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Evaluating Forest Land Development Effects on Private Forestry in Eastern Oregon

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Abstract

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Research suggests that forest land development can reduce the productivity of remaining forest land because private forest owners reduce their investments in forest management. We developed empirical models describing forest stocking, thinning, harvest, and postharvest tree planting in eastern Oregon, as functions of stand and site characteristics, ownership, and building densities. The models are based on USDA Forest Service Forest Inventory and Analysis data gathered in eastern Oregon in 1987 and 1998, and data describing building densities gathered by the Oregon Department of Forestry from aerial photographs taken over the same period. We used the models to examine the potential effects of population growth and development, as described by increasing building densities, on the likelihood that private forest owners maintain forest stocking, precommercially thin, harvest, and plant trees following harvest. Empirical results suggest that population growth and development have had no measurable effect on these activities in eastern Oregon during the period examined. Any development effects on private forest management and investment so far are likely to be fairly localized.

Keywords: Wildland-urban interface, nonindustrial private forest owners, urbanization.

Summary

Previous research conducted in the Southern United States and in western Oregon suggests that forest land development can reduce the productivity of remaining forest land because private forest owners reduce their investments in forest management. We tested for these effects in eastern Oregon by developing empirical models describing forest stocking, thinning, harvesting, and postharvest tree planting, as functions of stand and site characteristics, ownership, and building densities. The models are based on USDA Forest Service Forest Inventory and Analysis data gathered in eastern Oregon in 1987 and 1998, and data describing building densities gathered by the Oregon Department of Forestry from aerial photographs taken over the same period. We used the models to examine the potential effects of recent population growth and development, as described by increasing building densities, on the likelihood that private forest owners maintain forest stocking, precommercial thin, harvest, and plant trees following harvest. We found forest land development in eastern Oregon to be uncorrelated with forest stocking, and the likelihood of precommercially thinning, harvesting, and postharvest tree planting during the period examined. The empirical results suggest that population growth and development have had no measurable effect on these activities among private forest landowners in eastern Oregon during the period examined. These results differ from those found in western Oregon, where increased development was found to be correlated with lower forest stocking and reduced likelihood of precommercial thinning and postharvest tree planting. Our results likely owe to comparatively lower rates of forest land development and lower inherent site productivity found in eastern Oregon relative to that found for western Oregon. We suspect that any development effects on private forest management and investment in eastern Oregon so far are likely to be fairly localized.

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Introduction

Often cited research conducted in the Southern United States suggests that forest land development can reduce the productivity of remaining forest land because private forest owners reduce their investments in forest management and become less likely to harvest timber (Barlow and others 1998, Munn and others 2002, Wear and others 1999). Kline and others (2004) tested for these effects in western Oregon. Their results suggested that population growth and development are correlated with reduced stocking levels, and with reduced rates of precommercial thinning and postharvest planting, but not with reduced rates of harvest. Declining forest productivity resulting from development itself may not necessarily justify significant policy or management concern, and in fact, could simply reflect the workings of efficient land markets shifting forest land to more highly valued developed uses. However, changes in management could effect changes in the characteristics of remaining forests, with resulting policy- and management-relevant economic and ecological consequences. From an economic perspective, forest policymakers and managers might want to anticipate how much timber likely will be supplied from private forests in the future. From an ecological perspective, changes in management and harvesting can affect forests as ecological resources that provide wildlife habitat and other public benefits. Related changes also can influence fuel loads and corresponding wildfire risks in wildland-urban settings. Such possibilities might be of concern to policymakers and managers regarding future change.

Changes in management could effect changes in the characteristics of remaining forests, with resulting economic and ecological consequences.

A unique combination of forestry and land use data enabled previous analysis of forest land development effects on private forestry in western Oregon (Kline and others 2004). Recent acquisition of similar data now enables such analysis for eastern Oregon—east of the crest of the Cascades. Using the methods of Kline and others (2004) in western Oregon, we developed empirical models describing forest stocking, thinning, harvest, and postharvest tree planting in eastern Oregon as functions of stand and site characteristics, ownership, and building densities. The models are based on USDA Forest Service Forest Inventory and Analysis data gathered during 1987 and 1998 eastern Oregon inventories, and data describing building densities gathered by the Oregon Department of Forestry. We use the models to examine the potential effects of population growth and forest land development, as described by increasing building densities, on the likelihood that forest owners maintain forest stocking, precommercially thin, harvest, and plant trees following harvest. Empirical results suggest that population growth and development have had no measurable effect on private forest management and investment in eastern Oregon during the period examined. Any development effects on private forest management and investment in eastern Oregon so far are likely to be fairly localized.

