UM MODELO PARA ANÁLISE ECONÔMICA DE REFORMA EM POVOAMENTOS DE EUCALIPTO

Jagdish C. Nautiyal *
Luiz Roberto Graça **
Laercio Couto ***

RESUMO

É apresentado um modelo computarizado chamado "RENEWAL" para auxiliar na análise econômica da viabilidade de reforma ou do número de talhadias em povoamento de eucalipto. O modelo utiliza o critério de maximização do valor líquido presente (NPV) que leva em contas as seguintes variáveis: 1) preço de madeira de eucalipto; 2) custos de implantação e das talhadias; 3) produtividade dos diversos cortes; 4) taxa de crescimento dos preços de eucalipto; 5) taxa de juros. Um exemplo hipotético baseado em dados de *Eucalyptus saligna* em São Paulo é usado para se determinar a rotação ótima e o número de cortes intermediários. Vários cenários foram analisados e recomendações foram sugeridas.

Palavras-chave: Rotação ótima, talhadia, valor presente, Brasil.

ABSTRACT
A MODEL FOR ECONOMIC ANALYSIS OF RENEWAL OF EUCALYPTUS STANDS

A computerized model called "RENEWAL", which selects the best combination of rotation and number-of-times the crop should be coppiced, has been presented for economic analysis of eucalyptus plantations. The model utilizes maximization of net present value (NPV) criterion and takes into account the following variables: 1) eucalyptus stumpage price; 2) costs of seedling and coppice regeneration; 3) yields for all cuts; 4) expected rate of growth of real stumpage price; 5) real rate of discount. An hypothetical example based on *Eucalyptus saligna* growth dàta from São Paulo has been used to determine optimal rotation and number of coppicings. Various scenarios have been simulated and implications discussed.

Key-words: Optimal rotation, coppicing, net present value, Brazil.

* Professor Titular de Economia Florestal da Universidade de Toronto, Canada.

** Pesquisador em Economia Florestal do Centro Nacional de Pesquisa de Florestas da EMBRAPA, Curitiba, PR.

*** Chefia e Professor do Departamento de Engenharia Florestal da Universidade Federal de Viçosa, MG.

A MODEL FOR ECONOMIC ANALYSIS OF RENEWAL OF EUCALYPTUS STANDS

Introduction

Large areas are planted with different species of *Eucalyptus* in many tropical countries, most abundantly in Brazil. In 1988 at least 1.5 million hectares were under *Eucalyptus* plantations of pulp and paper companies alone in this country. The commonest species planted is *E. Grandis* W. Hill ex Maiden and it is used for charcoal, pulp, lumber and board production. Management pratices differ from company to company but generally an initial planting is harvested at around six years followed by one or two coppice crops which are also harvested at the same rotation. After two or three harvests the forest is replanted again and the operation is called "renewal".

Though coppicing is a low cost method of regenerating *Eucalyptus* it is accompanied by a decrease in yield. When coppicing is done successively the decreases are cumulative and can reach substantial proportions.

One way of dealing with the decreases in the coppice yields is to use those species for planting which suffer lower diminution at each cutting than currently used species. Another possible method is to apply augmented silvicultural inputs, such as fertilizers or water, so as to maintain the yields as much as possible. Nevertheless, there is always some reduction and therefore management has to decide how long the rotation period should be and how many times the crop should be coppiced. This decision will depend on the yield reductions and the costs of silvicultural operations, both normal and augmented. This paper outlines the basics of a mathematical model that can be used in getting some insights into the economics of this important decision and in determination of the length of rotation and the renewal cycle. It offers an alternative but complementary approach to the work done by BERGER (1985), COUTO et al. (1986a, 1986b), OLIVEIRA and COUTO (1986) and REZENDE et al. (1987). However, neither these authors nor the present paper take into account the possible changes in the overall supply of wood that may be caused by implementing renewal decisions on the basis of individual stand analyses.

The Model:

Let $V^0(t)$ be the yield function of the forest crop when raised from seedlings and $V^1(t)$, $V^2(t)$ etc. be the functions after first and second coppice, respectively. In consonance with current practice let us also assume that the rotation of seedlings and coppice origin crops is the same and that n coppice crops are harvested from the same area before renewal.

