Changes in Wood Product Proportions in the Douglas-Fir Region. with Respect to Size, Age, and Time

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SUMMARY. We examined both the variation and the changing proportions of different wood products obtained from trees and logs in the Douglas-fir region of the northwestern United States. Analyses are based on a large product recovery database covering over 40 years of recovery studies; 13 studies are available for Douglas-fir *(Pseudotsuga rnenziesii* (Mirb.) Franco). Visual lumber grades were combined into four broad value classes. We used the multinomial logistic model to estimate the yield proportion of each value class as a function of age, diameter, and their interaction. We also examine changes in wood product proportions with respect to future projections of forest management, harvesting trends, and sustainability. We see a clear shift away from appearance grades in the 1960s to construction grades by the late 1980s. This cor'esponds to a concomitant shift from high quality old-growth trees to young-growth plantations (age 50 to 60) of much smaller diameter. The projected relative proportions among the four product value classes is not expected to change much over current proportions, with

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construction lumber a dominant 70 to 80% of the total. Thus, we expect to remain at this new equilibrium, where very little appearance grade lumber is manufactured in the Douglas-fir region and price premiums have disappeared. doi:10.1300/7091v24n01_04 *[Article copies available for a fee from The Haworth Document Delivery Service: I-800-HAWORTH. E-mail address: <docdeliveo,@harvorthpress.con> Website: <1 ttp://wirw Haworth Press. com>. J*

KEYWORDS. Yield proportion, value class, construction grades. multinomial logistic, Douglas-fir, *Pseudotsuga menziesii*

INTRODUCTION

We focus on the Pacific Northwest, principally western Oregon and Washington, which is also called the Douglas-fir region (McArdle et al., 1961). This mountainous region is dominated by a large temperate rainforest that extends to southeastern Alaska (Haynes et al., 2003). These coniferous forests contain the highest quality wood-producing lands on the continent (Curtis and Carey, 1996), and exhibit some of the greatest biomass accumulations and highest productivity levels of any in the world, temperate or tropical (Franklin and Dyrness, 1973; Fujimori et al., 1976; Franklin and Waring, 1981; Walter, 1985; Franklin, 1988). These forests are valued for their scenery, recreational opportunities, watershed protection, and fish and wildlife habitat as well as abundant forest products (Peterson and Monserud, 2002). Moist maritime conditions characterize the region, producing expanses of forests dominated by massive evergreen conifers, including coastal Douglas-fir *(Pseudotsugct menziesii* (Mirb.) Franco var. *menziesii),* western hemlock *(Tsugci heterophylla* (Raf.) Sarg.), western redcedar *(Thuja plicata* Donn ex D. Don), Sitka spruce *(Picea sitchensis* (Bong.) Carr.), Pacific silver fir (Abies *amabilis* Dougl. ex Forbes), and noble fir *(A. procera* Relid.). A mediterranean climate of mild winters and relatively dry summers prevails (Walter, 1985), although summer dryness decreases markedly to the north. This climate favors needle-leaved conifers by permitting extensive photosynthesis outside the growing season and reducing transpiration losses during the summer months (Waring and Franklin, 1979). The summer climate is controlled by a large, semipermanent, high-pressure center in the Pacific Ocean, which greatly reduces the frequency and intensity of Pacific storms (Meidinger and Pojar, 1991). Infrequent catastrophic events, such as wildfires and hurricanes at intervats of several hundred years, allow for the genetic expression of enormous biomass and extremely tall and long-lived forest trees (Franklin, 1988). Such favorable conditions for forest growth result in dominance by coniferous species that are the tallest, largest, and oldest of their genera (Franklin, 1988). Unlike the other temperate rainforests of the world (see Walter, 1985), this is the only one dominated by conifers rather than hardwoods (Franklin, 1988).

Forest management in this region has been evolving for over a century. Experience in even-aged silviculture and plantation management accumulated in the past half-century is vast (Curtis et at., 1998). Methods for regenerating vigorous young stands of primary timber species following clearcut logging have been thoroughly researched and tested throughout the western Pacific Northwest (Loucks et al., 1996; Smith et al., 1997). Douglas-fir, the major timber species in the Pacific Northwest, can be grown at various densities. It rapidly responds to thinning at a variety of stand ages, with increased diameter growth as well as branch and crown development. Stocking control is important to promote vigorous growth (Barbour et al., 2003).

Silviculturists have studied the key steps in stand management with fruitful results. Nursery methods for efficiently raising healthy, superior planting stock are now common (Duryea and Dougherty, 1991), including techniques for inoculating roots with mycorrhizal fungi to promote quick establishment and sustained growth (Castellano and Molina, 1989). Average survival of seedlings has increased to 85% or better (Curtis et al., 1998). Effective methods have been developed for controlling competing shrub and nontimber vegetation, thus promoting rapid growth of established individuals (Walstad and Kuch, 1987). Various harvesting systems have been developed to reduce problems such as soil compaction (Curtis et al., 1998). Because of dependable stand establishment through the widespread sequence of clearcutting, burning, and planting, the length of commercial rotations on high-productivity lands decreased to as little as 40 to 50 years. Often, commercial thinning was eschewed in favor of earlier harvests (Curtis and Carey, 1996).

