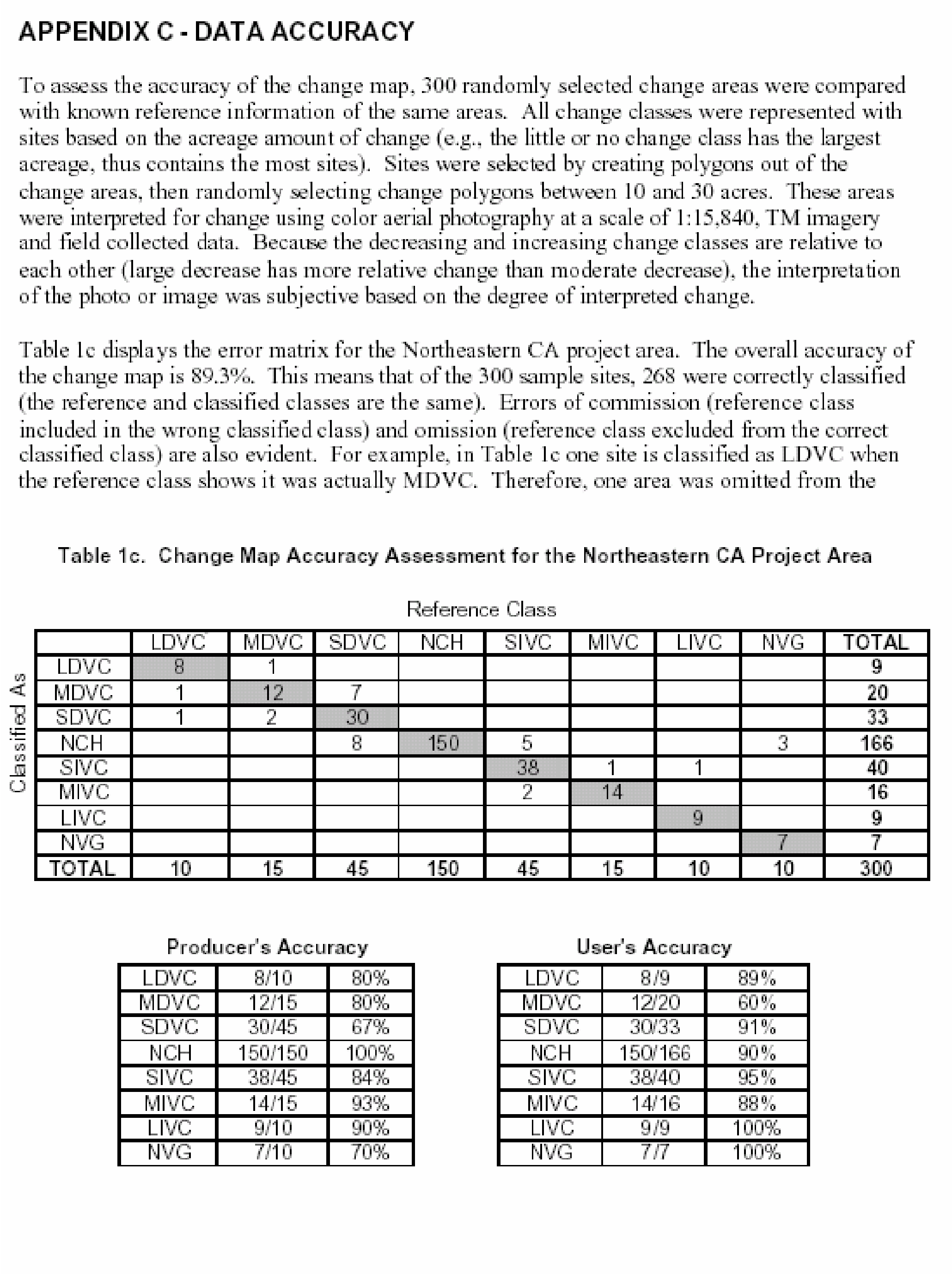
[a] 15 pixels removed because they were either nonforest or were in the same disturbance unit as another point.

[b] 70 pixels removed because they were either nonforest or were in the same disturbance unit as another point.

[c] 14 pixels removed because they were either nonforest or were in the same disturbance unit as another point.

[d] 70 pixels removed because they were either nonforest or were in the same disturbance unit as another point.

The following map accuracy results for California change detection maps are reproduced from published reports (Levien and others 2003a, 2003b).



