Lecture 14. Financially optimal rotation for a single tree and groups of trees

FOR 4684 Natural Resource Economics and Management

Rotation determination assumptions

- Landowner wants to maximize net present value
- Growing timber is most profitable use of land
- All trees and land reserved from timber production are excluded from analyses
- No forest-wide constraints on harvesting to consider at this point
- A single guiding rate (ARR) can be used to evaluate investments and reinvestments
- Analyses will be done in real dollar terms to remove inflation effect.

Uneven-aged management

- Step 1: Determine guiding rate (ARR)
- Step 2: Calculate current stumpage value of tree
- Step 3: Estimate future stumpage value of tree at various ages when the tree might be cut
- Step 4: Determine rate of value growth for tree at each time period
- Step 5: Set (tentative) harvest date at latest point where tree's value increases faster than guiding rate.

Note: These principles can be applied to even-aged rotation determination, as you will see in future lectures.

Example: cherrybark oak

- Landowner has guiding rate of 6% on his forestry investments in real dollar terms (after inflation)
- We will assume no real price increases in stumpage price
- Used stumpage prices from 2Q 2003 (Timber Mart South), south Arkansas
  - Oak $398 / MBF Doyle (2Q 2009 = $244)
  - Pine $399 / MBF Doyle (2Q 2007 = $216)
  - Hdwd $197 / MBF Doyle (2Q 2007 = $188)

Example: cherrybark oak

- Today:
  - Tree is 30 years old
  - DBH: 12.4 inches Height: 1 ½ logs
  - Volume: 36 board feet, Doyle
- Stumpage price
  - 2003: $398 / MBF   2009: $244 / MBF
- Tree value:
  - 2003 dollars: 0.036MBF x $398/MBF= $14.33
  - 2009 dollars: 0.036MBF x $244/MBF = $8.78

Example: cherrybark oak

- 10 years from now
  - Tree is 40 years old
  - DBH: 15.7 inches   Height: 2 ½ logs
  - Volume: 132 board feet, Doyle
- Stumpage price:
  - 2003: $398 / MBF   2009: 244 / MBF
- Tree value:
  - 2003 Dollars: 0.132MBF x $398/MBF= $52.54
  - 2009 Dollars: 0.132MBF x $244/MBF = $32.21

Example: cherrybark oak

- 20 years from now
  - Tree is 50 years old
  - DBH: 18.7 inches, Height: 3 logs
  - Volume: 256 board feet, Doyle
- Stumpage price
  - 2003: $398 / MBF   2009: $244 / MBF
- Tree value:
  - 2003 dollars: 0.256MBF x $398/MBF= $101.89
  - 2009 dollars: 0.256MBF x $244/MBF= $62.46

Example: cherrybark oak

- 30 years from now
  - Tree is 60 years old
  - DBH: 21.4 inches Height: 3 logs
  - Volume: 344 board feet, Doyle
- Stumpage price:
  - 2003: $398 / MBF   2009: $244 / MBF
- Tree value:
  - 2003 dollars: 0.344MBF x $398/MBF= $136.91
  - 2009 dollars: 0.344MBF x $244/MBF=$83.94

Calculate rate of value growth: 2003 dollars

For the value growth from today to 10 years:

$$Rate = \left[\sqrt[10]{\frac{V_{+10yrs}}{V_{Today}}} - 1 \right] 100 = \left[\sqrt[10]{\frac{\$52.54}{\$14.33}} - 1 \right] 100 = 13.9\%$$

For the value growth from + 10 to + 20 years

$$Rate = \left[\sqrt[10]{\frac{V_{+20yrs}}{V_{+10yrs}}} - 1 \right] 100 = \left[\sqrt[10]{\frac{\$101.89}{\$52.54}} - 1 \right] 100 = 6.8\%$$