From the 1940s until the late 1960s in the United States, there was general agreement among both federal and private land managers that ti mber production was the primary objective in management of most forest land (Curtis et al., 1998, Peterson and Monserud, 2002). Basic assumptions were that wood production in old-growth stands was essentially static (no net growth), and that insects and disease were diminishing the amount of usable wood in these stands. It seemed desirable, therefore, to replace old-growth forests with young, rapidly growing stands (USDA FS, 1963; Curtis et al., 1998). Furthermore, in the Douglas-fir region, clearcut logging and broadcast burning were justified as mimicking the catastrophic, stand-replacing fires typical of the region before fire suppression (Halpern, 1995). Management practices during this period attempted to meet increasing wood demands by relying on the economic efficiencies of clearcutting and plantation management (Haynes et al., 2003).

In the 1990s, it became increasingly clear that the public has strongly held values and opinions regarding the appropriate use of forest land (especially public forestland) in the Pacific Northwest (Haynes et al., 2003). The decision process has become increasingly difficult on how best to manage forestlands in the region. Simply put, public opinion has often been at odds with forest management goals, especially on public land. As a consequence of this shift in societal values, the focus of management in the Pacific Northwest during the 1990s shifted from producing timber to maintaining sustainable forest ecosystems (Behan, 1990). This shift culminated in the Northwest Forest Plan (USDA and USDI, 1994a, 1994b) for western Oregon and Washington and the new Forest Practices Code of British Columbia (1994). Emphasis on timber-stand management in the Douglas-fir region declined during the 1990s, especially on public forestland. The traditional goal of efficient wood production through even-aged plantations is shifting toward multi-resource ecosystem management, with related goals favoring old-growth characteristics (Monserud, 2003), protecting endangered species, fish habitat, and promoting biodiversity (FEMAT, 1993). This trend is also occurring to the north along coastal British Columbia (Clayoquot Scientific Panel, 1995), essentially the same temperate rainforest but outside the range of coastal Douglas-fir (Meidinger and Pojar, 1991). Science-based silvicultural practices and management regimes are needed to reduce conflicts among user groups while providing concurrent production of the many values associated with forestlands on a biologically and economically sustainable basis (Curtis et al., 1998; Committee of Scientists, 1999).

Because the goals of land managers have changed, silviculturists are examining new management methods (Haynes and Monserud, 2002). Whether they are called green-tree retention, variable-density thinning, or variable retention (Franklin et al., 1997), the silvicultural treatments under examination are intermediate between the traditional extremes of even-age plantation management, uneven-age selection management, and no management (see Hummel, 2003). Often, the goal is to increase rather than decrease structural heterogeneity within a stand and a watershed (Monserud, 2002). In a strong break from the uniform plantation management of the past, these silvicultural alternatives often include mixed-species compositions and attempt to obtain uneven-aged structures (e.g., by retaining legacy trees). They explicitly consider structural and spatial diversity as values, rather than the spatially uniform stand treatments common with traditional silvicultural systems (Monserud, 2003).

The Douglas-fir region remains one of the major timber-producing regions in the world and is recognized for its productive timberlands, forest management institutions, well-organized markets, and large-scale timber processing industries (Monserud et al., 2003). Current forest conditions in the Douglas-fir region are a function both of markets for various forest products and of various regulatory actions, past and current (Haynes, 2005). The Unites States has a total of 204 million hectares of timberland in all ownerships, where timberland is defined as forestland that is capable of producing at least 1.4 m^3 ha^{-1} yr^{-1} of industrial wood (Smith et al., 2004). Nationally, this timberland consists of 19% national forest, 10% other public land (e.g., state land, Bureau of Land Management), 13% forest industry, and 58% nonindustrial private ownership. However, the structure of ownerships for the Pacific Northwest is quite different. The Pacific Northwest has 16.7 million hectares of timberland, of which 43% is national forest, 14% are other public land, 22% is forest industry, and 21% is nonindustrial private land. This mixture of ownerships strongly affects timber supply because of the different policies and management objectives held by the various ownerships (Haynes, 2003).

Furthermore, timber availability in Washington and Oregon has changed dramatically since the late 1980s (Zhou et al., 2005). In 1988 the region produced about 37.1 million cubic meters (15.7 billion board feet) of timber. In 2001 it produced about 17.0 million cubic meters (7.2 billion board feet) (Warren, 2003), with the decline owing mostly to harvesting reductions on National Forest System land. There are 9.44 million hectares of timberland in these west-side forests. Half of this timberland is Douglas-fir. Approximately 53% of the land in the Douglas-fir region supports stands younger than 50 years old, compared to 13% of the land with stands older than 150 years. The majority of stands less than 150 years old are on other public (e.g., state land) or private land, whereas the majority of stands greater than 150 years old are on National Forest System land (Zhou et al., 2005).

Current policy on federally administered land effectively reserves all stands over about 80 years old from harvest and in practice restricts harvest to thinning of stands younger than about 50 years old. Managers of state land in both Oregon and Washington are under pressure to harvest only younger stands and then to create structural conditions for developing old forest characteristics that may eventually be managed for habitat protection (Zhou et al., 2005). Looking ahead 50 years, Haynes (2003) estimated that Douglas-fir will remain the major timber species, accounting for 63% of total removals for 1997-2056. Relatively quickly all Douglas-fir removals from private lands will represent the 45- to 65-year age classes (Zhou et al., 2005). The national forests will provide older Douglas-fir but in relatively limited volumes.

With this context, we are interested in examining the distribution (proportion) of various wood product classes with respect to this changing age and size distribution of the Douglas-fir resource. Specifically, we are looking for the relationship between product value classes (e.g., lumber grade) and information characterizing individual trees such as size and age. We focus on the relative proportions across these product value classes. We are also looking to see if this relationship changes over time.

