Return to Part B

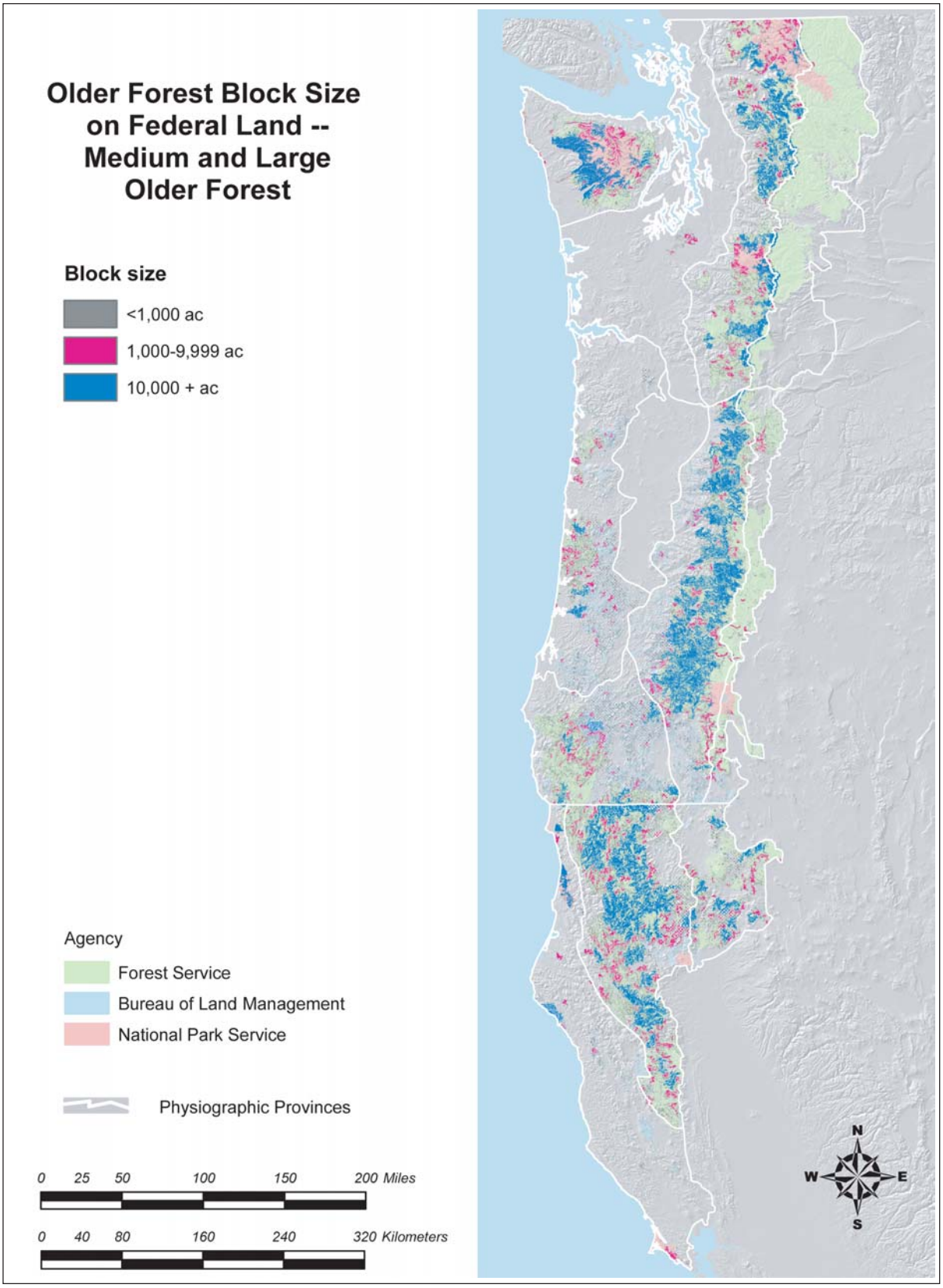


Figure 23a—Older forest blocks mapped according to ”medium and large older forest” definition

