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Nantahala and Pisgah National Forests

Final Environmental Impact Statement

for the Land Management Plan

Appendix D. Vegetation Modeling Methods

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Final Environmental Impact Statement
Nantahala and Pisgah National Forests
Appendix D. Vegetation Modeling Methods

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Appendix D. Vegetation Modeling Methods

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Model Contents and Structure

Spectrum is a linear programming model that has been the Forest Service standard for land management planning. It is used to estimate outcomes of applying passive or active management practices to forested stands and modeling changed conditions under multiple scenarios. In this analysis, Spectrum modelling software was used to construct a model of the forest lands, the potential management actions applied to them and the resultant activities, outputs and conditions that result from the management and natural processes. Spectrum creates a linear programming matrix, similar to a spreadsheet, where a column represents a management action applied to a specific class of land for 200 years, and a row represents some management objective for a specific 10-year period of that planning horizon. The coefficient at the intersection of a row and column is the per-acre amount that the management action on the specific class of land contributes to the management objective in that period. Most management objectives have some target value that we seek to equal, exceed or stay below. Hence, each row becomes a summation equation: the target is the right-hand-side of the equation; each column is a variable in that equation; and the value in the cell at the row-column intersection is the coefficient for that variable. The entire matrix is huge set of simultaneous equations that we ask a linear programming software solver to "solve". We are asking the solver, "for each land class, how many acres should be allocated to the different management actions available to it in order to meet all of our management objectives?"

In this section, we will describe the different components that make up the model and some of the processes used to create those components.

Land Classification

All lands on the forest were classified by six different attributes. Each analysis unit created was a unique combination of the six attributes. Like combinations of the attributes were bulked into analysis units (AU) and their acres tabulated. Therefore, most analysis units are comprised of 4-5 non-contiguous locations, each with the same set of land attributes. See the equation below:

AU (acres) = Step 1 Timber Suitability *Forest Type Group*Geographic Area* Age Class *
Step 2 Timber Suitability * Management Area

Each of the land attributes is discussed below.

Forest Type Groups

The many forest types found on the Nantahala-Pisgah were aggregated into 12 type classes (Table 1a). This classification was used to assign appropriate harvest and burning treatments and was used to determine production functions for volumes and seral state classification and changes. These forest type groups carried forth the convention identified during the FVS modeling effort which build the yield tables utilized within the Spectrum analysis. In essence they are a homogenization of the FSVeg forest type, FIA forest type and the ecozones. They also contain forest type groups that represent current conditions not identified in the ecozones such as white pine dominated forests. Refer to the white paper, FVS Modeling for the National Forests of North Carolina Land and Resource Management Plan (Keyser and Rodrigue 2015) for more information about the determination of forest type group.

Because the original intent of the Spectrum model land stratification scheme was to include the modeled ecozones (it was decided that adding the ecozones would produce too many analysis units for the model to function properly) the outputs produced by the model will need to be cross walked to ecozones for the analysis in the EIS. Refer to Table 1b for a suggested crosswalk.

Table 1a. Forest Types

Name	Description
01WP	01 - White Pine
02SF	02 – Spruce fir
03SLP	03 - Shortleaf pine
04PP	04 - Pitch/Virginia pine
05WpHw	05 - White pine/hardwood
06SlpH	06 - Shortleaf pine/hardwood
07PVH	07 - Pitch/Virginia pine/hardwood
08Doak	08 - Dry oak
09Ioak	09 - Intermediate oak
10CvHw	10 - Moist oak/Cove hardwood
11MxHw	11 - Mixed hardwood
12NoHw	12 - Northern hardwood
Other	Other FT, Shrub, or Non-forest
99	99 - Brush

Table 1b. Suggested Ecozone, Forest Type, and Forest Type Group Cross Walk

Ecozones	Forest Type - FSVeg Code	SPECTRUM FTG Code
Spruce-Fir	6, 7, 10, 17	02SF
Northern Hardwood	70, 81	12NoHw
High Elevation Red Oak	55	09Ioak
Acidic Cove	4, 5, 8, 9, 41, 50, 56, 83	10CvHw
Rich Cove	9, 41, 50, 56, 82, 83	10CvHw
Mesic Oak	10, 42, 48, 53, 54	10CvHw
Dry-Mesic Oak	3, 42, 48, 52, 53, 54	09Ioak
Dry Oak	42, 51, 52, 54, 57, 59, 60	08Doak
Pine-Oak/Heath	15, 16, 20, 25, 33, 38, 49	04PP, 07PVH
Shortleaf Pine-Oak	3, 12, 13, 14, 16, 21, 25, 31, 32, 33, 44, 49	03SLP, 06SlpH
Alluvial	72, 82	11MxHw
White Pine/White Pine HWD (Existing Condition)	3, 4, 9, 10,41,42	01WP, 05WpHw

