An Exploratory Analysis of Influences of Forestland Characteristics and Urban Infrastructure on Forestland Management Treatments

By

Margaret A. Hamilton

MPP Essay

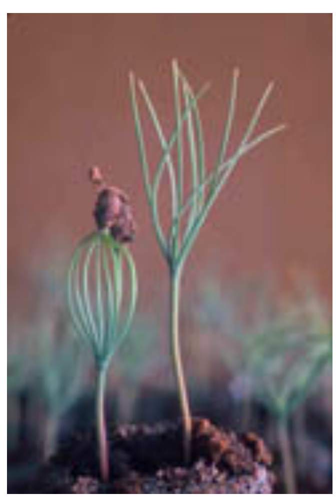
Submitted to

Oregon State University

In partial fulfillment of
the requirements for the
degree of

Master of Public Policy

Presented July 14, 2010



Abstract

Timber supply from Washington State may be reduced by non-industrial private forest owners' diverse purposes for holding timberland, which is a concern since they control 38% of Washington forestland. This study is an exploratory analysis of the effect of land and human infrastructural characteristics on landowners' likelihood to harvest, precommercially trim, and plant trees. Forest Service inventory data describing land characteristics is combined with structure counts from aerial photos, and urban growth area indicator data. Four land treatments: stocking, harvest, precommercial thinning, and planting are regressed in ordinary least squares, and logit models on independent variables representing land and human infrastructural characteristics. Industrial ownership was found to be positively associated with thinning and planting treatments, and higher timber-production lands, and non-industrial ownership was found to have positive relationships with urban indicators: building density and urban growth areas. Findings suggest industrial owners were more production oriented, also supported by their higher likelihood to precommercial thin and plant. The combination of urban growth area and high building density negatively affected the likelihood of thinning and planting by non-industrial owners, and less so for industrial owners. Timber supply and land conversion can be addressed with timber-production tax incentives, and thinning and planting support programs.

Table of Contents

An Exploratory Analysis of Influences of Forestland Characteristics and Urban Infrastructure on Forestland Management Treatments

Introduction/Problem Statement

The historical reserve of large trees has mostly been harvested (Haynes, 2008) and demand for wood products and land for housing and infrastructure continues to rise as a result of expanding population and prosperous socioeconomic conditions (Haynes, 2001). The current economic downturn has slowed the demand for wood products and land-use conversions, however once the economy recovers, the conversion trend is expected to continue. The need to predict timber supply and capacity, or conversely, whether developed uses are affecting the ability to produce adequate wood supply drives the question of this study of Washington State.

Of particular interest is whether nonindustrial private forest owners (NIPF) produce timber similarly to industrial owners, or whether they place higher value on non-timber outputs. NIPF owners are a growing influence with control of 38% of Washington timberlands (Campbell et al., 2010). Their harvest proportion in Oregon and Washington increased from 57% in the 1950s, to 74% in 2006 (Daniels and Warren, 2009: Table 16). Policy decisions at the state and federal levels resulted in limiting harvests from public forestlands and increased the dependence on NIPF timber production. The underlying economic theory assumes complete and well-ordered preferences and information (Ostrom, 2007), which applies to industrial owners operating in the timber producing market, as well as NIPF owners expressing their preferences in various, potentially competing, non-timber objectives. Researchers have asked if NIPF owners will produce timber on smaller parcels, and in proximity to developed lands. Projections suggest the mixed management objectives of NIPF ownership increase variation in projected harvests (Adams, et al., 1994). Adams, et al., (1982) further suggest that investment behavior of private owners will have a major impact on anticipated long-term price and consumption behavior in forest products markets. Dependence on NIPF for timber supply carries the risk of a high rate of ownership change with the potential for an increasing number of owners with non-timber goals. The increase of NIPF owners makes it difficult to make assumptions about the resources, information, and beliefs this ownership group uses to decide strategies. This study attempts to identify differences in preferences by ownership type.

Population growth is a root cause for changes in land use, but major demographic shifts compound the effect. Washington gained close to a million people each decade for the last three decades, from 3.8 million in 1979, to 6.6 million in 2009 (OFM, 2010). Since the change in U.S. immigration laws in 1965, immigration patterns have shifted from being mainly European in origin, to predominantly Asian and Hispanic (Haynes, 2001) with potential differences in values for ecosystem attributes. The baby-boom generation is approaching retirement age, carrying the potential for increased land transfers and parcelization (Zhang, Y., et al., 2009). The average household size for Washington was 2.53, compared to 2.58 for the U.S. Fertility rates in 1990 were about 2.1 children per woman, and age-related mortality rates are projected to continue declining. The U.S. population is projected to have more discretionary income and more opportunity to enjoy natural resources (Haynes, 2001). Median household income for Washington was $58,081, compared to a U.S. median of $52,029 (U.S. Census Bureau, 2008).

Migration of human inhabitants into rural areas has occurred in cycles and is changing how land is used. During the Rural Renaissance of the 1960-70s, people moved into rural areas looking for open space and nature-based lifestyles. Rural housing expanded in the 1970s, decreased during the 1980s, and recovered in the 1990s (Radeloff, et al., 2005). U.S. forest ownership grew 1.6 times faster than the population, with most of the increase in parcels of less than 100 acres (Mehmood and Zhang, 2001). Amenity migration, telecommuting, technological communication developments, and Hwy I-90, enabled people to live and work outside Washington urban areas. New rural residents value forestland for non-economic, aesthetic and recreational purposes, rather than solely for timber production. Changes in consumer preferences for land are red-flagged by property values in different uses. The average 2006 price for an acre in the Pacific Northwest was $1,500 in forest use and $166,000 in urban use (Alig and Plantinga, 2004). The stock market crash of the early 2000s, and the economic recession of 2009-2010 slowed housing starts and movement into rural areas. The next economic growth cycle may bring the next movement of people into rural areas.

This study of western Washington replicates the land-use study of western Oregon by Kline, et al. (2004). Western Washington provides a comparable study site to Oregon because the states share similar ecosystems and high timber productivity, although they differ in land-use regulations. The current study examines forestland treatments in relation to land and human infrastructural characteristics, such as ownership type, building density, and UGA. It examines whether different types of owners manage land differently to identify potential for timber supply and shifts in production capacity. One hypothesis is that non-industrial land owners are less likely to manage for timber production.

Study Area Description

From a timber-production perspective, the study area includes 19 Washington counties west of the crest of the Cascade Range, also called the Douglas-fir subregion, comprising one of the most important and productive timber producing regions in the western United States (Haynes, et al., 2007). The three species with the greatest volume are Douglas-fir (42%), western hemlock (28%), and red alder (1%) (Gray et al., 2005). During the 1980s this area supplied an average of 22% of the annual growing stock harvest in the western United States, yet contained only 8.5% of the western timberland base (Adams, et al., 1994). Thirteen of Washington's top 15 producing counties are located in western Washington (WDWCP, 2010). In terms of population, the western one-third of Washington has 78% of the population, and the eastern two-thirds of the state has only 22% of the population (WDWCP, 2010).

