Easy evaluation of establishment treatments*

Oscar García
Instituto Forestal, Chile

Abstract

The obvious approaches to comparing profitability of competing tree establishment techniques or treatments would require much data on growth, costs, and revenues. This in-depth knowledge is frequently unavailable or unreliable. A simple alternative is presented that often can determine economic viability with little detailed information. Specifically, assuming that an improved method shortens stand development time by δ years, it is shown that a break-even additional relative cost can be computed knowing just δ and the discount rate or internal rate of return.

Introduction

It is frequently necessary to evaluate alternative tree planting or regeneration methods, or soil preparation treatments such as ploughing, fertilization, and weed control. The profitability of a "new" technique or treatment has to be compared with that of a "standard" one. An obvious approach would: (a) estimate/simulate the development of a stand under the new and standard treatments using an appropriate model; (b) estimate/calculate the respective costs and revenues; (c) compute the net discounted value, land expectation value, or internal rate of return as a profitability measure; (d) compare, and carry out a sensitivity analysis.

Such an approach, however, requires a great deal of knowledge and detailed data, which may be unavailable or unreliable. In addition, the validity of the conclusions is obscured by the complexity of the procedure. It may be difficult to asess the impact of the various assumptions and estimation errors.

*Invited paper, IUFRO XX World Congress. Tampere, Finland, 6–12 August 1995

An alternative is presented here that often can determine the economic viability of a new establishment technique or treatment easily, and with little detailed information on growth, cost, and revenues. The assumptions are discussed first, followed by the main result and an example. The proof and further discussion of the growth assumptions are presented in the Appendices.

An earlier version of this paper was published in Spanish (García 1994a).

Assumptions

Growth

We assume that the *new* establishment method, compared to the *standard* one, causes a temporary increase (or decrease) in the rate of stand development. The magnitude of this change in growth rate may vary in an arbitrary manner over time, provided that the direct effect has vanished before reaching the cutting age. Specifically, let the nett revenue in dollars per hectare with the standard method be some function $R(t)$ of the cutting age t. Then, for ages around the optimal rotation, the nett revenue with the new method is

$$\overline{R}(t) = R(t + \delta) \ , \tag{1}$$

where δ is a certain *time gain*. The function $R(t)$ needs not be known, but we assume that an estimate of δ is available.

This model seems reasonable, at least as a first approximation, for treatments that affect the early growth of the trees but do not cause a permanent change in site quality. Initially the growth curves with and without treatment diverge, but when the direct treatment effect disappears trees of similar sizes will have similar growth rates. Note that this does not rule-out a persistent "indirect" effect of the establishment treatment; at any given age the trees will have different sizes and may grow at different rates because of that. The equal growth rates for equal sizes imply that the later portion of the growth (and revenue) curves will differ only by a horizontal time shift δ. A more formal discussion is included in Appendix 2.

Economics

Given an interest rate i, treatments may be compared through the net present value, or the land expectation value (LEV). This is the discounted cash flow, assuming constant prices and not including the land cost, over an infinite number of rotations of optimal length:

$$L = \max_t \{\sum_{k=0}^{\infty} \alpha^{kt} [\alpha^t R(t) - C]\} = \max_t \{\frac{\alpha^t R(t) - C}{1 - \alpha^t}\} \tag{2}$$

(for the standard method), where C is the establishment cost, and $\alpha = 1/(1+i)$ is the discount factor (Faustmann 1995, Leuschner 1990, for example).

Alternatively, the comparison may be in terms of the internal rate of return (IRR), which is the value of i for which the LEV equals the land cost (more precisely, the largest of these i, in case of multiple solutions.) The same equation (2) applies, where now i is interpreted as the IRR, and L as land cost.[1]

As is custommary in the textbooks, to simplify the presentation intermediate costs and revenues have not been indicated explicitly in (2). Some care in their treatment is needed to preserve the validity of (1). Ongoing costs and revenues that do not depend of the rotation age (overheads, protection) are considered included in L, as a present value. Those ocurring once in the rotation, independently of its length (e. g. respacing), would be discounted and included in C. Those affected by the time gain δ (production thinning) would be capitalized and included in R.

Results

Define the *break-even cost* $\overline{C}$ as the establishment cost for the new method that would give the same LEV (or IRR) as the standard method. Then,

$$\frac{\overline{C} - C}{L + C} = (1 + i)^{\delta} - 1 \ . \tag{3}$$

This is the break-even additional cost, relative to the value of a just-established stand. The proof is in Appendix 1.

Some values from (3), expressed as percentages, are shown in Table 1. In many instances the information available would be sufficient to make decisions about proposed treatments. At any rate, the simplicity of this relationship makes it easy to explain and to explore through sensitivity analysis the impact of various estimates.

[1]The IRR may not deserve all the "bad press" that it often receives (e. g. Leuschner 1990, Chap. 9). Under the usual assumptions of constant prices, etc., maximizing the LEV maximizes the return per unit area, as would be appropriate if land is the limiting factor. Maximizing the IRR might be preferable if the limiting factor is capital.

Table 1: Break-even relative additional cost (%)

Time gain	Discount rate or IRR (%)					
(years)	4	6	8	10	15	20
1	4	6	8	10	15	20
2	8	12	17	21	32	44
3	12	19	26	33	52	73
4	17	26	36	46	75	107

Example

It is estimated that certain treatment would result in a gain of two years, compared to current practice. Then, for a discount rate of 8%, Table 1 shows that the new treatment would be profitable if costs do not increase more than 17% of the stand value (land value plus establishment cost).