Population Growth, Development, and Private Forestry

Prevailing hypotheses suggest that forest land development can cause private forest lands to become less productive owing to (1) their gradual fragmentation into smaller management units, (2) related changes in the characteristics and management objectives of newer more urban-minded forest owners, (3) potential conflicts arising from conducting forestry in proximity to people, and (4) increasing uncertainty among remaining forest landowners about prospects for continued forestry in the future (for detailed discussion, see Kline and others 2004: 34-35). There also is growing concern among policymakers and managers that locating homes on predominantly forested landscapes may carry unacceptable risks associated with wildfire. How private forest lands are managed may greatly influence wildfire risks through changes in forest structure, stand density, fuel loads, and other factors. Empirical studies that have tested for potential correlations between private forest management and development include Barlow and others (1998), Munn and others (2002), Wear and others (1999)—all conducted in the Southeastern United States—and Kline and others (2004) conducted in western Oregon.

Barlow and others (1998) and Munn and others (2002) combined data describing plot-level harvest activities, and stand and site characteristics in Mississippi and Alabama (USA), with data describing human population densities and distances of forest stands to urbanized areas. Both studies found the likelihood that forest owners harvest timber to be negatively correlated with population density and urban proximity, suggesting potential impacts on stand density, age class, species composition, and successional stage. Wear and others (1999) used expert opinion to identify the likelihood that forest lands in five Virginia (USA) counties were managed for commercial timber production. They combined this information with data describing plot-level stand and site characteristics and population densities, and found the likelihood that forest lands are managed for commercial timber production is negatively correlated with population densities.

Building on these studies, Kline and others (2004) developed empirical models describing forest stocking, precommercial thinning, harvesting, and postharvest tree planting as functions of stand and site characteristics, ownership type, and building densities—a proxy variable for forest land development. Their empirical results suggest that increasing building densities have had no statistically significant effect on the likelihood that private forest landowners in western Oregon harvested timber from 1974 to 1994. However, their empirical results do suggest that increasing building densities are correlated with reduced forest stocking, and reduced likelihood of precommercial thinning and postharvest tree planting. Taken together, Kline and others (2004: 41) concluded that their results do support the general conclusion that population growth and forest land development may be reducing the intensity with which private forest owners in western Oregon manage their forest lands, but that so far only a small proportion of lands have been affected. Recent acquisition of similar data describing forest management and building densities in eastern Oregon enabled testing for development effects on private forestry there. The potential presence of these effects in eastern Oregon is of growing policy and management concern owing to rapid population growth and development in some regions (e.g., Deschutes County) and to the persistent wildfire threats characteristic of most east-side forests.

The potential presence of these effects in eastern Oregon is of growing policy and management concern owing to rapid population growth and development in some regions.

Modeling Stocking, Thinning, Harvest, and Planting

We combined plot-level data describing forest conditions and management activities with aerial photopoint data depicting historical building densities to examine the potential effects of population growth and forest land development on private forest management in eastern Oregon. We used these data to estimate empirical models describing forest stocking, precommercial thinning, harvesting, and postharvest tree planting as functions of stand and site characteristics, ownership, and building densities. The models cannot directly address hypothetical management effects regarding declining parcel size, changing owner characteristics, wildland-urban conflicts, and owners’ expectations about the future of forestry. However, the models can be used to test whether changes in forest management in locations experiencing population growth and development are consistent with these hypotheses, by examining how forest stocking, precommercial thinning, harvesting, and planting might differ as building densities increase. If population growth and development have reduced the intensity with which private forest landowners manage their lands in eastern Oregon, we would expect lower forest stocking levels, and less likelihood of thinning, harvesting, and postharvest tree planting in areas of higher building densities.

Forestry and Building Density Data

Plot-level forestry data were obtained from the USDA Forest Service Forest Inventory and Analysis Program’s regular inventories of forest land in western

Oregon (Azuma and others 2004). The inventories consist of periodic nationwide assessments of nonfederal land in the United States as authorized by the Forest and Rangeland Renewable Resources Research Act of 1974. Inventory data were gathered in eastern Oregon by using photointerpretation and ground-truthing on a systematic sampling of nearly 4,378 field plots. The inventories gathered detailed information regarding forest characteristics, as well as information about any precommercial thinning, harvesting, and tree planting observed from one inventory to the next as well as forest stocking. Eastern Oregon inventories are conducted on roughly a 10-year cycle. Data used for this study were gathered during the 1987 and 1998 inventories. The 1998 inventory indicated that forest land made up 35 pecent of all land in eastern Oregon (Azuma and others 2004: 12) with about 3.4 million acres under private ownership (Campbell and others 2003: 15).

