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SENSITIVITY OF ALLOWABLE CUTS TO INTENSIVE MANAGEMENT

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ABSTRACT

A sensitivity analysis of allowable cuts on two BLM master units shows that even-flow allowable cuts depend primarily on:

(1) assumed long-term growth potential,
(2) period that growth increases must be cumulated before they can be removed from the stands on which they occur, and
(3) amount and age-class distribution of the initial inventory.

Current allowable cut levels respond relatively more to changes in long-term growth where:

(1) the initial inventory is higher,
(2) the age classes are more evenly distributed,
(3) the growth increases can be cut sooner from the stands on which they occur, and
(4) growth increases are smaller in proportion to the allowable cut.

Current allowable cut levels respond relatively more to changes in inventory or short-term growth where:

(1) the initial inventory is lower, and
(2) the inventory is less evenly distributed.

Although these results apply to even-flow allowable cuts, they should be regarded as rough approximations when applied to allowable cuts with less restrictive periodic flow constraints. .

KEYWORDS: Allowable cut, management (forest).

CONTENTS

INTRODUCTION

The Bureau of Land Management (1970), the U.S. Forest Service,[1] and at least one major State forest management agency (Chambers and Pierson 1973) have all adopted some variant of even flow of timber volume as the basis for their timber harvesting programs. Constraints on the relation of harvests between time periods have a great impact on the timing and magnitude of benefits that result from other decisions such as growth-stimulating investments and changes in the land base devoted to timber production. Therefore, these and other agencies or firms for whom some variant of even flow is a possible policy, need answers to the following questions:

1. How will the allowable cut be changed by growth-stimulating treatments? Will the change in allowable cut equal the change in annual growth attributable to the treatment?
2. Will the cut continue to change in proportion to changes in annual growth as these successive changes are made?
3. How are answers to these questions affected by the volume and age-class distribution of initial inventory?

Others have argued the merits of even flow (Waggener 1969, Keane 1972) and the appropriate use of the change in allowable cut in making investment decisions (Schweitzer, Sassaman, and Schallau 1972; Teeguarden 1973; Schweitzer, Sassaman, and Schallau 1973; and Lundgren 1973). We make no judgment in our paper about either issue. We simply believe that because several important public forest management agencies are committed to this type of regulation model, it is important to understand its implications, regardless of the specific way in which this information is used.

Partial answers to the above questions are available as the result of extensive sensitivity testing of allowable cut levels for two Bureau of Land Management (BLM) management units.[2] These tests were made, using the SIMAC model (Sassaman, Holt, and Bergsvik 1972) to determine the impact on allowable cut of various changes in management intensity, area base, and units of measure.

However, an even-flow allowable cut model can be viewed as one end of a continuum of models with constraints on the relation of harvests between time periods. Therefore, although we may make quantitative estimates of the importance of various assumptions, we may be safe only in specifying the direction of change when generalizing to allowable cut models with less restrictive periodic flow constraints.

THE DATA BASE

The two forests selected for analysis are the 100,000-acre Columbia and Alsea-Rickreall Master Units of the Bureau of Land Management in western Oregon. While these forests are quite similar in estimated productive potential, they differ markedly in present age-class distributions and standing volumes of timber. The Columbia contains slightly more than 3 billion board feet of standing timber with only a minor old-growth component; the Alsea-Rickreall has nearly 4-1/2 billion board feet with approximately one-fourth over 100 years of age.[3]

[1] USDA Forest Service, Emergency Directive No. 16 (F.S. Manual; Chapter 2410, Timber Management Plans), May 1, 1973.

[2] Dennis L. Schweitzer and Roger D. Fight. An analysis of selected assumptions basic to "an allowable cut plan for western Oregon." Report submitted to Bureau of Land Management, Portland, Oregon, Aug. 4, 1972;

[3] All board-foot volumes are International 1/8-inch rule. Inventory figures are obtained by multiplying the age classes by the BLM yield equation volumes.

