Place your name on the back of each sheet!

ESRM 461 SP2017: Forest Economics & Management
Practice Final Test

- You are allowed to have two study sheets while taking the exam. The sheet may have notes on both sides. In addition, you will need a calculator, and a pen or pencil to complete the exam.
- Answer each question as succinctly as possible. Where calculations are involved, show your work. Partial credit can only be assigned if you show your work. Answers should be neat. I may take off points for messy or illegible answers.
- The total point value of this test is 109. Point values for individual questions are indicated in parentheses in bold.

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1. Calculate the land expectation value (LEV) for a tract of forest land under the following assumptions **(16 pts)**:

- the owner's primary objective for owning the land is income generation;
- the owner's nominal alternate rate of return is 7%, and inflation is expected to average 3%;
- the best prescription (given the owner's objective) for managing the stand is to plant 600 loblolly pine trees per acre, thin at age 18, and clearcut at age 28;
- the expected yield for the thin at age 18 is 12 cords of pine pulpwood per acre;
- the clearcut at age 28 is expected to yield 11 cords of pine pulpwood and 6 thousand board feet (mbf) of pine sawtimber per acre;
- the current pine pulpwood stumpage price is $22 per cord and the current pine sawtimber price is $390 per mbf;
- it costs $200 per acre to establish the stand;
- annual taxes and management costs together are $5 per acre,
- all prices, costs, revenues, and the real alternative rate of return are expected to remain constant in real terms.

2. The tract described in problem 1 is currently forested with loblolly pine. After cruising the property you estimated that there are 6 mbf of pine sawtimber, 16 cords of pine pulpwood, and 6 cords of hardwood pulpwood per acre. You have entered the stand data into a growth and yield simulator for loblolly pine, and it projects the stand will grow an additional 3.5 mbf of pine sawtimber and 1 cord of pine pulpwood per acre in the next 5 years. You estimate that the hardwood pulpwood volume will remain approximately constant. Assume that you will replant the stand after harvest and that the yield for the new stand will follow the yield data in problem 1. Use the economic data from problem 1, and assume that hardwood pulpwood sells for $12 per cord **(16 pts)**.

a. Calculate the forest value of this tract assuming you will cut it now **(6 pts)**.

b. Calculate the forest value of this tract assuming you will cut it in 5 years **(10 pts)**.

3. In what sense can you have too much inventory volume in a forest **(8 pts)**?

4. What is the difference between formulating and solving a linear programming problem **(8 pts)**?

5. Consider the development of a management plan for a 27,400 acre forest. The area has been classified into two site classes. The predicted yields for each site class for a range of rotation ages are given in Table 5.1. The current age class distribution of the forest by site class is shown in Table 5.2 **(65 pts)**.

Table 5.1. Yield Projections for Site Classes I and II.

Age (years)	Site I Vol./acre (cords)	Site II Vol./acre (cords)
10	2	5
20	10	14
30	17	22
40	21	26
50	22	28
70	23	29

Table 5.2. Initial forest acreage by site and age class.

Age (years)	Site I Vol./acre (cords)	Site II Vol./acre (cords)
1-10	0	4,500
11-20	5,000	3,700
21-30	7,500	6,700
Total	12,500	14,900

On the next page is a linear programming formulation designed to help develop a management plan for the 27,400 acre forest described above. The linear program minimizes the discounted costs over a 30-year planning horizon. The linear programming formulation was developed using a real interest rate of 4%. Real stumpage prices are assumed to be $35 per cord. It is assumed that stand establishment costs are $150 per acre and timber sale costs are $10 per acre plus $1 per cord sold. (Note: timber sale costs occur at the time of the final harvest.) Furthermore, all prices and costs will be assumed to remain constant in real dollars.

Note that the variable X_{ABCD} represents the number of acres from site class A, initial age class B, that are assigned to be cut first in period C and cut again in period D. If D is 0, the stand will only be cut once during the planning horizon, and if both C and D are zero, the stand will not be cut at all. The possible decisions are to cut in periods 1, 2, or 3 or cut in both periods 1 and 3, or to not cut at all.

As an example, X_{2310} is the number of acres from site class 2 (Site II) and initial age class 3 (age 25 initially) that are cut in decade 1 and not again. Pages 5 and 6 list the output from a commercial solver. The questions (questions 5.a through 5.g) on pages 4 through 6 test your ability to interpret the linear programming formulation of the forest management problem and its solution.

