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Changes in Development Near Public Forest Lands in Oregon and Washington, 1974–2005: Implications for Management

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Abstract

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Development owing to population increases over the last 30 years has greatly affected forested lands in the United States. To assess and compare increases in development, we counted changes in the number of structures on a systematic grid of photointerpreted points around public forest land in Washington and Oregon. Areas bordering public forest land are showing substantial increases in development, with the number of structures on private lands near almost all types of public forest more than doubling between the 1970s and 2000s. Lands bordering Washington's Department of Natural Resources lands have more than twice as many new structures along their edges compared to other public owners. In Oregon, the greatest amount of development occurred along the edges of Bureau of Land Management forests. The greatest increases in structure density along the borders of public forests occurred in Pierce, King, Snohomish, and Clark Counties in Washington, and Deschutes County in Oregon. The continuing development pressure along the edges of public forests in Washington and Oregon has numerous consequences, including increased road density with more human-caused ignition of wildfire, higher probability for invasive species, greater demand for local recreation, higher fire suppression costs, and increased complexity for managers trying to reduce wildfire hazard through fuel treatments.

Keywords: Development, public lands, Oregon and Washington, forest management.

Summary

Expanding development in forested lands of the United States over the last 50 years has raised concerns among resource managers. As low-density development occurs, management objectives can be altered owing to the challenges of the interactions between human and natural communities. People move into forested landscapes for many reasons: the draw of living in a natural setting, lower cost of land, fewer restrictions on property, fewer people around, and greater access to outdoor recreation.

Various effects result from houses being built in the forest. First, the house and access road supplant the forest. As more houses are built, the forest is slowly converted into a rural residential community. The road network that accompanies a housing development further fragments the surrounding forest. Management of the forest lands around these houses becomes complex in that not everyone living in developed areas necessarily views the forest as something that should be managed. Fire prevention and suppression take on new responsibilities of protecting property.

Although not necessarily subject to conversion to development, public forest lands such as those managed by the U.S. Forest Service, the Washington Department of Natural Resources (WA DNR), Oregon Department of Forestry, and the U.S. Department of the Interior, Bureau of Land Management (BLM) still face management issues at their edges. This paper examines the increase in development around these public ownerships in Oregon and Washington using a photointerpreted grid of points from the 1970s to the mid-2000s. This time period covers both before and after enactment of land use laws in Oregon and Washington.

The WA DNR has the highest number of structures around its lands with an average of more than two times the amount of the other owners considered in this study. The DNR also had the greatest amount of urbanized edge of the other owners. When considering land that stayed in a forest classification, all owners showed an increase of more than double between the 1970s and the mid 2000s. On an annualized basis, only the BLM in western Oregon and the WA DNR showed significant rises in the number of structures between 1970–1990 and 1990–2000. When considering all land, including land that had been converted from forest, only the WA DNR showed a significant increase between the two time periods. Although land use conversion has slowed in both states, the number of houses continues to increase around public lands.

Introduction

Population growth has had major impacts on forested ecosystems across the United States, including land use conversion, increases in invasive species, forest fragmentation, wildlife habitat loss, and increases in human-caused fire ignitions (Radeloff et al. 2005). Population growth and development have also been correlated with reduced forest management and investment on private forest land (Kline et al. 2004, Munn et al. 2002). In the Eastern United States, private owners hold the most forest land; however, in the West, public owners manage the most forest land. Private lands generally sustain the most land use conversion, forest fragmentation, and habitat loss from increasing development, but there are also questions about the impacts of development on adjacent public lands and their management (Stein et al. 2007).

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In Oregon and Washington, public ownership accounts for roughly 50 percent of forest land. This study analyzes the area around the majority holders, the U.S. Forest Service (National Forest System [NFS]), the Bureau of Land management (BLM), the Oregon Department of Forestry (ODF), and the Washington Department of Natural Resources (WA DNR). In Oregon and Washington, the U.S. Forest Service manages 9.1 million ha of forest land, the BLM about 1.5 million (with their productive forest mostly in southwest Oregon), ODF about 0.40 million, and the WA DNR about 1 million ha (Campbell et al. 2010, Donnegan et al. 2008). Some of the impacts that generally occur on private land, such as forest fragmentation and conversion, may not be as meaningful in reference to public forest land. However, problems occur at the interface between public and private lands where management differences between the owners are most evident.

In Oregon and Washington, a continuum of community types can be found at the edge of public land, including urban/residential, undeveloped commercial forests, and agricultural lands. The expansion of development at the edges of public land exacerbates management issues through various disturbances:

- Introduction of invasive plants
- Increases in unmanaged recreation
- Impacts on native fish and wildlife habitats
- Increased access by road, which can lead to a rise in human-caused ignitions (Nowak et al. 2005).

Also, public pressure and national policy may force priorities for fuel treatments and fire suppression into edge areas at the expense of surrounding natural resources. Federal wildland fire policy lists protection of human life as its first priority, followed by property and resource values (USDA Forest Service 2009).

As the number of structures increases near federal and state lands, this policy will drive increases in protection efforts for these structures. In the Western United States, development encroachment at the forest edge has also been linked to fire suppression costs (Gebert et al. 2007). In 1994, the U.S. Forest Service obligated $752 million to fire suppression, and in 2008 that number was $3.2 billion—a 325 percent increase in 14 years (Gorte 2008). Some of this increase may be due to the increased development near federal lands, and some to the doubling in average acreage burned between the 1990s and 2000s.

Fire exclusion policies of the past 100 years on certain forested lands have added to fire management issues for these forests by slowing the recycling of nutrients and not regulating the density and composition of young trees (Donovan and Brown 2007, Noss et al. 2006, Reinhardt et al. 2008, Stephens and Ruth 2005). A major tool forest managers can use to address these issues is prescribed fire. However, at the edges of public land, this method of fuel reduction can be highly controversial: for example, in 2000, an escaped prescribed burn near Los Alamos, New Mexico, resulted in nearly $1 billion in property damage. Although public forest lands may not be under pressure for development, development at the edge becomes a problem for managers considering the liabilities associated with fire prevention, protection, suppression, fuel treatment, and harvesting.

