Lecture 16. Even-aged rotation determination

FOR 4684 Natural Resource Economics and Management

UAM
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Arkansas Forest Resources Center

Even-aged management 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.

Methods

- Financial maturity
  - Equate marginal value growth of stand to guiding rate
  - Harvest stand when marginal value growth less than guiding rate
  - This will maximize NPV of current stand
- Maximum NPV
  - Convert all cash flows to PV and sum
  - Choose option with highest NPV
- Both of above methods ignore land holding cost
- Soil expectation value
  - Choose rotation with highest soil expectation value
  - This will maximize NPV of an infinite series of rotations
  - Assumes sustainability and best available technology

Assumption: starting with bare land

Natural regeneration

- Assume once site is harvested, no planting
- May or may not need to include site preparation costs
  - Seedbed scarification
  - Clearfelling residual, non-merchantable trees

Let's assume the following

- Naturally regenerated loblolly pine in SE US
- ARR = 4%
- Site prep costs = $25 / acre for prescribed burn
- No planting costs
- Precommercial thinning cost at stand age of 8 years at a cost of $85 per acre
- We'll conduct a commercial thinning at age 20 that yields 16 tons / acre pulpwood
- Stumpage prices are:
  - $50 / ton for sawtimber
  - $10 / ton for pulpwood
- Yields for the stand are predicted as follows from ages 25-60:

Volume production

	Sawtimber	Pulpwood
Age	Yield	Yield
25	12	42
30	36	36
35	63	21
40	81	20
45	99	17
50	121	10
55	137	7
60	150	7

Value at rotation…

Sawtimber	$50.00		
Pulpwood	$10.00		
	Sawtimber	Pulpwood	Value at
Age	Yield	Yield	Rotation
25	12	42	$1,020
30	36	36	$2,160
35	63	21	$3,360
40	81	20	$4,250
45	99	17	$5,120
50	121	10	$6,150
55	137	7	$6,920
60	150	7	$7,570

PV of previous management costs

$$PV = (\$25)(1.04)^{-0} \text{ site prep}$$
$$+ (\$85)(1.04)^{-8} \text{ precomm. thinning}$$
$$+ \$160(1.04)^{-20} \text{ com. thinning}$$
$$= (\$14)$$

Calculate NPW and SEV

Age	Value at Rotation	NPV of Prev. flows	PV of final harvest	NPV of Rotation	SEV
25	$1,020	-$14	$383	$369	$590
30	$2,160	-$14	$666	$652	$943
35	$3,360	-$14	$851	$837	$1,122
40	$4,250	-$14	$885	$871	$1,100
45	$5,120	-$14	$877	$863	$1,041
50	$6,150	-$14	$865	$851	$991
55	$6,920	-$14	$800	$786	$889
60	$7,570	-$14	$720	$706	$780

Optimal rotation length for only one rotation

Optimal rotation considering future rotations

(We could have ignored all cash flows that were identical among all options)

Artificial regeneration

- No difference in analysis methods
- Add in costs of planting
- Future yields need to reflect anticipated gains from all silvicultural activities

Plantation costs

- Site preparation at year 0
  - $135 per acre
- Planting 545 trees per acre at year 0
  - Cost: $60 per acre
- Competition control at year 1
  - $90 per acre
- Fertilization at year 10
  - $65 per acre
- Commercial thinnings
  - Age 15: 15 tons / acre = $150 / acre
  - Age 20: 30 tons / acre (20 tons pulp + 10 tons CNS worth $25 / ton) = $450

Volume production from plantation

	Sawtimber	Pulpwood
Age	Yield	Yield
25	33	101
30	85	85
35	170	50
40	214	40
45	231	20
50	260	17
55	280	12
60	300	8

Value at rotation for plantation…

	Sawtimber	Pulpwood	Value at
Age	Yield	Yield	Rotation
25	33	101	$2,660
30	85	85	$5,100
35	170	50	$9,000
40	214	40	$11,100
45	231	20	$11,750
50	260	17	$13,170
55	280	12	$14,120
60	300	8	$15,080

PV of plantation costs

$PV = [(\$135)+(\$60)](1.04)^{-0}$ site prep planting

$+(\$90)(1.04)^{-1}$ competition control

$+(\$65)(1.04)^{-10}$ fertilization

$+\$150(1.04)^{-15}$ thinning at age 15

$+\$450(1.04)^{-20}$ thinning at age 20

$=(\$37)$

Calculate NPV and SEV for our plantation…

Age	Value at Rotation	NPV of Prev. flows	PV of final harvest	NPV of Rotation	SEV
25	$2,660	-$37	$998	$961	$1,538
30	$5,100	-$37	$1,572	$1,535	$2,220
35	$9,000	-$37	$2,281	$2,244	$3,005
40	$11,100	-$37	$2,312	$2,275	$2,874
45	$11,750	-$37	$2,012	$1,975	$2,382
50	$13,170	-$37	$1,853	$1,816	$2,114
55	$14,120	-$37	$1,633	$1,596	$1,805
60	$15,080	-$37	$1,434	$1,397	$1,543