Age Class

Forested lands were classified by their age class at the beginning of the planning horizon. Ten-year age class increments were used (Table 2). This classification allowed the model to track stands as they age and apply treatments at the appropriate time. The age class calculations are based off the year 2018. Initial discussions included using multiple – age class structures that suited individual community types and their seral development. Adding multiple age class structures that suited individual community groups would add to many records and make the database unmanageable. This would also necessitate the ecozone layers to be added to the model that also compounds the multiplication of records. The age classes in this model were grouped past the latest onset of old growth conditions (140 years) according to the local NRV model.

Table 2. Spectrum Age Classes

Existing Age	End-point
0-10	10
11-20	20
21-30	30
31-40	40
41-50	50
51-60	60
61-70	70
71-80	80
81-90	90
91-100	100
101-110	110
111-120	120
121-130	130
131-140	140
141+	150+

Geographic Area

Twelve distinct, geographically contiguous areas were identified on the forest (see - Forest Plan, Geographic Areas Chapter). These delineations were created using a combination of natural features and land ownership patterns.

Table 3. Geographic Areas

Name	Description
BM	Bald Mountains
BK	Black Mountains
EE	Eastern Escarpment
FL	Fontana Lake
NM	Nantahala Mountains
GB	Great Balsam
HD	Highland Domes

Name	Description
HI	Hiwassee
NG	Nantahala Gorge
PL	Pisgah Ledge
NS	North Slope
UM	Unicoi Mountains

Management Area

Management Area is an administrative delineation that designates a general management focus for lands assigned to each Management Area class (See - Forest Plan, Management Area chapter). For Alternative A, the no action alternative, the management areas from the existing plan were used (1994). These management areas are listed in Table 4. For Alternatives B, C and D, a new management area classification was developed, shown in Table 5. See the discussion of the alternatives for details on management areas.

Table 4. Alternative A, Current Forest Plan, Management Areas

Management Area Number	Management Emphasis
1b	Emphasize sustained yield timber management
2a	Emphasize visually pleasing scenery, habitat of mature forest
2c	Emphasize visually pleasing scenery, habitat of older forests
3b	Emphasize sustained yield timber management
4a	Emphasize visually pleasing scenery
4c	Emphasize visually pleasing scenery
4d	Emphasize high quality wildlife habitat, particularly for black bear
5	Emphasize a semi-primitive recreational setting
6	Wilderness Study Areas
7	Wilderness
8	Experimental Forest
9	Roan Mountain
10	Research Natural Ares
11	Cradle of Forestry
12	Developed recreation areas
13	Special Interest Areas
14	Appalachian trail and corridor
15	Wild and scenic river and corridor
16	Administrative facilities

Management Area Number	Management Emphasis
17	Balds
18	Riparian areas
U	Unassigned
U-New	New Acquisitions

Table 5. Management Areas, Action Alternatives B, C, and D

Management Area Number	Management Emphasis
1	Matrix
2	Interface
3	Backcountry
4a	AT
4b	Scenic Byways
4c	Heritage Corridors
4d	Wild and Scenic Rivers
5a	Special Interest Areas
5b	Ecological Interest Areas
5R	RNA
6	WSA
6R	Rec Wilderness
7	Wilderness
8	Experimental Forest
9	Roan Mountain
11	Cradle of Forestry

Timber Suitability

Identification of lands as not suitable and suitable for timber production is required by the National Forest Management Act of 1976. The process is detailed in Forest Service handbook 1909.12 § 61 via a two-step approach. The results from both steps of timber suitability process were used within the Spectrum model as attributes to classify analysis units. The results of step one were incorporated into the dataset to aid in calculation of the sustained yield limit, which is determined based on the lands potentially suitable for timber production. Refer to the Determination of Sustained Yield Limit section below for more details. The results of step 2 of the timber suitability process identified the final allocation of lands suitable for timber production after each alternatives desired conditions, objectives, and management area allocations were considered. The use of the step 2 timber suitability results were important for adequately representing the planned actions on the Nantahala and Pisgah landscape over the modeled period highlighting management area allocation differences between alternatives. Refer to Forest Plan Appendix B or the EIS Timber section for detailed information regarding the determination of lands suitable for timber production. Detailed documentation of the process used the in EIS analysis can be found in Appendix B.