Figure 1 shows the age-class distribution of a fully regulated forest with a rotation of 85 years plus a 5-year regeneration lag. The diagonal line is a continuous age class representation while the bars represent stands classified into 10-year age classes. Figure 2 shows how the two BLM Master Units compare to a fully regulated forest.

In its 1970 allowable-cut plan (Bureau of Land Management 1970), the BLM calculated even-flow annual allowable cuts of 95 million board feet for the Columbia and 96 million board feet for the Alsea-Rickreall units. These cuts were based on the following assumptions:

--full regeneration of harvested stands **will** require **3** years from time of harvest,

--precommercial and commercial thinning will ultimately encompass about one-fourth of the area,

--the remaining three-fourths of the area will have increased yield of **11** percent because it will be of genetically improved stock,

--no fertilization will be done,

--the timber producing land base will remain constant, after minor adjustments in the first four decades.

By altering these assumptions, we are able to show the importance of long-term growth[4/] and the extent and age-class distribution of the initial inventory in determining allowable cuts.

[4/] "Long-term growth" is shorthand for **growth** that, once initiated, continues throughout the remainder of the period used in the allowable-*cut* calculation.

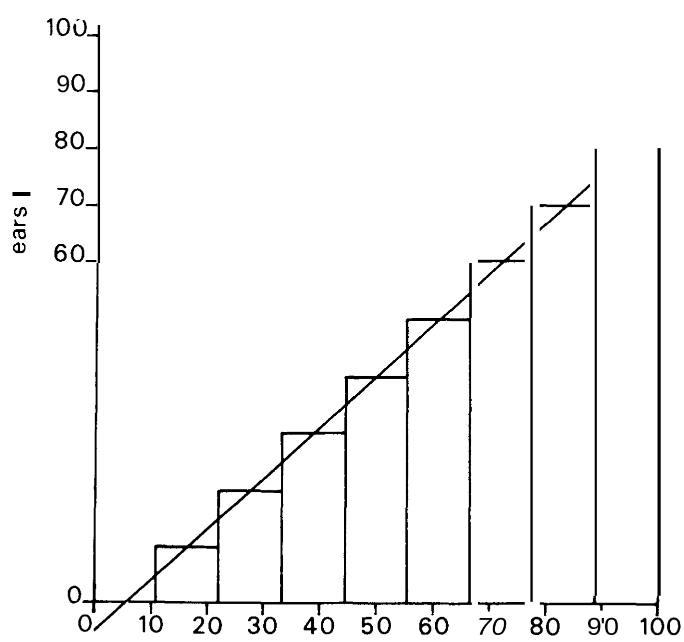

Figure 1.--Percent of area by age class for a fully regulated forest with rotation of 85 years plus a 5-year regeneration period.

