LOG GRADING TO MATCH FOREST RESOURCES WITH CUSTOMER NEEDS

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ABSTRACT

If log grades are to match forest resources and customer needs, some important questions should be answered. First is the purpose of log grading. Log grades can be designed to serve various purposes but it is assumed that the principal purpose is to form a basis for market transactions between a log seller and buyer. This leads to questions of what consumer markets will be served and what kinds of forests will supply raw material. It is concluded that future markets will be increasingly global and the diversity of consumer demands on wood quality will grow. Forests supplying raw material for these products will be plantations subject to much more intense silvicultural planning and control. On the basis of these conclusions, tree and log characteristics that are influenced by silviculture and which affect quality and value of products are discussed. This leads to a review of log grades and product recovery methods that have been used to estimate log value. Mill studies of old-growth and unmanaged regrowth have been the basis for developing log grades and recovery information and are deficient for intensively managed forests. New valuation and grading systems will be needed and new approaches, such as computer simulated recovery, will be more timely and flexible in developing them. Finally, the implications of these changes for log bucking are discussed.

INTRODUCTION

In developing this paper, it is assumed that the issue of effectiveness of log grading in matching forest resources with customer needs is primarily a concern regarding <u>future</u> forest resources and <u>future</u> customer needs. In viewing the subject this way, six questions arose:

1. *What function will log grading serve?*

2. *What product markets will be served in the future?*

3. *What kinds of forests will supply trees and logs in the future?*

4. *What tree and log characteristics determine the quality and value of products?*

5. *What methods can be used to assess and monitor these characteristics?*

6. *What are the implications for log bucking?*

The objective of this paper is to comment on these questions. Since my main experience is with the US and, particularly, the Pacific Northwest, my comments may have that region's bias. However, it is hoped that the main elements of the discussion are applicable elsewhere.

WHAT FUNCTION WILL LOG GRADING SERVE?

Log grading is the process of grouping logs into classes or grades that reflect characteristics of quality or potential product value. Grades can be designed for various purposes such as separating logs into major use classes, establishing merchantability standards, or forming the basis for tree grades, but I assume that the main purpose is to form a basis for transactions between log seller and log buyer. The term "potential product value" is used to reflect the fact that a log grade is only a predictor of the recovered value. Actual value may differ due to characteristics that could not be observed by the grader or which were important to the product but not taken into consideration by the grading rule.

Before continuing, it may be useful to define quality since this term is part of the definition of log grading. Quality is "fitness for use" (Montgomery 1991). This definition has many aspects such as attributes of the raw material, manufacturing attributes such as meeting size tolerances, sensory attributes such as color and odor, time related attributes such as product reliability and longevity, and market service attributes such as on-time delivery and packaging according to customer need. While this paper focuses on raw material attributes, the importance of product performance from the perspective of the user cannot be overemphasized. Your log customer may be just as concerned about having logs cut to length and diameter specifications as he is about knots, rings/inch, etc. The log consumer will convert the log to other products and this suggests that the product he intends to produce defines the type of log he wants.

Grades and product standards must be dynamic and adapt to changing needs of the consumer. If they do not adjust, they become ineffective. A common problem associated with systems of grades and specifications for logs or other products is the tendency for producers to develop a mentality in which they produce to the grade and specification and lose contact with the customer and his changing quality needs. The result is a producer who is perplexed by increasing consumer complaints about quality.

A log grading system will be effective only if it satisfies both seller and buyer. From the perspective of a land manager or log seller, a log grading system is effective if it improves the average selling price compared to selling on a woods-run basis. From the perspective of a log buyer, a grading system is effective if it allows procurement of only those logs best suited to his need. It is less expensive than purchasing woods-run logs since costs of handling, reselling or otherwise disposing of undesirable logs is avoided. An effective grading system should also provide a sound basis for comparing value when a log may be allocated to alternative processes. Finally, a grading system must be reasonably simple and practical to apply.

WHAT PRODUCT MARKETS WILL BE SERVED IN THE FUTURE?

Market forecasting is complex but must be confronted since consumer demands are the reason why trees are being grown to produce wood products and end-use performance is the reason why wood quality is a concern. The trend toward globalization of markets will continue (Haynes 1990) and this will present a challenging opportunity as the variety of products demanded, measurement systems involved and consumer preferences for quality become more diverse.

Some may believe that future markets will be satisfied and taken over by new technologies which reduce wood to chips and fibers that are reconstituted into products that replace traditional wood products. In this view, wood quality is assumed to become irrelevant. History and market forecasts do not support this view. In the US, lumber lost the home sheathing market to plywood which in turn is losing it to oriented-strand-board. However, lumber use did not decline or disappear. While the rate of growth declined, lumber consumption remained essentially constant as other uses such as pallets and engineered products were discovered. In the future, lumber consumption is expected to increase (Haynes 1990).