The inclusion of the results from the step 2 of the timber suitability process were originally not included in early model development of the EIS alternatives. This was because the EIS alternative data sets were developed sequentially using the sustained yield limit dataset. Step 2 was included after the action alternatives were under development and ultimately retrofitted to Alternative A to ensure that comparisons could be made across alternatives during the analysis in the EIS. Review of the model built for Alternative A indicated that step 2 could be added to the dataset while already in the model for several reasons: (1) Alternative A was not modeling a lot of harvest activities in the unsuitable land base currently. This reflects the current reality of management on the forest with the exception of burning. (2) The constraints that were already built into the model for Alternative A were implicitly describing the management area suitability decisions.

Management Actions

A range of land management actions that would be used to manipulate vegetation on the forest were represented in the model. One of the management actions is “no action”, a prescription that only represents the changes to the land from natural processes. For any analysis unit created from the land stratification process, a range of management prescriptions that are appropriate for the unique combination of criteria listed above are made available. The model chooses how many acres of each analysis unit will be assigned to each of the available management prescriptions. When some portion of an analysis unit is assigned to a management action, that assignment is assumed to continue through the entire planning horizon. Table 6 shows the management actions represented and their general description. Refer to the white paper, FVS Modeling for the National Forests of North Carolina Land and Resource Management Plan (Keyser and Rodrigue 2015) for more information about the management prescriptions included in this analysis.

The prescriptions listed in Table 6 are derived from the Keyser and Rodrigue 2015 paper but modified to meet the coarser requirements of the Spectrum model. For example, burning actions had to be bulked to the decade rather than occurring more often.

Table 6. Management Actions Used to Manipulate Forest Vegetation

Management Action	Description
Burn1	Continuous stand management through burning. Timing options of burning every 10 years or every 20 years are available.

Management Action	Description
Burning for Young Forest Creation	Regular prescribed burns every 10 years with the objective of creating some openings that will regenerate.
Clearcut with High Retention	A clearcut that maintains 20 to 30 basal area per acre for wildlife or future stand structure objectives.
Clearcut with Regular Retention	A clearcut that maintains 10 to 20 basal area per acre for wildlife, structure or visual objectives.
Group Selection	An area assigned to group selection will have small patches of the stand (roughly 0.25 acres) harvested. Every 15 to 30 years the area will be entered to harvest another set of small patches.
Individual Tree Selection	Partial harvest of roughly 25 percent of the stand to meet volume and stand composition objectives.
Loftis Shelterwood	A 3-step shelterwood initiated with a Loftis prep-cut, followed by a harvests 20-30 years and 40-50 years later, depending on forest type.
Minimum Level	No management, only natural processes occur.
Sanitation Thinning	Removal of part of the stand with the primary objective of improving stand health.
Shelterwood 2-Step with Loftis Cut	A shelterwood harvest with the initial, Loftis cut aimed at adjusting stand structure and composition, and the final cut happening 10 – 30 years later, depending on forest type.
Shelterwood with Conversion 2 Period	A 2-step shelterwood harvest followed by a final harvest 20 years later.
Shelterwood with Conversion 5 Period	A 2-step shelterwood harvest with an initial harvest followed by a final harvest 50 years later.
Spruce Fir Group Selection	Similar to group selection above.

Natural Disturbance Management Actions: After review of the Spectrum models for the draft alternatives in the DEIS and receiving public and partner input, the natural disturbance management actions were strengthened and broadened in the Spectrum model developed. Further information on the enhancements made to natural disturbance in the Alternative E model can be found in FEIS Appendix B and in the discussion of Alternative E below.

Assignment of Permissible Management Actions to Land Areas

Allowable management actions were assigned for each management area in the plan alternatives, as shown in Tables at the end of this section. For Alternative A, allowable management actions were set to reflect the management area emphases of the current plan. For Alternatives B, C and D, the same rules were used to construct management action options for analysis units. Assignment of management action options varied primarily by management area. Silvicultural and burning management action options also varied by the forest type attribute of analysis units. Once a permissible set of management actions was built into the model for an alternative, management objectives such as targets and limits were built into the model and controlled the final optimal solution for the alternative.