If the estimated price of stumpage in constant dollars (or BTN's) at the time of first harvest is P dollars per cubic metre, and at subsequent harvests it is P_1, P_2, ... P_n, respectively; the expected constant dollar cost of seedling regeneration at the beginning of the rotation is C_o and of coppice regenerations is C_1, C_2 etc., then the net present value (NPV) of one cycle of management is:

$$\frac{PV^o(t) - C_o(1+r)^t}{(1+r)^t} + \frac{PV^1(t) - C_1(1+r)^t}{(1+r)^{2t}} + \ldots + \frac{PV^n(t) - C_n(1+r)^t}{(1+r)^{nt}}$$

For an infinite number of cycles the NPV is:

$$\frac{(1+r)^t}{(1+r)^t-1}\left[\frac{PV^o(t)}{(1+r)^t}+\frac{PV^1(t)}{(1+r)^{2t}}+\ldots+\frac{PV^n(t)}{(1+r)^{nt}}-\right.$$

$$\left.-\left\{C_o+\frac{C_1}{(1+r)^t}+\frac{C_2}{(1+r)^{2t}}+\ldots+\frac{C_{n-1}}{(1+r)^{(n-1)t}}\right\}\right]$$

Let us now suppose that the yield and cost functions are such that for each value of t

$$V^1 = a_1 V^o;\ V^2 = a_2 V^o;\ \ldots\ V^n = a_n V^o$$

and

$$P_1 = P(1+i)^t;\ P_2 = P(1+i)^{2t};\ \ldots\ P_n = P(1+i)^{nt}$$

that is, coppice crops yield, respectively, $a_1, a_2, \ldots a_n$ proportion of seedling origin crop yields after consecutive cuttings; and real stumpage price escalates at a rate of i per annum, then

$$NPV = \frac{(1+r)^t}{(1+r)^t-1}\left[PV^o\cdot\frac{1}{(1+r)^t}+\frac{a_1(1+i)^t}{(1+r)^{2t}}+\ldots+\frac{a_n(1+i)^{nt}}{(1+r)^{nt}}-\right.$$

$$\left.-\left\{C_o+\frac{C_1}{(1+r)^t}+\frac{C_2}{(1+r)^{2t}}+\ldots+\frac{C_{n-1}}{(1+r)^{(n-1)t}}\right\}\right]$$

This expression will be maximized if the values of t and n are so chosen as to satisfy the following conditions:

(1) $\frac{\partial(NPV)}{\partial t} = 0;\quad \frac{\partial(NPV)}{\partial n} = 0$

(2) $\partial^2(NPV)/\partial t^2 < 0;\ \partial^2(NPV)/\partial n^2 < 0$ and

$$\frac{\partial^2(NPV)}{\partial t^2}\cdot\frac{\partial^2(NPV)}{\partial n^2}-\left[\frac{\partial^2(NPV)}{\partial t\,\partial n}\right]^2 > 0$$

It is tedious to work out these conditions for our NPV expression and so an analytical solution for optimal values of t and n cannot be profitably sought. However, a numerical solution can be obtained by computer simulation.

Solution and Discussion.

In the computer model called "RENEWAL" the user is required to input such data as P, i, V^0, and a_1, a_2,... a_n. It then calculates the NPV for various combinations of t and n for any selected range of r such as from 0.06 to 0.12 and allows selection of the combination that yields the highest NPV.

With such a simple model the question of optimal rotation (t) and the optimal number of times (n) a seedling crop of a given species should be coppiced, in a specified locality and with given cost and price scenario, can then be answered.