Substantial portions of private lands in eastern Oregon are in nonforest uses, including range (52 percent) and intensive agriculture (22 percent), as well as a small proportion (3 percent) in urban and low-density residential (Lettman 2004: 13). To describe forest land development in eastern Oregon, the Oregon Department of Forestry gathered building density data consisting of the numbers of buildings on nonfederal land observed in the 640-acre vicinity of sample points located on aerial photographs taken in 1975, 1986, and 2001 (Lettman 2004). With about 13,103 sample points, the data provide nearly 40,000 observations of building densities varying in space and time. Building densities for 1987 and 1998 were estimated by interpolating between 1986 and 2001 values, to roughly coincide with the 1987 and 1998 Forest Inventory and Analysis data. Cross-referencing between building density sample points and forest inventory field plots enables analysis of building densities and the forest stocking, thinning, harvest, and planting variables.

Empirical Modeling

Two types of data make up the dependent variables available for study: (1) discrete data consisting of dummy variables describing evidence of whether or not precommercial thinning, harvesting, or postharvest tree planting activities occurred from one forest inventory to the next; and (2) continuous data describing forest stocking at each inventory. The potential effects of various factors on each dependent variable can be analyzed by using the structural model

$$y_i^* = \beta' x_i + \varepsilon_i \tag{1}$$

where x is a vector of explanatory variables describing factors hypothesized to influence each dependent variable y, β is a vector of estimated coefficients, ε is an error term, and $i = 1, \ldots, n$ identifying individual observations in the sample.

Precommercial thinning, harvesting, and postharvest tree planting activities occurring between the two successive forest inventories are described by discrete data, and we define the probability that evidence of each activity was observed as y_i^*. Although y_i^* is unobservable, observed evidence of each activity can be described as a vector of binary variables y_i defined by

$$y_i = 1 \textit{ if } y_i^* > 0, 0 \textit{ otherwise} . \tag{2}$$

For example, when examining the likelihood of harvesting, y_i equals 1 for plots observed as harvested since the previous inventory and 0 if harvesting was not observed. We assume that error in the model is distributed normally and use the binary variable y_i to estimate a probit model. The model describes the likelihood that evidence of a harvest was observed from the 1987 to the 1998 forest inventory and is described as

$$P(y_i = 1) = \Phi(\beta' x_i) \tag{3}$$

where x_i are explanatory variables and β' are estimated coefficients. Two other probit models describe the likelihood that evidence of precommercial thinning and postharvest tree planting were observed. Forest stocking described by a continuous dependent variable—average basal area per acre of sample plots—can be examined by using ordinary least squares regression.

Testing the Influence of Building Density on Private Forestry

Several factors reasonably can be expected to influence forest stocking, thinning, harvesting, and postharvest tree planting on private forest lands. We analyzed each of the dependent variables by considering as many possible factors as feasible and using the best data available. The first empirical model describes forest stocking, as represented by basal area. The remaining three empirical models describe the likelihood that private forest owners precommercially thinned, harvested, and planted trees following harvest. In each case, the empirical analyses closely follow econometric model specifications reported in Kline and others (2004). Explanatory variables tested in each of the four models are described in table 1.

Table 1—Descriptions of explanatory variables tested in the empirical models

Variable	Description
AGE	Age of plot stand in years at current forest inventory occasion.
AGE^2	The variable AGE squared.
BASAL AREA $_t$	Basal area (square feet per acre) of the plot stand at current forest inventory occasion.
BASAL AREA $_{t-1}$	Basal area (square feet per acre) of the plot stand at preceding forest inventory occasion.
SITE INDEX	Site index of the plot.
SLOPE	Percentage slope at the plot.
DISTANCE TO ROAD	Distance of the plot to the nearest road in meters (100s).
NONINDUSTRIAL	Variable equals 1 if nonindustrial private owned; 0 otherwise.
BUILDING DENSITY$_t$	Number of buildings within a 640-acre circle (Lettman 2004) surrounding plot at forest inventory occasion.
BUILDING DENSITY$_{t-1}$	Number of buildings within a 640-acre circle (Lettman 2004) surrounding plot at preceding forest inventory occasion.

Note: Unless otherwise noted, all variables are from USDA Forest Service Forest Inventory and Analysis data (Azuma and others 2004).