In the late 1990s and into the next decade, the Forest Inventory and Analysis (FIA) unit of the U.S. Forest Service Pacific Northwest (PNW) Research Station and the ODF conducted a series of land use change studies (Lettman et al. 2011). Changes in land use were documented on nonfederal land for all of Oregon using a grid of photointerpreted points. These studies found a general slowing of land use conversion from more forested and rural types to more urbanized types after the implementation of Oregon's land use laws in the form of county comprehensive land use plans implemented in the 1980s (Lettman et al. 2009). They also showed that land use changes were focused in areas zoned for development, and that the number of structures in forested and rural settings continued to increase on the 2005 imagery. These studies focused on location and rate of land use change on private lands across the state, such as the areas where forest and agricultural lands were being converted to low-density residential or urban land use. In contrast, the objectives for this study were to investigate the increase in development on lands adjacent to Washington and Oregon's public forest lands and compare these increases among the different management agencies. Quantifying the increases in structures in areas that have not been converted in land use can serve as a surrogate for the broader risks associated with development near public lands.

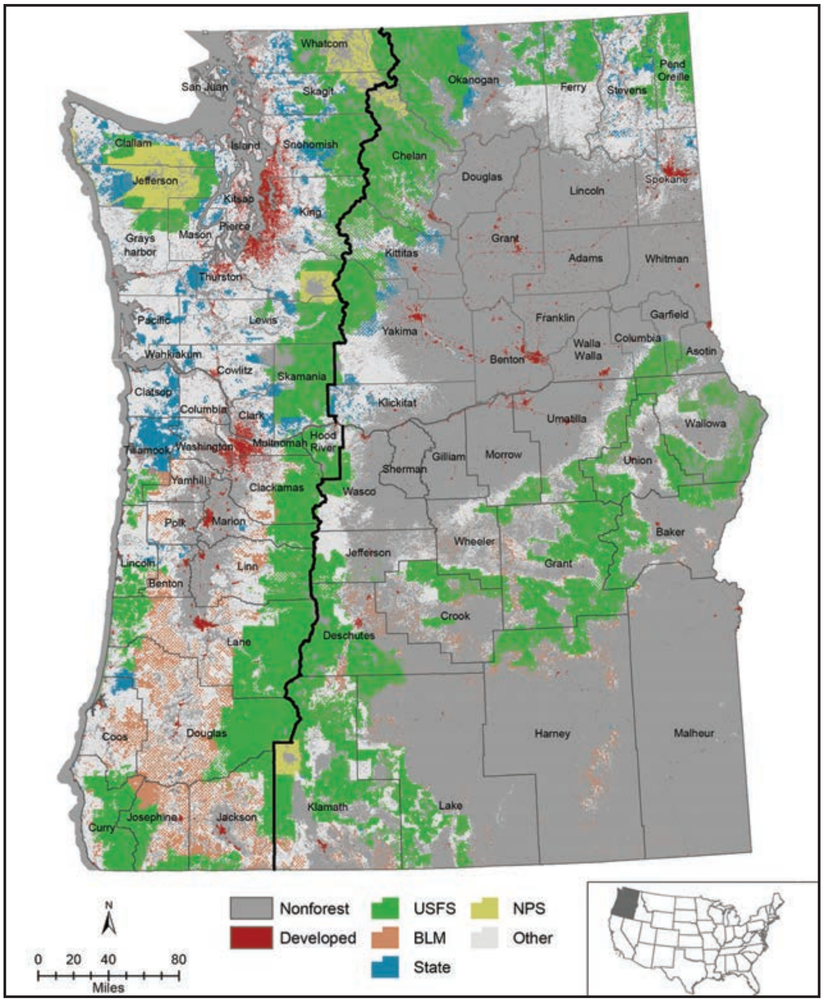

Figure 1—Ownership on forest land in Oregon and Washington. USFS = U.S. Forest Service, BLM = Bureau of Land Management, NPS = National Park Service.

Study Area

The study was conducted in Oregon and Washington, which jointly has 43.3 million ha of land, of which 21.4 million ha were forested (fig. 1). Public lands account for roughly 60 percent of the forested area. The photointerpreted grid includes all lands outside of federal (NFS, BLM, and National Park Service) ownership for Oregon and Washington. Because we intended to look at development around forest land, we limited the coverage on BLM land to western Oregon where the vast majority of BLM's productive forest lands exist; BLM does also manage large areas of juniper woodland and range land in eastern Oregon. The west-side forests are dominated by Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) forest types, while east-side forests are dominated by ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) with Douglas-fir being the second most abundant forest type.