On the other hand, if it is estimated that the additional cost does not exceed 8% of the value of the stand, it is seen that for the treatment to be profitable it would be sufficient to gain one year in its development.

Appendix 1. Proof

Because of the time invariance assumption, it is clear that the LEV can be written as a sum of the nett revenue from the first (optimal-length) rotation and the LEV of the stand left after that, with all quantities discounted to the present. For the standard method:

$$L = \max_t \{\alpha^t R(t) - C + \alpha^t L\} = \max_t \{\alpha^t [R(t) + L]\} - C \,. \qquad (4)$$

(Note that solving for L gives an alternative derivation of (2).) This is valid also for the IRR, with a change in interpretation of L and α (or i).

The break-even cost $\overline{C}$ is the value that gives the same L with the new method (or the same α under the IRR interpretation):

$$\begin{aligned} L &= \max_t \{\alpha^t [\overline{R}(t) + L]\} - \overline{C} = \max_t \{\alpha^t [R(t+\delta) + L]\} - \overline{C} \\ &= \max_t \{\alpha^{t-\delta} [R(t) + L]\} - \overline{C} = \alpha^{-\delta} \max_t \{\alpha^t [R(t) + L]\} - \overline{C} \,. \end{aligned}$$

Solving for $\overline{C}$, and using (4) to eliminate the term containing $R(t)$,

$$\overline{C} = \alpha^{-\delta}(L + C) - L \,,$$

and

$$\overline{C} - C = (\alpha^{-\delta} - 1)(L + C) \ ,$$

whhich proves (3).

Appendix 2. Relative growth rates

As in any dynamical system, the development of a forest stand can be modelled by a (local) *transition* function

$$\frac{d\mathbf{x}}{dt} = \mathbf{f}(\mathbf{x}, \mathbf{u}) \ , \tag{5}$$

and an *output* function

$$\mathbf{y} = \mathbf{g}(\mathbf{x}) \tag{6}$$

(Padulo and Arbib 1974, García 1994b). The *state* vector $\mathbf{x}$ describes time-varying characteristics relevant to the stand development. Its elements can range from a few aggregated variables such as basal area, trees per hectare, and top height, in stand-level growth models, to a list of all the individual tree sizes and spatial coordinates, in distance-dependent models. The *control* vector $\mathbf{u}$ represents silvicultural treatments and other inputs. The *output* vector $\mathbf{y}$ corresponds to quantities of interest such as crop volume and value. Difference instead of differential equations may also be used.

We assume that the effect of the improved establishment method is to alter the initial development rate by some factor, not necesarily constant, and that the (direct) effect vanishes some time before any potential rotation age. That is, (5) becomes

$$\frac{d\mathbf{x}}{dt} = h(t)\mathbf{f}(\mathbf{x}, \mathbf{u}) \ ,$$

where $h(t)$ can be any function of time such that $h(t) = 1$ for t equal to or greater than the rotation age. We assume further that any silvicultural treatments or other inputs are linked to the state of the stand, so that $\mathbf{u}$ may be a function of $\mathbf{x}$ but not of t.

With these assumptions, the effect of the new (improved) method can be seen as a deformation of the time scale in the early years through the mapping $dt \to h(t)\,dt$. Integration shows that the state of an improved stand at time t equals the state of the standard at an equivalent "physiological time"

$$\int_0^t h(s)\,ds = t + \int_0^t [h(s) - 1]\,ds \ .$$

The second integrand vanishes before rotation age, its integral reaching some final value δ. Clearly, any outputs from improved and standard stands at rotation age, being functions of $\mathbf{x}$, are related through the substitution $t \to t + \delta$.

Perhaps the most questionable assumption here is that the rates of change of all state variables are altered by the new method in the same degree, through the common factor $h(t)$. In reality, height growth might react differently than diameter growth, for example (Carson and García 1995). However, the approximation is probably sufficient for this type of analysis.

Incidentally, sustained growth differences from genetic improvement, periodic fertilizing, or other treatments causing permanent or long-term changes in site quality, are often modelled as percentage increases in yield and outputs. We would have then $\overline{R}(t) = kR(t)$, but this does not follow naturally from the system-theoretical considerations above. More satisfactory would be to use a constant gain factor $h(t) = k$, giving $\overline{R}(t) = kR(t)$ (García 1994b, Carson and García 1995). No results analogous to those for establishment effects have been obtained for this case.

References

Carson, S. D., and García, O. (1995). Genetic gain in *Pinus radiata* expressed as growth rate multipliers. Submitted to *Forest Science*.

Faustmann, M. (1995). Calculation of the Value which Forest Land and Inmature Stands Possess for Forestry (translation from the original German of 1849). *Journal of Forest Economics*, *1*, 7–44.

García, O. (1994a). The State-space Approach in Growth Modelling. *Canadian Journal of Forest Research*, *24*, 1894–1903.

García, O. (1994b). Un Método Simple para Evaluar Técnicas de Establecimiento. In Barros A., S., Prado D., J. A., and Alvear S., C. (Eds.), *Actas Simposio Los Eucaliptos en el Desarrollo Forestal de Chile*, pp. 295–301. Instituto Forestal, Santiago, Chile.

Leuschner, W. A. (1990). *Forest Regulation, Harvest Scheduling, and Planning Techniques.* Wiley, New York.

Padulo, L., and Arbib, M. A. (1974). *System Theory.* Hemisphere, Washington, D.C.