Literature Review

Many factors influence landowner decisions: regulation, owner preferences, land production capacity, competition for other land uses, and market conditions. Many researchers examined the influences of timber production land use. The first study was in 1998 by Barlow, et al. using demographic data from the U.S. Census Bureau and Forest Service Forest Inventory and Analysis (FIA) forestland survey data for Alabama and Mississippi. They found an increasing population density was negatively related to harvest probability. Wear, et al. followed with a study in 1999 examining the effects of population growth on timber production, using four sets of data: expert opinion maps of where forests would likely be managed for commercial forestry, U.S. Census population density, U.S. Forest Service inventory data, and USGS land-use categories. They found population density was negatively related to the probability of timber production management. This study raised concern for permanent land-use shifts by NIPF owners, and subsequent reduction of timber production area. In 2002, Munn, et al. examined the influence of urbanization on timber harvesting as a function of ownership and physical land characteristics in Mississippi and Alabama, and found that forest industrial (FI) and NIPF owners differed in terms of their propensity to harvest timber. The influence of ownership type on harvest was not supported by the Azuma, et al. (2002) study of eastern Oregon. Kline, et al. followed in 2004, with a study of precommercial thinning, harvesting, and planting activities as functions of ownership type and land characteristics in western Oregon, using Forest Service, Forest Inventory and Analysis (FIA) survey data. They found forestland development likely resulted in modest declines in forest stocking and precommercial thinning, but provided weak support for permanent land-use change. Alig and Plantinga (2004) found two key factors determining development of forestland: proximity to a city center and changes in the city's population. In 2005, Zhang, D. and Nagubadi quantified the influence of urbanization on timberland in eight southern U.S. states by forest type and concluded that urbanization, economic returns, demographics, economic growth, and land quality explained decline in timberland. In 2007, Kline, et al. replicated the western Oregon study in eastern Oregon, and found less effect from building density, possibly due to eastern Oregon's lower timber productivity. Recently in 2009, Vickery, et al. conducted a study in central New York using expert opinion, and found road and population density to be primary influences in the likelihood of sustained yield management. Previous research differed in the models and variables used, but the foci of interests were similar: Can timber supply be predicted, and how might investment in timber production be affected by increasing human presence and infrastructure? The studies commonly found negative relationships between indicators of population growth and timber management, but few found evidence of diminishing timber production capacity.

The influence of land-use regulations on timber management is supported by the literature on Washington and Oregon land-use regulation history. Oregon's land-use regulations were passed in 1973, during the environmental movement, and has been powerful in limiting urban development. Washington's Growth Management Act was passed much later, in 1990, and has been amended by almost every legislative session since passage, resulting in weaker ability to control urban sprawl. Oregon's Growth Management Act requires comprehensive land-use plans and protection of natural resources and environmentally critical areas, for every municipality, whereas Washington only requires plans for the largest and fastest growing areas. Oregon has a network of regulations, agencies, and enforcement teeth, whereas Washington is not required to complete an overall state plan, has no authority to declare plans out of compliance, and has limited enforcement teeth. Oregon has clearer urban growth delineations, whereas Washington allows contained communities and master planned resorts outside urban growth areas (UGAs, DeGrove, p. 240), leading to inconsistent land-use boundaries, and creating considerable variations between counties in classifying and designating resources (Bengston, et al., 2004). Evidence of the difference between the two states' abilities to contain growth is seen by the population expansion emanating from urban areas in Washington, compared to bounded growth areas in Oregon.

Washington's weaker land-use regulations were enacted to avoid opposition from slower growing communities (Downs, 2005), who need economic growth to create jobs and commerce for their communities. Counties that are in dire economic conditions with high rates of unemployment are not likely to enact policies that inhibit economic growth (Steel and Lovrich, 2000). Whereas, fast growing counties value protecting natural resource amenities found in the rural setting. Land use regulations have been a contentious issue. In Oregon, Measure 37 was passed to limit the construction of buildings outside urban growth areas. In 2004, it was amended to allow exceptions for building if the State was not willing to buy out the owners' right to build. Landowners inside the UGA are seen to profit through the increasing intensification of land use, while UGAs restrict the ability of owners outside the boundary to take advantage of the higher land prices from future development (Downs, 2005). This causes conflict between the desires to protect public goods and restrict private interests. Regulations affect land parcelization and timber supply by setting the environment for timber production and land investment.

Methods

Data Sources and Sampling

The data for this study are collected by the Forest Inventory and Analysis program (FIA), a nationwide program of the USDA Forest Service authorized in the 1930s to maintain an inventory of forest plots. Field crews visit site plots to measure and record 43 forest attributes such as basal area, species type and treatment activity. The current plots structures for the FIA data sampling system were established in the late 1960s, with minor adjustments during the transition from a periodic to annual surveying regime. Sampling is implemented on a permanent, systematic grid and produces an even geographic distribution of both field and photo plots (Gray, et. al, 2005). Sampling hexagons cover the conterminous 48 states with one plot in each hexagon making the sampling intensity close to 1 field plot per 6000 acres. Temporal and spatial regularity is incorporated in the annual surveys by assigning each hexagon to one of five panels, which are set up on a staggered, rotating schedule (Brand, 2005).

Two survey periods are examined; the first was conducted in 1978-79 (referred to as 1978 survey) and includes treatments applied since the previous survey conducted in 1968-69. The second survey examined was conducted in 1988-89 (referred to as the 1988 survey) and includes treatments applied since the previous survey in 1978. After the 1988 survey, the surveying schedule changed from periodic to annual, in response to the passage of the Agricultural Research, Extension, and Education Reform Act of 1998 (PL 105-185). Periodic sampling changed, from all plots surveyed at the same time on a ten-year cycle, to a sampling of ten percent of the plots each year. The 1978 and 1988 surveys are used in this study because they represent the same amount of time passage, whereas the survey periods vary during the transition from periodic and annual surveying so could not be compared. An inventory was conducted in 2000 to bridge the two sampling schedules, but it was three-fifths the sample size of the previous two surveys, so also could not be used in this study.

FIA inventory data was augmented with structures (buildings of any size) counted manually from 1976 aerial photos, and counted electronically from the 1990 and 2001 aerial photos. The FIA data set was further augmented with urban growth area (UGA) data indicating whether each plot was contained in a UGA.

The data set contained 1837 observations, 1002 in 1978, and 835 in 1988, a difference of 167 observations between the two periods. Observations were then excluded from the regressions for various reasons: unknown Forest Type, Stand Age greater than 200 years, Ownership types other than NIPF and FI, Estimated Structures that were converted to urban use, Estimated Structures in the highest two standard deviations, and plots with missing data. The remaining number of plots in the data set was 1297; 531 observations in the 1978 survey and 766 in the 1988 survey, still a difference of 117 between the two surveys. Adjustments are made in statistical summaries to account for this difference.

Variables Defined

To address land and human infrastructural influences on treatments, variables were selected to replicate the Kline et al. (2004) study. Past studies used varying sources to represent population growth and land site quality using informed opinion. The FIA data available is the same as in the Kline et al. (220) study, with a few exceptions, noted in variable definitions.