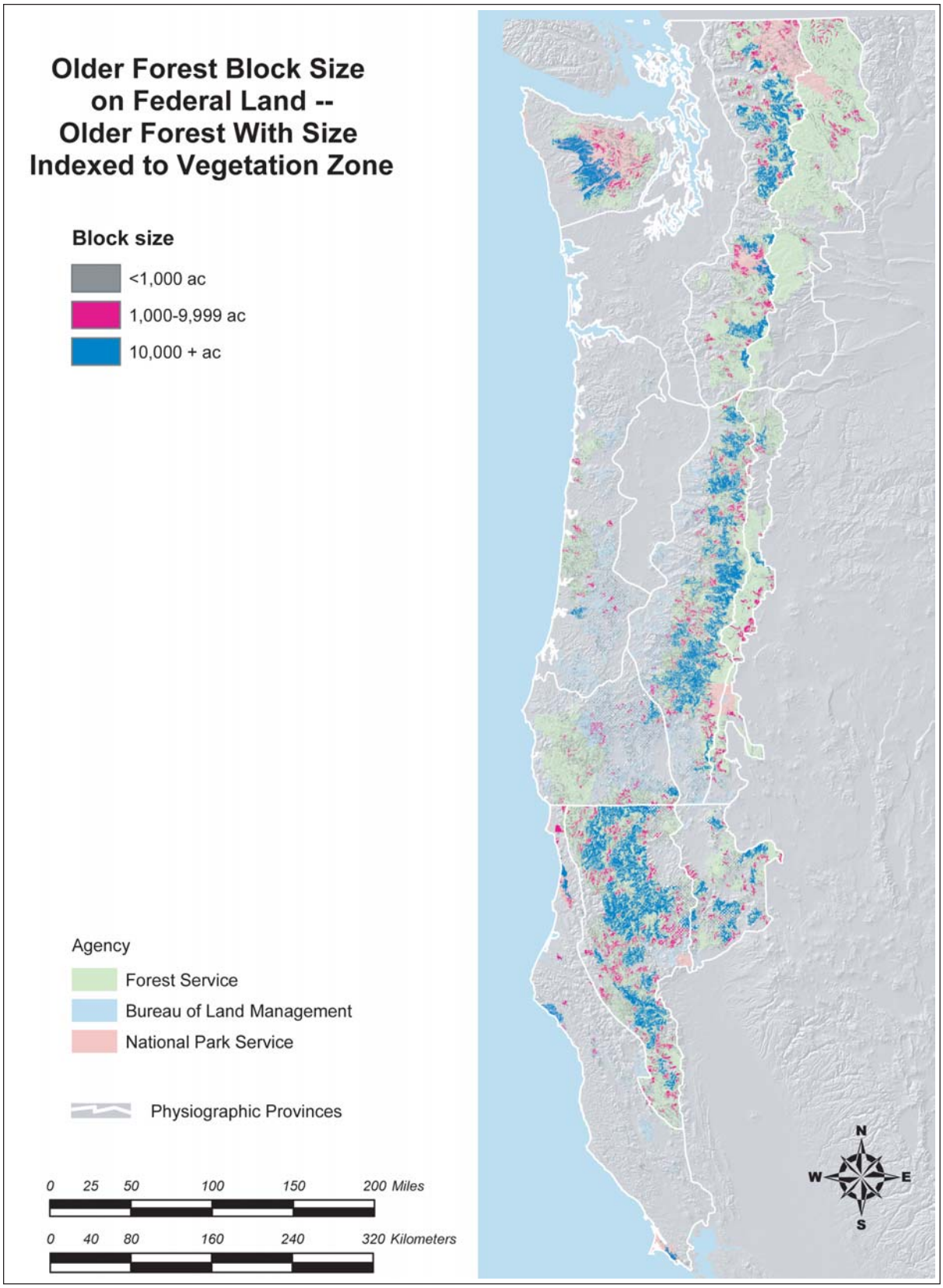


Figure 23b—Older forest blocks mapped according to "older forest with size indexed to vegetation zone" definition.

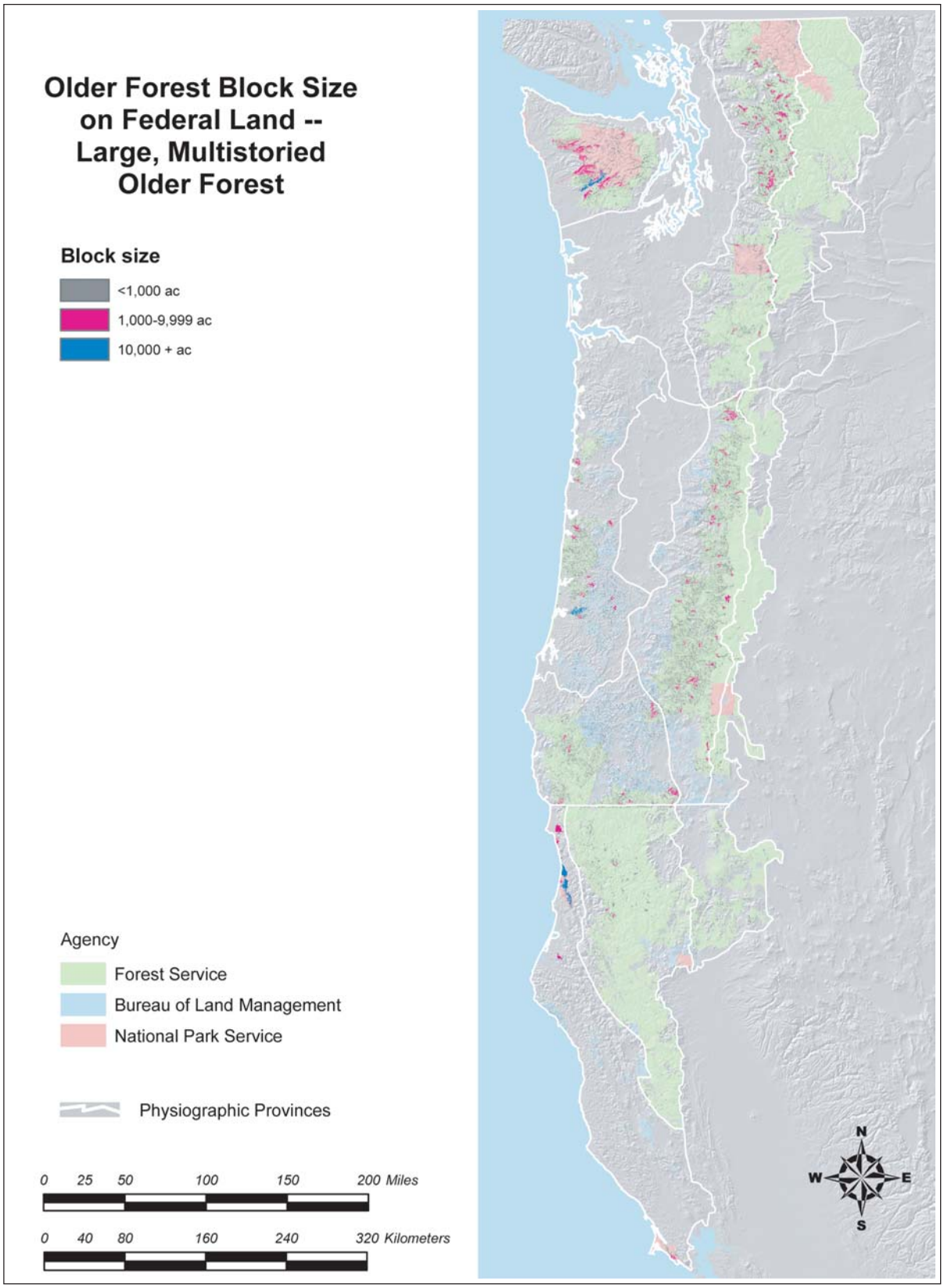


Figure 23c—Older forest blocks mapped according to “large, multistoried older forest” definition.

"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.