MATERIALS AND METHODS

Data

Because we are examining changes in the proportions of various wood product grades available over time, we need to use historical data collected on several different product recovery studies. The Ecologically Sustainable Production (ESP) team (and its predecessors) of the USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, has conducted product recovery studies over the past 40 years (Monserud et al., 2004), and has maintained a database of these past studies. These studies trace the processing of wood products (lumber and veneer volume and quality) from the tree in the forest to the final product on a log-by-log basis. One common objective of the studies was to obtain maximum product value recovery consistent with current industry practices. The working assumption was that if log identity could be maintained on every item through the manufacturing process (sawing or veneer slicing) then the product yield and grade proportions for sample logs with known characteristics could then be applied to a similar sample of logs or trees to predict product volumes and values when using similar processing technology. Although this database summarizes product recovery information on most of the major forest species in the western United States, we focus on Douglas-fir in western Oregon and Washington, a key species for construction lumber in the United States. We use the 13 studies available with complete records (i.e., individual tree data as well as long- and short-log information) for Douglas-fir, for a total of 1,535 trees (Table 1). Of these records, 443 lacked either diameter at breast height (dbh) or age, leaving us with 1,092 complete tree records. Height was also available on most records. Thus, the tree information includes dbh, age, height, lumber grade, and volume yield from each tree. In one sense, this is a meta-analysis across several studies, except that we have the complete raw data.

Eight of these studies were conducted in the 1960s and contain considerable numbers of large (dbh > 100 cm) old-growth trees, as does one study from 1982 (Table 1). Study objectives were to evaluate and improve the existing log grading and timber appraisal system. The remaining four studies were conducted in the 1980s and 1990s, and represent smaller and younger material more commonly found in the Douglas-fir region today (Table I). Study objectives included estimating lumber volume and value recovery, as well as study-specific objectives such as developing a model for predicting lumber and veneer quality from young-growth tree and log characteristics. Because we are looking for continuous relationships between tree characteristics and product recovery, this collection of studies should provide us with the desired wide range of conditions.

To simplify the analysis, visual lumber grades were combined into four product value classes: (1) Appearance (Shop and Better), (2) Select Structural, (3) General Construction (No. 1 and No. 2 Lumber), and (4) Utility and Economy. Table 2 summarizes the correspondence between the various lumber grades (WWPA, 1998; Barbour et al., 2005) and these four product value classes.

The Appearance category includes Selects and Factory Lumber such as Clears and Shops (Table 2). This lumber has the highest dollar value and is typically used for finish applications. Select Structural includes the Select Structural grade and was intended to indicate the amount of lumber that might be available for higher value structural uses. Construction lumber includes No. 1 and No. 2, Standard and Construction, and No. 4 and Better Commons, plus any heavy timbers or other grades that are typically used for structural purposes. Utility and Economy also includes No. 5 Common and other grades that constitute the lowest value lumber. All the lumber produced from each study tree is then

TABLE 1. Descriptive information for Douglas-fir product recovery studies in Oregon and Washington.

Old Study ID	New Study ID	Location	State	Year	Num. of trees	Min. dbh (cm)	Mean dbh (cm)	Max. dbh (cm)	Min. Age (yr)	Mean Age (yr)	Max. Age (yr)	Min. Height (m)	Mean Height (m)	Max. Height (m)
01-72	18	Chelatchie	WA	1965	48	35.0	86.4	172.0	102	270	610	21.9	44.8	78.6
01-73	19	Mapleton	OR	1965	88	30.5	81.3	143.5	58	140	317	22.5	46.6	74.7
01-74	20	Darrington	WA	1965	22	37.1	96.5	187.7	46	220	530	36.3	50.0	63.7
01-77	23	Shelton	WA	1965	204	34.5	88.9	225.5	29	**315**	647	26.8	48.8	84.1
01-78	25	Medford	OR	1966	114	26.9	91.4	179.8	75	234	576	21.9	45.4	71.0
01-82	27	Portland	OR	1966	111	27.2	86.4	201.4	60	189	400	25.3	47.2	82.3
01-83	30	Culp Creek	OR	1967	121	25.9	99.1	187.2	87	234	394	21.9	49.4	67.4
01-84	35	Redmond	OR	1968	155	30.0	81.3	126.7	106	244	550	27.1	39.3	53.3
01-08	101	Noti	OR	1982	126	50.8	94.0	143.8	53	217	480	39.3	48.5	75.6
01-09	102	Mapleton	OR	1982	114	23.4	50.8	81.3	52	105	256	4.0	35.7	57.3
01-14	118	Shelton	WA	1987	235	22.9	43.2	74.0	25	45	88	7.3	30.5	49.1
01-18	143	Mill City	OR/WA	1995	151	19.3	35.6	56.6	20	44	90	14.0	29.0	41.8
01-22	154	Pack Forest	WA	1998	46	14.2	33.0	53.3	76	76	76	21.3	29.6	37.8

TABLE 2. Product value classes based on combined lumber grade composition (WWPA 1998; Barbour et al. 2005).