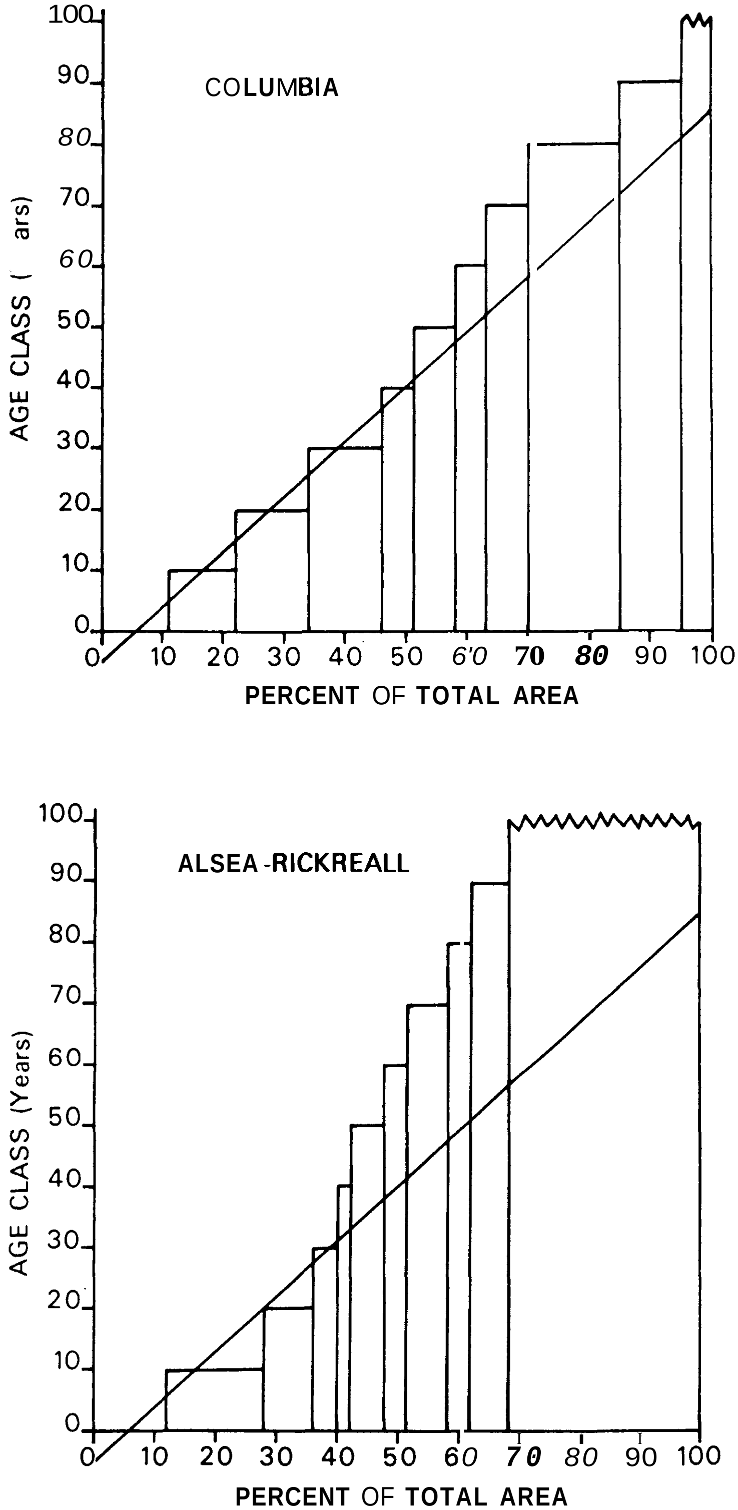

Figure 2.--Percent of area by age class for Columbia and Alsea-Rickreall Master Units.

RESPONSE OF ALLOWABLE CUTS TO MEW ASSUMPTIONS

Regeneration Period

In a forest with a normal distribution of age classes, shifting yields by 2 years in an 80-year rotation would change the mean annual increment of the forest by 2/80 or 2.5 percent. This hypothetical change in long-term growth is almost exactly reflected in the changes in allowable cut that would occur on the Alsea-Rickreall if the regeneration period were to be varied from the baseline 3 years to 1 year and to 5 years, as shown in table 1. But a much smaller change would be induced on the Columbia.

This provides data for answering each of the three questions we posed: (1) Yes, the increase in allowable cut may approach the increase in growth attributable to the new practice. (2) Yes, the increases may be proportional as successive increments of growth are added. (3) However, the above occurs when there is a large old-growth component to the inventory and is less likely to occur with a smaller inventory.

Thinning Yield

We tested the effect on the allowable cut of changes in the assumed yield response to thinning. We reduced the yield increases attributable to thinning by 25 percent and by 50 percent for both the "commercial thin only" regime and the "precommercial plus commercial thin" regime. For example, with the 50-percent reduction, the cumulative production to age 85 from stands that are commercially thinned from age 30 is reduced from 93 M bm/acre to 73 M bm/acre; the cumulative production to age 85 from stands both precommercially and commercially thinned is reduced from 102 M bm/acre to 78 M bm/acre.