For the value growth from + 20 to + 30 years

$$Rate = \left[\sqrt[10]{\frac{V_{+30yrs}}{V_{+20yrs}}} - 1 \right] 100 = \left[\sqrt[10]{\frac{\$136.71}{\$101.89}} - 1 \right] 100 = 3\%$$

Calculate rate of value growth: 2009 dollars

For the value growth from today to 10 years:

$$Rate = \left[\sqrt[10]{\frac{V_{+10years}}{V_{Today}}} - 1 \right] 100 = \left[\sqrt[10]{\frac{32.21}{8.78}} - 1 \right] 100 = 13.9\%$$

For the value growth from + 10 to + 20 years

$$Rate = \left[\sqrt[10]{\frac{V_{+20years}}{V_{+10years}}} - 1 \right] 100 = \left[\sqrt[10]{\frac{62.46}{32.21}} - 1 \right] 100 = 6.8\%$$

For the value growth from + 20 to + 30 years

$$Rate = \left[\sqrt[10]{\frac{V_{+30years}}{V_{+20years}}} - 1 \right] 100 = \left[\sqrt[10]{\frac{83.94}{62.46}} - 1 \right] 100 = 3\%$$

Decision

Plan to harvest this tree shortly after 20 additional years of growth

Equating value growth of tree to guiding rate is called *financial maturity* concept.

NPW of decision

- We can also calculate the NPW in current dollar terms of each action:
  - Using 2003 stumpage prices….
  - Harvest tree today: $14.33
  - NPW of cutting tree in future years:
    - 10 years: NPW = $\$52.54(1.06)^{-10}$=$29.34
    - 20 years: NPW = $\$101.89(1.06)^{-20}$=$31.77
    - 30 years: NPW = $\$136.91(1.06)^{-30}$=$23.84
- Best NPW is to harvest the tree in 20 years (NPW decision rule is to choose highest rotation with highest value)

One slight problem…

- Using financial maturity ignores future generations of trees!
- Compare harvesting today vs. harvesting in 20 years:
  - 20 years: 101.89 + bare ground
  - Today: $\$14.33(1.06)^{20} = \$45.96$ + 20 year old tree
- So, financial maturity and NPW ignore the value of the 20 year tree.

How long would future rotations be?

- If we assume that future trees will grow much better under management and we'll have the following values for future trees occupying the same space as our current tree:

Age	Value
30	$50
40	$135
50	$280
60	$370

Use SEV to determine rotation length

- SEV takes an infinite periodic series of payments and determines its present value

$$SEV = V_R \frac{1}{(1+i)^R - 1}$$

Applying SEV to rotations for future cherrybark trees

		SEV @	SEV @
Age	Value	6%	8%
30	50	$10.54	$5.52
40	135	$14.54	$6.51
50	280	$16.07	$6.10
60	370	$11.57	$3.69

So, if our ARR is 6%, future rotations will be 50 years, and if our guiding rate is 8% then future rotations will be 40 years.

Applying the value of future rotations of trees

- We can think of opportunity costs regarding harvesting a tree as two kinds:
  - Stock holding cost: The opportunity costs associated with the current tree value
  - Land holding cost: The opportunity costs associated with delaying all future rotations of trees

Our example: stock holding cost (SHC)

- SHC is the opportunity cost of harvesting or not harvesting caused by the value of the existing tree
  - Value today: $14.33
    - If I don't cut today, I forego $14.33 of monetary value today, an opportunity cost
  - Value in 10 years: $52.54
    - If I don't cut 10 years from now, I forego $52.54 (value in future dollars)
- SHC formula
  - $SHC = V_0(1+i)^n - V_0$
  - $SHC = 14.33(1.06)^{10} - 14.33 = \$11.33$
  - This is the lost interest gained because you did not cut the tree today but waited ten years to get the gain in growth and value from $14.33 to $52.54

Our example: land holding cost (LHC)

- LHC is the opportunity cost of delaying future rotations of trees
  - Based on the table, the optimal future rotations of trees will be 50 years and have a value of $16.07 (for the land area occupied by one tree)
  - If I wait 10 years to harvest, then I am delaying all future rotations of trees by 10 years
  - LHC = $SEV(1+i)^n$ – SEV
  - LHC = $16.07(1.06)^{10}$ - 16.07 = $12.71
  - The $12.71 is the value lost by not starting future rotations today.
    - It can also be thought of as the interest charges lost by delaying all future rotation 10 years.