In a hypothetical example based on *Eucalyptus saligna* plantations in the state of São Paulo we use the following yield table:

Age (t) (years)	Yield (V^o) (m^3/ha)	Age (t) (years)	Yield (V^o) (m^3/ha)
1	37.48	6	346.35
2	90.61	7	383.27
3	160.63	8	409.30
4	232.65	9	427.13
5	296.26	10	439.10

and assume that

a_1 = 0,68 a_2 = 0,55 a_3 = 0,59

a_4 = 0,50 a_5 = 0,45 a_6 = 0,40

C_o = \$690/ha, $C_1 = C_2 = C_3 = C_4 = C_5 = C_6$ = \$295/ha

P = \$18/m^3 and i = 0,02/annum

Computations of NPV at assumed real annual discount rates of 1% to 12% and for each value of t from 1 to 10 years and each value of n from 0 to 6 years shows the optimal combinations to be the following:

Discount rate (r) %	Rotation (t) years	Coppice Crops in a Cycle (n) No.
1 to 2	6	0
3 to 12	5	0

In this example the optimal rotation and the number of times the crop should be coppiced is quite insensitive in the range of discount rate examined, except at its lower extremity. In other words, if the yield, price and cost figures used here are realistic then *Eucalyptus saligna* plantations of São Paulo should be renewed after **each** harvesting and the rotation age adopted should be 5 years.

Knowing just this much, however, is not sufficient for the analyst or the decision maker. It is important to know the sensitivity of the results to variables other than the discount rate also. In Table 1 we examine the effect of stumpage price escalation rate on the results and present the optimal management indicated by the model RENEWAL for values of i from 0,0% to 5,0%.

It is apparent from this table that the indicated optimal management changes very sigificanty at discount rates in the vicinity of 5% to 7% if the escalation rate is between 3% and 4%.

TABLE 1. Optimal Rotation (t) in years and Number of Times the Crop should be Coppiced (n)

Real Rate of Discount %	Percentage at which real stumpage price is expected to increase annually											
	0.0		1.0		2.0		3.0		4.0		5.0	
	t	n	t	n	t	n	t	n	t	n	t	n
1.0	5	0	6	0	6	0	10	6	10	6	10	6
2.0	5	0	5	0	6	0	10	6	10	6	10	6
3.0	5	0	5	0	5	0	9	6	10	6	10	6
4.0	5	0	5	0	5	0	8	6	10	6	10	6
5.0	5	0	5	0	5	0	7	6	8	6	10	6
6.0	5	0	5	0	5	0	5	0	7	6	9	6
7.0	5	0	5	0	5	0	5	0	7	6	7	6
8.0	5	0	5	0	5	0	5	0	6	6	7	6
9.0	5	0	5	0	5	0	5	0	6	6	6	6
10.0	5	0	5	0	5	0	5	0	6	6	6	6
11.0	4	0	5	0	5	0	5	0	6	6	6	6
12.0	4	0	5	0	5	0	5	0	5	6	6	6

In order to examine the sensitivity of the results in this region we ran the model for escalation rates differing by 0.1% between 3.1% and 3.7% and for discount rates from 5% to 7%. The optimal rotations (t) and renewal time (n) are given in Tables 2 and 3, respectively. The NPV's for the optimal management regime are also shown in parenthesis in each table.

TABLE 2. Optimal Rotation (t) in years. (NPV in dollars/ha)

Real Rate of Discount %	Percentage at which real stumpage price is expected to increase annually						
	3,1	3,2	3,3	3,4	3,5	3,6	3,7
5,0	5 (18804)	7 (19198)	7 (19629)	7 (20073)	7 (20530)	8 (21026)	8 (21571)
6,0	5 (15136)	5 (15225)	7 (15375)	7 (15697)	7 (16027)	7 (16367)	7 (16717)
7,0	5 (12522)	5 (12597)	5 (12671)	5 (12747)	6 (12945)	6 (13174)	7 (13411)

TABLE 3. Optimal Number of Times (n) the Crop should be Coppiced. (NPV in dollars/ha)

Real Rate of Discount %	Percentage at which real stumpage price is expected to increase annually						
	3,1	3,2	3,3	3,4	3,5	3,6	3,7
5,0	0 (18804)	6 (19198)	6 (19629)	6 (20073)	6 (20530)	6 (21026)	6 (21571)
6,0	0 (15136)	0 (15225)	6 (15375)	6 (15697)	6 (16027)	6 (16367)	6 (16717)
7,0	0 (12522)	0 (12597)	0 (12671)	0 (12747)	6 (12945)	6 (13174)	6 (13411)

An examination of these two tables shows how important it is to be able to accurately estimate the rate of escalation of real stumpage price in the future, and the adoption of an appropriate rate of discount, so that the best management regime can be chosen in the present. If the discount rate is 5% and the escalation rate is just above 3.0% then it is of significance to know whether the rate is 3.1% or 3.2%. In the former figure is more correct then the optimal management regime is to adopt a rotation of 5 years and **not** plan to coppice. Renewal must be done after each harvesting. If, on the other hand, the escalation rate is 3.2% instead of 3.1% then optimal regime is to adopt a much longer rotation, 7 years, and take 6 coppice crops! A mistake in adopting the right discount rate and escalation can be costly for the management.