Even in products that have been reconstituted from chips and fiber, wood quality factors remain important (Wasniewski 1989). Rather than eliminate wood quality concerns, reconstitution shifts the emphasis from gross wood qualities (eg. knots, ring width, juvenile versus mature wood, etc.) to more fundamental qualities (eg. fiber dimensions, microfibril angle, wood density). Mixing chips or fiber from earlywood, latewood, juvenile wood, mature wood, and reaction wood as well as mixing species creates a host of different wood quality issues. Log grades may need redefinition to take into account shifts in emphasis among characteristics as consumer demands and technology change.

WHAT KINDS OF FORESTS WILL SUPPLY TREES AND LOGS IN THE FUTURE?

Young plantations, the result of intensive silviculture, are rapidly developing in many regions of the world and logs from these sources will increasingly replace supplies from unmanaged or natural forests. During intensive silviculture, selection of planting stock, initial spacing, thinning and weeding, fertilizing, pruning and harvest age are carefully analyzed and controlled. A key change in the transition to these forests is a shift in how quality and value are affected. In naturally developing forests, quality and value tend to change with time or tree age. Since tree size increases with age, many log grading and valuation systems were developed that depend on diameter.

All of this changes with intensive silviculture. Within broad limits, there are many ways to create logs of the same size which differ greatly in quality and value. Log grading systems may need redefinition to take into account the range of effects that silvicultural action can create. A good example is pruning.

WHAT TREE AND LOG CHARACTERISTICS DETERMINE THE QUALITY AND VALUE OF PRODUCTS?

Characteristics that will influence quality in the future are the same ones that inluence quality now. The key change is the shift from obtaining these characteristics as a result of Nature's whims in unmanaged forests to the use of silviculture in plantations where they will be subject to greater control and manipulation. Some determinants of quality and value that can be controlled by silviculture are:

Geometry

Diameter is manipulated by factors affecting growth rate and the harvest age decision. Recovery efficiency of lumber and veneer are affected by diameter. Further, in some structural lumber grading systems, there is an interaction between piece size and allowable knot size; in a given grade, wider pieces tolerate larger knots. Allowing trees to get to a larger diameter so they yield larger pieces may improve the grade mix of lumber obtained.

Taper tends to be greater in trees from open, rapid growing stands with fuller crowns. Taper influences product recovery efficiency and high taper may increase diagonal grain that degrades strength and appearance values of products.

Sweep, crook, and eccentricity reduce recovery efficiency and are indicators of the presence of reaction wood which reduces strength and causes shrinkage problems. Early stand treatments can select against stems developing these characteristics.

Quality

Knots, including both the actual branch wood and the distorted grain around it, have a major effect on value for structural, appearance and remanufacture uses. Knot size can be influenced by manipulating stand growth and crown recession. Live branches tend to increase diameter growth and persist longer following growth promoting treatments. Pruning can eliminate knots but sufficient time must be allowed for healover and growth of a shell capable of yielding adequate quantities of clear products.

Juvenile wood, composed of the rings surrounding the pith, is the result of wood formation processes within the live crown. Wood properties near the pith are generally poor but gradually improve through the juvenile zone which may last for 5 to 20 or more rings depending on species and property of interest. Outside these juvenile rings, properties stabilize in what is referred to as mature wood. Manipulating rotation age and growth rates during the juvenile and mature period of lower stem logs affects the percentage of juvenile volume a tree or log.

Wood density or specific gravity indicates the relative amount of wood substance in a unit volume and is associated with strength, machinability, and other properties. It is determined by the relative amount large diameter, thin walled cells in earlywood compared to narrow diameter, thick walled cells in latewood. It is correlated with ring position or age because crown processes affect the cells of earlywood and latewood during formation of juvenile and mature wood. In species such as Douglas-fir and loblolly pine, juvenile wood has a low density since relatively little latewood forms in juvenile wood rings and the latewood that does form in these rings is of low density (Megraw 1986). This is the rationale for using latewood percent in some grading rules as a crude visual means for identifying juvenile wood. Over wide limits, researchers have found that density is weakly correlated with growth rate if the confounding effect of age of ring formation is removed (Megraw 1986).

Sampling whole disks can lead to good regional models for predicting average wood density from log ring count (Megraw 1986, Briggs & Fight 1992). Nondestructive tests for density, stiffness, and strength exist for poles and piling are being evaluated for logs and trees (Ekstrom 1992, Pellerin 1992). Practical methods may develop to allow routine use of this approach for testing the strength potential of products from logs.

