Forest Management and Certification

Stand-Level Management – The Forest Value of Land and Trees

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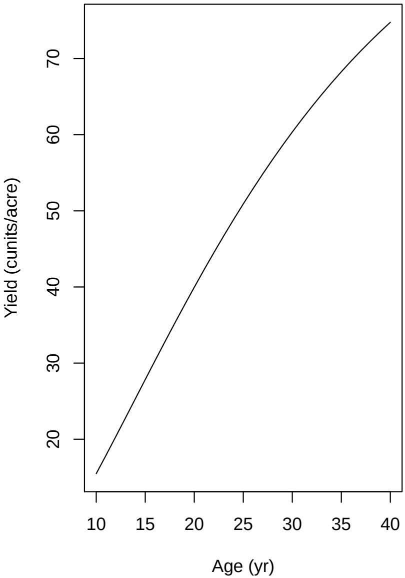
The Optimal Rotation

The Growth of Even-Aged Stands

- Even-aged stands have a definite beginning and en in time
- Stand establishment or regeneration marks the beginning of such a stand and, with the final harvest, the stand ceases to exist
- At any time during its life, the stand has a known or determinable age, and the total length of the growth period from stand establishment to final harvest is referred to as the *rotation*
- Plantations fit this description exactly, while some naturally regenerated stands, which become established over a period of a few years, lack an exact beginning but are still usefully conceptualized as being even-aged

The Growth of Even-Aged Stands



The Growth of Even-Aged Stands

- The graph of volume per unit area over time for any even-aged stand is a typical sigmoid curve
- During the early years of stand development, volume production proceeds slowly
- As the stand ages, the growth rate increases to a maximum and then declines
- If the stand is left long enough without harvest, the net growth rate will eventually fall to zero and then become negative when mortality exceeds accretion growth

The Growth of Even-Aged Stands

- Assume the yield curve $Y_{(t)}$ (in cubic units per acre) as a function of stand age t (years)

$$Y_{(t)} = 100(1 - \exp(-0.05t))^2$$

- The mean annual increment curve is obtained as

$$MAI_{(t)} = \frac{Y_{(t)}}{t}$$

- The current annual increment curve is obtained as

$$CAI_{(t)} = Y_{(t+1)} - Y_{(t)}$$

The Growth of Even-Aged Stands

Age	Yield	MAI	CAI
10	15.48	1.55	2.42
11	17.90	1.63	2.46
12	20.36	1.70	2.49
13	22.84	1.76	2.50
14	25.34	1.81	2.50
15	27.84	1.86	2.48
16	30.32	1.90	2.46
17	32.79	1.93	2.43
18	35.22	1.96	2.39
19	37.61	1.98	2.35
20	39.96	2.00	2.30
21	42.26	2.01	2.25
22	44.51	2.02	2.19
23	46.70	2.03	2.13
24	48.83	2.03	2.07
25	50.91	2.04	2.01
26	52.92	2.04	1.95
27	54.87	2.03	1.89
28	56.76	2.03	1.83
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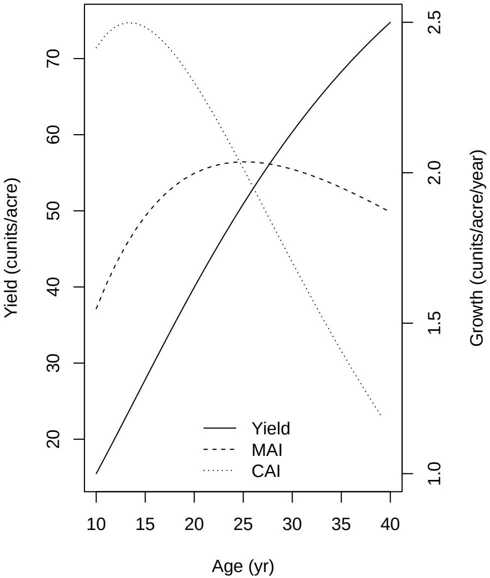
The Growth of Even-Aged Stands