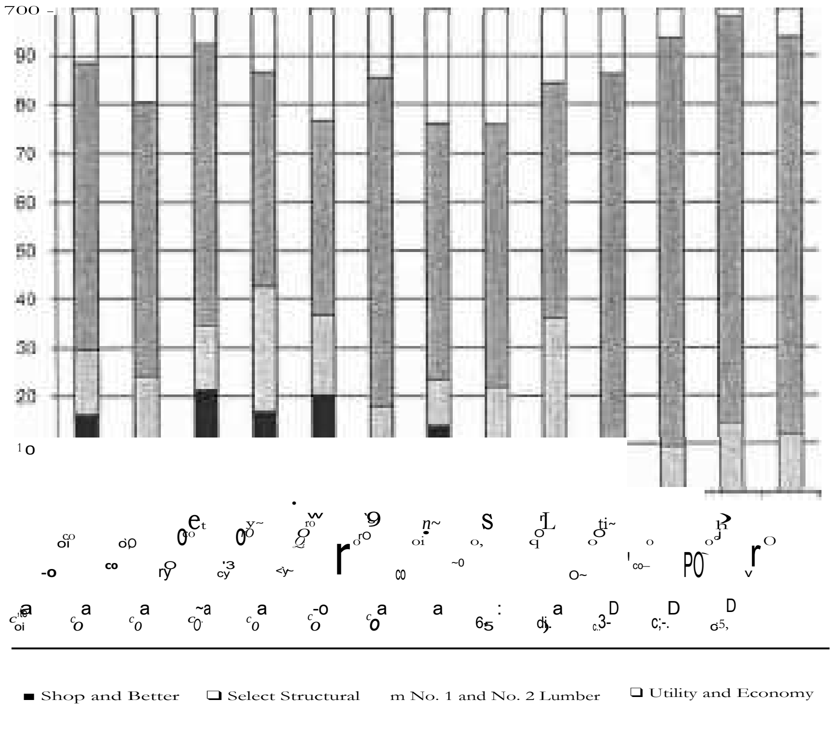
1. Appearance (Shop & Better)	2. Select Structural	3. General Construction (No. 1 & No. 2 Lumber)	4. Utility and Economy
B + Better Select	Export Select	Number 1	Utility
B Select	Structural	1 Common	Utility Stud
Supreme	Select Structural	2 & Better Common	Utility
C + Better Select	Select Stud	Export Standard	5 Common
C Select	Export Construction	Common	Economy
D & Better Select	2100 F	1650 F	1 x 2 Inch Side Cuts
Select	L-1	Standard & Better	4 Inch All Lengths Sf
Clear	Laminating Stock	Number 2 & Better	8 Inch 16-18 Ft Sc
D Select	Shop Out	1650 F Stud	Economy
Premium	Construction	1450 F	Economy Stud
Export Clear	L-2	Standard	Rip Stud
3 Clear	L-3	Number 2	Skip
Moulding & Better		1200 F	Mill Run
Moulding		Frame	Pallet Stock
Factory Select		2 Common	
1 Shop		Select Merchantable	
Pitch Select		Construction	
Stained Select		Standard	
2 Shop		3 & Better Common	
3 Shop		3 Common	
Stained Shop		Number 3	
Finger Joint		Pet Stud	
		88 Pet Stud	
		92 Pet Stud	
		8 Ft Stud	
		Stud	
		4-7" Stud	
		Utility & Better	
		900 F	
		4 Common	

grouped into these four product value classes. Totals by class are then converted to proportions (based on volume) for each study (Figure 1).

Analysis

Because we are working with data from several independent studies conducted over a period of four decades, we are limited in our choice of predictor variables to those in common to all 13 studies. Diameter at breast height (dbh), height, and age are available for each tree. We then look to the relation between these variables and the proportion of each of the four product value classes. Because we are working with proportions, they must sum to one and be bounded between zero and one. The multinomial logistic model is a logical choice to estimate the yield proportion of each value class because it satisfies both of these conditions,

FIGURE 1. The mean proportion of value products for each study.



is well-behaved, and requires few limiting statistical assumptions (Teeter and Zhou, 1999). An alternate approach, the ordered probit, was used by Prestemon (1998) to predict tree grades. The basic multinomial logistic model can be expresses as (Maddala, 1983):

$$P_j = \frac{\exp(B_j X)}{1 + \sum_{k=1}^{m-1} \exp(B_k X)} \qquad j = 1,2 \ldots m-1 \qquad (1)$$

$$P_m = \frac{1}{1 + \sum_{k=1}^{m-1} \exp(B_k X)} \qquad (2)$$

where P_l is the proportion of product class j across the nt = 4 products classes, X is the matrix of explanatory variables, B_l is the vector of parameters associated with product class j. Thus, the denominator is the same sum of exponentials for all to = 4 classes. The numerator in each equation is class-specific, with the numerator equal to unity in the final reference class.

The model was estimated by using multinomial logistic regression (Maddala, 1983). We used the logistic procedure of the SAS Institute (1999). The parameters of the proportion functions are estimated by using the fourth group (Utility and Economy) as the arbitrary reference category.

RESULTS

Maximum likelihood estimates were obtained for these multinomial logistic models. Because of the high correlation (0.82) between height and dbh, only dbh was significant when both were used in the same model. Thus, dbh and age remained as the predictor variables in X. In all cases dbh and age are all highly significant (beyond the a. = 0.01 level). Furthermore, their interaction (dbh · age) was also significant. In addition, the four product-specific estimates for a specific variable (dbh, age) are significantly different from each other (Table 3). The corresponding multinomial family of functions is:

$$P_1 = \frac{e^{-1.6584+0.1)0687\ dbh + 0.00213\ age + 0.00000372\ dbh\ age}}{D}$$

$$P2 \quad \frac{4467-0.0247\ dbh - 0.00205\ age + 0.000017\ dbh \cdot age}{D}$$

$$P_3 \quad \frac{4.2004-0.0257\ dbh - 0.0073\ age + 0.000044\ dbh\ age}{D}$$

$$P4 \ \frac{-}{D}$$

where the denominator D is one plus the sum of the first three numerators:

$$D = 1 + e^{-1.6584+0.00689\,dbh+0.00213\,age+0.00000372\,dbh\ u\ e} + e^{2.4467-0.0247\,dbh-0.00205\,age+0.000017\,rlbl\cdot age} + e^{42004-0.0257\,dbh-0.0073\,age+0.000044\,dbh\,age}$$

and where P_1, P_2, P_3 and P_4 are the proportions of Shop and Better, Select Structural, Construction No. 1 and No. 2 lumber, and Utility and Economy, respectively (Table 3). The sum of these fora- proportions is equal to one.