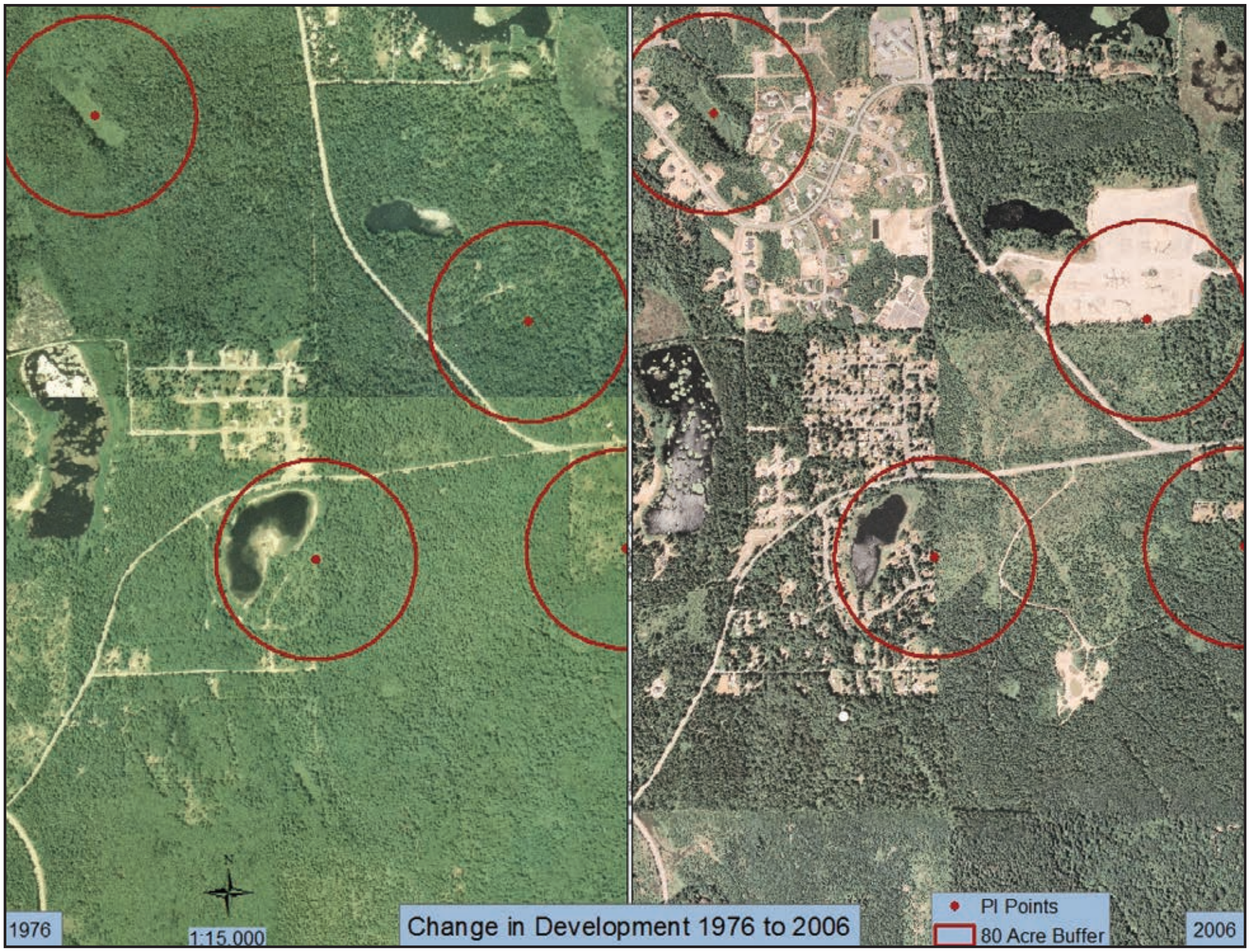

Figure 2—Change in development from 1976 to 2006.

Methods

A photointerpreted grid of points was established by the U.S. Forest Service PNW Research Station's FIA program for purposes of stratification for inventory estimates. These points and the attributes represent a systematic sample of roughly 37,000 points in Oregon and 44,000 in Washington on the land outside of federal ownership. This 1.4-km grid across Oregon and Washington was used to evaluate land use change for western and eastern Oregon (Lettman et al. 2011). Each point outside of federal land was assessed for land use in 1974, 1984, 1994, 2000, and 2005 for Oregon, and in 1976, 1994, and 2006 for Washington. The earlier dates were evaluated off 1:40,000 aerial photography. Lands were classified into the following types: wildland forest, mixed forest and agriculture, intensive agriculture, low-density residential, urban, wildland range, mixed range and agriculture, and other (Lettman et al. 2006). Along with delineating land use polygons for each point, interpreters also recorded the number of structures within a 32.3-ha circle (321-m radius) around all points (fig. 2), with the exception of those that were classified as urban. A structure denotes the presence of an improvement (most often a house and its associated outbuildings, a farmstead or isolated barn or agricultural building, or isolated commercial establishments). Structures were also counted for points that were classified as nonurban but had portions of the 32.3-ha circle that were designated as urban. Using the structure count information from each of these points, we estimated the average change in number of structures at various distances from public land over the period of time our aerial photos covered.

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In 2005, the land use change study was conducted using 0.5-m resolution National Agriculture Imagery 20 Program imagery, and National Digital Ortho Program imagery that was scanned and geo-registered in geographic information system (GIS) for the 1990s and 2000 dates (Lettman et al. 2006). The old points were transferred to the new imagery, and polygons of land use classes were delineated in GIS over displayed imagery for the 1990s and later dates. Each old point was classified again and structure counts were performed on the new imagery, capturing the location of each of the structures. In the 2005 data set, the actual locations of the structures were recorded as they were counted, and for eastern Oregon, the 1994 location was also noted. The distance to the four public land ownerships (ODF, BLM, NFS, DNR) was computed from each point to each ownership, and we evaluated sample points within three distance zones (<1, 1 to 2, and 2 to 5 km) around public land. Sample sizes were large for each ownership/distance-zone pairing, with the smallest being over 350 points. Using an ownership layer provided by ODF for Oregon state lands, Washington DNR's parcel layer (WA DNR 2012) and one that was developed by the U.S. Geological Surveys Gap Analysis Program, BLM, and U.S. Forest Service for federal lands, we were able to compute the amount of edge between various public owners and private ownership for each county in Oregon and Washington. The edge-to-area ratio (EAR) of public forest land to edge with private ownership was computed on a county basis.

Adjustments for Urban Counts

When a point was classified in the urban category (center fell on urban land use), structures in the surrounding 32-ha circle (321-m radius) were not counted. To estimate the change in density for points that changed from other uses to urban, we set the density for the urban class at 160 structures per 32-ha circle, roughly four times the average number of structures in our low-density residential zone and in line with the 6.1 houses per hectare for what Loy (2001) described as low-density urban in the *Atlas of Oregon*. Without adjustment, eliminating the urban classified points can result in a decrease in the average number of structures per point. For example, if in 1974, three points had 2, 3, and 45 structures, and by 1984 the third was called urban and eliminated, the average count goes from 16.7 to 2.5. To avoid

Table 1—Average number of developments per square kilometer on nonpublic land by distance from public owner for Oregon and Washington

	NFS			BLM[a]			State (ODF/DNR)[b]			All public[c]		
	Distance from public owner											
Year	<1 km	1–2 km	2–5 km	<1 km	1–2 km	2–5 km	<1 km	1–2 km	2–5 km	<1 km	1–2 km	2–5 km
	Average number of developments per square kilometer											
Oregon:												
1974	2.5(0.8)	3.9(1.8)	6.7(1.7)	2.1(0.3)	7.3(1.1)	13.4(1.3)	1.3(0.3)	4.3(1.0)	3.8(0.5)	1.6(0.3)	4.1(1.1)	9.0(1.5)
1984	3.4(0.9)	5.5(2.1)	8.4(1.9)	3.0(0.4)	9.7(1.2)	16.0(1.4)	1.6(0.3)	4.9(1.0)	4.6(0.6)	2.2(0.4)	5.4(1.3)	10.9(1.6)
1994	4.3(1.0)	6.1(2.2)	9.2(2.0)	3.7(0.4)	11.4(1.3)	17.6(1.4)	1.8(0.3)	5.4(1.0)	5.2(0.6)	2.7(0.4)	6.3(1.4)	11.8(1.6)
2000	4.7(1.0)	6.7(2.3)	10.4(2.1)	4.0(0.5)	12.0(1.4)	18.6(1.5)	1.9(0.3)	5.8(1.0)	5.6(0.6)	3.0(0.4)	7.0(1.4)	12.8(1.7)
2005	5.2(1.1)	7.3(2.4)	10.9(2.2)	4.4(0.5)	12.7(1.4)	19.5(1.5)	2.0(0.3)	6.1(1.0)	5.9(0.6)	3.3(0.4)	7.3(1.5)	13.4(1.7)
Washington:												
1976	1.1(0.2)	2.0(0.4)	3.1(0.4)	–	–	–	5.7(0.6)	14.1(1.4)	18.6(1.6)	5.4(0.5)	14.4(1.5)	19.5(1.8)
1994	1.7(0.2)	3.2(0.5)	4.5(0.5)	–	–	–	8.4(0.7)	18.9(1.7)	23.5(1.9)	7.9(0.6)	19.2(1.7)	24.5(2.0)
2006	2.2(0.2)	4.0(0.5)	5.8(0.6)	–	–	–	11.2(0.8)	24.0(1.9)	28.0(2.1)	10.6(0.8)	24.5(2.0)	29.2(2.3)