If the discount rate adopted is 6% then it would not matter whether the escalation rate is 3.1% or 3.2% but it would be very important to know whether the escalation rate is 3.2% or 3.3%. In one case a rotation of 5 years with no coppicing and in the other case a 7 year rotation with 6 coppices is indicated. Similarly, when the discount rate is 7% it is necessary to estimate the escalation rate very carefully if it happens to be between 3.4% and 3.5%.

Estimation of such rates for the future is an extremely difficult task and generally the best that can be done in most cases is to examine past trends and project them into the future with or without some modifications. Making an abrupt change in the current management pratices must, therefore, be very carefully considered. Models, such as RENEWAL, are essential for making decisions but must not be seen as the final answers to complicated questions such as deciding on renewal of forest crops. In addition to the sensitivity of the results to poorly estimated variables what must be examined is the difference between the NPV's for alternative management regimes.

From Tables 2 and 3 we can see that in the case where the discount rate is 6% the difference between adopting $t=5$, $n=0$ (for $i=3.2\%$) and a very different $t=7$, $n=6$ (for $i=3,3\%$) is that between \$ 15.225 and \$ 15.375 which is of the order of 1%. Therefore, even if the escalation rate was very confidently estimated to be 3.2% or 3.3% and the discount rate was well accepted as 6% there may be good reasons for not changing the existing pratice, if it happens to be one of the above. Not only would a change cause disruption in what is alredy well established but the gain from the change very slight. Furthermore, there cannot be too much reliance on this estimated gain as it is based on data that cannot be accurately estimated, and accuracy means much in this case.

Another Scenario:

For slightly modified data in which:

$$a_1 = 0{,}90; \quad a_2 = 0{,}80; \quad a_3 = 0{,}70$$
$$a_4 = 0{,}60; \quad a_5 = 0{,}50; \quad a_6 = 0{,}40$$
$$C_1 = C_2 = C_3 = C_4 = C_5 = C_6 = \$200/\text{ha} \text{ and } i = 0,$$

but everything else remains as before, the results are quite different. For discount rates ranging from 6% to 8%, the optimal rotation remains 5 years but renewal is indicated after taking one coppice crop. If the discount rate is from 9% to 18% the optimal rotation becomes 4 years but renewal is best done after one coppice. For higher discount rates, between 19% and 22%, the rotation stays at 4 years but now renewal should be done after taking two coppice harvests rather than just one. At still higher discount rates even shorter rotations and delayed renewals are indicated.

Conclusions:

Economic circumstances such as the appropriate rate of discount, costs and prices as well as technical situations, such as the yield and the expected decreases in coppicing, keep changing continuously. Therefore, a model on the renewal issue needs to be used almost every year to decide whether a given crop should be renewed that year or not. This is possible only if we have a model. Developing company specific or situation specific models is, therefore, highly recommended. However, blind application of any model should be avoid and detailed sensitivity analyses must be carried out before deciding whether to change the existing well established management practices.

In addition, it is necessary to see what implications follow regarding the overall supply of wood for a company, over the next few years, if individual stands are renewed on the basis of their own economics. The overall supply could increase if renewals are widespread and could decrease below the minimum acceptable to a company, if delayed renewals result from the analysis. This will particularly be so for companies that are obliged to keep a fixed area under plantations each year. Other companies would, of course, be able to deal with the situation by exercising their option to increase or decrease their area under plantations. Use of the linear programming approach could be promising in this respect as it could indicate which stands should be renewed while the overall supply remains within specified bounds, either with a fixed or variable area base. Clearly, even with the same technology, same costs and prices and same prognosis for the future, one company may find that its renewal decisions are not the same as those of another because its access to the open market for wood is different and, its capacity to accept variations in its supply is also different.

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