APPENDIX C - DATA ACCURACY

To assess the accuracy of the change map, 300 randomly selected change areas were compared with known reference information of the same areas. All change classes were represented with sites based on the acreage amount of change (e.g., the little or no change class has the largest acreage, thus contains the most sites). Sites were selected by creating polygons out of the change areas, then randomly selecting change polygons between 10 and 30 acres. These areas were interpreted for change using color aerial photography at a scale of 1:15,840, TM imagery and field collected data. Because the decreasing and increasing change classes are relative to each other (large decrease has more relative change than moderate decrease), the interpretation of the photo or image was subjective based on the degree of interpreted change.

Table 1c displays the error matrix for the Northeastern CA project area. The overall accuracy of the change map is 89.3%. This means that of the 300 sample sites, 268 were correctly classified (the reference and classified classes are the same). Errors of commission (reference class included in the wrong classified class) and omission (reference class excluded from the correct classified class) are also evident. For example, in Table 1c one site is classified as LDVC when the reference class shows it was actually MDVC. Therefore, one area was omitted from the

Table 1c. Change Map Accuracy Assessment for the Northeastern CA Project Area

Reference Class

Classified As

	LDVC	MDVC	SDVC	NCH	SIVC	MIVC	LIVC	NVG	**TOTAL**
LDVC	8	1							**9**
MDVC	1	12	7						**20**
SDVC	1	2	30						**33**
NCH			8	150	5			3	**166**
SIVC					38	1	1		**40**
MIVC					2	14			**16**
LIVC							9		**9**
NVG								7	**7**
TOTAL	**10**	**15**	**45**	**150**	**45**	**15**	**10**	**10**	**300**

Producer's Accuracy

LDVC	8/10	80%
MDVC	12/15	80%
SDVC	30/45	67%
NCH	150/150	100%
SIVC	38/45	84%
MIVC	14/15	93%
LIVC	9/10	90%
NVG	7/10	70%

User's Accuracy

LDVC	8/9	89%
MDVC	12/20	60%
SDVC	30/33	91%
NCH	150/166	90%
SIVC	38/40	95%
MIVC	14/16	88%
LIVC	9/9	100%
NVG	7/7	100%

LDVC - large decrease in vegetation cover; MDVC - moderate decrease in vegetation cover; SDVC - small decrease in vegetation cover; NCH - little or no change in vegetation cover; SIVC - small increase in vegetation cover; MIVC - moderate increase in vegetation cover; LIVC - large increase in vegetation cover; NVG - non-vegetation change; CLD/SHA - cloud or shadow correct MDVC class and committed to the incorrect LDVC class. The producer's accuracy for each change class ranged from 67% to 100% and the user's accuracy ranged from 60% to 100%. Producer's accuracy represents how well the reference data of each change class is classified. User's accuracy indicates the probability that a given change class actually represents that same change on the ground.

The accuracy assessment also shows how well the methods classify decreases and increases. Areas classified as a decrease were always a decrease, although the correct class was not always assigned. The same is true for the areas classified as an increase. Also, a decrease site is not classified into an increase class and an increase site is not classified into a decrease class. The small decrease and increase classes have sites classified into the little to no change class (eight and five out of 45, respectively). This is expected, however, as this type of change can be very subtle and the methods will have difficulty detecting it.

APPENDIX C - DATA ACCURACY

To assess the accuracy of the change map, 10 to 30 acre polygons for use as reference data were randomly selected from all of the change classes (see Table 1c for change class descriptions). The number of reference sites per change class was based upon the acreage amount of change (e.g., the little or no change class has the largest acreage thus the most sites), with a goal of 50 reference sites per change class.

Reference sites were interpreted for canopy cover and shrub/chaparral change using color aerial photography at a scale of 1:15,840, digital camera images at a scale of 1:3000, digital orthophoto quadrangles with a 1-meter cell size and field collected data. A number of the reference sites had to be discarded from the accuracy assessment because the data used to determine vegetation cover change for each of them was either absent or of poor quality. The final result was 382 reference sites. These 382 sites with known vegetation change were then compared to the classified change map to create an error matrix.