The Growth of Even-Aged Stands

- When the MAI curve intersects the CAI curve, the former reaches its maximum value
- The age at which MAI reaches the maximum is referred to as the *biological rotation age*
- Use of any other rotation age in the infinite series of plantations would result in a lower average annual production rate
- For a forest owner whose objective is maximum volume production, the rotation age used should be the rotation of maximum mean annual increment

Financially Optimal Rotation

- Consider a land area for which we want to calculate the optimum bare land strategy without thinning and whose growth is defined by the previous yield curve $Y_{(t)}$
- The economic values appropriate for the situation are

  S = per-cunit stumpage price = \$35
  P = per-acre regeneration cost = \$100
  i = inflation-free interest rate = 4%
  A = annual per-acre tax and administration cost = \$1.5

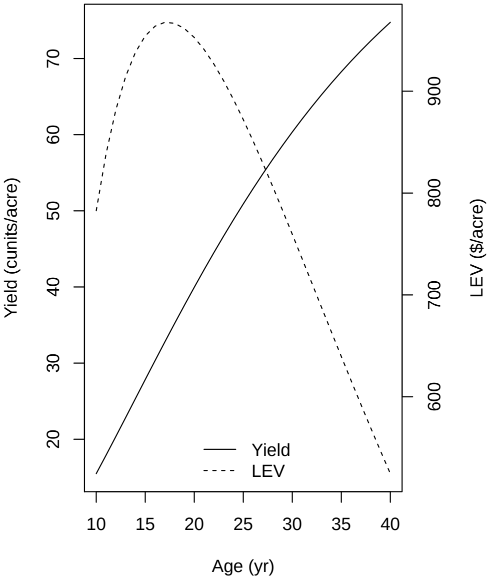
- For a given rotation age R, the LEV may be calculated as

$$\mathrm{LEV}_{(R)} = \frac{SY_{(t)} + P(1+i)^R}{(1+i)^R - 1} - \frac{A}{i} = \frac{35Y_{(t)} + 100(1.04)^R}{(1.04)^R - 1} - \frac{1.5}{0.04}$$

Financially Optimal Rotation

Age	Yield	MAI	CAI	NFV	NPV	LEV
...	...	...	...	...	...	...
13	22.84	1.76	2.50	608.09	365.21	914.32
14	25.34	1.81	2.50	686.39	396.37	938.10
15	27.84	1.86	2.48	764.26	424.37	954.20
16	30.32	1.90	2.46	841.30	449.18	963.71
17	32.79	1.93	2.43	917.15	470.84	967.56
18	35.22	1.96	2.39	991.51	489.44	966.56
19	37.61	1.98	2.35	1064.11	505.07	961.39
20	39.96	2.00	2.30	1134.74	517.88	952.66
21	42.26	2.01	2.25	1203.20	528.01	940.91
22	44.51	2.02	2.19	1269.35	535.61	926.59
23	46.70	2.03	2.13	1333.05	540.85	910.11
24	48.83	2.03	2.07	1394.20	543.91	891.83
25	50.91	2.04	2.01	1452.71	544.94	872.06
26	52.92	2.04	1.95	1508.52	544.11	851.08
27	54.87	2.03	1.89	1561.57	541.58	829.14
28	56.76	2.03	1.83	1611.83	537.51	806.44
...	...	...	...	...	...	...

Financially Optimal Rotation



The Forest Value

Decisions Concerning Existing Stands

- The Land Expectation Value (LEV) is the best criterion for selecting an optimal management regime consisting of an infinite series of similar rotations, starting from bare land
- Once such a series is underway, all future management activities are scheduled until changes in economics or mensurational inputs make a different infinite series optimal
- However, if there exists a stand on a particular site and it differs from the optimal infinite series stand, a decision problem exists

When to harvest the current stand

- How long the existing stand should be left before it is harvested and the first stand of the infinite series established?
- Although the details of the appropriate analysis may be complex, the concept involved is familiar and straightforward
- The **optimum** length of time to hold the existing stand is the specified **period that maximizes the present value of all future cash flows** – the so-called *forest value*

Definition of Forest Value

The **Forest Value** *is the present value, per unit area of forest, of the projected costs and revenues from a forested tract with or without an existing stand of timber, and on which an infinite series of identical future even-aged forest rotations will also be grown*

Forest Value Assumptions

In the case of **even-aged stands**, it is assumed that

i. The current stand will be harvested, either now or at some point in the future
ii. It will be replaced with a new stand
iii. All future rotations (after the current one) will be identical, with rotations of equal length and identical net revenue streams within a rotation

Generalization of the LEV

How does the **forest value generalize** the **LEV**?