The top half of table 2 shows the results for each management unit when the response to the "commercial thin only" regime is reduced 25 percent and 50 percent. Because commercial thinning without precommercial thinning occurs only in the first few decades, the change in this yield does not change the long-term growth

Table 1.--*Effect on annual allowable cut of changing regeneration period*

Years change from baseline regeneration period	Change in annual allowable cut	
	Columbia Master Unit (3 percent > 100 years)	Alsea-Rickreall Master Unit (28 percent > 100 years)
	- - - - - - - - - - - *Percent*	- - - - - - - - - - -
2 less,.	+1.4	+2.3
2 more	-1.9	-2.3

Table 2.--*Effect on annual allowable cut of reducing increases in yields attributed to thinning*

Change in response to thinning	Reduction in annual allowable cut	
	Columbia Master Unit (3 percent > 100 years)	Alsea-Rickreall Master Unit (28 percent > 100 years)
	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -	
Response to commercial thinning:1/		
Down 25 percent	1.4	0.1
Down 50 percent	2.8	.2
Response to commercial and precommercial thinning:2/		
Down 25 percent	2.4	4.5
Down 50 percent	4.8	8.7

1/ About twice as many stands will go into the "commercial thin only" regime on the Columbia Master Unit as on the Alsea-Rickreall.

2/ About 1-1/2 times as many stands will go into the "precommercial plus commercial thin" regime on the Alsea-Rickreall Master Unit as on the Columbia.

potential and is similar to a change in initial inventory; i.e., the effect is to change the amount of timber available for harvest in the first few decades. Because of the greater acreage of thinnable stands, about twice as many stands are thinned on the Columbia as on the Alsea-Rickreall. The reduction in allowable cut, however, is much more than twice that on the Alsea-Rickreall. Thus, we see that a change affecting the growth and yield of already existing stands (essentially an inventory change) has the greater impact on the area where inventory is relatively less abundant. We see on both areas that the response is directly proportional to the magnitude of the assumed change.

The bottom half of table 2 shows the results for each management unit when the response to the "precommercial plus commercial thin" regime is reduced 25 percent and 50 percent. Changes in yields from stands that have been both precommercially and commercially thinned are primarily changes in long-term growth because precommercial thinning is phased in over decades two to seven and continued throughout the planning period. The Alsea-Rickreall will have about 1-1/2 times as many acres precommercially thinned as the Columbia (29 percent of the area vs. 19 percent). The reduction on the Alsea-Rickreall, however, is almost twice as much, demonstrating that the allowable cut responds more to changes in long-term growth where there is relatively more inventory. Here again we see that with successive changes, the impact on the allowable cut is almost directly proportional to the assumed change in growth.

Genetics

Genetic improvement applies only to stands that will not be thinned; this will ultimately be about 80 percent of the area on the Columbia and 70 percent of the Alsea-Rickreall. Planting with genetically improved stock will be phased in during the second and third decades.

We tested the effect on the allowable cut of changes in the assumed yield response to genetically improved stock. First we increased the response 5 percent; then we decreased the response 5 and 10 percent.

The maximum change in cut that could be expected is the percentage change in yield times the proportion of acres treated. For the 5-percent change in yield, this would be approximately **5 x 0.75 = 3.7** percent. Figure **3** shows that on both units the change in cut is less than the change in growth. This demonstrates that even the ability of a forest with substantial old-growth to sustain an increase in allowable cut is limited; where the growth increase must be cumulated for long periods before it can be harvested from the stands on which it occurs, the increase in allowable cut is less than the increase in growth.

Figure **3** demonstrates the same kind of proportionality that we saw when the regeneration lag was varied. On the Alsea-Rickreall, which has an abundance of old growth, changes in cut are proportional to changes in growth. On the Columbia, as we added successive increments of growth, the change in cut became proportionately less--so much so, **in** fact, that additional anticipated increases in response to genetics would not likely have much impact at all on the allowable cut.