Basal area is the diameter measurement of a tree at breast height, measured in units of square feet of live trees per acre. In the modeling process, Basal area is used to represent stocking, defined by Campbell, et al., (2010) as the tree density required to fully use the timber growth potential of the land. It is used in this study to represent landowners' timber management activities as gauged by density of stand. Basal Area is also used as an explanatory variable to examine the effect on harvest, thinning, and planting treatments. It is assumed that average Basal Area will be low in relation to planting treatments, medium-low in relation to thinning treatments, and high in relation to harvest treatments. Basal Area will likely be low in relation to urban measurements of building density and UGAs.

Stand Age is measured in 10 year increments, ranging from 0 to 185 years. After 185, the scale changes to a choice of two age categories: 250 or 400 years. Estimation errors are likely for all plots with stand ages above 185 that are not 250 or 400, so the observations above 200 years are removed from the regressions. Stand Age serves as a check with Basal Area as they should have a strong positive relationship. Stand Age is squared to create a variable to detect non-linear variation in the model that Stand Age alone does not explain.

Slope is measured in percentage, and is used to find differences in general landholding type between ownerships. It is assumed slope will have a negative relationship with treatments, as higher elevation lands are generally publically owned and limited use for timber production.

Site quality, a forest's potential timber production capacity, is calculated using either Mean Annual Increment (MAI) or Site Index formulas. Site index compares dominant tree height at a specified age with the expected tree height by tree species and region, and is used as input to the MAI equations. MAI is the wood growing capacity of a site, based on species and geographic area, expressed by average increase in cubic foot volume per acre per year (Hanson, et. al, 2002). MAI is used to develop site classes in ranking site productivity from 1 (highest) to 7 (lowest). Site quality is used to reveal differences in land holding between Industrial and Non-industrial ownerships, the differences in treatments.

Hardwood describes whether plots are 70 percent dominated by hardwood species. Interactive variables are created between Hardwood and Stand Age to test their relation to each other. Hardwood and MAI are also combined to test their interaction. Hardwood is generally not used for production timber, so will likely be associated with non-industrial ownership and associated characteristics.

Ownership is classified into non-industrial (NIPF) and industrial (FI) ownerships, with the differentiating factor being that FI owners operate wood-processing plants (Gray, et al., 2005). The study does not include plots in public and tribal ownership. The differences in harvest rates will likely be similar between ownership types, matching statements by several literature sources. The study focuses on differences between NIPF and FI ownerships to identify potential for decreased timber supply and timber production capacity. Gauging by the exploratory statistics by ownership type shown in Table 1, Industrial owners generally hold higher timber producing land than NIPF owners, with higher average basal area, slope, and MAI. Whereas land near higher building density and UGAs is more likely to be owned by NIPF. Industrial owned lands are more likely to be planted and harvested, than NIPF-owned lands.

Table 1. Statistical Means by Ownership Type

	Industrial	**Non-Industrial**
Basal Area (sq ft/acre)	124	122
Slope (percent)	27	16
MAI (site quality)	177	145
Building Density	19	2
UGA (binary, 1=inside UGA)	0.005	0.06

Harvest (binary, 1=harvest)	0.29	0.3
Thin (binary, 1=thin)	0.13	0.19
Plant (binary, 1=plant)	0.21	0.1

To compare building structure density to site characteristics, photos taken in 1976 were matched with surveys completed in 1977-78. The 1988-89 survey did not match with the photos taken between 1990 and 2001. The extreme potential time mismatch is a case of a 1988 survey matched with a 2001 structure count, a time difference of 12 years. To compensate for the potential mismatch, an estimated structure count was calculated to interpolate structure counts between photo years, assuming linear increases in structure. The formula used was: StructureCount76 + (StructureCount94 - StructureCount76) / (PhotoYear94-1976)) * (Measurement Year - 1976).

Table 2. Photos and Surveys - Time Representation Comparison

Photos													
Surveys													
YEAR	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	198

Estimated Structures had extreme structure counts as a result of random sampling design. The measurement point within each plot is selected randomly for each plot. During data collection, if a plot's point of measurement indicates an urban area, the plot is designated Urban, and no longer measured in future inventories. Urban observations were dropped from this study. Whereas, if the plot's point of measurement centers in forestland, but urban area is included in the entire plot circle, then all structures are counted. Extreme structure counts were as high as 824 structures in 640 acres, or .78 acre per structure, which is considered small parcel size for timber production. This extreme structure count was rare in relation to the majority of plots with zero structures. Forty-five plots with structure counts above two standard deviations from the mean are dropped in one model specification to test the influence of extreme structures on treatments.

Urban Growth Area (UGA) indicates whether a plot is located in a UGA. Four survey plots were located in urban areas and subsequently dropped from the study, as noted in the Estimated Structures section above.

Survey Period was created as a variable to represent whether data were collected in the 1978 or 1988 survey periods, with 1 equaling 1988. Treatment decisions may differ over time and harvest likely increases the closer the plots are to urban areas. The sample number differed between the two survey periods by 117 observations. The means of the two surveys differed minutely in all variables, with a slightly more harvest during the 1988 survey period. A difference in the number of observations between the two surveys may account for some difference in results, but should not create a bias because the data were randomly sampled, and there are many observations.

Harvest is represented with a binary variable indicating whether a plot was harvested during the survey period, with 1 equaling a harvest occurred during the survey period. The variable includes varying levels of observed harvest codified as: Trees Removed, Improvement, Partial Heavy, and Clear Cut. The activity of harvesting is of interest because it signals potential transition into different land uses.

Precommercial Thinning is a binary variable representing whether a plot was precommercially thinned (e.g., unprofitable harvest for the purpose of encouraging growth of remaining stand) during the survey period or not, and is made up of one inventory code representing precommercial thinning, and no other thinning categories. This activity is of interest because it signals investment in timber harvest.

Planting is represented with a binary variable indicating whether planting was observed during the inventory period. The variable includes five classifications representing varying levels of planting: Planting - at least 50% of live trees resulted from planting; Planting Throughout - an area was planted to establish a management stand; Planting Holes - non-stocked openings were planted to fill in or create manageable stands; and Under-Planting - planting occurred under a saw timber over-story. Planting is the indicator treatment. It signals the intent to continue managing for timber.

Non-industrial-interactive variables were created by combining NIPF with each of the other characteristic variables to test the influence of ownership type on land treatments in relation to land and human infrastructural conditions. As the literature indicates, NIPF owners have a wider variety of reasons for owning land, so NIPF-owned plots will likely have less treatments associated with timber-production.

Model Building

Models are specified to replicate the Kline, et al. (2004) study of western Oregon using measures of ownership and urbanization. Model specifications differ between the state models due to data availability. The Oregon model included distance to road information, which was not available for Washington. The Washington model includes UGA information, which was not available for Oregon. Comparison between states on the effect of UGA and distance to road will not be possible, but a comparison can be made on the influences of building density and ownership type on treatment decisions. In this study, four models are specified to represent four land treatments. The first model is set up with Basal Area as a dependent variable to represent stocking. The other three treatment models use observations of harvesting, precommercial thinning, and planting to represent these activities.