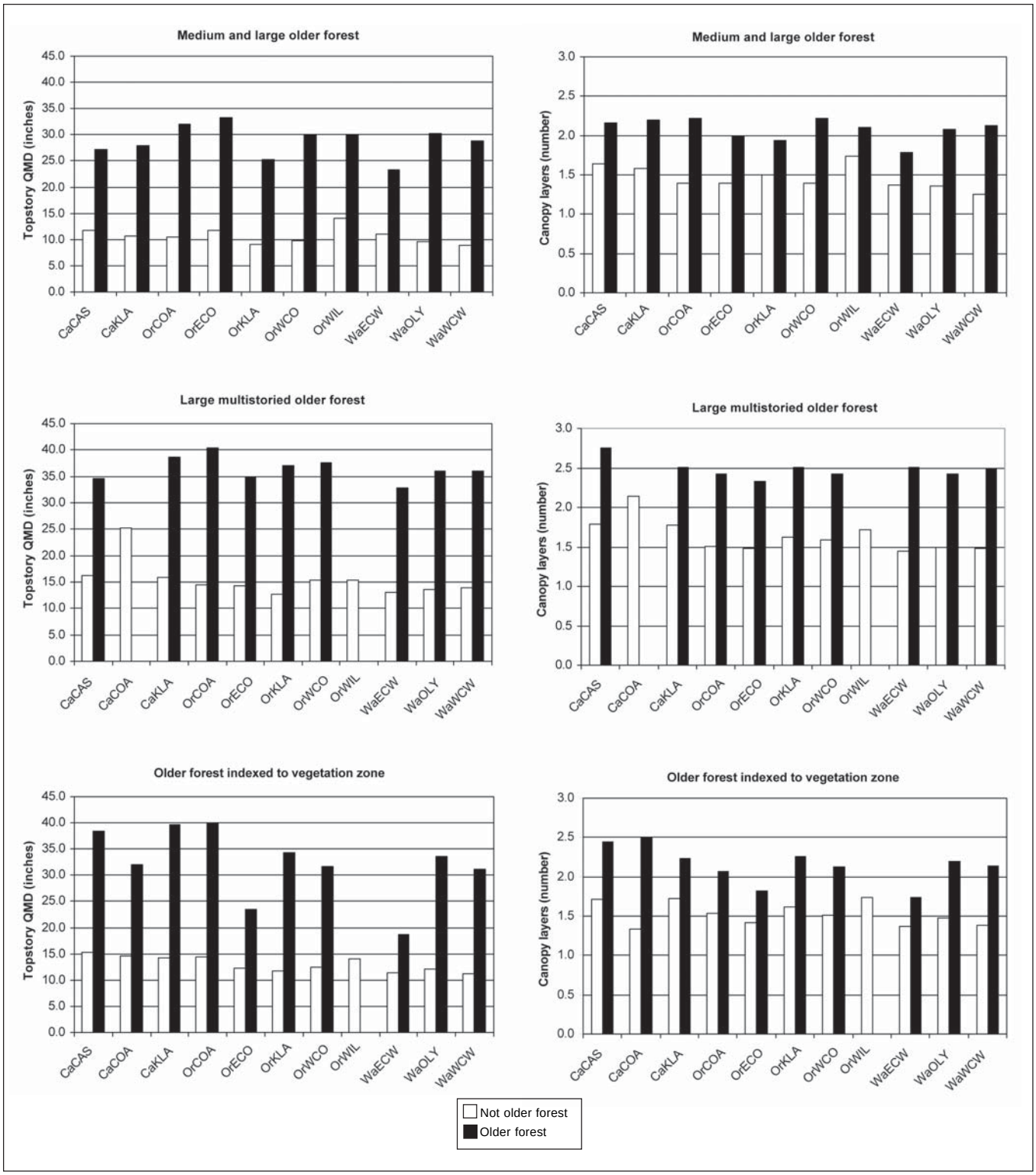


Figure 24a—Within-stand attributes of plots classified as "older forest" (dark bars) versus plots classified as '"not older forest" (light bars). Province codes: CaCAS = California Cascades; CaCOA = California Coast Range; CaKLA = California Klamath; OrCOA = Oregon Coast Range; OrECO = Oregon Eastern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