Optimal rotation length for only one rotation

Optimal rotation considering future rotations

(We could have ignored all cash flows that were identical among all options)

Next is considering existing stands in our analysis

Initial considerations

- Economic assumptions same as before
- Must consider when to replace existing stand
- Must know
  - SHC for existing stand
    - Current volume, growth and value data
  - LHC for future stands
    - Projected volume and value of future rotations

Initial stand conditions

- 160 acres of shortleaf pine in NW Arkansas
- Age: 25 yrs
- SI ~ 60
- Current stocking 70%
- Growth of current stand will be 85% of normal stands.
- Future stands will have 100% stocking and growth.
- Stumpage value is $240 per MBF

Shortleaf pine yield in board feet (International ¼-inch rule) per acre. From USDA For. Serv. Misc. Pub. No. 50.

Age (years)	Site index in feet at 50 years						
	40	50	60	70	80	90	100
	Yield in board feet (International ¼-inch rule) per acre						
15	--	--	--	--	--	200	1400
20	--	--	--	250	1600	3800	7500
25	--	--	800	2800	5700	10500	14950
30	--	900	3300	6900	11550	17000	23050
35	600	2800	6600	11750	17100	23750	30900
40	1750	5000	10200	16400	22450	29750	37600
45	3000	7500	13600	20250	27200	35300	43850
50	4200	9800	16600	23800	31600	40000	49000
55	5650	11900	19250	27000	35200	44200	53600
60	6900	13800	21500	29700	38200	47500	57300
65	8100	15400	23600	3200	40800	50400	60800
70	9200	16900	25300	34100	43200	53200	63750

Steps in determining when to harvest existing stand

- First, determine land holding costs, if applicable
  - Yes, since shortleaf is shade intolerant
- Find LHC from maximum SEV for future stands
- At 4%, optimal rotation is 45 years, SEV is $674 / acre

Age	Volume	$ / MBF	Value @ Rotation	SEV @ 4%
10	0	240	0	0
15	0	240	0	0
20	0	240	0	0
25	800	240	192	115
30	3300	240	792	353
35	6600	240	1,584	538
40	10200	240	2,448	644
45	13600	240	3,264	674
50	16600	240	3,984	652
55	19250	240	4,620	604
60	21500	240	5,160	542
65	23600	240	5,664	480
70	25300	240	6,072	417

$$LHC = \$674(1.04)^5 - \$674 = \$146$$

Determining when to harvest an existing stand

- Second, model existing stand growth and value increment

Today	Age	Volume
0	25	560
5	30	2685
10	35	5490
15	40	8550
20	45	11440
25	50	13990
30	55	16243
35	60	18155
40	65	19940
45	70	21385

Steps in determining when to harvest existing stand

- Step 3: Calculate net gain from holding, SHC and LHC

Today	Age	Volume	$ / MBF	Current Value	Gain from Holding	SHC	LHC	Net Gain From Holding
0	25	560	240	134				
5	30	2685	240	644	510	29	146	335
10	35	5490	240	1,318	673	140	146	388
15	40	8550	240	2,052	734	285	146	303
20	45	11440	240	2,746	694	445	146	103
25	50	13990	240	3,358	612	595	146	-129
30	55	16243	240	3,898	541	727	146	-333
35	60	18155	240	4,357	459	845	146	-532
40	65	19940	240	4,786	428	944	146	-662
45	70	21385	240	5,132	347	1,037	146	-836

Continue to hold existing stand as long as net gain from holding is positive

NPV method

- Determine NPV of holding existing stand:

$$NPV = (V_C + SEV_{\max})(1+i)^{-n}$$

NPV method

- Determine NPV of holding existing stand:

$$NPV = (V_C + SEV_{\max})(1+i)^{-n}$$

- Where:
  - N = number of years existing stand is permitted to grow
  - V_c = value of current stand
  - SEV_{max} = maximum SEV for future rotations at ARR

Select time of harvest

							PV of SEV
				Current		SEV + Current	+ Current
Today	Age	Volume	$ / MBF	Value	SEV	Value	Value
0	25	560	240	134	674	808	808
5	30	2685	240	644	674	1,318	1,084
10	35	5490	240	1,318	674	1,992	1,345
15	40	8550	240	2,052	674	2,726	1,514
20	45	11440	240	2,746	674	3,420	1,561
25	50	13990	240	3,358	674	4,032	1,512
30	55	16243	240	3,898	674	4,572	1,410
35	60	18155	240	4,357	674	5,031	1,275
40	65	19940	240	4,786	674	5,460	1,137
45	70	21385	240	5,132	674	5,806	994

- Choose age where PV is maximized
- The most you could pay for this land is $1561 per acre!

What's the rate of return on this decision?