An ordinary least squares (OLS) model is used for the continuous variable, Basal Area, with three specifications (Table 1). Basal Area is first regressed on ten independent variables representing: Stand Age, Age Squared, Mean Annual Increment, Hardwood, Hardwood*Age, Hardwood*MAI, Survey Period, Estimated Structures, Urban Growth Area, and NIPF. The model is respecified adding nine NIPF interactive variables including: Stand Age*NIPF, Age Squared*NIPF, Mean Annual Increment*NIPF, Hardwood*NIPF, Hardwood*Age*NIPF, Hwd*MAI*NIPF, Survey Period*NIPF, Estimated Structure Count*NIPF, and Urban Growth Area*NIPF. The third specification drops the highest two standard deviations of Estimated Structures. Dropping the outlier data drops 45 observations from the data, changing the sample size from 1342 to 1297.

Harvest, Precommercial Thinning, and Planting are regressed as binary variables using three Logit models estimating the probability that Y=1, or that treatments occurred, given a 1-unit change in X. The Kline, et al. (2004) study used a probit model, whereas this study uses a Logit model. The Logit model assumes a logarithmic distribution of the error term, where the probit model assumes a normal distribution. Probit and Logit models tend to yield similar results, so it is not a critical difference. Treatments are binary dependent variables regressed in three model specifications on thirteen independent variables. The first specification regresses seven independent variables including: Basal Area, MAI, Slope, Survey Period, Estimated Structures, UGA, and NIPF. Then all three treatment models are respecified to test the differences between ownership type by adding NIPF interactive variables including: Basal Area*NIPF, MAI*NIPF, Slope*NIPF, Survey Period*NIPF, Estimated Structures*NIPF, and UGA*NIPF. The third specification drops the highest two standard deviations of Estimated Structures to test the influence of high structure counts on treatments and other explanatory variables. One specification difference between the three treatment logit models is the absence of UGA in the Precommercial

Thinning model, due to quasi-complete separation error, indicating dependence between the dependent and independent variables (Allison, 1999). None of the Precommercial Thinning observations were associated with plots inside the UGA.

Using Basal Area as the regressor in the OLS model and as an explanatory variable in the three treatment logit models could lead to correlations between the models. Simultaneous causality runs from the dependent variable to a regressor causing the OLS regression to pick up both effects, making the estimator biased and inconsistent with correlation between the regressor and the error term. The correlation can be made precise mathematically by introducing an additional equation describing the reverse causal link (Stock and Watson, 2008:322), but is beyond the technical scope of this study. A simpler correction would be to drop the Basal Area model as a proxy for stocking, although it is informative about relationships between standing stock and other land characteristics and treatment decisions.

Another statistical issue when working with temporal data such as these is the decision variables, Harvest and Thinning, should be estimated on lagged explanatory variables to avoid an endogeneity problem. However, given there are only two periods of data available for this analysis, using lagged explanatory variable would reduce the sample size and limit the analysis to a single decision period. Therefore, endogeneity issues are being traded-off against retaining two periods of data in this exploration of factors affecting these decisions.

Statistical Results

The OLS Basal Area model results in eight significant independent variables, and an overall model R^2 of 0.71. Stand Age is positive and significant, and Stand Age Squared is negative and significant, both at the 99% level. They both remain significant after adding Stand Age*NIPF and Stand Age Squared*NIPF, which are also significant at the 99% level. Stand Age and Stand Age Squared remain significant across ownership types, confirming the dominance of physical process in the relationship between tree age and size. The model confirms the exploratory statistical finding that Stand Age was 53% correlated with Basal Area.

Site quality, measured in Mean Annual Increment (MAI) is positive and significant, and remains so when NIPF interactive variables are added. Although MAI* NIPF did not test as significant, the smaller coefficient supports the presupposition that quality timber-producing land is generally held by FI owners. FI lands were predominantly rated site class #2, representing an output of 165-224 cubic foot (cf) per acre per year, and NIPF lands were predominantly rated class #3, representing an output of 120-164 cf/acre per year.

Hardwood is positive and significant in the Basal Area model at the 99% level until NIPF variables are added, and then it becomes insignificant. Although Hardwood*NIPF is not significant, it has enough explanatory power to take away significance from Hardwood with FI ownership. Hardwood-dominated plots decreased from 28% in the 1978 survey period to 23% in 1988 survey period, confirming the propensity to replant merchantable softwoods over hardwoods. Hardwoods were generally located in lower quality growing areas, which were also both commonly connected by NIPF ownership. FI plots were 20% hardwood dominated, and NIPF plots were much higher at 45% hardwood, suggesting differences in goals between ownership types.

UGA is negative and significant at the 90% level, but loses significance when NIPF interactive variables are added. Although UGA*NIPF is not significant, it takes significance away from UGA. This agrees with the common conception in the literature that NIPF are moving into the wildland-urban interface. UGA's insignificance may be due to the small number (3%) of plots being in UGAs. Estimated Structures, while not significant, still reveals a negative relationship with Basal Area. Then it becomes positive when NIPF interactive variables are added, indicating industrial owners have a positive relationship with areas with higher wood content, and NIPF is the opposite. The relationship of basal area to FI owners remains positive after extreme Estimated Structures are dropped from the model, confirming FI owners have positive relationship with basal area in the lower structure-count areas.

Table 2. Basal Area OLS Regression.

Regressor:	**Base**	**+NIPF Interactive**	**Structures Truncated**
Stand Age	**5.25***** (0.13)	**5.73***** (0.14)	**5.73***** (0.14)
Age Squared	**-0.02***** (0.001)	**-0.03***** (0.001)	**-0.03***** (0.001)
Mean Annual Increment (MAI)	**0.23***** (0.3)	**0.21***** (0.03)	**0.21***** (0.03)
Hardwood	**43.13***** (11.00)	16.46 (14.38)	17.26 (14.55)
Hardwood*Age	**-1.29***** (0.12)	**-1.07***** (0.16)	**-1.08***** (0.16)
Hardwood*MAI	-0.02 (0.06)	0.03 (0.08)	0.03 (0.08)
Survey Period	2.65 (2.70)	3.57 (3.13)	3.67 (3.16)
Estimated Structures	-0.02 (0.04)	0.08 (0.09)	0.008 (0.25)
UGA	**-15.03*** (8.62)	-30.40 (21.26)	-32.51 (21.70)
NIPF	**-19.55***** (3.38)	**26.55*** (13.94)	**27.59**** (14.32)
Stand Age*NIPF		**-1.70***** (0.35)	**-1.63***** (0.36)
Age Squared*NIPF		**0.009***** (0.003)	**0.008**** (0.004)
MAI*NIPF		-0.02 (0.07)	-0.03 (0.07)
Hardwood*NIPF		26.44 (23.32)	25.70 (24.71)
Hardwood*Age*NIPF		-0.08 (0.26)	-0.07 (0.27)
Hardwood*MAI*NIPF		-0.04 (0.13)	-0.03 (0.13)
Survey Period*NIPF		0.74 (5.86)	-0.09 (6.17)
Estimated Structures*NIPF		-0.12 (0.10)	-0.12 (0.28)
UGA*NIPF		19.42 (23.19)	19.31 (24.46)
Intercept	-51.17*** (5.88)	-59.22*** (6.43)	-59.12*** (6.48)
N =	1342	1342	1297
Adj. R^2 =	0.69	0.71	0.71
F-stat =	306.16	172.69	167.08
P-value =	<.0001	<.0001	<.0001

Individual coefficients are statistically significant at the *10%, **5%, ***1% significance level.