Putting SHC and LHC together

Years into future	Tree Value	Tree value w/ +10 yrs	Value gain from holding	SHC @ 6%	LHC @ 6%	Total Holding Costs	Net gain from holding
0	14.33	52.54	38.21	11.33	12.71	24.04	14.17
10	52.54	101.89	49.35	41.55	12.71	54.26	-4.91
20	101.89	136.91	35.02	80.58	12.71	93.29	-58.27

- Net gain from holding tree 10 years is positive
- Net gain from holding tree between +10 and +10 years is negative

Decision: Harvest tree after 10 years!

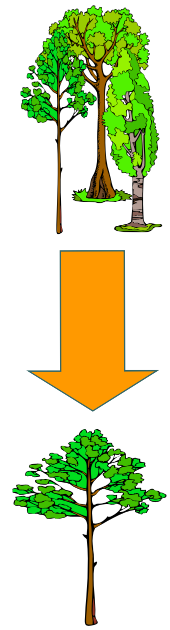
Deciding when to cut a tree

- Important to consider both SHC and LHC
- Including LHC may shorten rotations more than considering SHC alone.
- LHC application:
  - If current tree delays future tree's establishment, LHC is relevant and subtracted from holding gains
  - If current tree's presence is neutral towards establishing future tree(s), then only use SHC
  - If current tree's presence helps establish future tree(s), then ADD LHC to net gain.

Reality check

- Will we do this detailed analysis for every tree?
  - NO!
- Classify trees by site, diameter, and average growth
  - Determine points where, for a particular interest rate, you know you will either harvest or leave a tree
  - Must update decision criteria when interest rates or stumpage prices change significantly!

Groups of trees



- Assumption that 2 or more trees in a group will be replaced by a single tree in future rotations
- Decision on groups of N trees involves 2^N decisions
  - Usually N is less than 4
  - For example, N = 2 trees:
    - Cut none
    - Cut tree 1, leave tree 2
    - Leave tree 1, cut tree 2
    - Cut both trees
- More time periods also complicates situation…

The situation

- We have two oak trees growing on a site, where, in the future, we will have only one tree.
- We will not start next rotation until all initial trees are removed.
- We have to determine the optimal rotation for the future tree to establish land holding cost (LHC)
- We are considering harvest today, in 10 years, or in 20 years.

Tree	Value today	Value in 10 years	Value in 20 years
1	$85.54	$145.89	$221.37
2	$27.03	$87.27	$150.49

A total of nine possible alternatives…can you list them?

Determine LHC

- Value at rotation age for a single tree

Age	Value @ R		
30	20.00		
40	125.00		
50	440.00		
60	890.00		
70	1,290.00		
80	1,640.00		
90	1,970.00		
100	2,210.00		

Determine LHC

- Value at rotation age for a single tree
- Calculate SEV

		SEV @	SEV @
Age	Value @ R	6%	8%
30	20.00	4.22	2.21
40	125.00	13.46	6.03
50	440.00	25.26	9.59
60	890.00	27.82	8.88
70	1,290.00	22.21	5.93
80	1,640.00	15.65	3.48
90	1,970.00	10.45	1.94
100	2,210.00	6.53	1.01

Determine LHC

- Value at rotation age for a single tree
- Calculate SEV
- Optimal rotations:
  - 6%: 60 years and $27.82
  - 8%: 50 years and $9.59

		SEV @	SEV @
Age	Value @ R	6%	8%
30	20.00	4.22	2.21
40	125.00	13.46	6.03
50	440.00	25.26	9.59
60	890.00	27.82	8.88
70	1,290.00	22.21	5.93
80	1,640.00	15.65	3.48
90	1,970.00	10.45	1.94
100	2,210.00	6.53	1.01

SEV is the present value of bare ground when you create it.