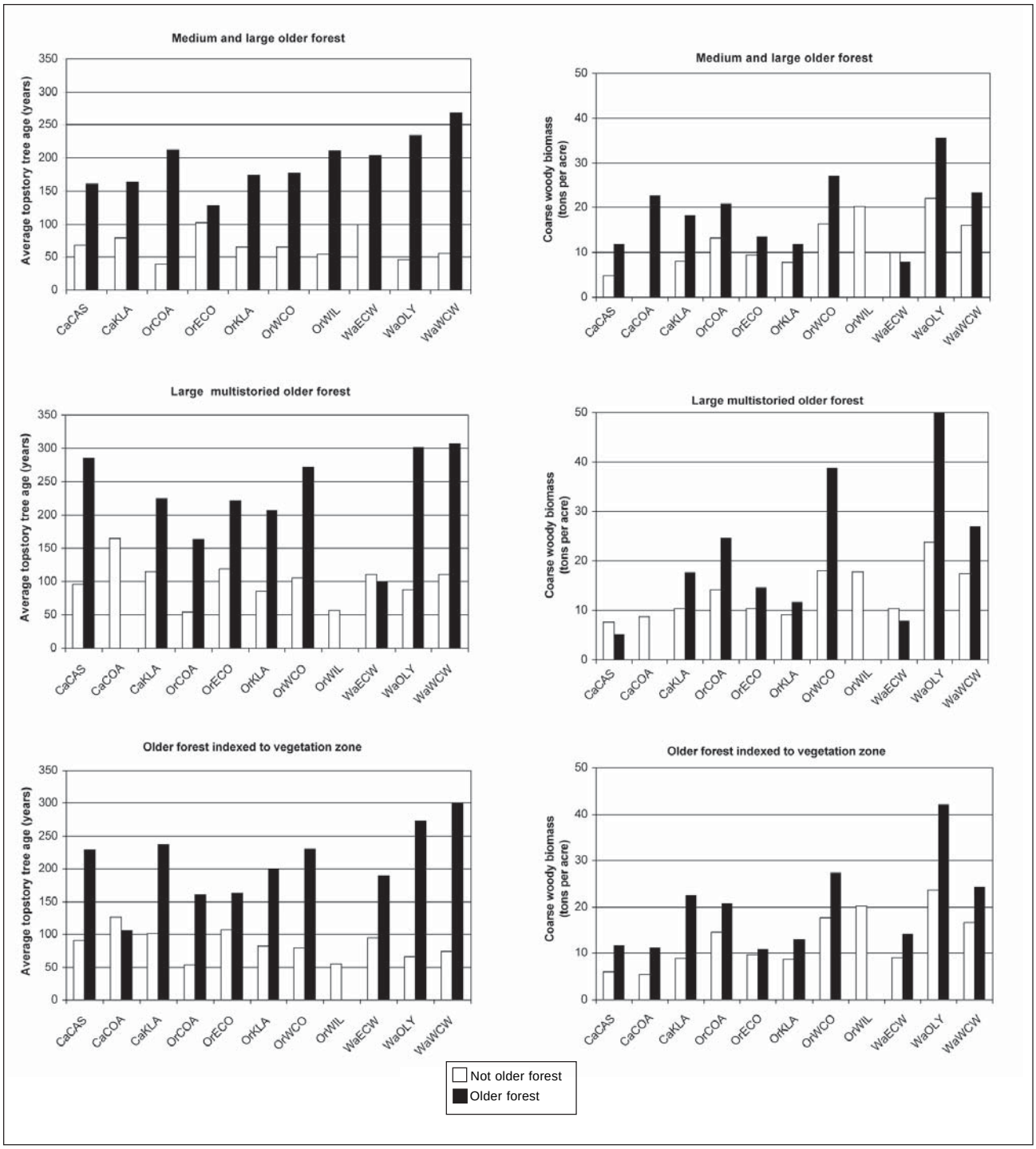
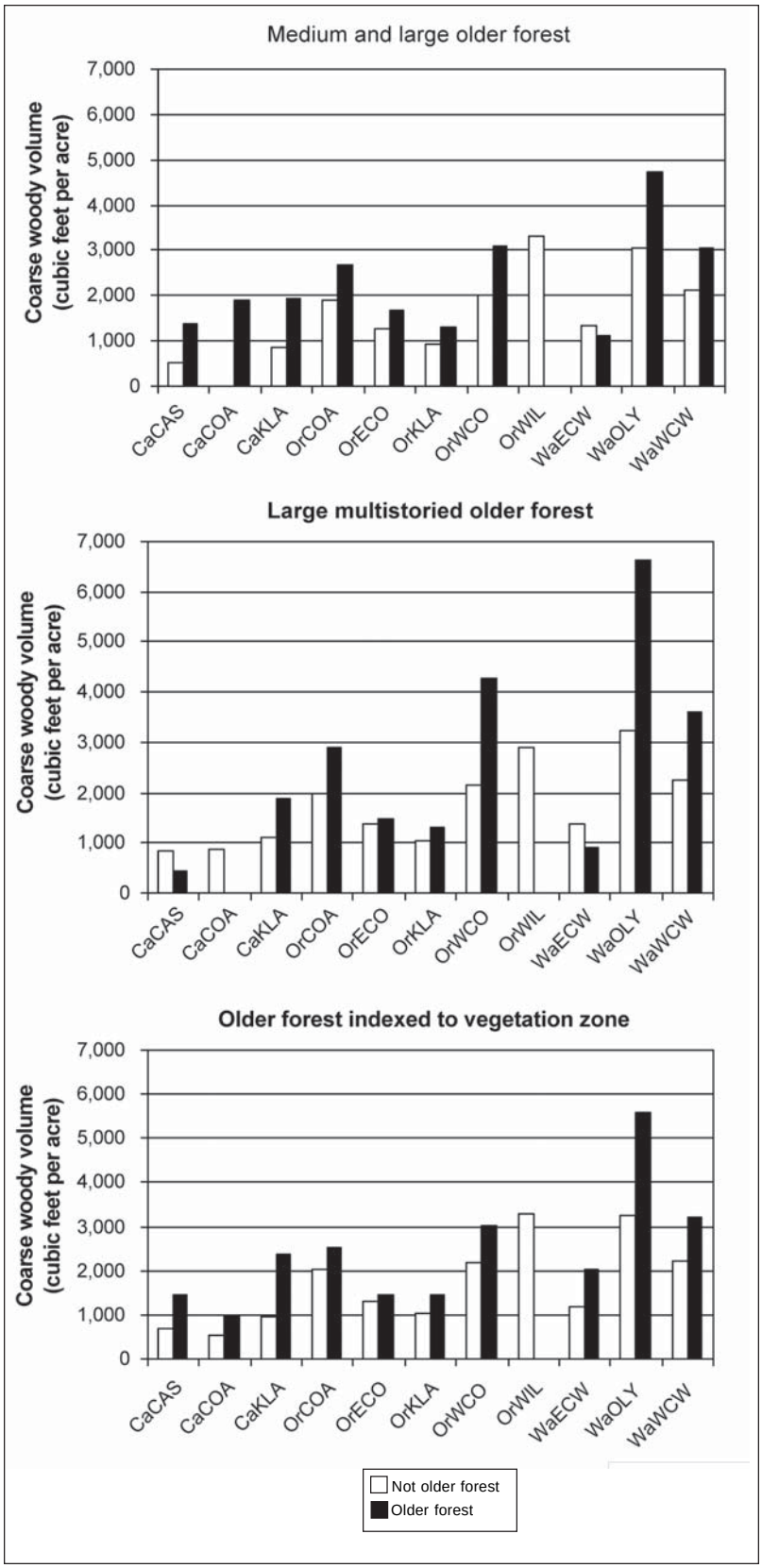


Figure 24b—Within-stand attributes of plots classified as “older forest” (dark bars) versus plots classified as ‘”not older forest” (light bars). See fig. 24a for province codes.



Western hemlock seedling regenerating on rotting log

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.