The odds ratio estimates are listed in Table 4 along with the 95% confidence intervals (see Allison, 1999). With a 5 cm dbh increase, the odds or probability of getting Shop and Better lumber will increase 3.5%, while the odds of Select Structural and No. 1 and No. 2 lumber will decrease by 12%. With a 10-yr increase in age, the odds or probability of getting Shop and Better lumber will increase 2%, while the odds of Select Structural and Construction (No. 1 and No. 2) lumber will decrease by 2% and 7%, respectively. Table 4 indicates that the interaction term has little effect, on average, with an odds ratio of 0.2% or less. The linear hypothesis test for estimated coefficients (Ho: L13 = c), including

TABLE 3. Multinomial logistic parameter estimates of Douglas-fir in Pacific Northwest region.

Parameters	Category (vafue class)		
	Shop and Better	Select Structural	No. 1 & No. 2 Lumber
Intercept	-1.6584	2.4467	4.2004
Dbh (cm)	0.00687	-0.0247	-0.0257
Age (yr)	0.00213	-0.00205	-0.0073
Dbh`Age	0.00000372	0.000017	0.000044

TABLE 4. Odds ratio estimates and the 95% confidence limits.

Effect	Group	Unit	Estimates	Lower Limit	Upper Limit
Dbh	1 (Shop & Better)	5 cm	1.035	1.034	1.036
Dbh	2 (Select Structural)	5	0.884	0.883	0.885
Dbh	3 (No. 1 & No. 2 Lumber)	5	0.880	0.879	0.880
Age	1 (Shop & Better)	10-year	1.021	1.020	1.023
Age	2 (Select Structural)	10	0.980	0.979	0.981
Age	3 (No. 1 & No. 2 Lumber)	10	0.930	0.929	0.930
Dbh"Age	1 (Shop & Better)	50 cm-year	1.000	1.000	1.000
Dbh"Age	2 (Select Structural)	50	1.001	1.001	1.001
Dbh"Age	3 (No. 1 & No. 2 Lumber)	50	1.002	1.002	1.002

slope parameters for dbh, age, their interaction (dbh-age), and the intercept parameters, also show significant differences among equations.

Figure 2 shows the change in the relative proportions with respect to age, while holding dbh constant at 50 cm (Figure 2a) and 100 cm (Figure 2b). Figure 3 shows the change in the relative proportions with respect to dbh, while holding age constant at 70 years (Figure 3a) and 150 years (Figure 3b).

FIGURE 2a. Douglas-fir product proportions by age at dbh = 50 cm.

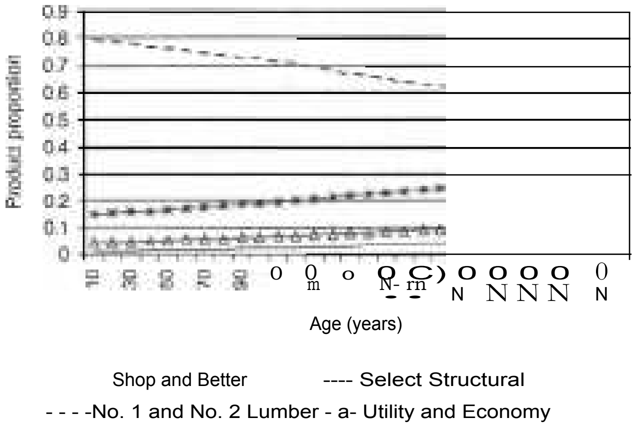


FIGURE 2b. Douglas-fir product proportions by age at dbh = 100 cm.

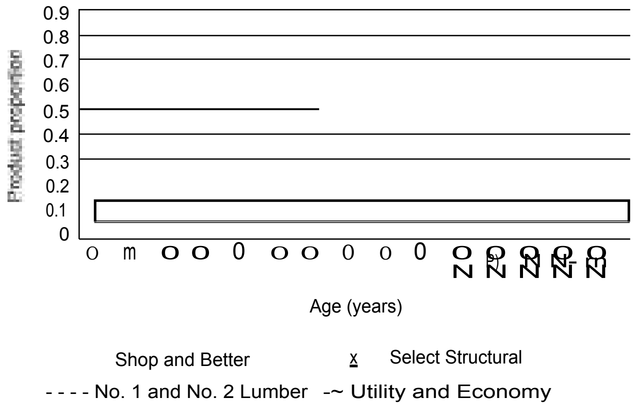


FIGURE 3a. Douglas-fir product proportions by dbh at age = 70.