Diagonal grain, caused by high taper or other factors adversely affects performance in any load bearing situation whether it is a rafter or a chair leg. Silviculturists can directly manipulate taper and select against trees developing other causes of diagonal grain.

Rings per inch, or growth rate, is not a major determinant of density or strength in most products. Number of rings per inch, usually in combination with latewood percent, is used in structural lumber grading rules as a visual aid for identifying pieces with juvenile wood. The premise for this is that, in naturally grown trees, wide rings are normally found near the pith with narrower rings near the bark. This situation may not occur in plantations and may result in misclassification of structural lumber.

Rings per inch can be important in other situations. Wide rings may result in imbalances between the amount of earlywood and latewood present in some products. For example, veneer from wide ringed logs may have very wide zones of weak earlywood making it unsuitable for some applications. Wide rings may result in poorer machining quality of wood surfaces; an example is rough veneer from fast growth logs. Aesthetic tastes may prefer narrow rings in some products.

WHAT METHODS CAN BE USED TO ASSESS AND MONITOR THESE CHARACTERISTICS?

Log Grading

Log grades were commonly developed by studying the results of mill studies and attempting to define a classification system based on factors affecting product yield. Examples are the peeler/sawmill grading log grades of the Northwest Log Rules Advisory Group (1982), the factory log grades for hardwoods (Rast et al 1976), and the ponderosa pine log grades (Gaines 1962). The former has requirements that a log must yield a minimum fraction in a given lumber or veneer grade (Table 1). The latter two are linked to the cutting requirements of the lumber grades for hardwood factory lumber and pine shop lumber. Generally, most systems assign a tentative log grade based on diameter and then examine quality and yield aspects to determine if it remains qualified or drops to a lower grade.

As markets and resources change, grading systems must adapt. Suggestions have been made for improved grades in the Pacific Northwest (Lane et al 1973, Parry 1989). One question to be raised is whether the product mix used to develop these grades will be appropriate for the future. Also, existing and suggested log grades were developed for naturally grown stands, whether old-growth or regrowth, and are likely to be inappropriate for a resource developed from intensively cultured stands. The peeler/sawmill grading system (Table 1) of the Pacific Northwest was developed for old-growth and is still widely used with young-growth. The diameter and rings/inch requirements exclude most young-growth and plantation logs from the upper grades; most logs from these new sources fall into the No 2 and No 3 sawmill grades (Fahey 1980).

Product Yield and Value Equations

The usual method for establishing product value of timber has been to sample representative stands and conduct recovery studies in mills representing the products of interest. Regression models relate overall conversion efficiency and grade recovery to some combination of geometry and quality characteristics. These relationships can be derived for mill-length logs, long logs as bucked in the woods, or whole trees. They do not establish value in a monetary sense; rather, they only link recovery to geometry and quality features. A difficulty with these regressions is that the large variability in the timber and milling methods leads to relatively weak relationships (Husch et al 1972). However, recovery studies do indicate the relative importance of geometry and quality features and therefore help in developing log grading systems.

Mill study results can be easily combined with product prices and and used to develop models that predict product value. Two general methods are:

<u>1.) Smoothed Recovery Equations and Product Prices</u>

The conversion efficiency and grade recovery regressions developed from the mill studies are used to predict the quantity of products by grade in a log. These estimates, multiplied by the appropriate prices, are summed to estimate log value. This method is used to estimate the value of single logs in the TREEVAL model (Briggs 1989).

<u>2.) Actual Recovery and Product Prices</u>

Rather than smooth conversion efficiency and grade recovery by regression, the actual volumes of products from each log are multiplied by the appropriate price and summed to give the actual value of products obtained from that log. These log values are related by regression to log geometry and quality. This approach has been applied to a variety of species (Lane et al 1970, Snellgrove et al 1973, Fahey 1980, Plank 1981). In general, these aggregate value equations have better statistical properties than equations attempting to predict quantities of individual product grades. Most have been developed for predicting lumber value from old-growth and unmanaged young-growth logs. It is a simple step to aggregate results obtained for mill logs and develop regressions for long logs or whole trees.

Each of these methods can be based on indexed prices where one product grade is chosen as a base against which prices of all other grades are expressed in relative terms. The total indexed value for the log or tree is regressed on geometry and quality characteristics (Hanks 1976, Strub 1979, Ernst & Hann 1984).