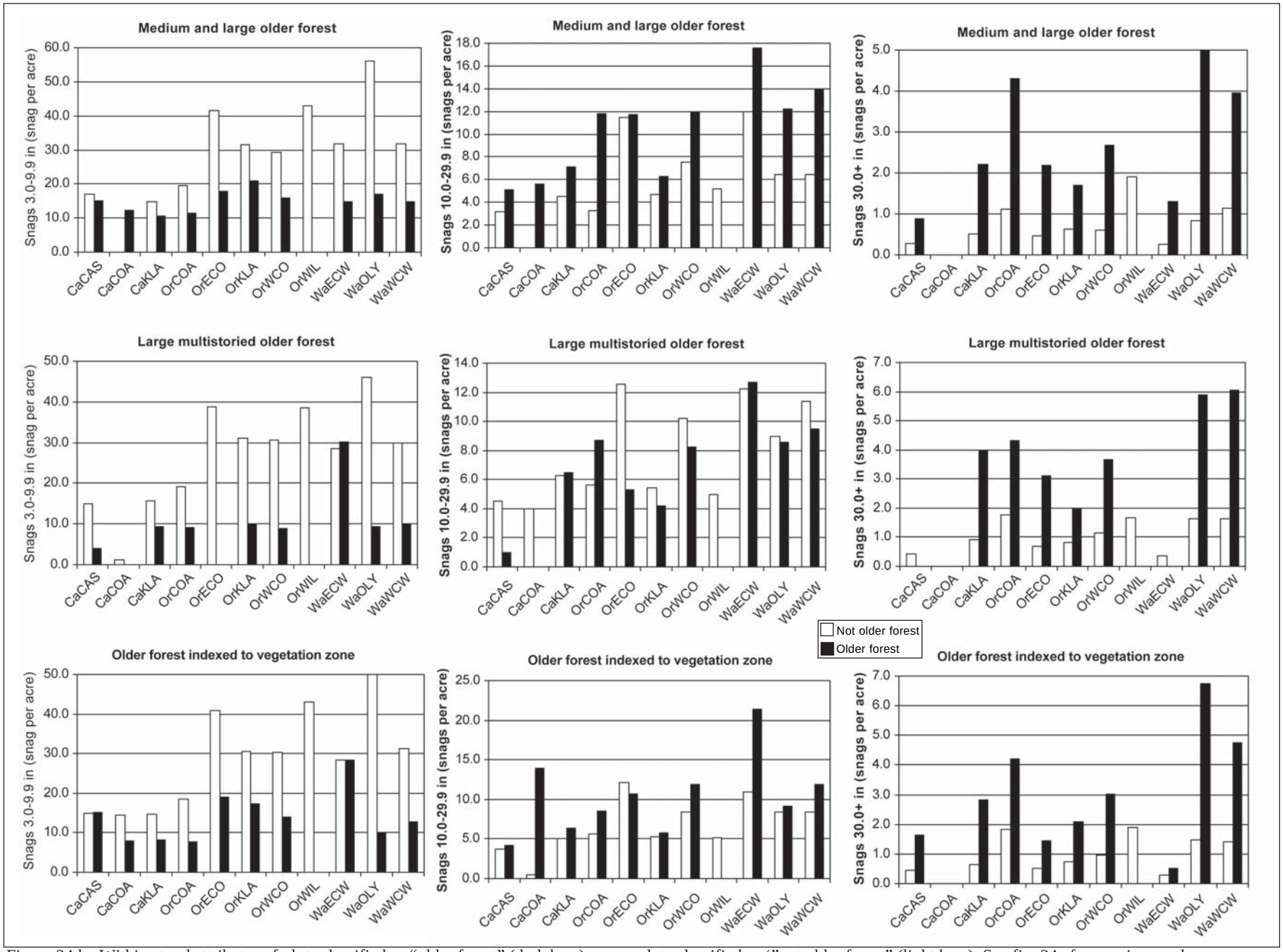


Figure 24d—Within-stand attributes of plots classified as “older forest” (dark bars) versus plots classified as ‘”not older forest” (light bars). See fig. 24a for province codes.