Analysis for first 10 yrs…

Cost of capital =	6%			
	Leave	both	Leave	Leave
Item	Tree 1	Tree 2	tree 1	tree 2
1 Value today	$85.54	$27.03	$85.54	$27.03
2 Value in 10 years	$145.89	$87.27	$145.89	$87.27
3 Value growth	$60.35	$60.24	$60.35	$60.24
		$120.59		
4 Stock Holding Cost	$67.65	$21.38	$67.65	$21.38
5 Land Holding Cost		$22.00	$22.00	$22.00
6. Total Cost		$111.03	$89.65	$43.38
7. Net gain from holding		$9.56	-$29.30	$16.86

- Net gain from holding both is positive, so you will keep both or at least one tree
- Net gain from holding tree 1 is negative
- Net gain from holding tree 2 is positive and higher than gain from holding both
- Decision is to hold tree 2 for another 10 years!

Analysis for second 10 yrs…

Cost of capital =	6%			
	Leave	both	Leave	Leave
Item	Tree 1	Tree 2	tree 1	tree 2
1 Value today	$145.89	$87.27	$145.89	$87.27
2 Value in 10 years	$221.37	$150.49	$221.37	$150.49
3 Value growth	$75.48	$63.22	$75.48	$63.22
		$138.70		
4 Stock Holding Cost	$115.38	$69.02	$115.38	$69.02
5 Land Holding Cost		$22.00	$22.00	$22.00
6. Total Cost		$206.40	$137.38	$91.02
7. Net gain from holding		-$67.70	-$61.90	-$27.80

- Net gain from holding both is negative, so you will cut at least one or both trees
- Net gain from holding tree 1 is negative
- Net gain from holding tree 2 is negative
- Decision is to cut both trees!

Can solve by NPW method

- As soon as you have cut both trees, you also receive SEV in that year
- We can make a 20 year cash flow table…

Cash flows for NPV analysis

Year	Alternative								
	1 today 2 today	1 today 2 10 yrs	1 today 2 20 yrs	1 10 yrs 2 today	1 10 yrs 2 10 yrs	1 10 yrs 2 20 yrs	1 20 yrs 2 today	1 20 yrs 2 10 yrs	1 20 yrs 2 20 yrs
0	85.54 + 27.03 + 27.82 = 140.39	85.54	85.54	27.03	0	0	27.03	0	0
10	0	87.27 + 27.82 = 115.09	0	145.89 + 27.82 = 173.71	145.89 + 87.27 + 27.82 = 260.98	145.89	0	87.27	0
20	0	0	150.49 + 27.82 = 178.31	0	0	150.49 + 27.82 = 178.31	221.37 + 27.82 = 249.19	221.37 + 27.82 = 249.19	221.37 + 150.49 + 27.82 = 399.68

Now let's discount these all at 6%…

NPV analysis completed…

Cash Flows									
Alternative	1	2	3	4	5	6	7	8	9
Tree 1 cut	0	0	0	10	10	10	20	20	20
Tree 2 cut	0	10	20	0	10	20	0	10	20
0	$140.39	$85.54	$85.54	$27.03	$0.00	$0.00	$27.03	$0.00	$0.00
10	$0.00	$115.09	$0.00	$173.71	$260.98	$145.89	$0.00	$87.27	$0.00
20	$0.00	$0.00	$178.31	$0.00	$0.00	$178.31	$249.19	$249.19	$399.68
NPV @	6%								
Year	1	2	3	4	5	6	7	8	9
0	$140.39	$85.54	$85.54	$27.03	$0.00	$0.00	$27.03	$0.00	$0.00
10	$0.00	$64.27	$0.00	$97.00	$145.73	$81.46	$0.00	$48.73	$0.00
20	$0.00	$0.00	$55.60	$0.00	$0.00	$55.60	$77.70	$77.70	$124.62
NPW =	$140.39	$149.81	$141.14	$124.03	$145.73	$137.06	$104.73	$126.43	$124.62

From the NPW analysis we see that alternative 2, cutting tree 1 today and tree 2 in 10 years has the highest NPV, which agrees with our previous analysis!