These methods are becoming popular since modern computers make it easy to combine the recovery information with new prices and re-estimate the equations. These value methods give a continuum of value over the independent variables and it would be possible to divide the range into whatever value categories or grades are desired. In a sense, this is like machine stress rating of lumber where stiffness and strength criteria that define MSR lumber grades are chosen from the continuous relation between stiffness and strength. This method of defining grades permits flexibility in setting grade limits according to user needs. A problem in these valuation systems is the need to update as prices change, particularly when real prices of grades within a product or between products change. This can be viewed as a disadvantage or an advantage since one can readily assess sensitivity to price changes.

Unfortunately, little research of this form is available in the Pacific Northwest for intensively managed plantations. Fahey et al (1991) present recovery equations for lumber (visual and machine stress graded) and veneer logs from Douglas-fir trees selected to represent outcomes of intensive culture. Key variables are diameter, taper, juvenile wood percent and a knot index. Briggs & Fight (1992) have substituted these results into the TREEVAL model which helps silviculturists understand the economic impacts of cultural practices on product quality and value. SYLVER is a similar model developed for Douglas-fir in British Columbia (Mitchell et al 1989).

WHAT ARE THE IMPLICATIONS FOR LOG BUCKING ?

Log grades have more commonly been used by buckers than the product valuation methods since buckers lacked the time and suitable aids to perform the calculations. Advances in computing are rapidly changing this situation and field implementation of computer-optimized bucking has been successful (Olsen et al 1991). Optimal log bucking can done using either the log grade method or the product yield and value method. Stem geometry and quality information is used to determine log grade or product yield which together with prices and costs drive the bucking optimization at it seeks to find the combination of logs that maximize stem value. These bucking systems can readily handle multiple products (lumber, veneer, pulp, etc.).

Expanded use of computer-assisted bucking will depend on developing more efficient methods for gathering quality and geometry data from stems and advances in computers that can be used in the field. It is likely that we will witness many improvements in both of these areas in the future. It is probable that computing advances will be so fast that this is not a major concern. An example is the "wallet" size computer envisioned by Bill Gates of Microsoft (Gates 1993). Another challenging opportunity will be to incorporate computers, nondestructive testing, and bucking optimization software into new mechanized harvesting systems or log concentration yards.

DISCUSSION

Conventional log grading and valuation systems have the following deficiencies

1. Lack of flexibility to adjust to resource changes.

An example is the inability of the current Pacific Northwest log grades to adequately stratify the young growth resource. When young growth Douglas-fir is graded in the peeler/sawmill system, virtually all logs fall into number 2 and 3 sawmill grades; this is based almost solely on log diameter. With the PNW timber cruising grades, more than 95% of young growth volume is in grade 3 (Fahey 1980). Since logs with important differences in wood properties all fall within the broad limits of one or two grades, there has been a proliferation of proprietary grading systems. A good example is the J, K, and C sorts in the Pacific Northwest which grade export logs. Most logs in these sorts would be classified as No 2 Sawlogs in the peeler/sawmill grading system (Table 1).

2. Inability to address silvicultural manipulation.

The best example is pruning. None of the present systems provide a mechanism for classifying pruned logs. A major impediment to wide use of pruning may be uncertainty fostered by grading systems that fail to differentiate pruned logs so they can be marketed to reap returns on the clear wood. New Zealand has done the most work on devising log grading systems that consider pruning (Park 1989).

3. Failure to link to the end-user.

Existing grading systems, which are based on visual characteristics, do a poor job of differentiating logs according to actual wood properties required for an end-use. Two logs may be in the same grade yet one may be vastly superior in yield of lumber or veneer for high value structural and engineered products. Existing grades misallocate logs, either by placing a log with poor properties in a process in which the subsequent products are ill suited and must be disposed of at low value or, by placing a log with superior properties in a process where these properties are never taken advantage of and the high value potential is never realized.

There are solutions to these problems. Fostering better communication between foresters, wood processors and end users would help resolve problem 3. Developing better grading systems requires market research to understand which characteristics are critical to consumers and why. Scandinavian mills consult with final users, understand their needs, and translate these into product and log grades (Ekstrom 1992).

New mill studies, sampling trees representing the resource that will be harvested in the future, could also be conducted. Unfortunately, mill studies have shortcomings including the mill technology used, products produced, and grading system used. Extrapolation to any situation which differs from the original conditions is dangerous. For example, in structural lumber, there is an interaction between lumber piece size, size and location of knots, and grade determination. As lumber width increases, the size of acceptable knots increases in each grade. If a study is conducted in a mill that produces only 2x4 and 2x6 lumber, the grade mix obtained does not predict the grade mix of a mill that would cut larger sizes from the same logs. In addition to these problems and expense, it will be difficult to conduct mill studies when an adequate supply of trees and logs needed to fill out the sampling frame may not yet exist.