Activities, Outputs, Conditions

To represent the results of applying management actions to analysis units, a set of activities, outputs and conditions were constructed in the model. For each management action, a sequence of management activities and the resultant outputs and condition changes was specified. Table 7a shows the activities, outputs and states that are tracked in the model.

Table 7a. Activities, Outputs, and States

Activity Name	Description	Units
ThinAcre	Acres thinned	Acre
OthrHarvAcre	Individual tree selection and group selection	Acre
OthrSheltAcr	Acres of prep or overwood removals for shelterwoods	Acre
RegenAcre	Acres receiving regeneration cuts	Acre
Burning	Prescribed burning	Acre
PCT	Pre commercial thinning	Acre

Condition Name	Description*	Units
LateSerlClos	Late Seral State, closed canopy	Acre
Young Forest	Young Forest, created with management	Acre
MidAgeOpen	Middle Age Seral State, open canopy	Acre
LateSerlOpen	Late Seral State, open canopy	Acre
YoungGaps	Small areas of young forest created by natural disturbance	Acre
OldSerlOpen	Old Seral State, open canopy	Acre
OldSerlClose	Old Seral State, closed canopy	Acre
Burned	Not used	Acre
MixedAge	Mixed age state	Acre
MidAgeClosed	Middle age seral state, closed canopy	Acre

*Refer to Table 7b for the seral age class structure.

Output Name	Description	Units
LTSY	Long Term Sustained Yield – Predefined	MCF
AllHarvAcre	Acres harvested, any method	Acre
Volume	Volume harvested	MCF

The seral conditions displayed as part of the Spectrum outputs were defined using the NRV model description of the ecozone communities (approximated from silvics manuals for white pine) with adjustment made to age class breaks that fit within model parameters (10-year increments and the class number being at the end of the class increment) (Table 7b). These were linked to the forest type group developed in the classification structure above. Initially all analysis units were assumed to be in a closed condition but the open seral condition was included to test open condition objectives in the plan. The seral class outputs were derived for the Alternatives but not included in the sustained yield limit calculations.

Table 7b. Spectrum Seral Class Structure

Forest Type Group	Successional Class			
	Young	Mid	Late	Old
01WP (W. Pine)	0-20	30-90	100-130	140+
02SF (Spruce/Fir)	0-30	40-70	80-120	130+
03SLP (Shortleaf)	0-20	30-70	80-100	110+
04PP (Pitch)	0-20	30-70	80-130	140+
05WpHw (W. Pine/Hwd)	0-20	30-90	100-130	140+
06SlpH (Shortleaf/Hwd)	0-20	30-70	80-100	110+
07PVH (Pitch/Hwd)	0-20	30-70	80-130	140+
08Doak (Dry oak)	0-20	30-70	80-100	110+
09Ioak (Intermediate oak)	0-20	30-80	90-130	140+
10CvHw (Cove Hwd)	0-10	20-100	110-140	150+
11MxHw (Mixed Hwd)	0-10	20-100	110-140	150+
12NoHw (N. Hardwood)	0-20	30-80	90-130	140+

Production Functions for Activities and Outputs

For each analysis unit, the combination of land attributes was translated into a beginning seral condition. For each seral condition, a rule set known was created to control when an acre changed from one condition to another as a result of management, natural disturbances or the aging of the forest. This rule set is known as a production function. Within the production function, management activities were uniquely scheduled by management action. For harvests, the resultant volumes produced were determined by yield tables constructed from yield simulations run in the FVS simulation model.

Expression of Management Objectives in the Spectrum Model

Management objectives for the Spectrum model by alternative are displayed in Tables at the end of this appendix. The most direct expression of management objectives in the Spectrum model are those taken from forest plan objectives for activities or desired outcomes. Examples of these are “prescribe burn 65,000 acres in each 10-year period” and “create 11,000 acres of young forest in the first two 10-year periods.”

Another type of management objective are ones that limit or prohibit activities forest-wide or on subunits of the forest. Examples of these are “no burning for young forest creation in Management Area 8” and “total acres harvested cannot be more than 30,000 acres in any 10-year period.”

