

Reprinted from the JOURNAL OF FORESTRY
Vol. 80, No. 1 January 1982

Regeneration Delay: Economic Cost and Harvest Loss

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ABSTRACT—Failure to regenerate stands immediately after harvest results in losses of value and volume yield. The amount of loss differs when the effect of delay is assessed for an individual stand or forestwide. For the forest, the loss will depend on methods of determining the allowable cut and on inventory age-class distributions. A regeneration delay that results from transitory physical or budgeting constraints will have a different effect than delays programmed into all future rotations. Losses that appear massive when assessed at the stand level may have little effect on the allowable cut, while failure to rapidly regenerate stands that are economically marginal may greatly affect allowable cut on some forests.

Stumpage prices in the West have quadrupled in real terms since the 1960s, substantially increasing the value of forestland. Attention has therefore been focused on the losses that occur when valuable land is left idle because of regeneration delay. In this article, we will briefly examine methods for evaluating costs of regeneration delay at the stand level and loss of harvest for the forest as a whole. The costs differ, depending on whether delay is "transitory" (not expected to continue) or "programmed" (a planned feature of each rotation). The impact will also vary with differing rules and constraints set for determining allowable cut and with differing inventory (whether the inventory is surplus or deficit to growing stock necessary to support sustained yield).

Stand Costs Assessed per Acre

When we assess costs at the stand level, we look at the effect of delay on an individual acre. *Table 1* shows losses from regeneration delay on two sites at two discount rates. Rotation and regeneration costs for these sites are identical, but the better site is twice as productive in harvest value. The soil expectation value of these

sites is the amount a buyer could pay for them if he wished to earn the indicated discount rate on all costs, including the purchase price. The high-site soil expectation value is more than double that of the low-site value, even though the high site is only twice as productive, because costs do not correspond directly to lower productivity.

If a five-year delay is programmed for all future rotations, the soil expectation value will be reduced. If a five-year delay occurs in a single rotation only, we can express the loss either as an annual cost or as a single five-year, present-net-worth loss. At higher interest rates, both soil expectation and delay costs are lower, but they are a larger proportion of total worth; therefore a minor delay of five years could eliminate the site value. A negative value means that alternate rate of return will exceed earnings on investments in the site and that funds are better invested elsewhere for as long as delay is permitted. Thus, where bare-land values are negative but regeneration must be undertaken to satisfy regulations, delay may be economically desirable. Details of computing loss are provided in *table 1*.

Public foresters are often concerned whether land-use opportunity costs such as soil expectation and present net worth are appropriate measurements for land dedicated to public ownership and to multiple-use management. It should be understood that the costs originate from loss of five years' timber productivity on the site, and that such measurement is clearly appropriate where timber production is the most valuable among restricted or unrestricted land uses.

The stand-level costs we have discussed, and values in *table 1*, suggest that the costs of regeneration delay are specific to interest rate and site value. The fact that delay will cost less on poorer than on better sites suggests rules for allocating the regeneration budget.

Table 1. Indicators of regeneration delay loss for high-site A and low-site B at two interest rates.

Interest rate and site ¹	SE ²	SE ₅ ³	ΔSE ₅ ⁴	AC ⁵	ΔPNW ₅ ⁶
----- Dollars per acre -----					
5 percent					
A	1,033.11	781.46	251.65	51.66	223.64
B	370.86	280.53	90.33	18.54	80.28
8 percent					
A	123.95	83.08	40.87	9.92	39.59
B	-69.05	-46.28	22.77		-22.06

¹At age 40 years, harvest value of site A is \$8,000 per acre and regeneration cost \$250 per acre; harvest value of site B is \$4,000 per acre, regeneration cost \$40 per acre.

²SE = $\frac{HV - RC(1+i)^{40}}{(1+i)^{40} - 1}$, where SE is soil expectation value, HV is

harvest value, RC is regeneration cost, and i is interest rate. This is the basic formula when final harvest and regeneration are the only revenue and cost.

³SE₅ = $\frac{HV - RC(1+i)^{40}}{(1+i)^{45} - 1}$ Soil expectation value with a programmed

delay—each future regeneration postponed five years. Planting cost is carried 40 years; harvest is postponed 5 years.

⁴ΔSE₅ = SE - SE₅. Change in soil expectation value with a programmed delay of five years.

⁵AC = SE(i). Annual cost is the loss of one year's rent from the land, which equals one year's interest on the soil expectation value.