Forest Stocking Levels

Stocking may not necessarily be treated as a choice variable by private forest owners, but less intensive management could lead to lower stocking on private forest stands. We examined the basal area—our proxy for stocking—on sample plots observed during the 1998 inventory and whether basal area varied by building densities. Changes in procedures from the 1987 to 1998 inventories prevent us from pooling 1987 and 1998 data, because the 1987 inventory described stand age—a key explanatory variable in forest stocking models—at the plot level, whereas the 1998 inventory data described stand age at the subplot or “condition class” level. We examined 1998 basal area because it would have been subject to greater levels of forest land development than 1987 basal area. We estimated an ordinary least squares regression model describing average basal area per acre as a function of stand age, site index, nonindustrial private ownership, and building density. The model describes how average basal area might have varied by building density after accounting for stand and site characteristics. Although past management practices, such as thinning, likely affect current stocking levels, including explanatory variables describing past activities was not possible because such data were not available for prior years. We restricted the analysis to even-aged stands owing to difficulties posed by modeling basal areas of uneven-aged stands. Also, because few plots comprised hardwoods, we restricted the model to conifer stands alone. These restrictions reduced the basal area sample size to 268 observations when combined with other explanatory variable data.

The estimated model is quite weak, with an adjusted R^2 of just 0.01 ($F = 1.44$, $df = 5$, $P = 0.201$) (table 2). Alternative specifications of the basal area model were tested—several versions including dummy variables to account for different forest types, for example—but these consistently failed to improve model fit. The weak empirical results suggest that just describing a significant portion of the variation in the basal areas of eastern Oregon forest inventory plots is challenging much less showing any statistically significant negative correlation between basal area and building densities. We did find stand age to have a statistically significant positive but diminishing influence on average basal area per acre, as would be expected. The estimated coefficient for nonindustrial private ownership is negative, consistent with lower forest stocking on these lands, but its statistical significance is rather weak ($P = 0.16$). The estimated $\text{BUILDING DENSITY}_t$ coefficient is negative, but is not statistically significant ($P > 0.75$), suggesting that forest stocking did not vary by building densely in eastern Oregon in 1998.

Likelihood of Precommercial Thinning

Forest inventory data indicate that just 3 percent of sample forest plots were precommercially thinned from 1987 to 1998. We estimated a probit model describing the likelihood that forest owners precommercially thinned, as a function of basal area, site index, slope, road distance, ownership, and building density. These inventory data provided 415 observations when combined with other explanatory variable data of which 20 observations represent forest stands that were precommercially thinned. The resulting estimated model is quite weak, with a chi-square value of 6.59 ($df = 6$, $P = 0.360$) (table 2). Only the negative estimated coefficient for SLOPE was found to be statistically significant ($P < 0.10$), suggesting lower incidence of precommercial thinning on forest stands located on steeper slopes, consistent with likely higher thinning costs on steeper slopes. The estimated $\text{BUILDING DENSITY}_{t-1}$ coefficient is negative but statistically insignificant ($P > 0.35$), suggesting that the likelihood of precommercial thinning on private forest land did not vary by building density in eastern Oregon.

Likelihood of Harvesting

Forest inventory data for 1987 to 1998 indicate that 52 percent of sample plots retained for analysis (after combining with other explanatory variable data) had experienced some type of harvest more significant than firewood cutting or other

Table 2—Estimated coefficients of the ordinary least squares basal area model and precommercial thinning, harvest, and postharvest tree planting probit models for eastern Oregon

	Basal area		Precommercial thinning		Harvesting		Postharvest planting	
Variable	Estimated coefficient	t-statistic	Estimated coefficient	t-statistic	Estimated coefficient	t-statistic	Estimated coefficient	t-statistic
Intercept	28.496	0.43	-1.460^{**}	-2.287	-0.156	-0.44	-1.567	-1.559
AGE	2.507^{**}	2.11	—	—	—	—	—	—
AGE^2	-0.016^{*}	-1.65	—	—	—	—	—	—
BASAL AREA $_t$	—	—	—	—	—	—	-0.014^{**}	-2.04
BASAL AREA $_{t-1}$	—	—	-0.001	-0.27	0.006^{***}	5.12	—	—
SITE INDEX	-0.224	-0.32	0.001	0.14	0.001	0.25	0.012	1.09
SLOPE	—	—	-0.016^{*}	-1.90	-0.012^{***}	-2.85	-0.017	-1.07
DISTANCE TO ROAD	—	—	-0.007	-0.19	0.009	0.46	-0.254	-1.34
NONINDUSTRIAL	-33.199	-1.40	0.148	0.64	-0.207	-1.55	—	—
BUILDING DENSITY $_t$	-0.331	-0.26	—	—	—	—	—	—
BUILDING DENSITY $_{t-1}$	—	—	-0.070	-0.91	-0.001	-0.25	-0.040	-0.46
Summary statistics	N = 268		N = 415		N = 415		N = 207	
	Adj. $R^2 = 0.01$		Log-L = -76.86		Log-L = -265.63		Log-L = -32.21	
	F = 1.44		$X^2 = 6.59$		$X^2 = 43.18$		$X^2 = 15.69$	
	df = 5, 262; $P = 0.201$		df = 6; $P = 0.360$		df = 6; $P < 0.001$		df = 5, $P = 0.008$	