Other types of constraints are used to keep the mix of management actions chosen to be “implementable,” to ensure the model behaves as we would as managers. Flow constraints that control periodic changes in activities or outputs prevent dramatic changes through time. A flow constraint example is “the number of acres receiving regeneration cuts must not increase or decrease more than 15 percent between periods.” Proportional constraints help distribute activities geographically, or balance activities among management areas. An example of this constraint is “of all acres allocated to clearcut with high retention in Management Areas 1 and 3, no more than 40 percent can be in the Highland Domes geographic area.”

Ultimately, we ask the model “what is the best mix of management actions to apply to each of the analysis units in order to meet all of our objectives?” After all objectives have been met, what decides the “best” is an *objective function*: some output or condition that we want to maximize. There may be many ways to meet all of the objectives, but we ask the model to find the “solution” that will meet all of the objectives, and give us the highest value for the chosen objective function. For example, in Alternative A we asked the model to emphasize our harvest in areas that have been previously treated. For Alternatives B, C and D we asked the model to emphasize the amount of young forest maintained through time (while still meeting all other objectives).

Interpretation of Objective and Constraint Tables for Alternatives

In the tables that list the objectives used in the model for the different alternatives, there is a column showing what constraints are limiting, and in what periods they are limiting. Objectives that describe what we want, such as “at least 65,000 acres per decade should be burned for the first two decades”, might show a lower limit (LL) in period 1 or 2. If only 65,000 acres are burned (the objective is at lower limit), this indicates that the model has no incentive to burn more acres to achieve a higher objective function value. Objectives that describe what we don’t want, such as “no more than 8 percent of all management can happen outside of Management Area 1”, might show an upper limit (UL) in period 1. If exactly 8 percent of all management happens outside of Management Area 1 (the objective is at upper limit) this indicates that allowing more to happen outside of Management Area 1 would increase the value of the objective function.

Natural Disturbance

See Appendix D, Vegetation Modeling Methods. Natural disturbances through time have been integral in shaping structurally diverse forests and maintaining a diversity of flora and fauna (Greenberg, 2015). Severe natural disturbances can create canopy openings in a dominant canopy closed forest. Larger canopy openings can create young forests seral states while smaller openings develop edge effects and increase heterogeneity within a forest. The forest planning team investigated the natural disturbance types, frequencies and effects on vegetation structure. The results were used in the vegetation model (Spectrum) for the NP Forest Plan and FEIS.

Analysis Area

The national forest boundary is the analysis area, as this is the same area used in the Spectrum model. The choice of scale for an analysis area is important for determining the return interval for disturbances. For example, the return interval for tropical storms in the state of North Carolina is about 1.3 years, the return interval for Orange County, North Carolina is about 50 years, while the return interval for a particular stand of trees within Orange County is in excess of 100 years (White, et al, 2011). The national forest ownership is approximately 25 percent of the western NC. The analysis area for determining the natural range of variation was western NC.

Method

Defining young forest

Early successional habitat (ESH) is defined more broadly than young forests. The vegetation structure of early successional habitats could vary widely from grasslands with little tree component to thickets of shrubs and vines. (Greenberg, et al, 2011). However, two structural attributes essential for ESH are that they have a well-developed ground cover or shrub and young tree component and they do not have a closed, mature tree canopy. (Greenberg, et al. 2011).

The Forest Service considers a forest as the following: Forest land—Land at least 120 feet (37 meters) wide and at least 1 acre (0.4 hectare) in size with at least 10 percent cover (or equivalent stocking) by live trees including land that formerly had such tree cover and that will be naturally or artificially regenerated. Trees are woody plants having a more or less erect perennial stem(s) capable of achieving at least 3 inches (7.6 cm) in diameter at breast height, or 5 inches (12.7 cm) diameter at root collar and a height of 16.4 feet (5 meters) at maturity in situ. (Oswald, 2019).

In defining ESH, in addition to the structural attributes, sizes and width, and percent cover (above), the function of young forests for wildlife uses were considered. Young forests function as high-quality food patches for many wildlife species. (Greenberg, et. al, 2011). Open, recently disturbed forests provide an abundance of native fruits, woody browse, nutritious foliage and flowers that attract arthropods and high densities of small mammals that serve as prey for numerous snakes, bird, and mammalian predators. (Greenberg, et al, 2011).