- It applies to forested properties **at any stage of development**, not just at the beginning of the rotation
- It includes the **value** of both the **land** and the **trees**
- It allows to make **different assumptions** about the **current rotation** than those made about **future rotations**
- It allows to assume that **prices** will **change**, at least during the **current rotation**

Forest Value Calculation

- For the previous example it has already be established that the optimum economic rotation is 17 years and the bare land value is $967.56
- Consider now that a site with the same characteristics currently supports a stand with a standing volume of 10.1 cunits per acre
- Projected future values for the next 10 years are

Years hence	Yield (cunits/acre)
1	11.8
2	13.7
3	15.2
4	16.7
5	18.1
6	19.3
7	20.3
8	21.1
9	21.8
10	22.5

Forest Value Calculation

- If the current stand is harvested 5 years from now, the infinite plantation series would begin at that time and the present value 5 years hence, of all subsequent cash flows, would be $967.56
- The cash flow summary for the strategy of holding the current stand 5 years is

Year	Cash flow ($)
1	-1.5
2	-1.5
3	-1.5
4	-1.5
5	18.1(35) + 967.56 - 1.5 = 1599.56

- With an interest rate of 4%, this cash flow has a present value of $1309.28

Forest Value Calculation

- A general formula for the present value strategy (forest value, FV) involving harvest n years hence is

$$\mathrm{FV}_{(n)} = \frac{\$35\,Y_{(n)}}{1.04^n} + \frac{\$967.56}{1.04^n} - 1.5\frac{1.04^n - 1}{0.04\,(1.04)^n}$$

- The first term is simply the present value of the income received from harvest of the current stand
- The second term contains the present value of all cash flows generated by the infinite series of subsequent plantations
- The third term includes the present value of tax and administrative costs through the year of harvest of the current stand (all tax and administrative costs following that year are included in the LEV)

Forest Value Calculation

- Forest values for strategies with various times to initial harvest

n	$Y_{(n)}$	PVIH	PVLEV	PVTAC	ForestValue
0	10.1	353.50	967.56	0.00	1321.06
1	11.8	397.12	930.35	-1.44	1326.02
2	13.7	443.32	894.56	-2.83	1335.06
3	15.2	472.95	860.16	-4.16	1328.94
4	16.7	499.63	827.08	-5.44	1321.26
5	18.1	520.69	795.26	-6.68	1309.28
6	19.3	533.86	764.68	-7.86	1290.67
7	20.3	539.92	735.27	-9.00	1266.19
8	21.1	539.61	706.99	-10.10	1236.50
9	21.8	536.07	679.80	-11.15	1204.72
10	22.5	532.01	653.65	-12.17	1173.49

Separating land and timber values

- With the optimum strategy of harvest 2 years hence, the current value of land and timber is \$1335.06 per acre

$$\text{Forest value} = \text{Timber value} + \text{Land value}$$

- What portion of this total value is properly ascribed to the land and what part should be considered timber value?
- Regardless of the timber stand characteristics, the **value of the land** is always given by the **LEV** which, in this case, is \$967.56 per acre
- Therefore, the **timber value** is

$$\begin{aligned} \text{Timber value} &= \text{Forest value} + \text{LEV} \\ &= \$1335.06 - \$967.56 = 367.50 \text{ per acre} \end{aligned}$$

Separating land and timber values

- If the existing merchantable timber was harvested immediately, the income would be 10.1 cunits per acre times \$35 per cunit, or \$353.50
- This merchantable timber value is one component of the total timber value
- The remaining \$14.00 (\$367.50 - \$353.50) is the *incremental growing stock* value and the fact that it is positive confirms the conclusion that immediate harvest is not the optimum strategy

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