Note: The *, **, and *** indicate that the probability of the *t*-statistic exceeding the critical *t*-value is greater than 90 percent, 95 percent, and 99 percent, respectively. Explanatory variables are defined in table 1. Basal area model describes 1998 inventory basal area. Precommercial thinning, harvesting, and postharvest planting models describe activities occurring from 1987 to 1998 inventory.

incidental harvest. We examined the likelihood that forest owners harvested between the inventory years of 1987 to 1998, and whether harvesting varied by building densities. Conversion of forest land to residential uses often involves harvesting existing forest stands prior to new construction. However, such harvests are not explicitly reported in Forest Inventory and Analysis Program inventories, because they occur on plots considered to have converted to nonforest uses, and the inventories do not report forestry data for such plots. Also, the potential number of plots experiencing preurban-conversion harvesting likely is small, because the actual total number of forest plots converting to urban uses have been few. For these reasons, we restricted our analysis to inventory plots on which forest use continued.

We estimated a probit model describing the likelihood of any harvest activity more significant than firewood cutting or other incidental harvest. The resulting estimated model is relatively strong with a chi-square value of 43.18 (df = 6, $P < 0.001$), but yielded only two estimated coefficients that were statistically significant at a high level of confidence (table 2). We found basal area to have had a statistically significant positive influence ($P < 0.01$) and slope to have a statistically significant negative influence ($P < 0.01$) on the likelihood of harvest activity. These results are consistent with greater harvest activity among higher stocked stands and lower activity on steeper slopes, which likely increase harvest costs. The estimated negative coefficient for NONINDUSTRIAL suggests that harvest activity has been lower among nonindustrial private forest owners; however, its statistical significance is somewhat weak ($P = 0.12$). The estimated BUILDING DENSITY$_{t-1}$ coefficient is negative but statistically insignificant ($P > 0.80$) suggesting that harvest likelihood on private forest land did not vary by building density in eastern Oregon.

Likelihood of Tree Planting Following Harvest

Forest inventory data indicate that just 10 of the harvested sample plots retained for analysis in the harvest model had been planted with trees by the 1998 inventory. Oregon’s Forest Practices Act has evolved over time but generally requires reforestation following harvest on lands identified as timberland—those lands capable of annual wood production of at least 20 cubic feet per acre at culmination of mean annual increment (Oregon Department of Forestry 2006). Rules do allow natural regeneration in place of planting, as well as other exemptions. Artificial reforestation such as tree planting generally must be completed within 2 years, and harvested stands generally must be brought up to minimum stocking standards within 6 years (Oregon Department of Forestry 2006). Forest inventory data indicate that 90 percent of harvested sample plots retained for analysis in the harvest model were classified as timberland, and these included the 10 plots on which tree planting had been observed. Although no tree planting had been recorded on sample plots retained for analysis that were classified as "other forest"—forest lands that do not meet timberland criteria—those plots were retained for analysis in the tree-planting model as owners could have opted to plant trees on those stands.

We estimated a probit model describing the likelihood that forest owners planted trees following harvest between the inventory years of 1987 and 1998. Data were restricted to plots on which harvesting had occurred since 1987. Basal area observed at the current (postharvest) inventory, rather than the preceding (preharvest) inventory, was used as a proxy for stocking following harvest and prior to planting. Basal area measurements include only trees having a minimum 2.5 centimeters diameter at breast height—recently planted seedlings generally would not be included. On recently harvested stands, inventory-observed basal areas would indicate the amount of postharvest re-stocking needed. The resulting estimated model is fairly strong with a chi-square value of 15.69 (df = 5, $P = 0.008$) (table 2). However, only the estimated negative coefficient for BASAL AREA was found to be statistically significant at a high level of confidence ($P < 0.05$), consistent with our expectation that residual basal area following harvest would indicate restocking needs. The variable NONINDUSTRIAL was omitted from model estimation because no nonindustrial private-owned inventory plots included in the sample had been planted following harvest by the 1998 inventory. The estimated coefficient for DISTANCE TO ROAD is negative but its statistical significance is rather weak ($P = 0.18$). The estimated BUILDING DENSITY$_{t-1}$ coefficient is negative but statistically insignificant ($P > 0.80$) suggesting that postharvest planting likelihood on private forest land in eastern Oregon did not vary by building density.