A group of wildlife biologists were requested to give opinions on bird and bat habitat uses of open, recently disturbed forests. Seven canopy opening sizes were evaluated: 0-0.25 ac, 0.25-0.5 ac, 0.5-2.0 ac, 2-5 ac, 5-10 ac, 10-20 ac, and >20 ac. The term “gaps” was applied to canopy openings less than about 0.5 ac, and the term “patch” was applied to openings about greater than 0.5 acre. Bird and bat species were considered. (Bryan, S., et al, 2020). Fifty-four bird species were evaluated for the uses of gaps and patches. Thirty-three (61%) use gaps; of those, 13 (24%) use only gaps and not patch sizes. Forty (74%) species use patches; of those, 22 (41%) use patch sizes exclusively and not gaps. Twenty-one (39%) use both gap and patch sizes. Fourteen bat species were evaluated for uses of gaps and patches. Seven (50%) use gaps, but only 1 bat species uses gaps exclusively. Whereas thirteen (93%) use patches and 7 use patch size exclusively. Six (43%) use both gap and patch sizes.

Defining high or low quality ESH must be tempered by the suite of species that require specific structural conditions. Some may require grass dominated habitat, others may require brushy areas, some require open areas with presence of nesting cavities, or those that require high elevation habitats such as Chestnut-sided warblers and Golden winged warblers. (Greenberg, 2011).

Additional consideration of canopy openings is the size at which enough sunlight penetrates to the forest floor. Disturbances occur along a gradient that spans from broad-scale, stand-replacing events where most of the overstory is removed, to fine-scale events which result from the removal of a single canopy individual or a small cluster of trees. The disturbance regimes of most stands in the Central Hardwood Region are characterized by fine-scale events. (Hart, 2015). At the stand scale, these localized and asynchronous events can create a patch-work mosaic of microsites comprised of different tree species, ages, diameters, heights, crown spreads, and growth rates. Through the modification of fine-scale biophysical conditions, these localized canopy disturbances promote heterogeneity and biodiversity in forest ecosystems. (Hart, 2015).

Small canopy gaps typically close quickly by lateral crown expansion. As such, small gaps may not permit enough time for even fast-growing shade-intolerant species to colonize the gap and therefore, small gap-scale disturbances typically favor shade intolerant species. (Hart, 2015). Small gaps can also advance succession by releasing older trees that are growth stunted due to the absence of light. When a canopy opening allows enough light to penetrate to the forest floor, the stunted growth trees advance into the canopy but are nearly the same age as their adjacent cohorts.

Gaps in older stands may have larger crowns and therefore may create larger (rather than smaller) gaps that would restrict later crown expansion. Thus, new individuals may be recruited and grow into the canopy and create a multi-aged stand. (Hart, 2011)

The stage of growth in a canopy opening relates to forage quality for a given species, whether herbaceous or woody. New growth of any plant is more digestible than older growth, as plants mature, cell walls thicken and lignin content increases. Thus, increased young foliar growth and higher biomass are attributed to new, young over older plants (Greenberg, 2011).

Severity of disturbance is key factor in the resulting quality of the habitat. In general, contribution of seed sources increases with disturbance severity. (White, 2011). Greater contribution from seed sources can increase abundance of early successional and shade-intolerant species, many of which regenerate from buried seeds or from seeds carried into the site by wind or animals.

However, the low frequency of disturbance at the local scale, along with the narrow range of stand ages, reduce structural heterogeneity and current successional processes suggest loss of abundant early successional habitats, at least that generated by natural disturbance alone, at a scale relevant to conservation and management. We do not know if the frequency, patch size, and spatial distribution of natural disturbance-generated early successional habitat will be sufficient to sustain biological diversity (or for any other management goal) (White, 2011)

Conclusion

For the purposes of this analysis, we define a young forest along the gradient from stand-replacement to fine scale. The disturbance should be of sufficient size to allow abundant sunlight to penetrate to the forest floor and thereby provide the opportunity for a well- developed ground or shrub cover and a tree component. The young forest would be patch of at least ½ acre with recent severe disturbance such that no mature canopy exists. It is a size where lateral crown expansion would not be a factor in canopy closure. This patch size creates edge for multiple species, but allows enough open space that recruitment of new, young individuals is available. The minimum patch size is less than stand-replacement disturbances but larger than fine scale disturbances. It is less than the 1-acre minimum size used by Resources Planning Act Assessment for defining a forest, but it meets the policy of the minimum size for a regeneration unit using group selection in southern Appalachian forests. It provides for a wide range of wildlife species to use these patches.