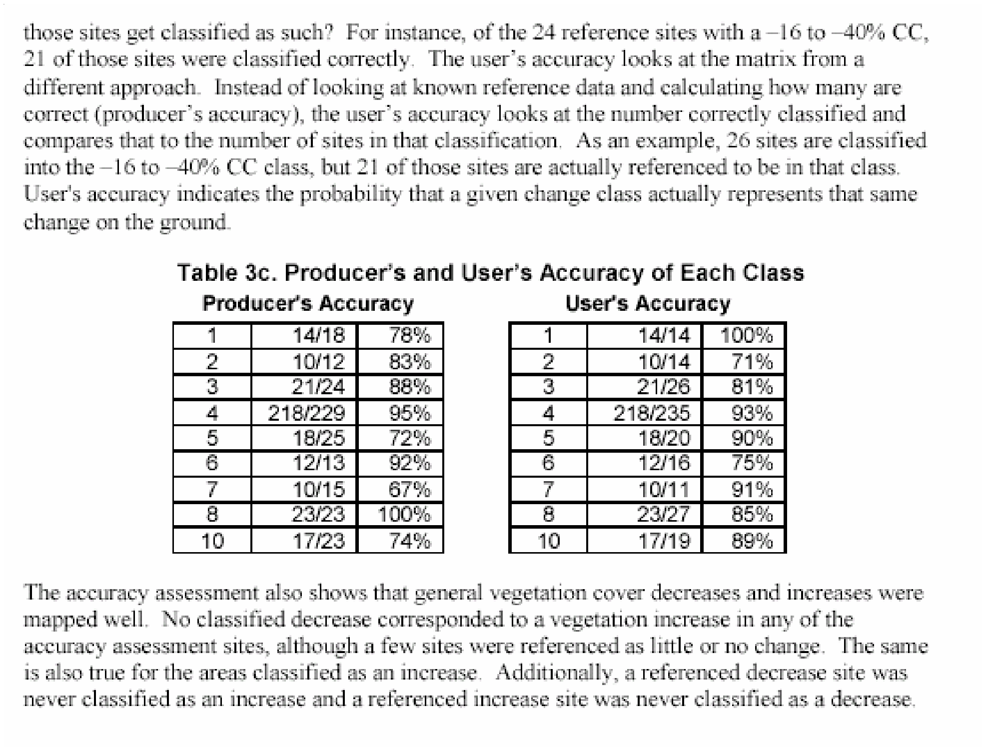
Table 1c. Change Code and Corresponding Change Class

Change Code	CHANGE CLASS
1	-71 to -100% CC
2	-41 to -70% CC
3	-16 to -40% CC
4	+15 to -15% CC (Little or No Change)
5	+16 to +40% CC
6	+41 to +100% CC
7	Shrub/Grass Decrease > 15%
8	Shrub/Grass Increase > 15%
9	Change Within Existing Developed Area
15	Cloud or Cloud Shadow

Table 2c displays the error matrix for the North Coast project area. (See Table 1c for change code descriptions). The overall accuracy of the change map is 89.8%. This means that of the 382 sample sites, 343 were correctly classified (the reference and classified classes are the same; Congalton and Green, 1999). Errors of commission (reference class included in the wrong classified class) and omission (reference class excluded from the correct classified class) are also evident. For example, Table 2c shows that one site was classified as +16 to +40% CC when the reference class shows it was actually little or no change. Therefore, one area was omitted from the correct little or no change class and committed to the incorrect +16 to +40% CC class. The producer's accuracy of each change class ranged from 67% to 100% and the user's accuracy ranged from 71% to 100% (Table 3c). Producer's accuracy represents how well a particular class is classified. Or, in other words, of all the referenced sites that have a particular change class, how many times (or what proportion) did

Table 2c. Change Map Accuracy Assessment for the North Coast Project Area

		Reference Class									
	Change Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Classified As	**1**	14									**14**
	2	3	10	1							**14**
	3	1	2	21	2						**26**
	4			2	218	4		5		6	**235**
	5				1	18	1				**20**
	6				1	3	12				**116**
	7				1			10			**11**
	8				4				23		**27**
	9				2					17	**19**
	Total	**18**	**12**	**24**	**229**	**25**	**13**	**15**	**23**	**23**	**382**



those sites get classified as such? For instance, of the 24 reference sites with a –16 to –40% CC, 21 of those sites were classified correctly. The user's accuracy looks at the matrix from a different approach. Instead of looking at known reference data and calculating how many are correct (producer's accuracy), the user's accuracy looks at the number correctly classified and compares that to the number of sites in that classification. As an example, 26 sites are classified into the –16 to –40% CC class, but 21 of those sites are actually referenced to be in that class. User's accuracy indicates the probability that a given change class actually represents that same change on the ground.

Table 3c. Producer's and User's Accuracy of Each Class

Producer's Accuracy

1	14/18	78%
2	10/12	83%
3	21/24	88%
4	218/229	95%
5	18/25	72%
6	12/13	92%
7	10/15	67%
8	23/23	100%
10	17/23	74%

User's Accuracy

1	14/14	100%
2	10/14	71%
3	21/26	81%
4	218/235	93%
5	18/20	90%
6	12/16	75%
7	10/11	91%
8	23/27	85%
10	17/19	89%

The accuracy assessment also shows that general vegetation cover decreases and increases were mapped well. No classified decrease corresponded to a vegetation increase in any of the accuracy assessment sites, although a few sites were referenced as little or no change. The same is also true for the areas classified as an increase. Additionally, a referenced decrease site was never classified as an increase and a referenced increase site was never classified as a decrease.

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