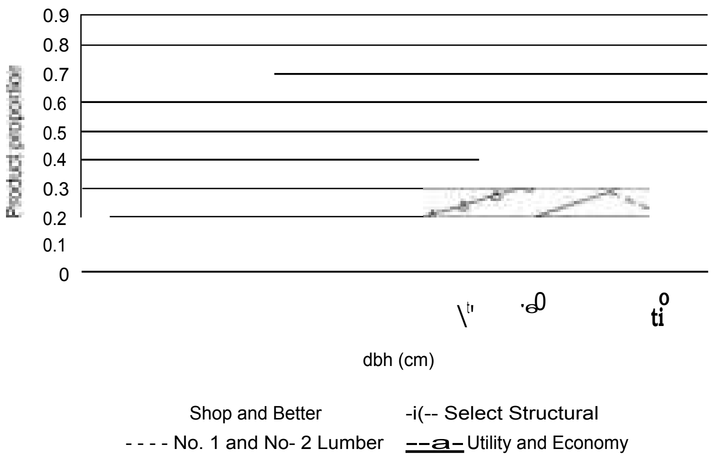
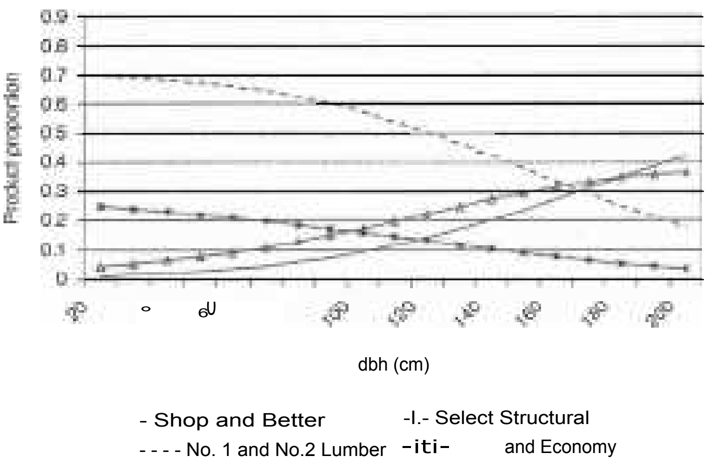


FIGURE 3b. Douglas-fir product proportions by dbh at age = 150.



DISCUSSION

The dominant feature of Figure 2 (holding dbh constant) is that Construction lumber (mostly No. t and No. 2 grades) dominates the three other value classes regardless of age, with the proportion of the total between 0.5 and 0.8. This simply reflects the well-known suitability and desirability of Douglas-fir as a construction material. The second feature is that the Construction proportion declines as the resource ages. With dbh fixed at 50 cm (Figure 2a), the proportion of Select Structural ranges from 0.15 to 0.3 of the total. With dbh fixed at 100 cm (Figure 2b), the proportion of the three non-Construction classes is nearly the same, with a slightly positive slope that ranges from 0.1 to 0.2 of the total. The Construction proportion ranges from 0.7 to 0.45 as age increases. A dbh of 40 to 50 cm approximates today's mean dbh at harvest, whereas a mean diameter of 100 cm reflects the past harvest sizes in studies from the 1960s (see Table 1).

Figure 3 (holding age constant) tells a more complex story. In Figure 3a, age is held at a 70-year harvest age. Although we show model behavior over the full range of diameters, only the left half of the graph is realistic; the cross of class proportions near dbh 170 cm is not reachable in 70 years. Below diameters 90 cm, we again see Construction grades dominating, with proportions between 0.8 and 0.7. In this range of diameters, Select Structural is also declining slightly (ranging from 0.20 to 0.15), while the remaining two classes increase slightly.

Figure 3b (age = 150 yrs) corresponds more to practices in the past (e.g., the 1960s), when very large old-growth trees were both plentiful and frequently harvested. This resource was characterized by narrow rings and clear boles, resulting in high wood quality that often produced a premium price over lumber from other regions (I Iaynes, 2005). The full range of diameters up to 200 cm is adequately represented in the numerous studies that we used from the 1960s (Table 1). Again we see the dominance of the Construction grades, but past a diameter of 170 cm its proportion of the total is passed by the highest quality products (Shop and Better) and also by the lowest quality class (Utility and Economy). These large, old trees had both high-quality clear wood and considerable defect in abundance. At this point we have three different value classes, each constituting one-third of the product mix. Note also the decline in the proportion of Select Structural as dbh increases, in both Figure 3a and 3b. Because of the decreasing age and dbh of harvested trees from the 1960s to the 1990s, the proportion of the highest value group (Shop and Better) is diminished, while more Select Structural and Construction products were produced. This is akin to reacting Figure 3b from right to left.

We compared the current multinomial logistic model with a dbh•age interaction to one without the interaction. In addition to the interaction term being significant, both Akaike's information criterion (AIC) and the Bayesian information criterion (BIC) were lower (i.e., more desirable; see Allison, 1999) for the model with the interaction term than the model without it. When comparing graphs of the two models (e.g., Figure 2 or Figure 3), we found that the interaction term had the most effect in the extremes, and none near the mean. The odds ratios also bear this out (Table 4). With the interaction term included, the proportion in the Construction class was higher at young ages and small diameters (0.80 vs. 0.75) and lower at advanced ages and large diameters (0.20 vs. 0.25) than the model with no interaction. Thus, the relatively constant proportion for the Construction class is nearly 0.80 in Figures 6 and 7 instead of 0.75 without the interaction term.

Looking to the Future

Current forest conditions in the Douglas-fir region are a function of both markets for various forest products and various regulatory actions, both past and current (Haynes, 2005). Because of the long time horizons common in wood production, current management is always geared to expectations of future market conditions. Haynes (2005) pointed out that the 20% price premium for Douglas-fir stumpage relative to southern pines and other regions has largely disappeared, primarily owing to the loss of the export market. The resultant focus on the domestic market shifts the emphasis to commodity grades such as Construction (No. 1 and No. 2), where no price premium exists (Haynes and Fight, 2004). Haynes (2005) found that the implication of these changes is that market incentives will favor the transition to managed stands that produce relatively uniform logs (both quality and size) with reduced market opportunities for logs that do not conform to processing standards (e.g., logs greater than 60-cm diameter). Zhou et al. (2005) expect that the mode of the age-class distribution of Douglas-fir removals will continue to decline over the next 50 years (Figure 4), to age 60 in 2020 and age 50 in 2040; currently there are two peaks, at age 60 and age 110. Based on the fifth Forest and Rangeland Renewable Resource Planning Act timber assessment (Haynes, 2003), the projection of future removals in the Douglas-fir region tends toward younger and smaller trees. The projected relative proportions among the four product value classes is not expected to change much over current proportions, with Construction lumber a dominant 70% of the total (Figure 5, which is from Zhou et aI., 2005).