Gaps are 0.25 to 0.5 acres, and small gaps are less than 0.25 acres. Gaps are important for biodiversity as gap disturbances do create edges. (White, 2011). Small gaps are likely to close through lateral crown extension. Larger gaps may have enough light, nutrient, and seed dispersal gradients across edges allow open-site and early successional species to establish and persist in edge zones. (White,2011).

Types of natural disturbances

Three types of disturbances were considered for the recent past: wildfire, storms, insects and disease.

Wildfires are unplanned ignitions. All wildfires on the national forests were considered in this analysis, although most wildfires result from human interactions rather than from natural causes. Since 1992, there were 337,000 acres of wildfires burned in the Southern Appalachian national forests (Chattahoochee; Cherokee; Nantahala; Pisgah). Of that amount 56% were burned resulting from arson and 18 percent from other human causes (James, et al).

Storms include remnant hurricanes, tropical storms, derechos (Petersen, et al, 2015) and landslides (Wooten et al, 2015). Information about insect and disease was confined to southern pine beetle, balsam wooly adelgid, and hemlock wooly adelgid.

Determining Frequency of natural disturbances

Natural disturbances were considered from three different perspectives. The long-term past looks at disturbances 1,000 years before European settlement up to the time of European settlement. This timeframe was used in the natural range of variation model (NRV). As there are few recorded and creditable data from that timeframe, many assumptions are required. The next timeframe is the recent past (50 years) and the near future (10 to 50 years). This is the timeframe used for the ecological sustainability evaluation (ESE Tool). The final timeframe is the long-term future, from 50 to 200 years from present. There are many uncertainties in the long-term future due to climate change.

NRV (also called Historic Range of Variability (HRV))

HRV describes the variation in physical and biological conditions exhibited by ecosystems as a consequence of climatic fluctuations and disturbance regimes. An HRV assessment is useful for understanding past ecological processes and the resulting biological diversity under those conditions (2012 Planning Rule FEIS, p. 88). As such, the 2012 planning rule uses NRV as a reference for assessing ecological integrity. NRV provides insight into the temporal dynamics of an ecosystem and provides context for assessing ecological integrity. (Plan Directive, p 18.)

The use of NRV as a reference condition carries the uncertainty associated with trying to find historical time periods that remain analogous to present and future conditions in the context of global change. Although NRV assessments can help explain the processes that contributed to current spatial and temporal patterns of ecosystems, there are limitation in their application. Data availability for reconstructing a disturbance history for some areas may make completing a NRV assessment more difficult, particularly in the Eastern United States where land-use history is a much more important concept to consider than it is in many areas of the West (2012 Planning Rule FEIS, pp 88-89).

Land use in Western NC has changed from pre-European settlement. The presettlement forest landscape was largely forested with dominant trees surviving to ages of 300-500 years. Mortality of canopy trees occurred at a low rate. Large stand-replacing natural disturbances were infrequent relative to tree lifespans, with return intervals in the 100s of years. Thus, the return intervals are longer than the current forests have existed (White, 2011).

Another challenge with estimating and applying NRV is that disturbance rate and severity are contingent on current structure and composition and ultimately on successional history. The result of broad scale human disturbance 70-100 years ago is a homogenous forest of the present with high densities and uniform canopy of trees (White, 2011).

The 1,000-year timeframe used in the NRV model for the Nantahala and Pisgah NFs provides insights for how ecosystems and species evolved over time. During that timeframe, human impacts on the environment were less evident than today. As such, natural disturbances would have been more widespread, especially wildfires. For example, the estimated number of fire-adapted ecosystems in Western NC is about 2,490,000 acres. It would take hundreds of thousands of acres per year of fire to shape the extent of those systems. Fire compartments would have been much larger during the NRV timeframe. By comparison, in 2019 the amount of prescribed fire in Western NC was estimated at 1,400 acres.

The 1,000-year timeframe for NRV allows for return intervals of natural disturbances to occur. For fire adapted ecosystems, return interval for fires are shorter, within several years but severe fire disturbance rates that reset succession could occur within 25 years for some ecozones (e.g. dry oak). Conversely, mesic sites have stand replacement disturbance rates at 300 years or more. Having a long time period of analysis in the NRV allows for disturbances to occur multiple times in order to shape the ecosystems.