— = no estimate, owing to lack of photopoint around ownership.
[a] The numbers for Bureau of Land Management (BLM) are western Oregon.
[b] ODF/DNR = Oregon Department of Forestry and Washington Department of Natural Resources.
[c] All public includes ODF and DNR, National Forest System, and BLM where applicable.

this problem, we adjusted the count by multiplying 160 times the proportion of the 32.3-ha circle that was urban for points that had a center classification of urban.

Quality Assurance

In the original study, polygons were drawn by multiple observers and compared for multiple areas as a training tool. Because each increment in time involved the classification of every point, we checked each point on the imagery that changed in land use to ensure that the change was real. All structure counts that had decreased or increased by more than two were rechecked by another observer (Lettman 2006).

Statistical comparisons between ownerships or distance classes are based upon a t-test for the differences in means with unequal variances.

Results

Current Density

The greatest structure density in the closest distance class (within 1 km) in the mid-2000s occurred around WA DNR lands (11.2 structures per square kilometer, statistically different from all other owners). The next highest estimates were around U.S. Forest Service and BLM lands in Oregon, with 5.2 and 4.4 structures per square kilometer, respectively (table 1). These numbers correlate with the amount of edge each owner has with urban and low-density residential land uses (fig. 3). The NFS lands in Washington and the state lands in Oregon have roughly the same average number of structures per square kilometer within 1 km of their

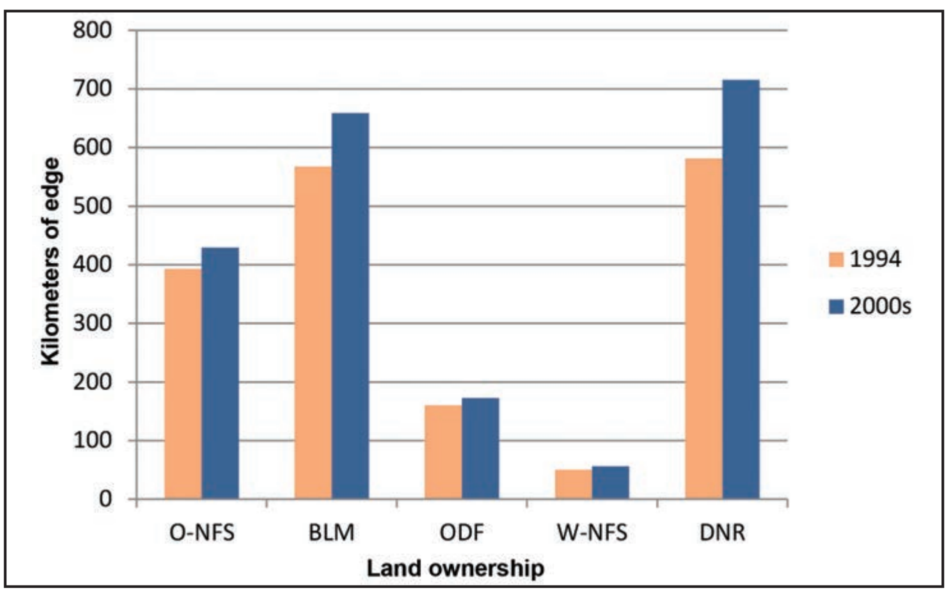

Figure 3—Amount of edge with urbanized land use by public ownership for two time periods in Oregon and western Washington. O-NFS = Oregon National Forest System, BLM = Bureau of Land Management, ODF = Oregon Department of Forestry, W-NFS = Washington National Forest System, DNR = Department of National Resources.

Table 2—Population increase (1974–2005), area of forest, edge-to-area ratio (EAR)[a] of forest land, and increase in development denisity for public owners in selected counties in Oregon and Washington

	Population		NFS			BLM			ODF/DNR		
County	Thousands	% increase	Area (1000 ha)	EAR (m/ha)	DEV[b] (No./km^2)	Area	EAR	DEV	Area	EAR	DEV
Oregon:											
Eastern—											
Baker	16	11	247	4.7	1.1	24	112.9	1.7	2	9.1	–
Cook	21	146	146	3.9	0.4	120	23.0	1.4	2	45.5	2.4
Deschutes	158	400	356	2.4	44.9	72	20.5	24.5	–	–	
Grant	2	10	612	3.7	0.2	20	112.5	0.5	7	5.4	0.2
Harney	7	6	187	2.5	0.2	131	56.0	0.2	15	42.1	0.1
Jefferson	22	151	71	12.9	3.1	2	263.8	1.9	–	–	–
Klamath	66	31	683	5.4	1.4	77	23.8	3.0	17	6.9	1.3
Lake	8	19	370	5.8	0.5	78	49.5	0.7	–	–	–
Malheur	31	37	–	–	–	32	183.4	0.3	4	122.1	0.4
Morrow	11	169	40	5.0	0.6	–	–	–	–	–	–
Umatilla	76	60	139	5.9	0.4	3	93.7	2.9	3	5.9	–
Union	26	30	206	3.6	0.8	–	–	–	3	21.6	0.9
Wallowa	7	14	275	5.2	0.4	2	202.0	0.2	2	14.5	0.1
Wasco	25	20	67	4.3	4.7	6	192.2	1.0	7	9.4	0.9
Wheeler	1	-15	56	3.3	0.4	25	50.3	0.5	–	–	–
Total	487	90	3,485	4.6	2.9	592	55.1	1.7	62	34.9	1.7
Western—											
Benton	86	56	12	5.5	1.6	27	19.2	2.0	9	21.1	1.4
Clackamas	376	120	213	1.0	4.9	9	71.5	8.6	2	2.0	4.7
Clatsop	37	30	–	–	–	–	–	–	39	22.7	1.0
Columbia	49	63	–	–	–	2	73.4	6.1	3	36.0	0.5
Coos	63	11	26	11.2	1.7	68	22.3	1.3	29	6.5	1.0
Curry	22	64	233	2.3	0.8	17	29.8	2.3	7	12.8	0.4
Douglas	108	45	374	2.6	0.5	261	24.5	2.7	21	9.8	1.1
Hood River	22	61	81	2.6	6.4	–	–	–	3	17.6	–
Jackson	203	110	221	3.8	7.1	141	30.9	6.5	6	7.8	5.2
Josephine	83	127	149	1.7	11.9	126	17.2	9.8	5	11.6	4.6
Lane	352	58	530	3.3	3.6	104	31.9	5.3	16	2.4	1.9
Lincoln	46	73	83	8.8	3.8	5	48.9	3.0	13	17.4	1.4
Linn	117	51	176	4.2	0.1	36	22.0	1.5	6	1.7	1.0
Marion	315	103	77	1.8	0.3	3	93.4	4.1	12	7.5	1.1
Multnomah	735	27	27	3.4	58.9	2	34.9	5.3	–	–	–
Polk	75	89	–	–	–	19	23.6	2.3	5	14.0	0.8
Tillamook	25	41	37	12.3	2.2	9	16.2	2.9	128	4.4	0.8
Washington	530	217	–	–	–	3	61.4	3.0	35	8.4	1.5
Yamhill	99	128	9	6.8	0.2	20	22.5	2.6	2	14.5	1.3
Total	3,343	78	2,248	3.3	4.7	852	26.0	5.1	341	9.4	9.4
All Oregon	3,843	79	5,733	4.2	3.4	1,444	45.4	2.6	403	10.0	1.4