Adding Fertiliration

We tested the effect of fertilizing at 10-year intervals all stands that would be thinned, using a 15-percent increase in periodic increment. For example, the cumulative production at age 80 for

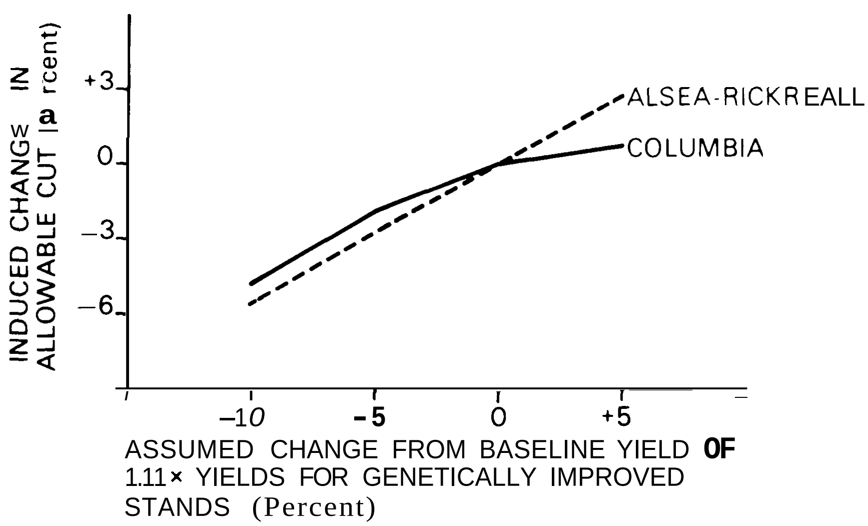

Figure 3.--Effect on allowable cut of changing increases in yields attributed to genetic improvement.

precommercially and commercially thinned stands with and without fertilizer would be **116** M bm and **102** M bm/acre, respectively*

Since the Columbia would have more stands fertilized initially (it has more "commercial thin only" acres) but the Alsea-Rickreall would have more stands fertilized in the future (it will have more "precommercial plus commercial thin" acres), we cannot make a complete analysis of the results. However, the allowable cut would increase by **3.8** million fbm/year on the Columbia and by **4.6** million fbm/year on the Alsea-Rickreall, indicating a considerable potential for the allowable cut to respond when the growth increase can be removed relatively quickly from the stands on which it occurs. Differences in the inventory do not appear to be very important.

Changing the Acreage Base

We tested the effect on the allowable cut of adding **1,000** acres of nonstocked land to the acreage base. This addition would be from converting 1,000 acres of hardwoods or brushland to conifer stands, if there were such acres outside the allowable-cut base.

The maximum per-acre impact that we could expect from an increase in the area base would be the sum of the proportion of acres in each management regime times the mean annual increment at culmination for that regime. Figure **4** shows these maximums to be 990 fbm/acre/year on the Columbia and **1,064** fbm/acre/year **on** the Alsea-Rickreall. Using the allowable cut model, the increases in allowable cut were **600** fbm/acre/year and **900** fbm/acre/year on the Columbia and Alsea-Rickreall, respectively. This again demonstrates that when increased growth must be held for considerable periods before it can be cut from the stands on which it occurs, the change in allowable cut will be less than the change in growth. Furthermore, the more inventory there is, the more responsive the allowable cut **will** be to growth changes.

Figure 4.--*Calculation of mean annual increment (MAI) per acre*

[**Proportion of acres with genetics only**] x [MAI with genetics] + [**Proportion** of acres with thinning] x [MAI with thinning] = [MAI/acre/year **for the forest**]

Columbia	(0.8)	x	(840)	+	(0.2)	x	(1,588)	=	990	fbm/acre/year
Alsea-Rickreall	(0.7)	x	(840)	+	**(0.3)**	x	(1,588)	=	1,064	fbm/acre/year

HOW INVENTORY AFFECTS THE ALLOWABLE CUT

Using the BLM management assumptions and base runs, we looked at the effect of the initial age-class distribution. We determined the allowable cut that would result if the initial inventory were fully regulated, i. e., each age class occupied $\frac{1}{\text{number of years in the rotation}}$ of the area (fig. 1). We compared that with the base run and with an accelerated harvest that dropped the initial inventory to the level of the fully regulated forest in the first decade. These comparisons indicate that at and above the inventory level of the fully regulated forest, an even distribution of age classes is more important than the level of inventory.