The Harvest logit model is initially specified with seven human and land characteristic variables including: Basal Area (used as an explanatory variable), Mean Annual Increment (MAI), Slope, Survey Period, Estimated Structures, UGA, and NIPF. The model is then respecified adding NIPF interactive variables including; Basal Area*NIPF, MAI*NIPF, Slope*NIPF, Survey Period*NIPF, Estimated Structures*NIPF, UGA*NIPF.

In the Harvest model, the independent variable, Basal Area, is positive and significant at the 99% level before and after adding NIPF interactive variables. Basal Area*NIPF is positive and significant at the 90% level, signaling Basal Area's influence on Harvest across ownership types. It increases in significance to 95% level when extreme Estimated Structures are dropped from the model.

Slope is negative and significant at the 95% level, and increases in magnitude and significance at 99% level after adding the NIPF variables. Although Slope*NIPF is not significant it affirms the presupposition that FI owners generally own higher-elevation lands. Forestlands with higher Slope had lower likelihood of Harvest.

Survey Period is positive and significant at the 99% level, confirming the statistical explorations showing harvesting on FI and NIPF plots increased from 24% in the 1978 survey period, to 35% in the 1988 survey period (adjusting for the difference in number of plots between the two survey periods). This is consistent across ownership types, and truncated Estimated Structures, so does not appear to be biased.

Estimated Structures is negative and significant at the 90% significance level before and after NIPF variables are added, but changes to positive and increases in significance to 99% level, when extreme Estimated Structures are dropped from the model in the third specification.

Urban Growth Area is negative and insignificant, and changes to positive after NIPF interactive variables are added. UGA*NIPF is negative and significant, suggesting FI owners are more likely to harvest near UGAs than NIPF owners. This reflects an active forest products industry with timberlands located in the midst of relatively large urban areas. UGA remains positive, and gains significance at the 90% level when extreme Estimated Structures are dropped, confirming a positive relationship between building density and UGAs.

UGA*NIPF is negative and significant, and Estimated Structures*NIPF is significant after extreme Estimated Structures are dropped, drawing connection between NIPF and urban areas in relation to harvesting activities. This may indicate NIPF owners are generally delaying harvests in favor of older aged stands with larger trees for the ecosystem services these types of stands provide.

Table 3. Harvest Logit Model.

Regressor:	**(1) All Structures No NIPF Interactive**	**(2) All Structures +NIPF Interactive**	**(3) Structures Truncated +NIPF Interactive**
Basal Area	**0.01***** (0.001)	**0.01***** (0.001)	**0.01***** (0.001)
MAI	0.0003 (0.0012)	0.0008 (0.001)	0.0011 (0.0014)
Slope	**-0.007**** (0.003)	**-0.01***** (0.004)	**-0.01**** (0.004)
Survey Period	**0.67***** (0.13)	**0.82***** (0.17)	**0.83***** (0.17)
Estimated Structures	**-0.004*** (0.002)	**-0.007*** (0.004)	**0.03***** (0.01)
UGA	-0.10 (0.43)	1.26 (0.91)	**1.61*** (0.93)
NIPF	0.13 (0.16)	0.84 (0.55)	0.87 (0.59)
Basal Area*NIPF	----	**-0.004*** (0.002)	**-0.004**** (0.01)
MAI*NIPF	----	-0.001 (0.003)	-0.001 (0.003)
Slope*NIPF	----	0.01 (0.008)	0.012 (0.007)
Survey Period*NIPF	----	-0.33 (0.29)	-0.38 (0.29)
Estimated Structures*NIPF	----	0.003 (0.005)	**-0.02*** (0.01)
UGA*NIPF	----	**-1.71*** (1.04)	**-1.9*** (1.1)
Intercept	-2.54*** (0.28)	-2.78*** (0.33)	-2.97*** (0.34)
N =	1342	1342	1297
P-value =	<.0001	<.0001	<.0001

Individual coefficients are statistically significant at the *10%, **5%, ***1% significance level.

The Precommercial Thinning Logit model is initially specified with six variables representing land and human infrastructure including: Basal Area, MAI, Slope, Survey Period, Estimated Structures, and NIPF. The model is then respecified adding six NIPF interactive variables including: Basal Area*NIPF, MAI*NIPF, Slope*NIPF, Survey Period*NIPF, and Estimated Structures*NIPF. It does not include UGA and UGA*NIPF because they lack independence from thinning activities. The model is then respecified dropping the two highest standard deviations of Estimated Structures.

Basal Area is significant across the three model specifications, suggesting it dominated the influence of Precommercial Thinning decisions. The insignificance of Basal Area*NIPF suggests that FI dominated Precommercial Thinning activities.

Site quality, as measured by MAI, is significant at the 90% level across all three model specifications, suggesting timber-quality lands were more likely to be precommercially thinned. This supports the relationship between FI ownership of timber-quality lands, and their higher likelihood of conducting Precommercial Thinning.

NIPF is negative and significant at the 99% level for Precommercial Thinning. NIPF interactive variables take explanatory power from NIPF, but it remains negative across all three model specifications. Precommercial Thinning by FI owners is negatively related to Basal Area confirming that forests are precommercially thinned at lower basal areas.

Table 4. Precommercial Thinning Logit Model.

Regressor:	**(1) All Structures No NIPF Interactive**	**(2) All Structures +NIPF Interactive**	**(3) Structures Truncated +NIPF Interactive**
Basal Area	**-0.01*** (0.001)	**-0.01*** (0.001)	**-0.01*** (0.001)
MAI	**0.003*** (0.002)	**0.003*** (0.002)	**0.003*** (0.002)
Slope	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)
Survey Period	-0.14 (0.20)	-0.18 (0.20)	-0.18 (0.20)
Estimated Structures	-0.02 (0.01)	-0.04 (0.03)	-0.04 (0.03)
UGA	----	----	----
NIPF	**-1.70***** (0.44)	-1.75 (1.41)	-1.94 (1.47)
Basal Area*NIPF	----	0.004 (0.006)	0.003 (0.006)
MAI*NIPF	----	-0.006 (0.008)	-0.006 (0.008)
Slope*NIPF	----	0.005 (0.02)	0.008 (0.02)
Survey Period*NIPF	----	0.82 (0.81)	0.77 (0.81)
Estimated Structures*NIPF	----	0.03 (0.03)	0.04 (0.03)
UGA*NIPF	----	----	----
Intercept	-1.33*** (0.38)	-1.29*** (0.39)	-1.29*** (0.39)
N =	1342	1342	1297
P-value =	<.0001	<.0001	<.0001

Individual coefficients are statistically significant at the *10%, **5%, ***1% significance level.

The Planting Logit model is initially specified with six land and human infrastructural variables including: Basal Area, MAI, Slope, Survey Period, Estimated Structures, and NIPF. The model is respecified adding six NIPF interactive variables including: Basal Area*NIPF, MAI*NIPF, Slope*NIPF, Survey Period*NIPF, and Estimated Structures*NIPF. It includes UGA and UGA*NIPF, but Planting in relation to UGA is similar to the Precommercial Thinning model in the lack of independence from the dependent variable, Planting. The model is then respecified dropping the two highest standard deviations of Estimated Structures.