Table 2—Population increase (1974–2005), area of forest, edge-to-area ratio (EAR)[a] of forest land, and increase in development denisity for public owners in selected counties in Oregon and Washington (cont.)

County	Population		NFS			BLM			ODF/DNR		
	Thousands	% increase	Area (1000 ha)	EAR (m/ha)	DEV[b] (No./km^2)	Area	EAR	DEV	Area	EAR	DEV
Washington:											
Western—											
Island	81	199	–	–					2	55.75	32.06
King	1,826	58	123	7.26	.32				33	17.74	44.77
Kitsap	241	135	–	–	–				11	20.48	34.78
Pierce	767	85	200	2.31	1.01				12	22.07	49.78
San Juan	15	293	–	–	–				6	18.36	7.21
Skagit	116	119	132	2.25	.86				42	28.00	9.73
Snohomish	670	151	198	2.15	1.47				64	12.10	34.40
Whatcom	186	130	144	.80	.51				46	18.32	15.32
Clallam	70	100	78	3.39	2.23				68	20.37	6.86
Grays Harbor	72	19	51	4.01	.13				46	12.31	4.41
Jefferson	29	172	69	1.39	1.05				88	9.48	6.00
Mason	56	162	48	1.93	1.39				28	14.22	6.46
Thurston	235	203	–	–	–				20	20.56	31.02
Clark	413	219	2	.83	9.44				22	17.02	40.29
Cowlitz	100	44	14	3.68	0.01				48	9.80	4.38
Lewis	74	60	186	2.16	1.39				39	20.56	4.27
Pacific	22	36	–	–	–				43	11.00	2.50
Skamania	11	80	132	2.24	3.98				34	12.13	4.21
Total	4,987	67	1,419	2.39	1.60				659	15.73	18.04
Eastern—											
Chelan	71	70	471	3.56	7.34				13	31.01	10.08
Kittitas	37	52	168	8.46	2.11				48	24.66	2.12
Klickitat	20	63	–	–	–				35	34.58	1.13
Okanogan	40	52	571	1.42	1.67				106	17.55	1.70
Yakima	233	59	–	–	–				37	31.11	5.02
Asotin	21	52	17	3.44	0.17				2	108.22	9.73
Columbia	4	-11	59	1.42	0.22				2	68.35	.18
Ferry	8	105	177	2.54	1.96				12	29.35	1.97
Garfield	2	-27	42	.91	0.75				–	–	–
Lincoln	10	7	–	–	–				3	198.83	0
Pend Oreille	13	110	200	6.35	1.59				9	33.23	2.19
Spokane	447	56	–	–	–				15	35.49	7.63
Stevens	43	137	82	7.74	2.04				77	19.99	2.47
Total	1,408	93	1,973	3.45	2.28				361	26.86	5.52
All Washington	6,395	90	3,393	3.00	2.01				1,020	19.67	9.74

— = no estimate, due to lack of photo point around ownership.

NFS = National Forest System, ODF = Oregon Department of Forestry, BLM = Bureau of Land Management.

[a] Edge-to-area ratio, calculated as the linear distance of edge between public and private ownership in the county divided by area of public forest land ownership, in m/ha.

[b] DEV = average development count increase per km^2 for all distance classes around public lands, 1974–2005.

land at 2.18 and 1.98, respectively. The greatest structure 8 density within 5 km of public lands are in areas with high population, such as Pierce, King, and Clark Counties in western Washington and Clackamas, Multnomah, Lane, and Jackson Counties in Oregon (table 2). There are some curious exceptions such as Deschutes County in Oregon, which has a high number of structures around NFS land, with intermediate population levels and the largest amount of population growth in the study period.

Changes in Density

The large increases seen around BLM and DNR land are related to the increases in urban/low-density edge.

Increases in structures between the 1970s and 2000s differed among owners in the shortest distance class, with the largest difference in structure density occurring on lands in proximity to the WA DNR, followed by the NFS and BLM in Oregon, and NFS in Washington and ODF land in Oregon (fig. 4). The mean increase in structure density was greater for the farthest distance class compared to the closest for all owners except for NFS land in Oregon (fig. 4). In Washington, the largest increases occurred in counties with the largest populations, such as Pierce, King, Snohomish, and Clark. In Oregon, the greatest increase occurred in Deschutes County around NFS land; the next largest differences in Oregon were in counties that had large population centers. The BLM had some relatively large increases in Oregon's southern counties of Jackson, Josephine, and Lane at 6.5, 9.98, and 5.3 structure densities, respectively (table 2). The large increases seen around BLM and DNR land are related to the increases in urban/low-density edge (fig. 3). With the