Reality?

- Won't do such detailed NPV analysis for all groups of trees
  - Too much data
  - Too much time
- But marking guides for a site can be developed
  - Knowing when certain trees have reached financial maturity
  - Classifying trees by "definitely grow", definitely cut, and "make a call…"
    - Like the old Kenny Rogers song, "You gotta know when to hold 'em and when to fold 'em"

Dealing with depressed timber markets

- What if you had that 40-year old cherrybark oak today, and it has 132 bf volume but due to depressed timber prices it has a market value of $32.21.
- If markets don't improve, in 10 years, the tree would be worth $62.46
- If we assume our bare land value is still $16.07, then our decision looks like it has before, but the values are smaller:

Years into future	Tree Value	Tree value w/ +10 yrs	Value gain from holding	SHC @ 6%	LHC @ 6%	Total Holding Costs	Net gain from holding
0	8.78	32.21	23.43	6.94	12.71	19.65	3.78
10	32.21	62.46	30.25	25.47	12.71	38.18	-7.93
20	62.46	83.94	21.48	49.40	12.71	62.11	-40.63

- But what happens if stumpage markets recover in 10 years?

Effect of market projection…

- What happens if 10 years from now, the oak stumpage rises to $398 per MBF, which was the 2003 price (2003 values used in orange sells)?

Years into future	Tree Value	Tree value w/ +10 yrs	Value gain from holding	SHC @ 6%	LHC @ 6%	Total Holding Costs	Net gain from holding
0	8.78	52.54	43.76	6.94	12.71	19.65	24.11
10	52.54	101.81	49.27	41.55	12.71	54.26	-4.99
20	101.89	136.91	35.02	80.58	12.71	93.29	-58.27

- Now, we'd cut the tree after 20 years, not ten, because of the effect of market recovery!

Effect of market projection…

- What happens if 20 years from now, the oak stumpage rises to $398 per MBF, which was the 2003 price (2003 values used in orange sells)?

Years into future	Tree Value	Tree value w/ +10 yrs	Value gain from holding	SHC @ 6%	LHC @ 6%	Total Holding Costs	Net gain from holding
0	8.78	32.21	23.43	6.94	12.71	19.65	3.78
10	32.21	101.81	69.60	25.47	12.71	38.18	31.42
20	101.89	136.91	35.02	80.58	12.71	93.29	-58.27

- Now, we'd cut the tree after 20 years, not ten, because of the effect of market recovery!

Important when making projections about future markets

- Since the timing of anticipated market jumps is highly variable, USE CAUTION!
- Better to base long-term management on long-term average prices and price increases
- However, delaying harvest in short-term might yield valuable returns!

Making a good choice in a depressed market…

- If I have that 40-year old oak tree today, worth $32.21 in the depressed timber market, and I expect prices to rise in two years to $321/MBF (50% price recovery)
- SHC = $\$32.21(1.06)^2 – 32.21 = \$3.98$
- LHC = $\$16.07(1.06)^2 – 16.07 = \$1.99$
- Gain from holding two years, assuming tree doesn't grow at all:
  - Tree value in 2011 = 132bf x $321/MBF = $43.37
  - Net gain from holding tree two years:
  - $43.27 – 32.31 – 3.98 – 1.99 = $4.19
- HOLD THE TREE!

Next lecture….

Optimal levels of reserve growing stock in uneven-aged forests