**FORMULATION FOR SPECTRUMLITE**

Strata are indexed by which represents a unique combination of six “Landtype Association Groups” layers.

**Layer 1: Vegetation Desired Future Condition Areas**

Bitterroot Mtns. (M333D) Breaklands B

Bitterroot Mtns. (M333D) Uplands U

Bitterroot Mtns. (M333D) Subalpine S

Idaho Batholith (M332A) Breaklands K

Idaho Batholith (M332A) Uplands R

Idaho Batholith (M332A) Subalpine C

**Layer 2: Roadless Status**

Roadless and undeveloped R

Roaded and developed N

**Layer 3: Timber Suitability**

Not Available or Not Suited; No Timber Harvest Allowed N

Generally Suitable for Timber Harvest for Other Resource Obj, no output O

Generally Suitable for Timber Harvest, for other resource Obj P

Suited for Timber Production S

**Layer 4: Resource Condition Zones**

Lynx habitat – conserve watershed L

Lynx habitat – restore watershed H

Conserve watershed outside of lynx habitat C

Restore watershed outside of lynx habitat R

**Layer 5: Cover Type**

Ponderosa pine P

Dry DF/GF D

Mesic DF mix W

Grand fir/Cedar C

Cold DF mix I

Subalpine fir mix A

Lodgepole pine L

**Layer 6: Size Class**

Seed/Sap (0-5”) S

Small (5-10”) P

Medium (10-15”) M

Large (15”+) L

None N

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**Parameters:**

the forest age class at the beginning of period 1 of the existing strata indexed by

the total number of periods (decades) across the planning horizon

the total area (number of acres) of the strata at the beginning of period 1

the lower bound of the soft constraint

the lower bound of the hard constraint

the upper bound of the soft constraint

the upper bound of the hard constraint

the weight for 1 unit falling short of the lower bound of the soft constraint

the weight for 1 unit exceeding the upper bound of the soft constraint

**Sets:**

the set of available prescriptions (timing choices) for Group Selection method

the set of available prescriptions (timing choices) of Prescribed Burn method

**Indexes:**

indicates forest age class for regenerated vegetation (one unit of age class is 10-year long; i.e. age class 2 means 20 years old forest).

timing choice that indicates a specific prescription of Prescribed Burn method or a specific prescription of Group Selection method across the entire planning horizon.

silvicultural method : NG (Natural Growth)

: PB (Prescribed Burn)

: GS (Group Selection)

: EA (Even Age)

a strata with 6 indexes which represents a unique combination of 6 layers

a binary index to indicate the forest would be scheduled an Even Age final cut. After the cut, the regenerated forest in the next time period would have cover type

time period (each period is 10-year long)

**Variables:**

the area of strata (acres) would be selected for implementing silvicultural method for the entire planning horizon.

the area of strata (acres) with existing forest remained intact from period 1 to period . Although this area is assigned to EA method, no EA action has been implemented yet since period 1 to period . Note that we can use to refer to the age class of existing forest (age class in period would be ).

the area of strata (acres) with existing forest that would be selected for implementing Even Age final cut in period . This cut would change the current forest in time period to the regenerated forest with cover type in the next time period .

the area of strata (acres) with regenerated forest at age class in period . This area is remained intact from age class 1 (in period ) to age class in period . Note: is removed for the advantage of merging strata.

the area of strata (acres) with regenerated forest at age class in period that would be selected for implementing Even Age final cut in this same period. This cut would change the current forest in time period to the regenerated forest with cover type in the next time period .

the area of strata that would be selected for implementing Group Selection method with timing choice across the whole planning horizon. This is model I set up for Group Selection method.

the area of strata that would be selected for implementing Prescribed Burn method with timing choice across the whole planning horizon. This is model I set up for Prescribed Burn method.

the area of strata that would be selected for Natural Growth across the whole planning horizon.

the total units falling short of ()

the total units exceeding ()

the user-defined soft (goal) constraint with penalty being put into objective function

the user-defined hard constraint without penalty being put into objective function (). Note when we set these bounds in CPLEX, Eq. (4) and (5) are not needed.

**Formulation:**

A hybrid formulation of model I and model III is used. Model I set up requires that an area of a strata can only be applied a single silvicultural method across the entire planning horizon as illustrated below.

Three silvicultural methods including Natural Growth, Prescribed Burn, and Group Selection would be also based on model I: The area selected for applying a specific silvicultural method would be divided into multiple sub-areas; each sub-area would be implemented a specific prescription of that silvicultural method across the entire planning horizon. For example, if Group Selection method have 5 prescriptions (i.e. 5 timing choices) then the yellow area of Figure 1 would be divided into 5 smaller sub-areas, each would be implemented an i.i.d. GS prescription across the entire planning horizon.

Even Age method would be based on model III which allows the implementation of flexible and multiple final cuts of the forest at different age classes in different time periods. For example in a specific time period, the blue area in Figure 1 would be divided into multiple smaller sub-areas, each represents a forest with an i.i.d. age class. If a final cut is implemented then the forest age class in that sub-area would be reset to one at the beginning of the next time period; otherwise the current forest age class would increase by one. Note that the final cut can change the cover type of the current forest to several allowed cover types. Across all strata, all forests in the sub-areas being applied final cuts at the same time period would become regenerated forests with age class one at the beginning of the next time period; Regenerated forests with the same cover type would be merged.