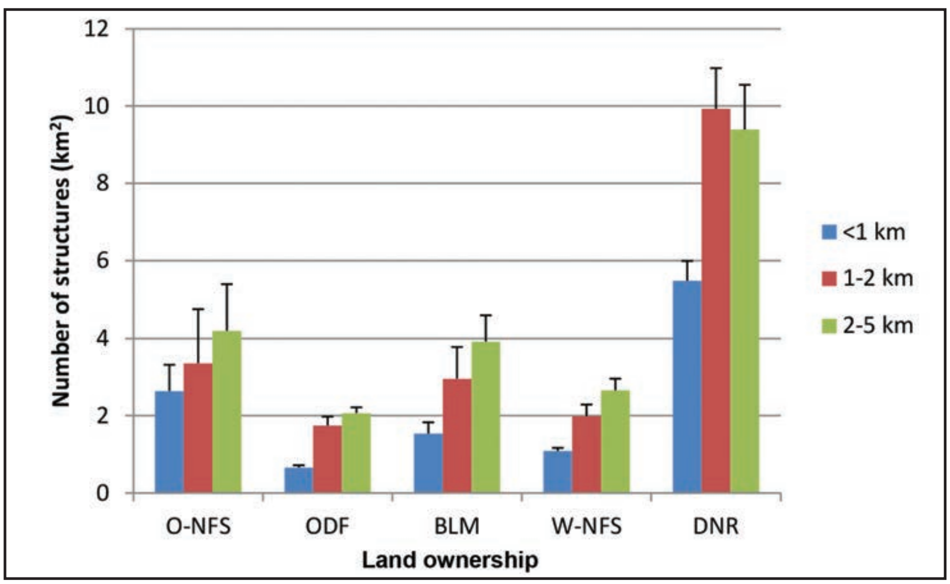

Figure 4—Increase in structure density by owner and distance for the study period in Oregon and Washington. O-NFS = Oregon National Forest System, ODF = Oregon Department of Forestry, BLM = Bureau of Land Management, W-NFS = Washington National Forest System, DNR = Department of National Resources.

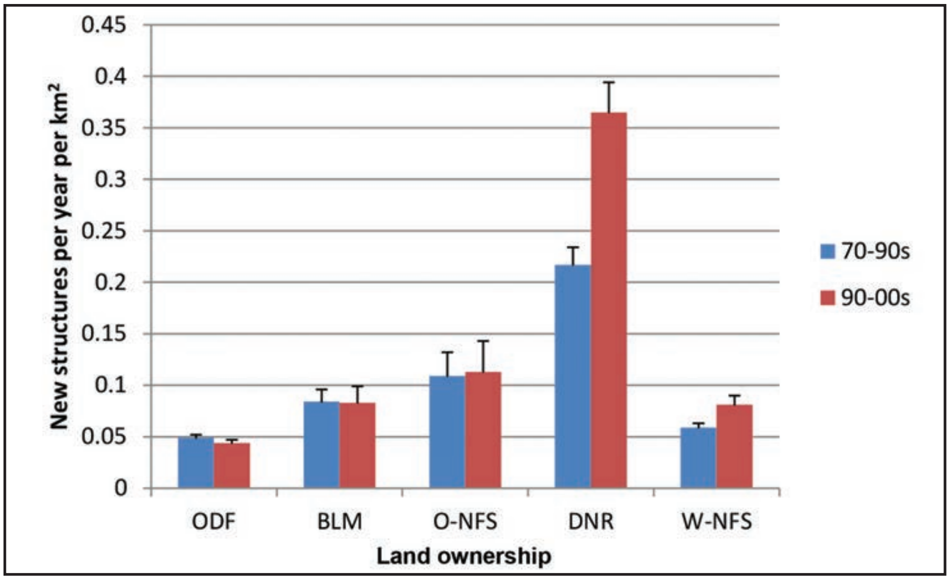

Figure 5—Annualized increases in structure density by ownership for two time periods for all lands. ODF = Oregon Department of Forestry, BLM = Bureau of Land Management, O-NFS = Oregon National Forest System, DNR = Department of National Resources, W-NFS = Washington National Forest System,

exception of land around ODF structure density tends to increase with the distance interval, the two farther distances are virtually the same. This may indicate the greater chance of hitting an urban or low-density residential area as you move away from blocks of public land.

An annualized look at all distance classes combined and for two time periods, 1970s to 1990s and 1990s to 2000s, showed that the numbers of new structures around various public owners remained relatively constant with the exception of lands around the WA DNR, which had significantly more new structures in the second period (fig. 5).

Land Remaining in a Forested Land Use

When limiting the analysis to points that have remained in some partially forested zone (excluding points that changed land use), such as a wildland forest zone or a mixed-forest/agricultural zone, the average number of structures in most cases more than doubled between the 1970s and the mid-2000s. Within 1 km of public forest, structure density more than doubled for each of the owner groups (table 3). The mean differences remain relatively constant across distances classes with only the WA DNR lands having a statistical difference between the closest (≤1 km) and farthest (2 to 5 km) distance class. When combining all distance classes, both BLM and WA DNR lands tend to have more development than other public owners with the WA DNR having significantly more development in the second time period, 1994 to 2000s versus the 1970 to 1994 period (fig. 6).

Table 3—Average number of developments per square kilometer on nonpublic forest land by distance classes from public owner for Oregon and Washington

	NFS			BLM[a]			State (ODF/DNR)			All public		
	Distance from public owner											
Year	**<1 km**	**1–2 km**	**2–5 km**	**<1 km**	**1–2 km**	**2–5 km**	**<1 km**	**1–2 km**	**2–5 km**	**<1 km**	**1–2 km**	**2–5 km**
	Average number of developments per square kilometer											
Oregon:												
1974	.32(.08)	.32(.08)	.48(.07)	.65(.03)	.82(.08)	1.00(.05)	.38(.03)	.73(.08)	.76(.05)	0.50(.03)	0.81(.08)	1.13(.12)
1984	.51(.11)	.57(.21)	.68(.10)	.94(.05)	1.21(.11)	1.51(.07)	.51(.04)	1.00(.11)	1.08(.07)	0.74(.04)	1.21(.13)	1.63(.17)
1994	.67(.12)	.73(.28)	.89(.12)	1.18(.06)	1.63(.15)	1.78(.09)	.66(.06)	1.25(.15)	1.41(.09)	0.93(.05)	1.56(.17)	1.99(.20)
2000	.74(.13)	.81(.29)	.98(.13)	1.31(.06)	1.87(.17)	2.02(.10)	.70(.06)	1.39(.17)	1.55(.10)	1.03(.05)	1.80(.19)	2.26(.24)
2005	.88(.15)	.91(.31)	1.14(.14)	1.57(.07)	2.12(.19)	2.25(.11)	.80(.07)	1.63(.18)	1.83(.11)	1.23(.06)	2.02(.21)	2.51(.25)
Washington:												
1976	.34(.03)	.43(.06)	.37(.06)	–	–	–	.66(.03)	1.42(.10)	1.24(.09)	0.63(.03)	1.47(.11)	1.33(.10)
1994	.65(.05)	.81(.09)	.70(.07)	–	–	–	2.03(.05)	2.20(.16)	2.01(.11)	1.15(.05)	2.67(.17)	2.12(.13)
2006	.85(.06)	1.14(.13)	.91(.08)	–	–	–	1.83(.08)	3.65(.12)	3.05(.17)	1.72(.38)	3.75(.44)	3.31(.44)

— = no estimate, due to lack of photo point around ownership.
NFS = National Forest System, ODF = Oregon Department of Forestry, DNR = Washington Department of Natural Resources.
[a] The numbers for Bureau of Land Management (BLM) are western Oregon.