The fairly small number of sample plots recorded as planted likely confounds model estimation. Given the fairly large number of sample plots that were harvested between the 1987 and 1998 inventories, the relatively low number of plots recorded as planted by the 1998 inventory may seem surprising given Oregon's reforestation requirements. Stands that still meet minimum stocking standards even after harvest are not subject to reforestation requirements, but it is not possible to identify such stands because stocking standards depend on the sizes of residual trees and include stems per acre and basal area criteria. Conceivably, harvested but still unplanted sample plots included in the tree planting analysis either were (1) not subject to reforestation requirements because they already met minimum stocking standards, (2) harvested just prior to the 1998 inventory and still within their reforestation compliance period based on either artificial or natural regeneration, or (3) potentially out of compliance with reforestation requirements. Another possible explanation is that some forest landowners were anticipating changing their land use either to agriculture or development, which leads to a waiving of reforestation requirements, although at least in the case of development this explanation seems unlikely given relatively low rates of development on eastern Oregon forest lands (e.g., Kline and others, in press). Still one other possible explanation is that in some cases, the Forest Inventory and Analysis data gatherers may have missed observing existing evidence of postharvest tree planting. The relative merit of any of these possible explanations cannot be known with certainty.

Discussion

The empirical results suggest that increasing building densities have had no statistically significant effect on forest stocking and the likelihood that private forest owners precommercially thinned, harvested timber, and planted trees following harvest in eastern Oregon from 1987 to 1998. These results differ from those found in western Oregon by using similar methods. Kline and others (2004) found that private forest landowners in western Oregon tended to have lower forest stocking, and showed lower likelihood of precommercial thinning and postharvest tree planting as building densities increased. Although Kline and others (2004) found harvest rates to be unaffected by building densities, they suggested that these forest land development effects may not yet be observable in western Oregon. From our examination of forestry and building density data from eastern Oregon, it would appear that forest land development effects on stocking, thinning, harvest, and postharvest planting either are not prevalent in the region or are not yet observable from available Forest Inventory and Analysis data.

A relatively small proportion of all forest land in eastern Oregon currently is located in places where significant residential and other development has taken place.

A relatively small proportion of all forest land in eastern Oregon currently is located in places where significant residential and other development has taken place. Of sample plots evaluated in this analysis, only 5 percent of plots were located in areas having building densities over 10 buildings per square mile in 1998. Although some locations in eastern Oregon—Deschutes County, for example—have been experiencing significant population growth and development in recent years, most eastern Oregon forest land remains sparsely populated. Also, from 1975 to 2001, more than twice as much eastern Oregon rangeland was converted to low-density residential and urban uses as forest land (Lettman 2004: 16). Such conversions also have been more prevalent on agricultural lands. These factors would tend to limit opportunities for observing development effects on private forestry in eastern Oregon.

In addition to finding little empirical evidence of forest land development effects on private forest management, our analysis also yielded generally weak empirical results describing forest stocking and management activities. Typically, indicators of forest management intensity, such as stocking, precommercial thinning, harvesting, and postharvest planting are assumed to be functions of stand and site characteristics as well as forest owners' management objectives. Kline and others (2004) generally found robust relationships between these same indicators and stand age, basal area, site index, and slope in western Oregon (table 3). Our models for eastern Oregon generally are empirically weaker than those of Kline and others (2004) in terms of their ability to predict forest management indicators, and also have fewer statistically significant variable coefficients. Only stand age is statistically significant in the eastern Oregon basal area model, only basal area and slope are statistically significant in the harvesting model, and only basal area is statistically significant in the postharvest tree planting model (table 3). The statistical significance of those estimated coefficients for each of these variables certainly is reasonable in each respective model. The poor statistical significance of other candidate explanatory variables could owe to the much smaller sample sizes available for analysis compared to those available to Kline and others (2004).