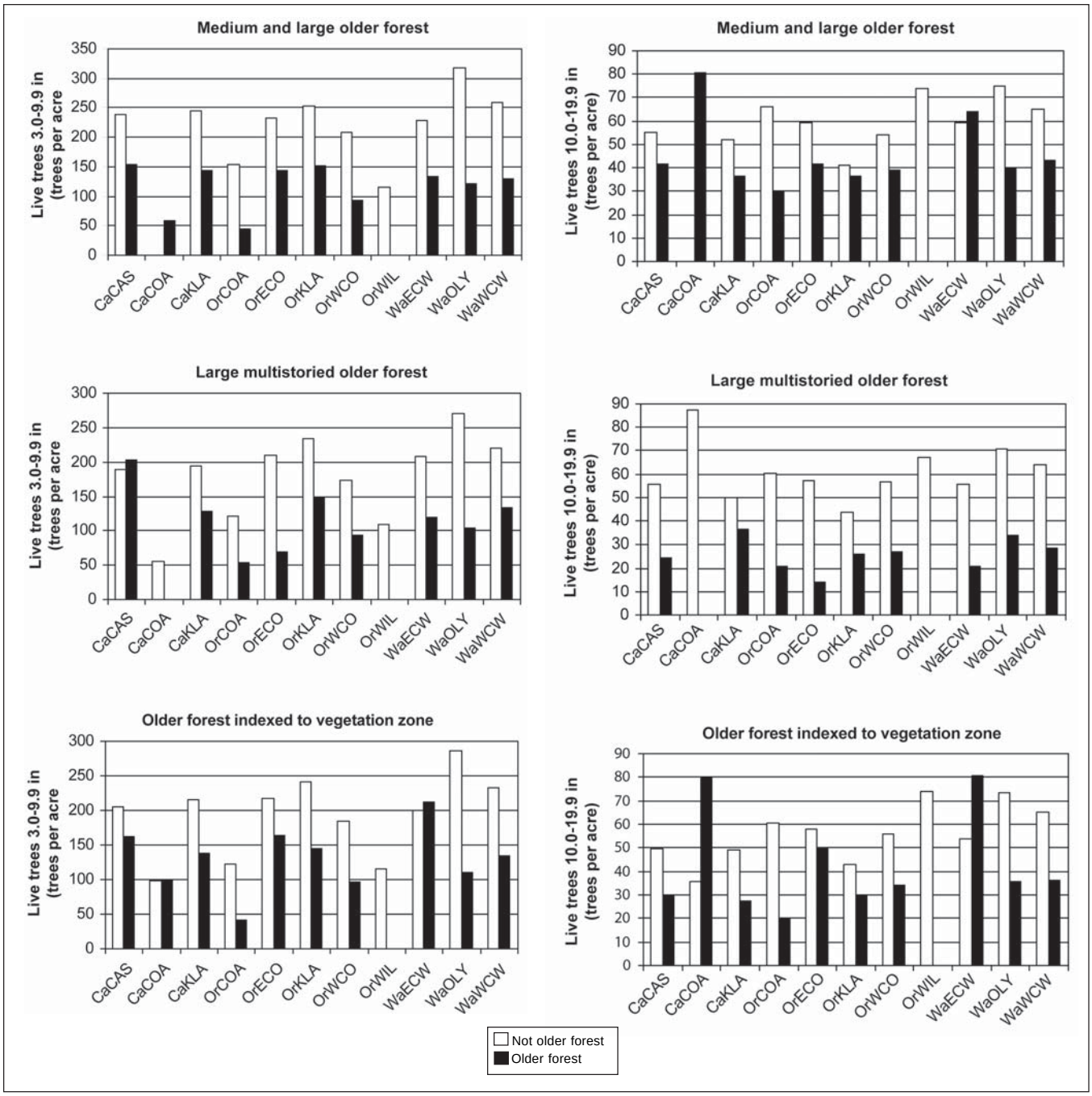


Figure 24e—Within-stand attributes of plots classified as "older forest" (dark bars) versus plots classified as '"not older forest" (light bars). See fig. 24a for province codes.

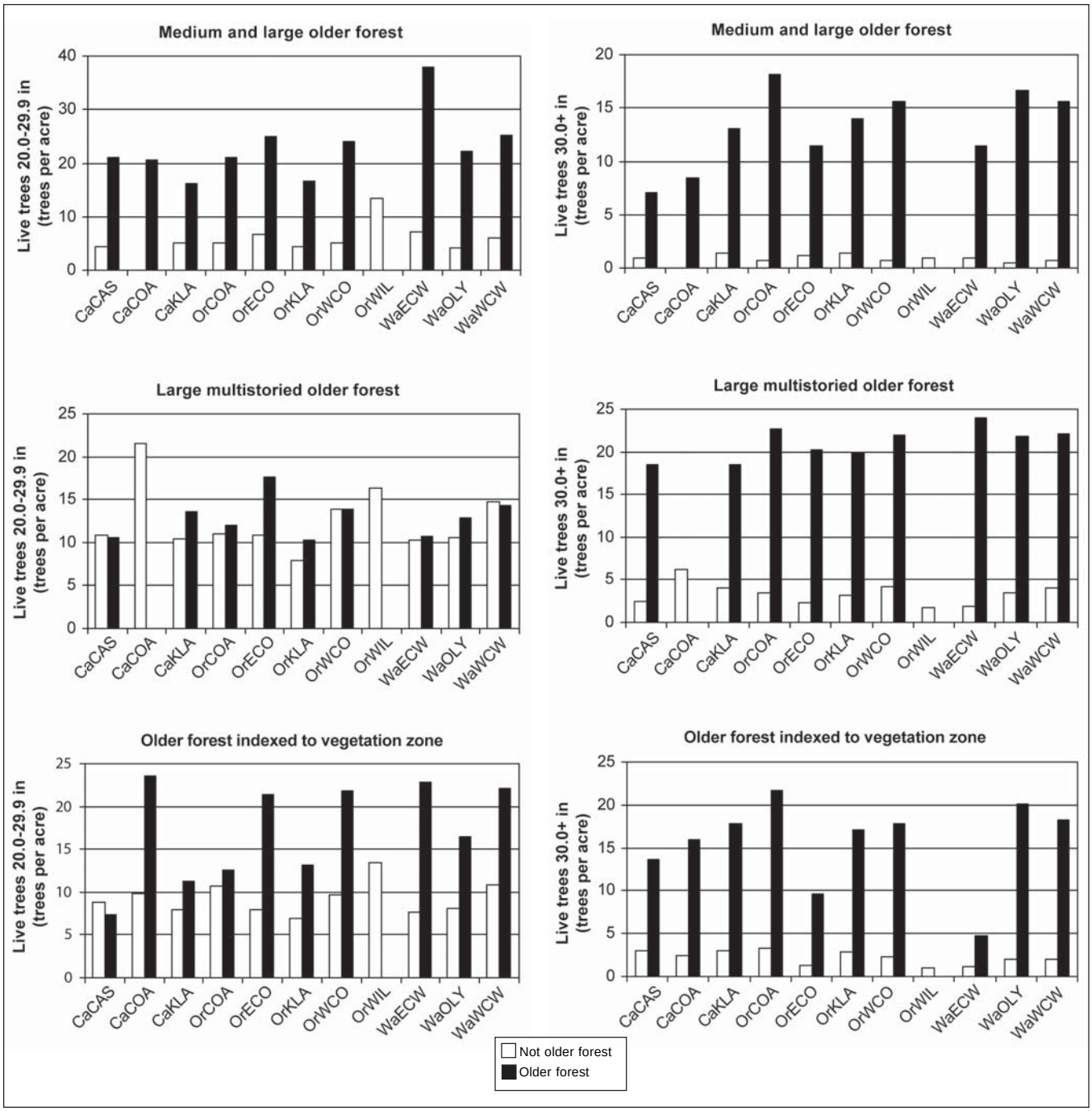


Figure 24e—Continued.

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.