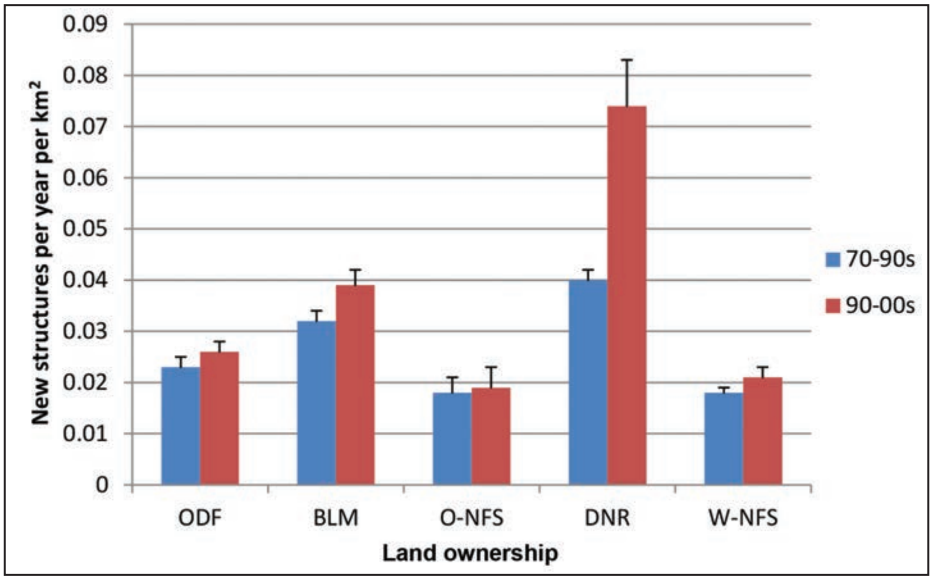

Figure 6—Annualized increases in structure density by ownership for two time periods for forested lands. ODF = Oregon Department of Forestry, BLM = Bureau of Land Management, O-NFS = Oregon National Forest System, DNR = Department of National Resources, W-NFS = Washington National Forest System, .

County-Level Edge-to-Area Ratios and Development

As for counties that had large amounts of public forest land, Deschutes stands out with its large increase in structure density (from 1974 to 2005) near NFS land and low EAR; this was the result of 27 of the 290 points changing from a nonurban to urban land use. Lane, Jackson, and Josephine Counties also stand out with large increases near BLM land, and Snohomish and Whatcom Counties showed double digit increases around WA DNR lands (table 2). For Oregon counties with the four largest forest-land areas, the EAR is nearly eight times as great on BLM lands as on NFS lands. Although Lane County had a modest population increase of 59 percent, the EAR for 104 000 ha of productive BLM forest land is high at 31.9 m/ha, possibly contributing to the large structure count increase. Snohomish, Whatcom, Clalam, and Mason Counties in western Washington had over 100 percent population growth and relatively high EARs for DNR lands; however, the NFS lands in these Washington counties had relatively small increases in structures and low EARs.

Discussion

Edge-to-Area Ratio With Private Owners

The EAR of a public to private ownership affects the public owner's ability to manage fire and resources in proximity to structures. The greater the amount of edge with respect to area, the greater the possibility for development on the edge, assuming that very little development will occur on public lands. For counties with over 100 000 ha of forest land in a public ownership, the BLM in southwestern Oregon and the DNR in western Washington have a large amount of edge with private owners. The EAR for the BLM is largely due to the Oregon/California railroad lands that were returned into federal management in the early 1900s (Horning 1940). The railroads had been granted every other section of land in a swath in the southern Oregon counties (Douglas, Lane, Jackson, Josephine), creating a checkerboard of ownership (fig. 1). Most of BLM's productive forest ownership in Oregon falls into these counties. Not all of the edge is with private owners, however; there is a substantial amount of edge with the NFS. The WA DNR lands tend to be lower in elevation and closer to developed areas where the EAR can produce high structure counts, whereas the ODF lands tend to be in the coast range farther away from developed areas (fig. 1). The greater amount of edge between BLM/DNR and private land has an effect on the number of structures closer to these ownership groups. If development continues to occur in these counties on nonpublic forest land, fire and fuel management will continue as a problem for the BLM and WA DNR.

Implications With Fire Suppression and Fuel Treatments

Considerable attention has been paid to the ecological alteration of fire-prone western forests by grazing, harvesting, and fire suppression during the 20th century (Donovan and Brown 2007, Noss et al. 2006), which may have led to the increases in annual burned area of the last decade (Stephens and Ruth 2005). The combination of these changes and development at or near the edges of these forests is becoming a prime consideration for forest managers. The rising cost of fire suppression has been linked to both altered fire regimes and development (Liang et al. 2008). Forest Service research indicates that the characteristics of houses and their immediate surroundings are the primary determinants of whether a house burns (Cohen 1999). Nonetheless, fuel treatments on public land will continue to be used to attempt to change fire behavior from crown to surface fire so that suppression efforts will be more effective around homes (Murphy et al. 2007).

The changing of fuel structures in forests to reduce fire hazard is well documented (Agee and Skinner 2005) and has been shown to change fire behavior in wildland-urban interface (WUI) areas, although under extreme conditions, treated areas may not be enough to protect homes (Safford et al. 2009). In areas on the edge or where mixed public/private ownership exists, the objectives for fuel treatment can be quite different than in areas further away. When treating boundary areas, the primary focus of a public forest manager may be fire risk as opposed to more broad ecological objectives for a more remote setting. Treatment options are more limited on lands at the edge; public land managers place a greater emphasis on mechanical treatments here, whereas they can use prescribed fire and wildland fire in other areas (Reinhardt et al. 2008). Public land managers must also gain acceptance for their treatments among a mixed audience on the edge, and some private owners may not want any treatment near their homes (Winter and Fried 2000).

Although less conversion of land from forest to nonforest was reported from 2000 through 2005 compared to the 1970s and 1980s in Oregon, the number of structures continues to increase next to public forest lands in both states.