*Objective:*

(1)

The objective function Eq. (1) uses “NON-PREEMTIVE GOAL PROGRAMMING” method to minimize the total weighted deviations from the goals.

*Constraints set 1: user-defined expectation*

(2)

(3)

(4)

(5)

Eq. (2) and (3) implement the soft (goal) constraints. The units lower than the lower bound or higher than the upper bound will be weighted and put into the objective function.

Eq. (4) and (5) implement the hard constraints where *user-defined expectation* must be archived.

*Constraints set 2: initial forest conditions*

(6)

(7)

(8)

(9)

(10)

(11)

Eq. (6) states that a different silvicultural method can be implemented in each different area of strata , and the sum of all those areas must be equal to the total area of strata .

Eq. (7) identifies the total area of Natural Growth for strata .

Eq. (8) states that the total area of Prescribed Burn for strata can be divided into different sub-areas, each would be implemented a specific prescription of Prescribed Burn across the entire planning horizon.

Eq. (9) states that the total area of Group Selection for strata can be divided into different sub-areas, each would be implemented a specific prescription of Group Selection across the entire planning horizon.

Eq. (10) states that in the first planning period , the total area of Even Age for strata with the existing forest condition can be divided into multiple sub-areas. One sub-area would be remained intact. The others could be implemented multiple types of EA final cut that aim to create new regenerated forests with multiple cover types .

Eq. (11) requires that during the planning horizon, any acre that has been assigned for implementing Even Age method (any acre of ) must have at least one EA cut. This can be guaranteed by forcing to be zero.

*Constraints set 3: transitional forest conditions for Even Age method*

(12)

(13)

(14)

Eq. (12) and (13) requires that each sub-area for Even Age of strata , if not being implemented an EA final cut in period , would have its forest age class increased by one unit in time period . That sub-area in period can be divided into multiple sub-areas in period . One sub-area would be remained intact. The others could be implemented multiple types of EA final cut that aim to create new regenerated forest with multiple cover types .

Eq. (14) requires that all sub-areas that being implemented EA final cuts in time period would be merged in time period , and then split into multiple sub-areas of regenerated forest at age class in time period . One sub-area would be remained intact. The others could be implemented multiple types of EA final cut that aim to create new regenerated forest with multiple cover types . Since all forests are existing forests at the beginning of the first planning period, there would be zero acre of regenerated forest in the first period and therefore the term in eq. (14) would be removed for the case when .

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**Linking Variables to Database Yield Tables**

is linked to a specific NG yield table with cover type , and size class .

is linked to a specific PB yield table with cover type , size class , and timing choice .

is linked to a specific GS yield table with cover type , size class , and timing choice .

is linked to **one** specific row in a specific EAe yield table with cover type , size class , and age class .

is linked to specific rows in a specific EAe yield table with cover type and size class , and age classes from to . For example, would be linked to 3 rows for existing vegetation with age classes .

is linked to **one** specific row in a specific EAr yield table with cover type , and age class .

is linked to specific rows in a specific EAr yield table with cover type , and age classes from 1 to . For example, would be linked to 4 rows for regenerated vegetation with age classes .

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**Recursive Track Equations**

Recursive track is necessary because the two variables and do not reflect what really left due to the design of the Even Age cuts. The following example will describe why we need this set of equations.

Assume that we have 100 acres of which will be implemented only 2 future EA cuts:

* The first EA cut is scheduled in time period 3 for 30 acres
* The second EA cut is scheduled in time period 5 for 50 acres

After solving the model we would have:

(due to the first EA cut)

(due to the second EA cut)

Using cannot check the correct information of what left in period 1 because 30 acres of that 100 acres should be referred to the EA first cut yield table, and 50 acres of that 100 acres should be referred to the EA second cut yield table, only 20 acres are actually left intact. The same thing happens for other time periods.

Problems can be solved by adding the effect of future EA cuts into equations from (10) to (14). However, it would make those equations complicated. Another simple solution is adding 2 more variables to capture what really left.

the correct area to link to the yield table of

the correct area to link to the yield table of

The following equations would be needed:

(15)

(16)

Note: for the term in eq. (15) and in eq. (16) would be removed.

Come back to the example, we would have:

acres

acres

acres

acres

acres

Note that across all time period we have

Now, the correct link can be done by using and as follow:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Period | Variables (and acres) to be used | | | Total Acres |
| 1 |  |  |  | 100 |
| 2 |  |  |  | 100 |
| 3 |  |  |  | 100 |
| 4 |  | 30 acres regenerated |  | 100 |
| 5 |  | 30 acres regenerated |  | 100 |

The yellow cells have 30 acres of regenerated forests, and Eq. (16) would be used to capture the correct links.

Note that EQ (15) is only needed if we do not use Eq. (11). When Eq. (11) is in use, all the will be forced to be zero. All existing forest left will be totally captured by the natural growth variables . Also note that we can only use either (11) or (15) for not violating the logic. For example if we activate (11) and set up the user constraint to only apply EA method for all strata then in (15) we will have

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**User Constraints Guide**

The following variables will be used in user constraints as defined by SpectrumLite GUI

Variables Static Identifier

NGe

PB

GS

NGe

EA

NGr

EA

In the GUI, time period is also added as a static identifier to help finding the correct single row in the yield table. Note that the as in GUI is different from the in the variable index. Below is an example to illustrate the logic:

in the GUI variables in variables row in yield table

(Index = )