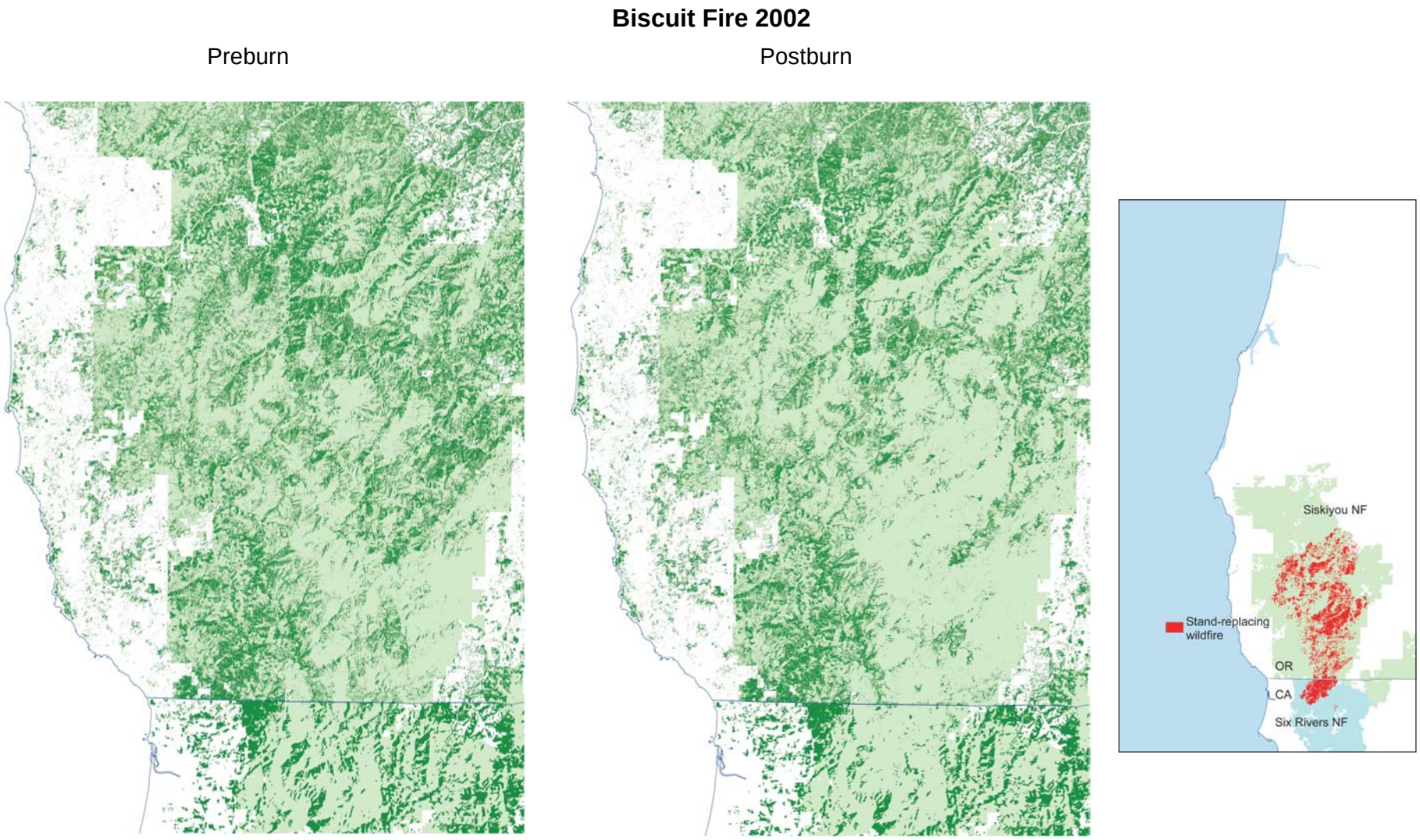


Figure 25—About 78,700 ac of older forest was burned during the 2002 Biscuit fire, Siskiyou National Forest, as detected by remote sensing. Light green = national forest; dark green = medium and large older forest.

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.

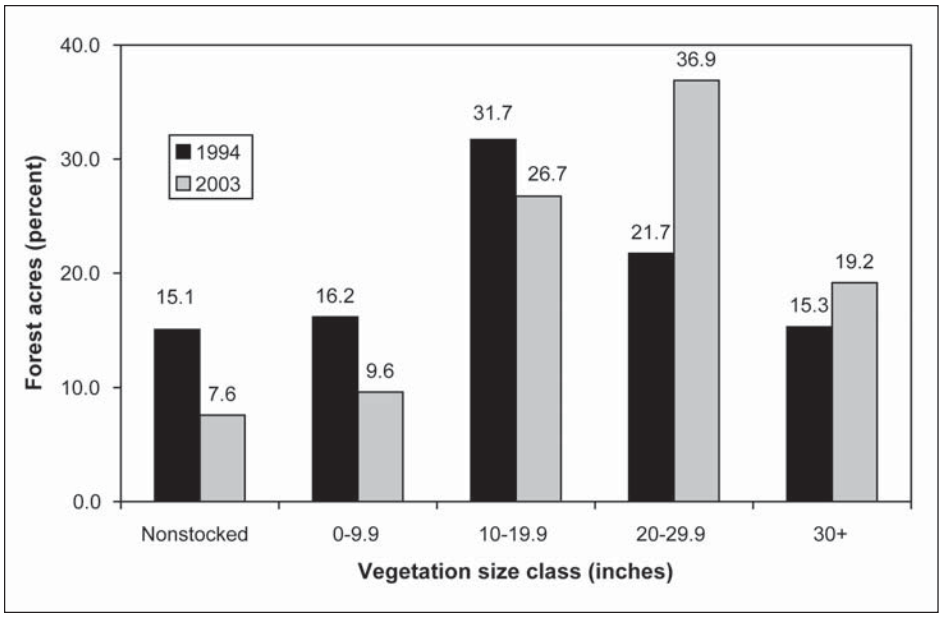


Figure 26—Percentage of forest by diameter class in 1994 and 2003 as estimated from remeasured plot data on Forest Service-Region 5 and Forest Service-Region 6 nonwilderness land. The nonstocked class has canopy closure <10 percent.

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

Vegetation zone group	Coast			West Cascades			East Cascades			Klamath			Northwest Forest Plan	
	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

Province	Condition class 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.

[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

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.

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.