Although Lettman et al. (2011) reported less conversion of land from forest to nonforest use from 2000 through 2005 compared to the 1970s and 1980s in Oregon, the number of structures continues to increase next to public forest lands in both states. This study shows that areas closest to DNR in Washington, and BLM lands in western Oregon (less than 1 km), had the greatest percentage of increase in the average number of structures. If rates of development continue as in the recent past, we might expect a double digit percentage increase in the number of structures per square kilometer in the next 10 years near public forest lands in Oregon and Washington. The relatively low number of structures around NFS lands in Washington is due to a buffering effect of both DNR lands and commercial forest lands, as is evidenced by the low amount of edge with low-density residential and the lack of urban edge (fig. 1).

Road Network Implications

Increases in structures within 1 km of public lands, will result in increased road density near the public/private boundary. Increases in road networks can have a positive impact on forest management activities through reduced access costs to managed forests. Negative ecological impacts of roads on both terrestrial and aquatic systems range from declines in stream health, to habitat fragmentation, to habitat degradation (Trombulak and Frissell 2000). Increased road access can have both benefits and costs for protecting resources and people from wildfire. Increased human access generally increases the frequency of wildfire ignitions: 74 percent of the fires from 2001 through 2008 were caused by humans, with only 26 percent caused by lightning (NIFC 2010) in the Pacific Northwest. Although human-caused fires close to development can be catastrophic, they are typically in accessible areas, and thus can often be controlled more quickly; for example, in the Pacific Northwest, only 27 percent of the hectares burned in 2001 through 2008 were in human-caused fires (NIFC 2010). If the roads are mapped and marked (so that fire crews can find their way) and are sufficiently wide for firefighting equipment, increased access can allow for faster control efforts, and probably reduces the risk of a structure being burned. Research is also needed to better understand the effects of the increase in road network where the number of structures has increased.

Comparing Two Time Periods

When comparing the annual increases in density for the 1970s to 1990s with the 1990s to 2005, public lands have roughly the same new development (structures per square kilometer) in both time periods (fig. 6), with the exception of the WA DNR. Lands near the WA DNR had more development growth in both periods than other public owners. It was hypothesized that Oregon's land use laws, which were in play during the second period, may have resulted in differences (Lettman et al. 2011), and Washington's Growth Management Act, which was just starting to take effect, would not show differences. These legislative acts focus development into areas designated for growth and may be effective in land use conversion, but isolated structures occurring in forested landscapes may not be affected.

Although structure density remained low, the points remaining in forested land use classes from 1974 to 2006 show large percentage increases, more than doubling in structure density for all distance classes and ownerships.

Development in Forested Landscapes

It is important to estimate low-density development, as opposed to land use conversion (the upper left point in fig. 2). Future studies may be able to use these estimates of changing low-density development to model where land use change will occur. Although structure density remained low, the points remaining in forested land use classes from 1974 to 2006 show large percentage increases, more than doubling in structure density for all distance classes and ownerships. Thus, despite Oregon's land use planning laws or Washington's Growth Management Act, development adjacent to public forest continues. This is an indication that public land has an allure for people who want to live in a forested setting. The natural amenities of public lands continue to be a draw for population growth (Kaplan and Austin 2004, Stein et al. 2007), which could help explain the case of Deschutes County, which had a 400 percent increase in population. Much of the increase may be due to the mild climate that boasts 300 days of sunshine per year and the recreational opportunities that are generally associated with federal lands, such as skiing, fishing, hunting, and hiking. Also, land is cheaper in more remote areas in comparison to areas closer to metropolitan areas.

Implications for Other Areas in the United States

This study only addresses the circumstances around public lands in Oregon and Washington. However, similar conditions exist around the 54.6 million ha (Smith et al. 2009) of public lands in the Western United States. Other studies (Radeloff et al. 2005) speak to the relevance of the WUI across the Nation and the Western United States (Hammer et al. 2007) in general. The liability associated with forest management operations on surrounding structures has to be considered in areas where actively managed forest lands adjoin developed lands. Losses of houses owing to wildland fire within the last decade in Arizona, California, Colorado, and New Mexico have brought a magnified focus to the management of forest lands around the WUI (Cohen 2008). Although public forest lands dominate in the Western United States, in the Northern and Southern United States, private forest land owners can face similar challenges with development.

Limitations and Advantages

This study differs from others in that it provides statistical estimates of increases in structures around public land, but it does not supply a spatially explicit product. There are several model-based products that provide spatially explicit maps of WUI based on modeled census block information (Hammer et al. 2007, Radeloff et al. 2005, Theobald and Romme 2007). The accuracy of these products is based on assumptions of how population is distributed across a census block. In areas where population is sparse and census blocks are large, the difficulty in accurately modeling the population across the landscape becomes problematic. In sparsely populated areas, it will be difficult to distinguish between land use and land cover with coarse-resolution remotely sensed products. Consequently, clearcuts can appear as development, and heavy tree cover on low-density residential can appear as forest (Kline et al. 2009). Verification of what occurs on a specific piece of ground is difficult with either type of study. By using statistical estimates, we do not attempt to map what is specifically on the ground, but instead obtain average structure counts with an associated error for an area of interest. In areas where development is sparse, this method may be the best way to track change. The strength of this study is the ability to track small changes in the number of structures in areas that have remained forested. The major drawback of this method is the initial mapping of the land use polygons onto the imagery and the counting of structures, both of which can be fairly labor intensive.

The strength of this study is the ability to track small changes in the number of structures in areas that have remained forested.

Conclusion

Managers of public forest land must deal with development near the edges of their land. The WA DNR has by far the greatest numbers of structures at 11.2 per km^2 within 1 km of their boundaries, followed by the U.S. Forest Service and BLM lands in Oregon, with 5.2 and 4.4 structures, respectively. The ODF and U.S. Forest Service in Washington lands seem to have the most insulation, having the lowest structure counts near their lands at 2.0 and 2.2, respectively. Although land use laws had been put into effect in both states, development at the edges of public land continues. These laws may be more effective in controlling land use conversion than containing development in the forested landscape. On an annualized basis, all public owners except the WA DNR have roughly equivalent development for the time periods of the 1970s to 1990s vs the 1990s to the mid 2000s, with the WA DNR having a significant increase in the second time period. The greatest development increases tend to be correlated to areas with a high edge-to-area-ratio between public and private ownerships and with large population centers in proximity.

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English Equivalents

When you know:	Multiply by:	To Find:
Meters (m)	1.094	Feet
Kilometers (km)	.621	Miles
Hectares (ha)	2.47	Acres
Square kilometers (km^2)	.386	Square miles

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