Basal Area and Basal Area*NIPF are positive and significant at the 99% level in the Planting model. The sign is opposite of expectations since average basal area should be close to zero at planting time and for a short period afterwards. This is a result of comparing basal area measurements to after treatments, rather than before treatments.

Survey Period is positive and significant at the 99% level and Survey Period*NIPF is positive and significant at the 95% level, indicating survey period 1988 had more observations of planting by both ownership types than survey period 1978. This may be an effect of the differences between survey periods discussed in the Variables Defined section of this report. The number of observations of Plantings was few, making small differences between the two survey periods a larger portion of the total observations.

Estimated Structures and UGA both change from negative to positive when NIPF variables are added to the Planting model. Estimated Structures was negative and significant at the 90% level until NIPF interactive variables were added, then Estimated Structures lost significance, giving it to Estimated Structures*NIPF, which was negative and significant at the 90% level, increasing to 95% significance when extreme Estimated Structures were dropped. Although UGA does not test as significant, the coefficient is negative until NIPF variables are added, and then it changes to positive. UGA*NIPF is also negative, and even though not significant, adding supports to the premise that NIPF have a negative effect on Planting near UGAs. The relationship between Estimated Structures, UGA and NIPF is supported by the exploratory statistics describing a 15% correlation between UGA and Estimated Structures, and 16% correlation between UGA and NIPF; and 54% correlation between NIPF and Estimated Structures. These findings are likely weakened by lack of independence between UGA and Planting, as there were few observations of planting near UGAs.

Occurrence of Planting increased from survey period 1978 to 1988 for NIPF and FI owners, although planting rates substantially between ownership types. The likelihood of planting on NIPF plots increased from 4% to 15% from the 1978 survey to the 1988 survey (adjusting for a difference in total number of plots between the two survey periods). While the likelihood of planting on FI plots increased from 18% to 25% from the 1978 survey to the 1988 survey.

Table 5. Planting Logit Model.

Regressor:	(1) All Structures No NIPF Interactive	(2) All Structures +NIPF Interactive	(3) Structures Truncated +NIPF Interactive
Basal Area	**0.006***** (0.0008)	**0.007***** (0.001)	**0.007***** (0.001)
MAI	0.001 (0.001)	0.0006 (0.001)	0.0007 (0.001)
Slope	-0.003 (0.004)	-0.005 (0.004)	-0.004 (0.004)
Survey Period	**0.60***** (0.15)	**0.50***** (0.17)	**0.49***** (0.17)
Estimated Structures	**-0.01*** (0.006)	-0.006 (0.005)	0.01 (0.01)
UGA	-0.37 (0.76)	0.99 (0.95)	1.13 (0.93)
NIPF	**-0.64***** (0.22)	-0.92 (0.78)	-0.90 (0.79)
Basal Area*NIPF	----	**-0.007***** (0.002)	**-0.007***** (0.002)
MAI*NIPF	----	0.006 (0.004)	0.006 (0.004)
Slope*NIPF	----	0.002 (0.01)	0.002 (0.01)
Survey Period*NIPF	----	**0.99**** (0.43)	**0.94**** (0.43)
Estimated Structures*NIPF	----	**-0.02*** (0.01)	**-0.04**** (0.02)
UGA*NIPF	----	-14.62 (642.2)	-14.51 (569.6)
Intercept	-2.64*** (0.30)	-2.55*** (0.33)	-2.61*** (0.34)
N =	1342	1342	1297
P-value =	<.0001	<.0001	<.0001

Individual coefficients are statistically significant at the *10%, **5%, ***1% significance levels.

Discussion

Harvest choice is primarily determined by the presence of harvestable timber (Kuuluvainen, et al., 1996; Butler, 2008). Variables representing physical processes, (e.g., tree growth and size) were more responsive in the models than human infrastructural variables (e.g., owning land, building structures, and bounding urban growth). Stand Age dominated the influence on Basal Area, positively for FI owners, and less positively for NIPF owners. Kline et al. (2004) found stand age and site index to be significant positive influences in the basal area model representing stocking. In turn, Basal Area was the dominant influence in all treatments: Harvesting, Precommercial Thinning and Planting.

When ownership type was combined with land capacity and presence of timber, influence on treatment decisions was notable. Ownership was related to plot characteristics. FI owners generally held higher elevation and timber-quality production lands, with less: hardwoods, structures and proximity to UGAs. In contrast, NIPF owners generally held lower elevation and production lands, near: hardwoods, structures, and UGAs. Ownership type was also related to likeliness of land treatments. NIPF and FI owners harvested at comparable rates, but FI maintained higher stocking levels, and were more likely than NIPF owners to conduct precommercial thinning, and planting activities near structures and UGAs. The Kline et al. (2004) study found similar difference in activities by ownership with a significant negative influence from NIPF ownership on the likelihood of precommercial thinning and planting. Owner groups harvested similarly, but it is not possible to interpret the purpose for harvests, whether they were regeneration cuts to provide for the next stand, or conversion cuts to prepare for land-use change (Munn, et al., 2002). The rate of conversion to urban uses is not evident until planting and thinning treatments signal the next intended land use. Predictability of timber supply and land use shifts is confounded by the high rate of change in land ownership.

The influence of land availability, growing stock, and ownership type, is further influenced by proximity of plots to structures and UGAs. Precommercial Thinning and Planting were unlikely to be conducted near Estimated Structures and UGAs by FI owners, and even less likely to be conducted by NIPF owners. The Kline et al. (2004) study also found that stocking, precommercial thinning, and planting were affected by building density. They found road distance and building density, two indicators of parcel size, to be significant negative influences on the likelihood of precommercial thinning and planting, supporting the concern for decreased timber production area due to land conversions to urban use. Washington models do not include distance to road, a proxy for parcel size, but do include building density and UGA, which reflect parcel size, making inferences possible. Using estimated structures, and its affiliation with NIPF ownership and their lack of observations of thinning and planting near UGA and high building structures, it may also be generalized that NIPF owners' differing land uses make future land area used for forest timber management is less predictable and open for conversion to other uses.

NIPF ownership makes up a small portion of the forestlands, but provides a notable portion of the supply provided by private landowners. This supports the potential for reduced timber-production capacity, but is weak evidence for the use of end of survey period basal area in comparison to treatments that occurred in the corresponding preceding 10-year period. The evidence is also weakened by lack of independence between UGA and the dependent variables Thinning and Planting. However, the effect of urbanization on timber management treatments is confirmed by structure density data that both the Oregon and Washington studies found to have a negative effect on timber management.

Policy Implications and Recommendations

Based on the finding that non-industrial owners are less timber-production oriented, and based on the literature stating NIPF area of land ownership is increasing, the predictability of timber supply will continue to decrease. Based on the findings that non-industrial owners are less likely to conduct timber treatments in proximity to urbanization, and urbanization is expanding, land will continue to shift from forest uses into other uses. Allowing Urban Growth Areas and Estimated Structures to represent parcelization, the relationship between reduced investment treatments in proximity to parcelization suggests that timber management activities will decrease.