Implications of this expected trend to smaller and younger stands are clear. The relations graphed in the left third of both Figures 2a and 3a

FIGURE 4. Projected age class distribution of Douglas-fir removals for all ownerships (RPA 2000 base case projection) from using data from Zhou et al. (2005).

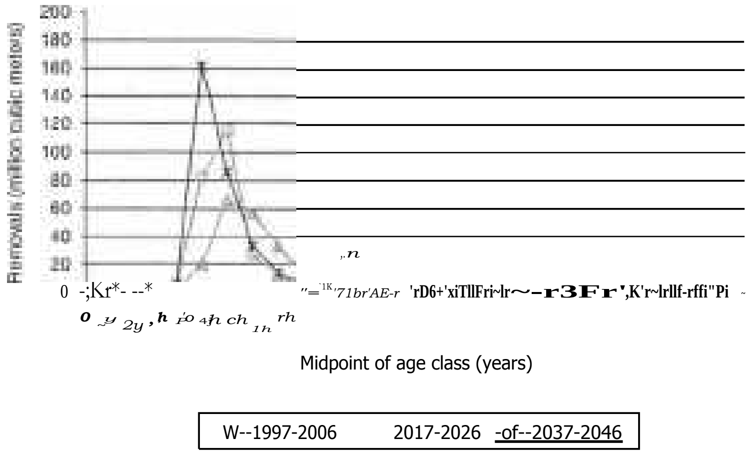
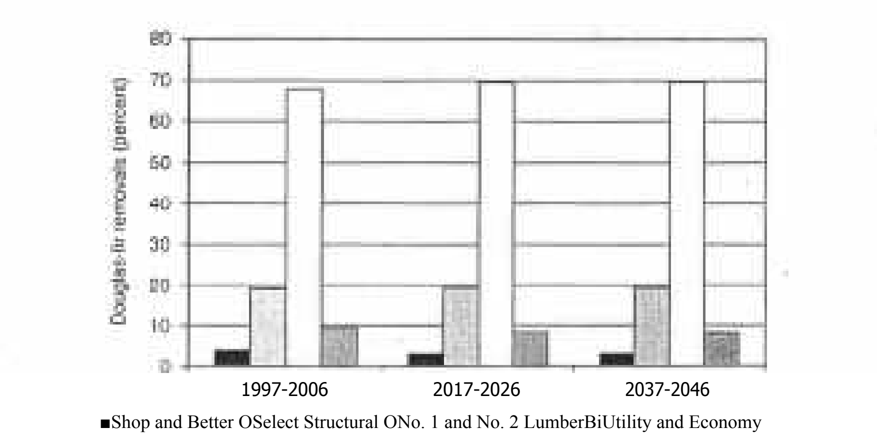
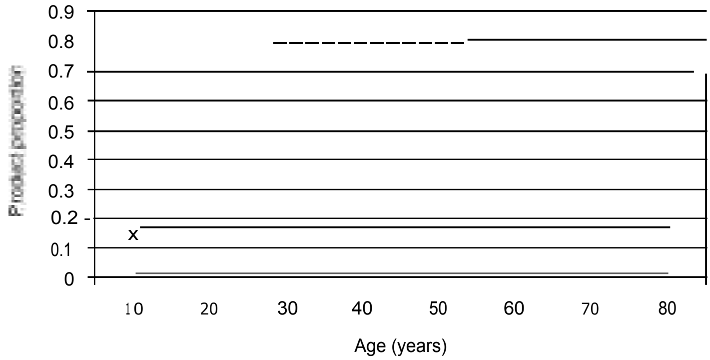


FIGURE 5. Projected percentage of each value class from Douglas-fir removals by period, all ownerships.



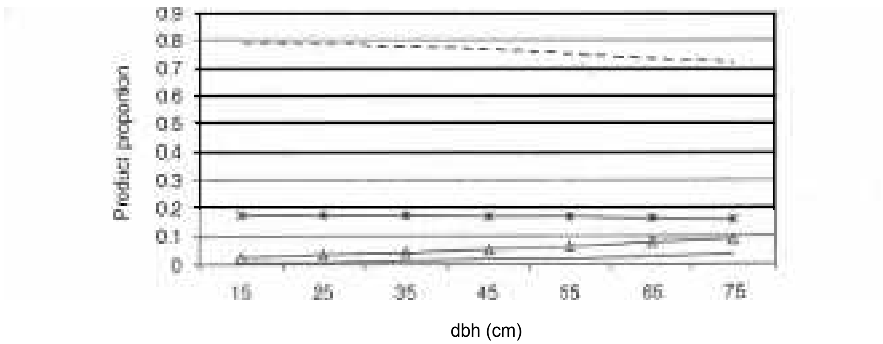
are relevant, whereas the right two-thirds of these same figures are not. Likewise, the very large diameters and advanced ages assumed in Figures 2b and 3b will not be relevant. To this end, we offer Figure 6 (product proportions by age at dbh = 40 cm) and Figure 7 (product proportions by dbh at age = 50). The much smaller range of ages and diam-

FIGURE 6. Douglas-fir product proportions by age at dbh = 40 cm.