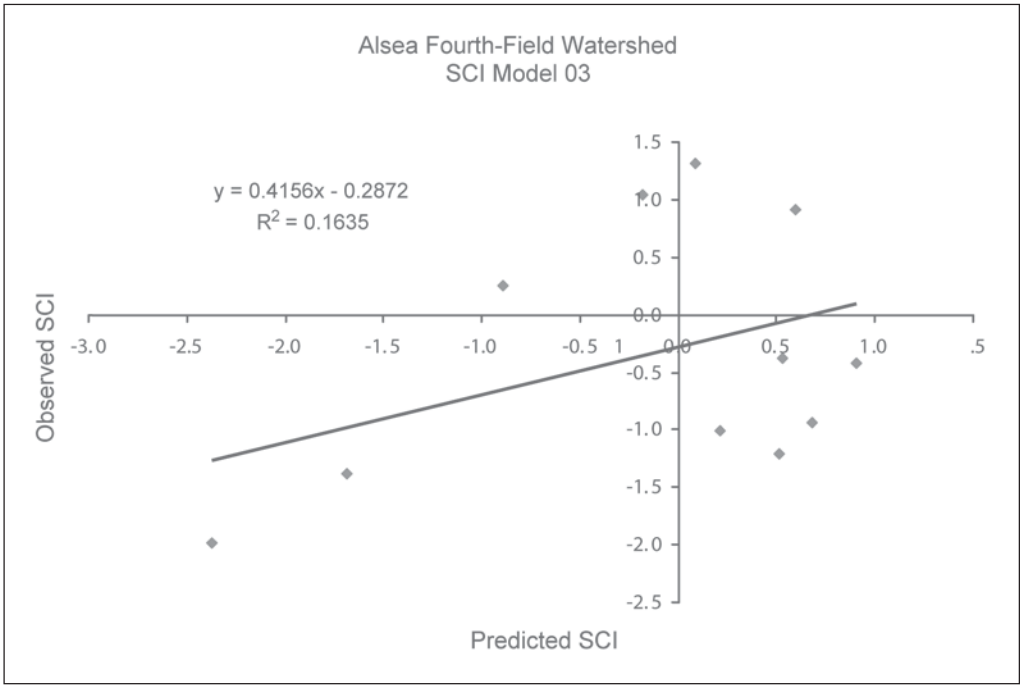
Alsea Fourth-Field Watershed

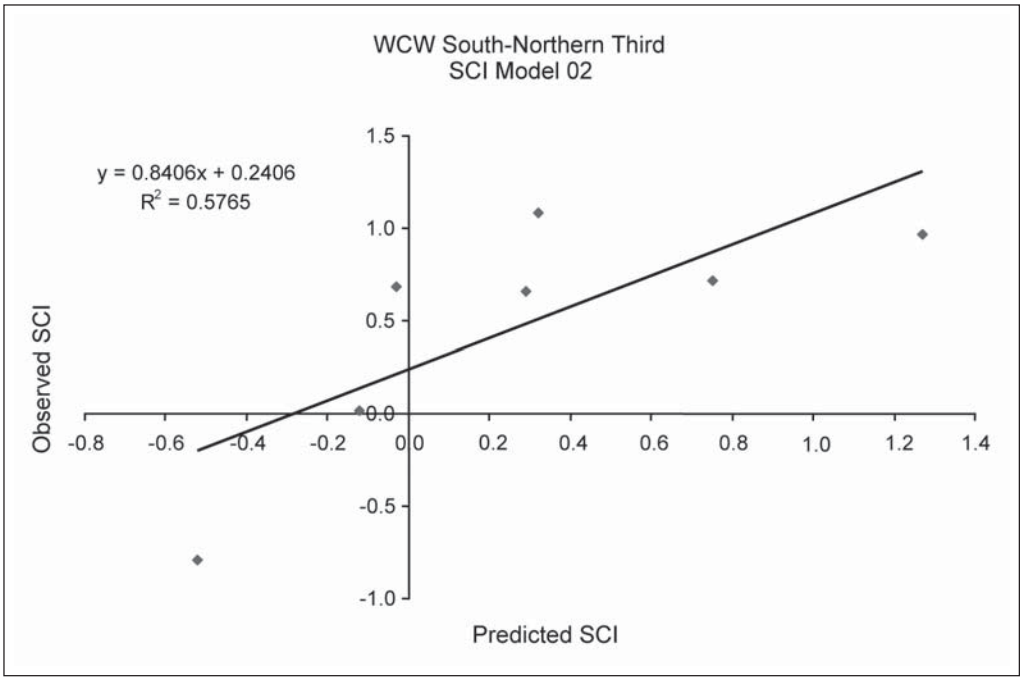
Model	R-Square	Variables in Model
3	0.6582	U_GREEN SD_R01 SD_T01
5	0.7075	U_GREEN SD_GREEN SD_MIR02 SD_T01 SD_T02
5	0.7045	U_GREEN SD_GREEN SD_MIR02 SD_R01 SD_T01
5	0.6966	U_GREEN SD_GREEN SD_NIR SD_MIR02 SD_T01

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
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0


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

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					User's accuracy
Map	**Deciduous**	**Conifer**	**Agriculture**	**Shrub**	**Row total**	**(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	Reference plots 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)

Map	Accuracy type	Reference plots 0-19.9 inches	Reference plots 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

Map	Accuracy type	Reference plots 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)

Map	Accuracy type	Reference plots 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/ image subset	Canopy structure[a]	Accuracy value			Number of reference obs[b]	
		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.

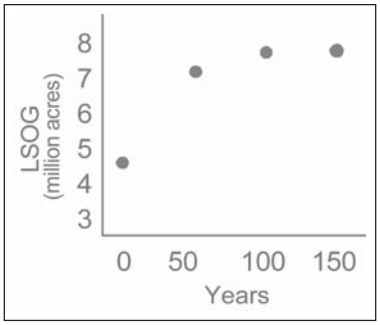


Figure 4-1—Expected trend in amount of late-successional and old-growth forest (LSOG) after implementing the Northwest Forest Plan for the next 150 years (Hemstrom and others 1998).

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

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
	Reference plot class (disturbance year)																
	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)												User's accuracy
	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	
	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

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

Reference Class

Classified As: Change Code	1	2	3	4	5	6	7	8	9	Total
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**

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

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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