- Forgo cutting today
  - Opportunity cost of $808 (existing timber + bare land value)
- Harvest in 20 years and receive $3420 (current stand's value + bare land value)

$$ROR = \left[\sqrt[20]{\frac{\$3420}{\$808}} - 1 \right] 100 = 7.5\%$$

Real vs. nominal dollars

- Ok, all the previous work has been in real dollars
- Real dollars are inflation-adjusted – they buy the same amount of goods and services in any year.
  - A fictional concept
  - A real dollar always buys the same amount of goods and services in any given year – that's why we say inflation is built into real dollars.
- Nominal dollars are not inflation adjusted, they don't buy the same amount of goods
  - The goods my mother could buy with $100 in 1963 (the year I was born) would cost $631 in 2005.

A comparison of real dollars vs. nominal dollar analysis

- Real dollars
  - Timber price today is $240/MBF
- Nominal dollars
  - Timber price today is $240 / MBF
  - All prices will increase 3% / yr (*inflation*)
- We will do our nominal analysis with an ARR of 7%.
  - ARR_{real} + inflation rate = $ARR_{nominal}$

Determining LHC

Real dollars

Age	Volume	$ / MBF	Value @ Rotation	SEV @ 4%
10	0	240	0	0
15	0	240	0	0
20	0	240	0	0
25	800	240	192	115
30	3300	240	792	353
35	6600	240	1,584	538
40	10200	240	2,448	644
45	13600	240	3,264	674
50	16600	240	3,984	652
55	19250	240	4,620	604
60	21500	240	5,160	542
65	23600	240	5,664	480
70	25300	240	6,072	417

Optimal rotation = 40 yrs

SEV = $674 (real 2005 dollars)

$$LHC = \$674(1.04)^5 - \$674 = \$146$$

Nominal dollars

Age	Volume	$ / MBF	Value @ Rotation	SEV @ 7%
10	0	240	0	0
15	0	278	0	0
20	0	323	0	0
25	800	374	299	68
30	3300	433	1,430	216
35	6600	503	3,317	343
40	10200	583	5,942	425
45	13600	675	9,184	459
50	16600	783	12,996	457
55	19250	908	17,471	433
60	21500	1,052	22,621	397
65	23600	1,220	28,785	359
70	25300	1,414	35,774	317

Optimal rotation = 45 yrs

SEV = $459 (nominal dollars)

$$LHC = \$459(1.07)^5 - \$459 = \$185$$

Select time to harvest current stand – real dollars

Today	Age	Volume	$ / MBF	Current Value	SEV	SEV + Current Value	PV of SEV + Current Value
0	25	560	240	134	674	808	808
5	30	2685	240	644	674	1,318	1,084
10	35	5490	240	1,318	674	1,992	1,345
15	40	8550	240	2,052	674	2,726	1,514
20	45	11440	240	2,746	674	3,420	1,561
25	50	13990	240	3,358	674	4,032	1,512
30	55	16243	240	3,898	674	4,572	1,410
35	60	18155	240	4,357	674	5,031	1,275
40	65	19940	240	4,786	674	5,460	1,137
45	70	21385	240	5,132	674	5,806	994

Harvest 20 years from now at age = 45

Maximum value of land and timber is $1561 / acre in 2005 dollars

Select time to harvest current stand – nominal dollars

Today	Age	Volume	$ / MBF	Current Value	SEV	SEV + Current Value	PV of SEV + Current Value
0	25	560	240	134	459	593	593
5	30	2685	278	747	459	1,206	860
10	35	5490	323	1,771	459	2,230	1,133
15	40	8550	374	3,197	459	3,656	1,325
20	45	11440	433	4,959	459	5,418	1,400
25	50	13990	503	7,030	459	7,489	1,380
30	55	16243	583	9,462	459	9,921	1,303
35	60	18155	675	12,261	459	12,720	1,191
40	65	19940	783	15,611	459	16,070	1,073
45	70	21385	908	19,409	459	19,868	946

Harvest 20 years from now at age = 45

Maximum value of land and timber is $1400 / acre in nominal dollars

Rates of return

- REAL DOLLARS
  - Give up $808 today
  - Receive $3420 in 20 years

$$ROR_{real} = \left[\sqrt[20]{\frac{\$3420}{\$808}} - 1\right]100 = 7.5\%$$

- Real rate of return is 7.5% *above inflation*

- NOMINAL DOLLARS
  - Give up $593 today
  - Receive $5418 in 20 years

$$ROR = \left[\sqrt[20]{\frac{\$5418}{\$593}} - 1\right]100 = 11.7\%$$

- Nominal rate of return is 11.7% (but dollars will buy less)

Key point!

- Done correctly, nominal and real dollar analyses should result in the same decision.
  - In our case, both suggested harvesting the current stand in 20 years.
- $ARR_{nominal}$ - inflation rate ≈ ARR_{real}
  - Why? Real dollars buy the same amount of goods and services every year, so we don't need to discount them by the inflation rate

Next lecture…

The normal forest model!