Table 3 shows that if the Alsea-Rickreall were fully regulated, the annual allowable cut would be only 0.4 million fbm (0.4 percent) less than the base run, even though the initial inventory was 37 percent less than in the base run. If the inventory is dropped to the fully regulated level by increased harvesting in decade one, however, the allowable cut is 4.5 million fbm (4.7 percent) less than the base run. This shows that the growth potential and the amount of inventory are not sufficient indicators of the ability of a forest to sustain a level of cut; the age-class distribution is also important.

For an additional comparison of the effect of inventory and age-class distribution, we "harvested" or "killed" by insect, disease, or fire 200 million fbm from the oldest age classes on each management unit by adjusting the initial inventory. We did this for the base run inventories and for the fully regulated inventories. The loss of 200 million fbm is a loss of 4-1/2 percent of the inventory on the Alsea-Rickreall and a loss of 6-1/2 percent on the Columbia for the base runs. For the fully regulated inventories, the loss of 200 million fbm is about 7 percent of the inventory in both cases. Table 4 shows that an inventory loss of a given amount reduces the allowable cut less when there is a larger inventory or a more evenly distributed inventory.

Table 3.--*Inventory and allowable cut for forest with annual growth potential of 93 million board feet*

Alsea-Rickreall	Inventory: Initial	Inventory: End of decade 1	Annual allowable cut
	- - - Billion board feet - - -		*-Million board feet-*
Base run	4.3	--	96.2
Fully regulated	2.7	2.6	95.8
Accelerated harvest	4.3	2.6	91.7

Table 4.--*Annual allowable cuts with and without an inventory loss of 200 million board feet*

Master unit	Base run		Fully regulated	
	Base run inventory	Less 200 million board feet	Fully regulated inventory	Less 200 million board feet
	Million board feet			
Alsea-Rickreall (28 percent > 100 years)	96.2	96.1	95.8	95.3
Columbia (3 percent > 100 years)	94.9	92.6	97.4	97.0

Irregularities in the age-class distribution affect the allowable cut primarily through their effect on growth. When the highest sustainable even-flow cut is achieved, the cutting age tends toward the age of culmination of mean annual increment. When there are irregularities in the age-class distribution, some stands will be held beyond the age of culmination, and/or some stands will be cut earlier than the age of culmination. In either case, total growth is reduced and the allowable cut is affected accordingly.

CONCl

These analyses provide a basis for estimating the effect on the allowable cut of changes in the extent or growth response of growth-stimulating treatments, changes in the acreage base, and changes in the extent or age-class distribution of the inventory.

These analyses show that allowable cut responds more to changes in long-term growth:

(1) Where there is a high initial inventory that can support a level of harvest above the growth in merchantable stands for a long period during which growth is building up.

(2) Where the age classes are well distributed so that the imbalances brought about by the change in assumed growth do not create more extreme imbalances. The possibility exists that an imbalance would complement rather than amplify existing imbalances, but this would not appear to be the usual case.

(3) Where growth increases can be cut sooner from the stands on which they occur, thus reducing the need to accelerate the rate of harvest from other stands.

(4) Where growth increases are not too large. At some level, the change in allowable cut is proportional to the change in growth. However, as growth increases are added, a point will be reached where the imbalance imposed becomes constraining and the increase in allowable cut becomes smaller with each successive increment of growth.

These analyses show that the

allowable cut responds more to changes in the initial inventory or short-term growth:

(1) Where the initial inventory is already low and the inventory is being fully utilized to counterbalance the existing imbalance in cut and growth.

(2) Where the initial inventory is not well distributed and the inventory is being fully utilized to counterbalance the existing imbalance in the age-class distribution.

These conclusions provide a basis for quantitative estimates of the effect of various changes in assumptions in calculating even-flow allowable cuts. However, an even-flow allowable cut model can be viewed as one end of a continuum of models with constraints on the relation of the level of harvest between time periods. These conclusions can therefore be expected to apply qualitatively to models with less restrictive periodic flow constraints.

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