Demand for wood products and land is not easily controlled because it is caused by accepted population growth and desired socioeconomic conditions. Consumptive lifestyles drives price higher for lands in developed uses, more than in forestry and farming uses, with less risk and shorter investment period.

Timber supply is an issue surrounding changing forest management practices of NIPF owners in areas traditionally used for timber production. NIPF owners may be induced to harvest with price mechanisms, as past research indicates price elasticities in timber supply are higher for NIPF than for FI owners (Adams and Haynes, 1996:22). NIPF owners have a slightly lower propensity to harvest timber, so timber availability can be coaxed from NIPF with price increases. This understanding has been the key component of past policy recommendations, suggesting ways to increase NIPF timber supplies.

Timber production could be encouraged using several government incentive approaches. Tax structures could be designed to recognize changing value of forestland at different stages of the growth cycle (DeCoster, 1998). Taxes would be reduced during planting and thinning stages (with confirmed treatments), and then taxes paid at harvest. Cyclical tax structures may exist in Washington, similar to Oregon's tax deduction for small woodlot tax less than 20 acres. Timber production could also be encouraged with forest management assistance programs focusing on replanting and thinning activities. Government assistance has worked in the past with reforestation increases in the mid 1970's and early 1980's while state and federal cost-share programs were in place (Alig, et al., 1990). However, there are problems with government assistance. Landowners do not trust government, which precludes most formal or legal cooperation (Cubbage, 1983). Landowners may question the role of governments in designing tax and assistance programs. Changing tax structures could have counterproductive effects by creating unpredictable investment environment, and increasing uncertainty about owning forestland. Insecurity about property rights has been linked to decreases in productivity and loss in forest value (Mehmood & Zhang, 2001). One concern with government assistance is the potential for capital substitution where government payments substitute for private investment that would have occurred otherwise (Alig, et al., 1990). Alternatively, assistance could bring forestry management within profitability levels for land-use decisions that may have otherwise shifted out of forest use.

The issue of timber supply leads to concern about shifting land uses into permanent residential and infrastructural uses, taking land out of timber production, and permanently decreasing the U.S. production capacity. Wear, et al. (1999) expressed potential for active forest management and associated timber harvests falling as residential development took place in rural areas. The conversion to non-timber uses could be happening at a higher rate than is evident because it is not possible to know when owners have changed their land management goals and are waiting for favorable market conditions or regulatory environment. A sign of impending forest conversion is owners forgoing investments in timber production. In this study, NIPF were found to conduct less intermediate timber management activities near structures and UGAs, however, the concern applies across ownership types because NIPF and FI have similar responses in areas where forestlands have high propensity to shift uses, as both share the same time value of money.

Assuming building density and UGA are indicators of land-use shifting out of timber production, investment in forest land could be encouraged with stable tax structured around long-term land management goals. Promote contiguous land management patterns with tax incentives to large land holders. The most viable-size forest ownerships need help resisting parcelization to remain productive (DeCoster, 1998). Recognize larger productive parcel sizes with reduced tax levels. Penalize parcelization activities with a transaction cost for splitting parcels. Continue to ease estate taxes that allow families to pass forests intact from generation to generation (Franklin and Johnson, 2007).

Smaller parcel owners may be encouraged to manage timber stands and maintain parcel sizes with incentives for ecosystem services by offsetting the forgone profit of converting to developed uses. Given the predicted decrease in size of forest holdings and other societal factors, ecosystem interactions are likely to increase in importance. The value of nontimber outputs relative to timber products seems to be growing as society becomes more affluent (Alig, et al., 1990). Encourage societal benefits that cannot be imported such as open space, habitat, or carbon sequestration. Growing public recognition of the array of goods and services provided by forests has changed the nature of governance for forest management actions (Haynes, et al., 2007). The Kyoto Protocol allows the use of selected carbon sinks to meet emission reduction targets. Carbon markets could provide incentives for forest managers to manage lands in ways that sequester carbon. Landowners who could document increased carbon storage from management actions could take advantage of the opportunity to sell carbon credits (Hoover, et al., 2000). But carbon generally reaches a plateau long after the economic age for removing biomass for products (Lippke, et al., 2003). The optimum age for maximum storage (200-500 years) is much older than the typical harvest rotation (30-100 years) in the Pacific Northwest (Krankina and Harmon, 2004). There would need to be incentive for managing for carbon, and until public policy requires control of carbon emissions, carbon sequestration in forests will have little market value (Franklin and Johnson, 2007).

Conclusion

This is an exploratory analysis of the effect of land and human infrastructural characteristics on the likelihood of harvesting, precommercially trimming, and planting trees. The major influences on forestland treatment decisions emerged as basal area, ownership type, and urbanization. Basal area is an obvious indicator of forestland management; land and trees must exist to make decisions necessary. Ownership type was related to land characteristics and treatments. Industrial ownership was positively associated with thinning and planting treatments, and higher timber-production lands. While non-industrial owners were positively associated with urban indicators: building density and urban growth areas. The likelihood of harvest was similar between ownership types, but investment treatments were least likely for non-industrial plots in urban growth areas, and near areas of high building density. These findings are similar to those of the Kline et al. (2004) study, which found that ownership, land, and infrastructural characteristics affected intermediate timber management treatments. This study adds support, however weak, for concerns about timber supply and land use shifts, but does not add predictability for NIPF management behavior. The common conception of the negative effect of NIPF ownership on forestland management is strengthened.

Appendices

Literature Cited

Adams, D.M. and R.W. Haynes. 1996. The 1993 timber assessment market model: structure, projections and policy simulations. Gen. Tech. Rep. PNW-GTR-368. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p.

Alig, R.J.; K.J. Lee; and R.J. Moulton. 1990. Likelihood of timber management on nonindustrial private forests: evidence from research studies. Gen. Tech. Rep. SE-GTR-60. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 17 p.

Alig, R.J. and A.J. Plantinga. 2004. Future forestland area: impacts from population growth and other factors that affect land values. *Journal of Forestry.* 102(8): 19-28.

Allison, P.D. 1999. Logistic regression using the SAS® system, Theory and application. Cary, NC: SAS Institute Inc.

Azuma, D.L.; K.R. Birch; A.A Herstrom; J.D. Kline; and G.J. Lettman. 2002. Land use change on non-federal land in Western Oregon, 1973-2000. Oregon Department of Forestry, Salem, Oregon. 80 p.

Barlow, S.A.; I.A. Munn; D.A. Cleaves; and D.L. Evans. 1998. The effect of urban sprawl on timber harvesting. *Journal of Forestry.* 96(12): 10-14.

Bengston, D.N.; J.O. Fletcher; and K.C. Nelson. 2004. Public policies for managing urban growth and protecting open space: policy instruments and lessons learned in the United States. *Landscape and Urban Planning*. 69: 271-286.

Brand, G. 2005. Forest Inventory and Analysis Sampling Hexagons. FIA Fact Sheet Series. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 2 p. Accessed 01/10/10 at http://www.fia.fs.fed.us/library/fact-sheets.

Butler, B.J. 2008. Family forest owners of the United States, 2006. Gen. Tech. Rep. NRS-27. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 78 p.

Campbell, S.; K. Waddell; A. Gray, tech. eds. 2010. Washington's forest resources, 2002-2006: five-year Forest Inventory and Analysis report. Gen. Tech. Rep. PNW-

GTR-800. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 189 p.