However, the characteristics of eastern forest lands examined in this paper also differ from those of western forest lands examined by Kline and others (2004). These differences conceivably could influence our ability to find robust empirical models describing private forest management. For example, lower average site indices—and thus lower inherent site productivity—on eastern Oregon forest lands examined compared to those found on western Oregon forest lands (table 4) may inspire less intensive private management among eastern Oregon forest landowners generally. Timberland accounts for 70 percent of the 14.9 million acres of forest land in eastern Oregon versus 90 percent of the 15.3 million acres of forest land in western Oregon (Campbell and others 2002, 2003). Forest stocking rates (basal areas) found on eastern Oregon forest lands examined also tended to be lower than those found on western Oregon forest lands (table 4), possibly providing less incentive for precommercial thinning. Similarly, postharvest forest stocking rates (basal areas) on eastern Oregon forest lands examined tended to be higher than postharvest stocking rates on western Oregon forest lands (table 4), providing less incentive for postharvest tree planting. Lastly, lower average building densities found on eastern Oregon forest lands examined compared to those found on western Oregon forest lands (table 4) provide fewer opportunities to observe the potential effects of forest land development on private forestry in eastern Oregon.

Table 3—Comparison of western Oregon models describing basal area, and precommercial thinning, harvest, and postharvest planting likelihood with eastern Oregon models, based on estimated coefficients of common explanatory variables found to be statistically significant ($P < 0.10$)

	Basal area		Precommercial thinning		Harvesting		Postharvest planting	
Variable	**Western Oregon**	**Eastern Oregon**	**Western Oregon**	**Eastern Oregon**	**Western Oregon**	**Eastern Oregon**	**Western Oregon**	**Eastern Oregon**
AGE	+	+						
AGE^2	-	-						
BASAL AREA $_t$							-	-
BASAL AREA $_{t-1}$			-		+	+		
SITE INDEX	+		+		+		+	
SLOPE				-	-	-		
DISTANCE TO ROAD			-		-		-	
NONINDUSTRIAL	-		-		-		-	
BUILDING DENSITY $_t$	-							
BUILDING DENSITY $_{t-1}$			-				-	

Note: Presence of a “+” or “-” indicates sign of estimated coefficients for explanatory variables that generally were found to be statistically significant ($P < 0.10$) in estimated models; absence of a sign indicates the estimated coefficients generally were not found to be statistically significant. Explanatory variables are defined in table 1. Western Oregon model information from Kline and others (2004); eastern Oregon model information from table 2.

Table 4—Comparison of mean values of explanatory variables tested in western and eastern Oregon models describing basal area, and precommercial thinning, harvest, and postharvest planting likelihood

	Basal area		Precommercial thinning		Harvesting		Postharvest planting	
Variable	**Western Oregon N = 901**	**Eastern Oregon N = 268**	**Western Oregon N = 1,563**	**Eastern Oregon N = 415**	**Western Oregon N = 1,551**	**Eastern Oregon N = 415**	**Western Oregon N = 416**	**Eastern Oregon N = 207**
AGE	37.1	57.2	—	—	—	—	—	—
BASAL AREA $_t$	—	—	—	—	—	—	66.9	76.8
BASAL AREA $_{t-1}$	—	—	107.0	65.8	106.8	65.8	—	—
SITE INDEX	114.4	89.0	111.7	88.4	111.7	88.4	112.3	89.2
SLOPE	—	—	30.1	18.1	30.1	18.1	27.0	16.0
DISTANCE TO ROAD	—	—	3.1	2.6	3.1	2.6	2.9	2.7
NONINDUSTRIAL	0.26	0.34	0.35	0.41	0.35	0.41	0.38	0.33
BUILDING DENSITY $_t$	4.9	2.1	—	—	—	—	—	—
BUILDING DENSITY $_{t-1}$	—	—	6.6	3.3	6.6	3.3	7.0	2.6

Note: Table compares explanatory variable mean values from those western Oregon models reported in Kline and others (2004) that are most similar to the eastern Oregon model in their econometric specification and estimation. Explanatory variables are defined in table 1.