An alternative that can use a more limited database, exercise greater control over some of the variables influencing mill studies, and is flexible and easily replicated is to adopt the idea of "computer simulated" recovery. In this approach a detailed database of actual or hypothetical "glass" logs is linked with computer models that simulate manufacturing processes. These models provide flexibility in defining milling technology, product line, grading system and pricing. It is possible to systematically process the same batch of logs under many different sets of conditions, in effect allowing the computer to simulate mill studies conducted under different product and grading assumptions. In this fashion, resource, mill and economic factors can be separately controlled and analyzed. Limited mill studies are used to collect key data and verify model results. This approach is probably in its most advanced development in New Zealand and was used to develop a successful new grading system for pruned radiata pine logs (Park 1989).

A key element missing from these suggestions is the need to do a better job of predicting actual properties of the wood in trees and logs, rather than rely on geometry and quality characteristics observed on the surface of ends of logs. Nondestructive testing (NDT) has been investigated for logs, utility poles and piling (Pellerin 1992). NDT tests of logs can predict potential yield of structural products and are a promising method for sorting logs, perhaps integrated into future mechanized harvesting machinery. Further research may lead to a grading system in which logs can be initially classified according to their suitability for engineered versus non-engineered uses and then divided into additional subclasses.

CONCLUSION

In reexamining the questions posed in the introduction, conclusions are:

1. There is a need for awareness of the wood characteristics that are important in markets and where these markets are going in the future.

2. Future systems to predict log grading and product values will need to be tailored to forests that are more strongly influenced by silvicultural practices. Grading systems based on unmanaged forests where quality relationships are dominated by diameter (age) will be replaced by more dynamic systems in which several geometric and quality characteristics are combined.

3.) Research is needed to identify which characteristics will be most important in different markets and improve understanding of their silvicultural control. Methods to efficiently sample and measure these characteristics in logs and standing trees are needed. Further development of techniques such as nondestructive testing may provide new methods for measuring quality in the field.

4.) Most of the existing grading and valuation methods are based on mill studies which have limitations. Further, it may be impossible to conduct mill studies of stands representing future plantations because mature versions are currently lacking. Use of existing grading and valuation systems as logs from these plantation resources emerge may either ignore or improperly emphasize certain characteristics and lead to negative experiences and attitudes that will be difficult to overcome. Promising solutions are to focus on defining end-user requirements, nondestructive testing, and computer simulated recovery.

5.) Future log bucking systems will need to adapt to these changes. This is viewed as simply modifying existing bucking optimizers in terms of how information is used to arrive at decisions. Advancements in computing, nondestructive testing, and harvesting technologies will create opportunities for many innovations in how and where bucking is accomplished.

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Table 1. Pacific Northwest Peeler/Sawmill Log Grades for Douglas-fir

	Peeler 1	Peeler 2	Peeler 3	Sawmill 1	Sawmill 2	Sawmill 3	Sawmill 4	Special Mill	Utility
Min. gross diameter, in.	30	30	24	30	12	6	--	16	6
Min. gross length, ft.	17	17	17	16	12	12	--	17	12
Min net Scale: % of gross scale	50	50	50	33	33	33	33	50	50
volume, BF	-	-	-	-	60	50	10	-	-
Min rings/inch:	8	8	6	8	-	-	-	6	-
Clear Surface %:	90	75	-	90	-	-	-	-	-
Knot indicators:	A	A	B	A	C	C	C	B	C
Knots:	A	A	D	A	E	F	C	G	C
Product Yield:	H	I	J	K	L	M	M	N	O

Notes:
A = allowed in the non-clear region
B = ignore indicators 0.5" & smaller; indicators up to 1.5" allowed as long as occurrence is less than one per foot
C = unlimited
D = up to 2 knots allowed
E = allows sound, tight knots up to 2.5"
F = allows sound, tight knots up to 3"
G = ignore knots 0.5" & smaller; knots up to 1.5" allowed as long as occurrence is less than one per foot. Two larger knots are allowed if the required product recovery is met.
H = minimum 50% net scale as clear uniform veneer
I = minimum 35% net scale as clear uniform veneer
J = 100% net scale as corestock or better veneer
K = minimum 50% net scale as B & Btr lumber
L = minimum 65% net scale as Const. & Btr lumber or 25% net scale as B & Btr lumber
M = minimum 33% gross scale as Std & Btr lumber
N = minimum 65% net scale as Select Merch & Btr lumber or 100% net scale as corestock & better veneer
O = 100% net scale chippable

For further details see (Northwest Log Rules Advisory Group 1982)