Shop and Better * Select Structural
- - - - No. 1 and No. 2 Lumber -A-Utility and Economy

FIGURE 7. Douglas-fir product proportions by dbh at age = 50.



Shop and Better * Select Structural
- - - -No. 1 and No. 2 Lumber -A- Utility and Economy

eters illustrated in Figures 6 and 7 correspond more closely with the shorter rotations expected on nonfederal land in the future. We expect that the mix of product classes will be dominated by Construction grade lumber (mostly No. I and No. 2 grades), with the proportion of the total between 0.7 and 0.8. The second largest class will be Select Structural, with a proportion of the total near 0.2.

Basically, the shift away from the highest quality visual grades has already occurred, with the proportion of Appearance Shop and Better grades being only 0.05 of the total. This means that as the industry continues the shift to harvesting and processing smaller, younger trees, little change in visual lumber grade yield should be expected (Zhou et al., 2005). Additional evidence of this shift to Construction grades and away from Appearance grades from the 1960s through the late 1980s is documented by Warren (1991, 2003). In recent years, the industry summaries reported by Warren (2003) have leveled off to a new equilibrium where very little appearance-grade lumber is manufactured in the Douglas-fir region, and the bulk of the production is in the general construction lumber category. This is typical of young, vigorous stands of managed timber where defects are minimal and branch size is controlled by early spacing (Barbour et al., 2005).

Wood quality implications are not so clear. As harvested trees become younger, the proportion of juvenile wood (e.g., the inner core up to age 20) will increase. Knots will also become more prominent in the resulting mix of boards, for less time will be available for trees to produce clear wood after shedding lower branches. Overall, these effects could result in a reduction in mechanical wood properties, especially regarding the suitability of this material for engineered wood products. Barbour et al. (2003) compared yields of machine stress-rated lumber from Douglas-fir in the 40-to-60-year age class and trees in the 40-and-under age class. They found a major drop in the yield of higher stress ratings of mechanically graded lumber. This result suggests that although manufacturers will be able to produce lumber with acceptable visual characteristics from a resource less than 40 years old, the lumber might not have mechanical properties that meet the requirements of the higher grades (Zhou et al., 2005). Because of the great genetic variability among Douglas-fir populations, this potential problem could possibly be ameliorated through genetic selection of planting stock (Vargas-Hernandez and Adams, 1991, 1992; Vargas-Hernandez et at., 1994; Barbour and Marshall, 2002; Rozenberg et al., 2001).

Adams and Latta (2005) examined future timber harvest potential from private lands in the Pacific Northwest. They suggested that private lands in the Pacific Northwest should be able to sustain at least recent historical harvest Ievels over the next 50 or more years, given unchanged policies and the anticipated levels of private management investment. They consider that these harvests could be realized with stable to rising inventories-growth would be at least as large as harvest. Accompanying such a trend, Adams and Latta (2005) expect continued concentration of industrial lands in younger age and smaller size classes and a continued decline in the average age and size of timber harvested. They suggested that shifts toward more intensive management regimes will be gradual, relatively limited, and have a relatively minor impact on harvest potential over the next 50 years. They do not anticipate a wave of intensive forest plantations with genetically modified trees managed on short rotations.

Alig (2005) examined the dynamic effect of land use changes on sustainable forestry in the Pacific Northwest. This will affect the region's progress toward sustainability at the same time that population is expected to increase. The United States is expected to add around 120 million people, an additional 40 percent, to its population in the next 50 years. The Pacific Northwest is expected to experience above-average population growth, including immigration from other regions. This will likely intensify land use pressures (Alig, 2005), especially in the forest-urban interface. In the most recent national comprehensive survey, the rate of conversion of rural land to developed land increased, with forest land the largest source (Alig, 2005). As populations in the national and regional landscapes increase, so too will their effect on sustainability options for agriculture, forestry, residential communities, biodiversity, and other land-based goods and services.

Haynes (2005) examined the role of markets and prices in providing incentive for sustainable forest management. His market analysis concluded that the majority of timberland will be lightly managed, while a small minority of acres will be heavily (or actively) managed on relatively short rotations. The net effect is that prices, although not a barrier, will not provide a strong incentive to intensify timber management by many landowners. Put another way, relatively stable price expectations are necessary for intensive timber management but not necessarily a sufficient condition for sustainable timber management (Haynes, 2005).

Regarding implications for the future (see Figures 4 and 5), the future is already here. The transition from an old-growth lumber economy with large premiums (Haynes, 2005) to dominance of Construction-grade products has been completed. The younger and smaller material harvested today (and expected in the future) is dominated by Construction-grade products. Even if future harvest ages were doubled to 100 years, relative proportions predicted by our multinomial model show little change from the current proportions illustrated in Figures 6 and 7.

It is tempting to generalize to other regions in the world. Although France (e.g., Rozenberg et al., 2001) and New Zealand have large areas of managed Douglas-fir, the species is an introduced exotic, and thus conversion from an old-growth Douglas-fir economy does not apply, although conversion from a native hardwood economy in New Zealand does. Coastal British Columbia is also experiencing a shift in forest management away from a dependence on clearcutting old-growth (Forest Practices Code of British Columbia, 1994; Clayoquot Scientific Panel, 1995), although this northern region is mostly outside the range of coastal Douglas-fir. Perhaps the southeastern United States is also a possible analogue *(scuts* Douglas-fir), for this large region has experienced a broad conversion from natural southern pines to planted southern pines such as loblolly pine *(Pines taeda* L.) (Haynes, 2003). In the end, our large historical product recovery database is unique in allowing us to examine product changes over time.

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