⁶ΔPNW₅ = SE - $\frac{SE}{(1+i)^5}$. The loss from a single five-year delay.

Harvest Loss Assessed Forestwide

At the forest level, the impact of regeneration delay depends on the methods and constraints used in determining allowable cut and on the nature of the delay—whether it is transitory or programmed. As we have noted earlier, impact will also differ between forests with surplus and deficit growing stock. Major federal agencies have for some time had a policy of nondeclining even-flow (NDEF) harvest scheduling. Allowable cuts on forests with surplus growing stock are not permitted to rise above sustained yield. The policy has little effect on forests with a deficit growing stock. Extensive discussion of methods for calculating NDEF harvest schedules is given in Hann and Brodie (1980). An alternate policy traditionally followed by forest planners allows the cut to rise above the sustained yield as long as surplus growing stock exists. Because declines in harvest are permitted, we may call this more traditional policy declining-flow (DF) harvest scheduling.

Declining-flow harvest paths in situations of inventory surplus originate from the application of many formulae (Davis 1966): the Hanzlik formula, the Austrian formula, and the Kemp formula. Newer methods, such as ECHO harvest scheduling (Walker 1975) and linear programming, also may give declining harvest schedules. We can examine two broad categories of allowable cut, nondeclining and declining flow; two kinds of inventory, surplus and deficit relative to sustained yield; and two kinds of regeneration delay, programmed and transitory. Regeneration delay may affect harvest differently with each of the eight possible combinations, but the effect of delay on the allowable cut can be generalized in each instance, regardless of the harvest-scheduling method used.

It is often assumed that different conditions prevail in the first rotation than in subsequent rotations—thus the phrase, "first-rotation effects." By using the terms "transitory" and "programmed," we hope to emphasize that even a short delay of regeneration will affect the harvest

flow in a predictable manner for a given inventory and schedule.

Figure 1A-D shows the effect of programmed regeneration delays with NDEF and DF harvest and with surplus and deficit inventories. Programmed delays result in a reduction in the forest's mean annual increment, and because NDEF harvest may not rise above the programmed increment for sustained yield, even with surplus growing stock, the effect is an immediate drop in allowable cut that continues throughout the planning period (fig. 1A). Under an NDEF schedule and a deficit growing stock, the near-term allowable cut is more likely to be constrained by deficit of immediately harvestable material than by long-term growth capacity; thus a programmed delay may have little immediate effect on allowable cut. Later in a harvest period, however, a programmed delay may cause the cut to rise more slowly, and a lower sustained yield will be reached (fig. 1B).

When declines in harvest levels are permitted, a programmed delay means that any surplus growing