LINEAR PROGRAMMING FORMULATION FOR QUESTION 5

```
MIN 139.7276 X1210 + 203.4975 X1213 + 98.28181 X1220
    + 67.89614 X1230 + 145.4811 X1310 + 209.2509 X1313 +
    100.5029 X1320 + 68.27126 X1330 + 135.618 X2110 + 200.8883
    X2113 + 96.61603 X2120 + 68.27126 X2130 + 143.0153 X2210 +
    208.2856 X2213 + 101.0581 X2220 + 69.77173 X2230 + 149.5907
    X2310 + 214.8611 X2313 + 103.2792 X2320 + 70.52196 X2330

SUBJECT TO
2) X1210 + X1213 + X1220 + X1230 + X1200 <= 5000
3) X1310 + X1313 + X1320 + X1330 + X1300 <= 7500
4) X2110 + X2113 + X2120 + X2130 + X2100 <= 4500
5) X2210 + X2213 + X2220 + X2230 + X2200 <= 3700
6) X2310 + X2313 + X2320 + X2330 + X2300 <= 6700
7) 10 X1210 + 10 X1213 + 17 X1310 + 17 X1313 + 5 X2110 + 5 X2113
   + 14 X2210 + 14 X2213 + 22 X2310 + 22 X2313 >= 200000
8) 17 X1220 + 21 X1320 + 14 X2120 + 22 X2220 + 26 X2320 >=190000
9) 10 X1213 + 21 X1230 + 10 X1313 + 22 X1330 + 14 X2113 +
   22 X2130 + 14 X2213 + 26 X2230 + 14 X2313 + 28 X2330 >=180000
10) X1330 + X2330 + X1300 + X2300 >= 2000
11) X1200 + X1300 + X2200 + X2300 >= 2000
12) 6 X1210 - 14 X1213 - 4 X1220 - 14 X1230 + 6 X1310 - 14 X1313
    - 4 X1320 - 14 X1330 - 26 X1200 + 36 X1300 >= 0
13) 6 X2110 - 14 X2113 - 4 X2120 - 14 X2130 + 6 X2210 - 14 X2213
    - 4 X2220 - 14 X2230 + 6 X2310 - 14 X2313 - 4 X2320 –
    14 X2330 + 16 X2100 + 26 X2200 + 36 X2300 >= 0
Plus non-negativity constraints for all X_ABCD
END
```

a. Show how the objective function coefficient on the variable `X2313` was calculated **(8 pts)**.

b. What is the purpose of the constraint in row 7? State precisely what it requires **(8 pts)**.

c. What is the purpose of the constraint in row 11? State precisely what it requires **(8 pts)**.

LINEAR PROGRAMMING SOLUTION FOR PROB. 5: VARIABLE VALUES

```
OBJECTIVE FUNCTION VALUE
1) 3034403.
VARIABLE  VALUE            REDUCED COST
X1210     .000000          51.229160
X1213     .000000          68.377340
X1220     3416.263000      .000000
X1230     .000000          4.287049
X1310     3094.118000      .000000
X1313     .000000          17.148090
X1320     2405.882000      .000000
X1330     1583.737000      .000000
X2110     .000000          108.517000
X2113     .000000          108.516900
X2120     .000000          21.730390
X2130     4500.000000      .000000
X2210     .000000          41.616220
X2213     .000000          41.616110
X2220     3700.000000      .000000
X2230     .000000          19.069110
X2310     3403.015000      .000000
X2313     3296.985000      .000000
X2320     .000000          21.070550
X2330     .000000          31.565530
X1200     1583.737000      .000000
X1300     416.263000       .000000
X2100     .000000          34.296510
X2200     .000000          36.217330
X2300     .000000          57.287870
```

d. How should the *reduced cost* value associated with variable `X1230` be interpreted? **(8 pts.)**

e. Fill in the harvest acreage for period 3 in the harvest schedule table (Table 5.3) below. (I have done periods 1 and 2.) **(12 pts.)**

f. Fill in Table 5.4. to show the projected age-class distribution of the forest at the end of period 3 for Site Class 2. **(12 pts.)**

Table 5.3. Harvest schedule table.

Age at Harvest	Site Class I	Site Class II
	Period 1	
30	3,094.1	6,700.0
	Period 2	
30	3,416.3	3,700.0
40	2405.9	0
	Period 3	
20		
30		
40		
50		

Table 5.4. Age-class distribution at the end of Period 3.

Age Class	Site Class I	Site Class II
0-10	1,583.7	
11-20	5,822.1	
21-30	3,094.1	
31-40	0	
41-50	1,583.7	
51-60	416.3	

LINEAR PROGRAMMING SOLUTION FOR PROBLEM 5: SLACK AND SURPLUS VALUES AND DUAL PRICES

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.000000	34.296510
3)	.000000	63.270320
4)	.000000	34.296510
5)	.000000	70.513840
6)	.000000	120.558200
7)	.000000	-12.279490
8)	.000000	-7.798725
9)	.000000	-4.662171
10)	.000000	-28.973810
11)	.000000	-34.296510
12)	29266.440000	.000000
13)	30560.310000	.000000

g. Interpret the dual price (also known as the "shadow price") on row 4. **(9 pts.)**

6. Pacific International Corp. has 200 acres that it wants to plant with pine seedlings. The area silviculturalist wants to plant as much of the area as he can with longleaf pine. However, the company accountant has said that he must plant at least 60 of the acres in loblolly pine. Furthermore, he has been given a budget of $45,000 for the job. Longleaf costs $240 per acre to plant, while loblolly costs only $180 per acre to plant. (**12 pts**)

a) Define the decision variables you would use in formulating this problem as a linear program (**4 pts**).

b) Show how you would formulate the budget constraint for this problem (**8 pts**).