Cubbage, F. 1983. Economics of forest tract size: theory and literature. Gen. Tech. Rep. SO-41. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 91 p.

Daniels, J.M. and Warren, D.D. 2009. Production, Prices, Employment, and Trade in Northwest Forest Industries. All Quarters 2008. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/ppet/16.shtml

DeCoster, L.A. 1998. The boom in forest owners – A bust for forestry? *Journal of Forestry.* 96(5): 25-28.

DeGrove, J.M. 1994. Following in Oregon's footsteps. In: Planning the Oregon Way. Eds.: Abbott, C.A.; D. Howe, and S. Adler. Chapter 11. Oregon State University Press, Corvallis, Oregon. p. 227-244.

Downs, A. 2005. Smart Growth: why we discuss it more than we do it. *Journal of American Planning Association.* 71(4): 367-378.

Franklin, J.F. and K.N. Johnson. 2004. Forests face threat: global market changes. Issues in Science and Technology. http://www.accessmylibrary.com Accessed: May 14, 2010.

Gray, A.N.; C.F. Veneklase; and R.D. Rhoads. 2005. Timber resource statistics for nonnational forest land in western Washington, 2001. Res. Bull. PNW-RB-246. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 117 p.

Hanson, E.J.; D.L. Azuma; and B.A. Hiserote. 2002. Site index equations and mean annual increment equations for Pacific Northwest Research Station Forest Inventory and Analysis inventories, 1985-2001. Research Note PNW-RN-533. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 25 p.

Haynes, R.W. 2001. 2000 RPA assessment of forest and range lands. PNW-FS-687. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 78 p.

Haynes, R.W. 2008. Emergent lessons from a century of experience with Pacific Northwest timber markets. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

Haynes, R.W.; D.M. Adams; R.J. Alig; P.J. Ince; J.R. Mills; X. Zhou. 2007. The 2005 RPA timber assessment update. Gen. Tech. Rep. PNW-GTR-699. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 212 p.

Hoover, C.M.; R.A. Birdsey; L.S. Heath; and S.L. Stout. 2000. How to estimate carbon sequestration on small forest tracts. *Journal of Forestry.* 98(9): 13-19.

Kline J.D.; D.L. Azuma; and R.J. Alig. 2004. Population growth, urban expansion, and private forestry in western Oregon. *Forest Science.* 50(1): 33-43.

Kline, J.D. and D.L. Azuma. 2007. Evaluating forest land development effects on private forestry in eastern Oregon. Res. Paper, PNW-RP-572. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Krankina, O.N. and M.E. Harmon. 2006. Forest management strategies for carbon storage. In: Carbon and Climate Change: summary of science findings. *Oregon Forest Resources Institute*.
p. 79-99.

Kuuluvainen, J.; H. Karppinen; and V. Ovaskainen. 1996. Landowner objectives and nonindustrial private timber supply. *Forest Science.* 42(3): 300-309.

Lippke, B.; J. Perez-Garcia; and C. Manriquez. 2003 [unpublished document]. Executive Summary: the impact of forests and forest management on carbon storage. 8 p.

Mehmood, S.R. and D. Zhang. 2001. Forest parcelization in the United States: a study of contributing factors. *Journal of Forestry.* 99(4): 30-34.

Munn, I.A.; S.A. Barlow; D.L. Evans; and D. Cleaves. 2002. Urbanization's impact on timber harvesting in the south central United States. *Journal of Environmental Management.* 64: 65-76.

OFM - Office of Financial Management, State of Washington. http://www.ofm.wa.gov/pop/april1/cociseries/default.asp Accessed: 5/14/2010.

Ostrom, E. 2007. Institutional rational choice: an assessment of the institutional analysis and development framework. In: Theories of the Policy Process. Paul A. Sabatier, Ed. *Westview Press,* Boulder, CO. p. 21-64.

Radeloff, V.C.; R.B. Hammer; and S.I. Stewart. 2005. Rural and suburban sprawl in the U.S. Midwest from 1940 to 2000 and its relation to forest fragmentation. *Conservation Biology* 19(3): 793-805.

Steel, B.S. and N.P. Lovrich. 2000. Growth management policy and county government: correlation of policy adoption across the United States. *State and Local Gov. Review.* 32(1):7-19.

Stock, J.H. and M.W. Watson 2008. Introduction to Econometrics. *Pearson Addison Wesley*. 379 p.

U.S. CENSUS BUREAU http://quickfacts.census.gov/qfd/states/53000.html Accessed 5/19/2010.

Vickery, B.W.; R.H. Germain; E. Bevilacqua. 2009. Urbanization's impact on sustained yield management as perceived by forestry professionals in central New York. *Forest Policy and Economics*. 11: 42-49.

Wear, D.N.; R. Liu; J.M. Foreman; and R.M. Sheffield. 1999. The effects of population growth on timber management and inventories in Virginia. *Forest Ecology Management.* 118: 107-115.

Zhang, D. and R.V. Nagubadi. 2005. The influence of urbanization on timberland use by forest type in the Southern United States. *Forest Policy and Economics* 7: 721-731.

Zhang, Y.; X. Liao; B. Butler; and J. Schelhas. 2009. The increasing importance of small-scale forestry: evidence from family forest ownership patterns in the United States. *Small-scale Forestry.* 8: 1-14.

Acknowledgements

Many people and organizations contributed to this project, and I am deeply grateful.

Ralph Alig - Research Forester, USDA Forest Service, PNW Research Station, Corvallis, Oregon.

Robert Buckman - Retired, Deputy Chief, USDA Forest Service, Corvallis, Oregon.

CRAG Scholarship Fund, USDA Forest Service, PNW Research Station, Portland, Oregon.

Pat Cunningham - Mathematical Statistician, USDA Forest Service, PNW Research Station, Corvallis, Oregon.

Robert Dillinger - Wildlife Biologist, Coast Range Ecological Services, Inc., Columbia City, Oregon.

Rodger Evenson - Retired, carpenter, and master woodworker, Portland, Oregon.

Andy Gray - Research Ecologist, Forest Inventory and Analysis program, USDA Forest Service, PNW Research Station, Corvallis, Oregon.

Richard Haynes - Retired, Chief Economist, Program Manager, Human and Natural Resources Interaction Program, USDA Forest Service, PNW Research Station, Portland, Oregon.

Jeff Kline - Masters Committee Member, Research Forester, USDA Forest Service, PNW Research Station, Corvallis, Oregon.

Laurels Scholarship Fund, through the MPP Program, Corvallis, Oregon.

Joseph and Jennie Lines - My parents, in my heart and Dallas, Oregon.

William Lunch - Masters Committee Member, Professor and Chair of Political Science Department, Oregon State University.

Luke Rogers - University of Washington, from Community Trade, and Economic Development (CTED) Sam Wentz, Growth Management GIS, Olympia WA.

Randy Rosenberger - Masters Committee Chairman, Associate Professor, Forest Ecosystems and Society Department, Oregon State University.

Brent Steel - Director and Professor, Masters Public Policy Program, Oregon State University.

Daniel Stone - Assistant Professor, Economics Department, Oregon State University.