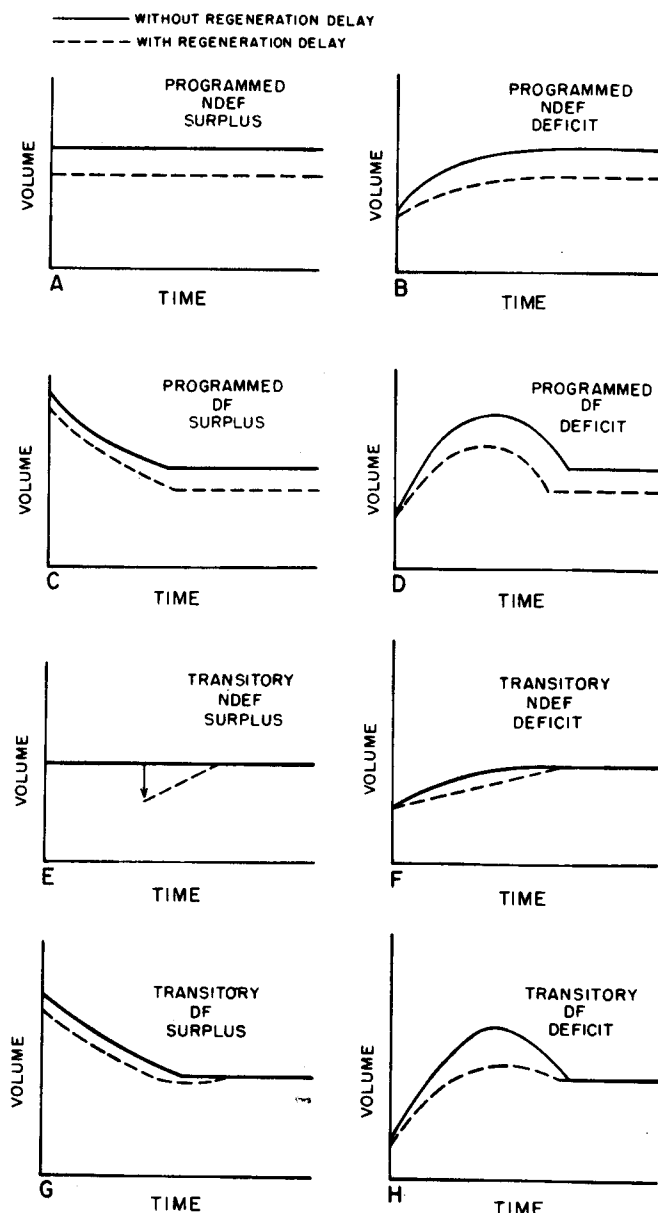


Figure 1. Allowable cut, with and without regeneration delay, for forests with programmed and transitory delays, nondeclining even-flow (NDEF) and declining-flow (DF) harvest schedules, and surplus and deficit inventories.

stock must be rationed for a longer period: thus the eventual sustained yield is again lower and reached later (fig. 1C). Any of the several methods for computing DF schedules calls for an immediate harvest reduction that increases as sustained yield is approached. When no harvestable surplus exists, the programmed delay may have no immediate effect; however, the harvest will rise more slowly and reach lower limits in both the conversion and sustained-yield periods (fig. 1D).

Transitory delay reflecting short-term problems of budget or access has no effect on the sustained yield, but it will affect conversion-period harvests and will postpone the achievement of sustained yield (fig. 1E, F).

Forests that are subject to NDEF harvest constraints and that have surplus growing stock can sustain transitory delay with no effect on harvest level. Reduced stock from the delay is compensated by liquidation of surplus. But at some point, if delay is sustained, the surplus will be depleted and the cut must be reduced to compensate. At such time, a decision must be made as to whether the delay is indeed transitory, or one that should be programmed into a lower NDEF schedule (fig. 1E). With NDEF constraints and a deficit growing stock, transitory delay will mean that the programmed sustained yield is approached more slowly over a longer time (fig. 1F). That substantial transitory delay in regeneration may not affect NDEF harvest levels is another example of the perverse results outlined by Bell et al. (1975) and articulated satirically by Klemperer (1976).

With a DF harvest schedule, transitory delay will result in reduced harvest in the conversion period (fig. 1G, H).

Considerations for Managers

A deficit growing stock, irrespective of allowable cut constraints, creates a similar reaction to regeneration delay—little immediate reduction in a cut already constrained by available harvestable material. Delay suppresses the rate of increase of the cut, and, if it is programmed, lowers the eventual sustained yield.

With a surplus growing stock, NDEF harvest shows the most drastic and erratic delay effect. Programmed delays result in immediate reduction of the cut, reflecting the reduced mean annual increment, while modest transitory delay may have no effect whatsoever. Where there is surplus growing stock and DF is permitted, the impact will be immediate—decreased harvest during the conversion period when delay is transitory and during both the conversion and sustained-yield periods when delay is programmed.

Recent withdrawal of site-preparation and regeneration tools such as phenoxy herbicides may lengthen the period before a plantation is certified free to grow—a delay in regeneration. This means a longer rotation, but unlike the example in table 1, the regeneration cost must be carried for the full term of the lengthened rotation. In analyzing such a situation, several questions should be asked. Will a new technology of regeneration eventually replace the proscribed techniques? If the answer is “yes,” then the impact is transitory; if the answer is “no,” or “partially,” then the impact must be programmed into both conversion and sustained yield. Are the constraints on allowable cut strict, as with NDEF, or flexible? Rigid constraints mean that responses to regeneration delay are less predictable—ranging

from maximum and immediate to none. Is there a growing stock surplus or deficit? With flexible constraints or transitory delay, surplus inventory softens impact. With a deficit inventory, the effect may appear only gradually over time. The time of impact will differ for public and private owners.

Regeneration delay has always been of academic interest in harvest scheduling and stand prescription. High prices for forestland and scarcity of harvestable inventory have now made it of practical interest. Analysis and assumptions must be carefully scrutinized in each situation and many aspects must be taken into consideration before generalizations about the effect of delay can be made. Nevertheless, such scrutiny is worthwhile. At today's prices for forest products, losses from delay are substantial, and efforts at reducing delay through improved organization and supervision will probably be cost-effective. ■

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