The relative lack of statistically significant variable coefficients in eastern Oregon models also could mean that private forest landowners there respond to narrower ranges of stand and site characteristics than those found to influence western Oregon owners. One reason for this could be that in eastern Oregon, forests generally might be managed less intensely by private forest landowners than in western Oregon. Timberland, with its greater inherent potential site productivity, is where we would expect the most intensive forest management. But private landowners own just 26 percent of the timberland in eastern Oregon versus 74 percent owned by public agencies such as the national forests and the Bureau of Land Management. Of that private timberland, 30 percent is owned by nonindustrial private owners (Azuma and others 2004: 14). As is common among nonindustrial private forest landowners in western Oregon (Johnson and others 1999: 24), nonindustrial private forest landowners in eastern Oregon tend to manage their lands according to multiple objectives, including aesthetics and recreation along with timber production among their management goals. Campbell and others (2003: 15) estimated that less than half (43 percent) of nonindustrial private forest land in eastern Oregon is managed with "income from timber" as the most important benefit perceived by owners. Many owners cited other benefits as most important to them, including aesthetic enjoyment, potential increases in land value, and recreation. Owners of these lands likely respond to other factors in addition to or in place of stand and site characteristics when making forest management decisions.

There are other likely factors as well that may confound empirical analysis of forest management activities in eastern Oregon. From 1980 to 1994, much of eastern Oregon experienced an outbreak of western spruce budworm (*Choristoneura occidentalis*), which by 1987 had damaged 1.1 million acres of private forest land (Azuma and Overhulser 2006). Extensive salvage harvesting of damaged stands, combined with a general slowdown in national forest harvests during the late 1980s and a corresponding increase in harvests on private forest lands, led to unusually high harvest rates over the period examined (1987 to 1998). Also, in contrast to western Oregon forests where tree growth can be limited by light, leading to a greater prevalence of precommercial thinning, tree growth in eastern Oregon forests tends to be limited more by lack of water such that few private landowners there see much value in precommercial thinning. More private forest landowners also tend toward multiaged management, now and then harvesting just a few large trees rather than clearcutting. Lastly, given the greater propensity of wildfire in eastern Oregon, there is the possibility that some owners conduct certain management activities in response to recent fires or to reduce future wildfire threat. All of these factors would tend to confound our ability to describe forest management activities in terms of stand and site characteristics alone. An alternative explanation is simply that private forest management in eastern Oregon may not lend itself to easy description by using Forest Inventory and Analysis data. The relative validity of any of these explanations cannot be known with certainty.

Forest land development to date does not appear to have affected the ways in which private forest landowners in eastern Oregon have managed their forest lands.

Conclusions and Policy Implications

Forest land development to date does not appear to have affected the ways in which private forest landowners in eastern Oregon have managed their forest lands based on the data and period examined. This result differs from results found in studies conducted in the Southeastern United States (Barlow and others 1998, Munn and others 2002, Wear and others 1999) and in western Oregon (Kline and others 2004), which all suggest that the intensity of private forest management may decline with increasing forest land development. Prevailing hypotheses suggest that increasing population densities reduce the productivity of private forest lands through parcelization, changing forest owner characteristics, forest-urban conflicts, and reducing owners' expectations regarding the future productive potential of their forest lands. We are unable to find empirical results in eastern Oregon that are consistent with these hypotheses by using the data examined. Possible explanations for these contrary results include lower levels of forest land development, less intensive forest management (e.g., lower rates of precommercial thinning), and unusually high levels of salvage harvesting in eastern Oregon relative to locations where forest land development effects on forestry were found. Because 74 percent of the most productive forest lands in eastern Oregon—those classified as timberland—are under public and especially federal ownership (Azuma and others 2004: 14), we suspect that future timber production in eastern Oregon likely will be influenced more by federal forest policy and management than by forest land development. Potential ecological effects are uncertain and remain to be evaluated.

Our results should not imply that forest policymakers and managers should not remain vigilant to possible forestry effects resulting from forest land development in eastern Oregon. Significant population growth and development often can be unforeseen, and can occur rapidly in places where it was little expected. If such growth were to occur in eastern Oregon, more significant forestry effects might be found in the future. Still, we have to consider the likelihood of such events in eastern Oregon and also consider what types of land are most likely to be affected. Although previous research did find some effect of forest land development on private forestry in western Oregon (Kline and others 2004), additional research suggested that those effects in the future could be relatively modest owing to relatively low rates of projected forest land development over a large proportion of private forest land and the relative isolation of many private forest lands from faster growing population centers (Kline and Alig 2005: 717). Existing projections of potential future development in eastern Oregon tend to suggest relatively modest rates of development as well over a broad range of private forest lands (Kline and others, in press). This implies too that future development effects on private forestry in eastern Oregon could be relatively modest or at least highly localized to those few regions that do experience significant population growth and development in sufficient proximity to forest lands in coming years.

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Metric Equivalents

When you know:	Multiply by:	To find:
Acres	0.405	Hectares
Square feet	.093	Square meters
Square miles	2.590	Square kilometers
Cubic feet	.028	Cubic meters

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