Regardless of the challenges of applying NRV to the forest landscape of today, it has provided significant contributions to forest planning. The first and most significant contribution is the recognition and mapping of ecological types. This is the starting point for any analysis of the natural range of variation. There have been three approximations of the mapping of ecozones (Simon, 2011) and plan components require the restoration of ecological types. This provides guidance for what the forest composition will be in the future, a significant step towards ecological integrity.

Another contribution of the analysis in NRV is the dynamics of ecological systems relative to each other. The structure and function of the ecological types identified in the NRV analysis are largely regulated along energy, moisture, nutrient, and disturbance gradients. NRV helps to inform the differences of the ecological types among the gradients. For example, the types and relative amounts of disturbances are much different on xeric sites than on mesic sites. In regard to the amounts of the seral states for each ecological type in NRV, there has been one approximation using the knowledge and tools of today. Subsequent approximations are needed to support future planning processes.

Data for the recent past and near future

A wide variety of data sources were used to develop the historic pattern of disturbances that resulted in young forest patches and gaps. Where possible, remote sensing data were collected using Lidar, Sentinel2, and or Landsat to formulate some blueprints about disturbance patterns. Forest Service records were used to verify information from remotely sensed data. When primary data were not available, information from the literature was used to formulate the historic pattern of young forest patches and gaps.

Analysis using Lidar

2005 Lidar. A study of the 2005 Lidar was conducted in support of the planning analysis for the Draft EIS (Lewis, et al, 2017). Approximately 18,000 canopy openings were found that totaled about 13,000 acres. About 80 percent of the openings were less than 0.5 acres and about 5 percent were five acres or larger. This would equate to approximately 2,600 acres in young forest patch and 10,400 acres in gaps, using the concept described above. The study has some limitations as follows. The lidar data were not available for the Grandfather Ranger District, where there are high wildfire occurrences. Also, there were no identifications of whether the canopy openings were the result of human or natural disturbances.

2017 Lidar. An analysis of the 2017 Lidar was conducted in support this study of disturbances for the Final EIS. The criteria used for the 2017 Lidar study were similar to the previous work. However, all patches (0.5 acres or greater) were reviewed and correlated with aerial photography and Forest Service records. That review categorized patches into the following: 1) human caused; 2) natural features, such as rock outcrops, rivers, etc., or 3) natural disturbance.

Approximately 189,570 canopy openings were found that totaled about 9,300 acres. The total amount of young forest patch was approximately 5,870 acres. Of that acreage, about 3,730 were human caused, about 2,140 were natural features of the landscape, and about 1,300 acres were attributed to natural disturbances.

About 1,860 canopy openings were gaps (0.25 – 0.50 ac), and about 179,690 canopy opening were small gaps (less than 0.25 acres). The total amount of gaps and small gaps was about 3,450 acres.

Using the 2017 Lidar, a check was made for the number of patches and gaps in existing wildernesses where minimal human caused disturbances have occurred. Table 8 shows the amount of canopy openings in wildernesses.

Most of the canopy openings in wildernesses are small gaps, with the exception of Linville where wildfire is frequent and often high severity. Many of the canopy openings are small gaps that are natural features of the landscape, such as rock outcrops that are present in Middle Prong and Ellicott Rock. The wildernesses that have more mesic ecozones, such as Joyce Kilmer and Southern Nantahala have almost no canopy openings.

Table 8 Number and Acreages of Canopy Openings in Wildernesses

Wilderness	# Of Patches	Ac of Patches	# Of Gaps	Ac of Gaps
Ellicott Rock	0	0	2	<1
Joyce Kilmer	0	0	2	<1
Linville	181	44	10,368	288
Middle Prong	4	11	216	8
Shining Rock	22	94	463	21
S. Nantahala	1	<1	27	<1

Data for Wildfire

Wildfire data and information was obtained from Southern Research Station scientist Steve Norman (Norman, 2021), who has been studying fire in Southern Appalachians for several years. Fifty years of data (1970-2019) was used to estimate the historic pattern of wildfire.

To use remotely sensed data from Landsat and Sentinel 2, Norman took a random sample of fires on the Nantahala and Pisgah NFs in the 1990's through 2019. A NDVI value (Normalized Difference Vegetation Index), which can measure the area where vegetation loss and gain occurs, was calculated to estimate the percentage of fire perimeter that had high, moderate, and low severity. Using the random sample of 34 fires, about 10 percent of a burned area would result in high severity, but that included fires in the Eastern Escarpment Geographic Area, which has a disproportionate amount of high severity fires. This is also demonstrated in Table 8 (above) for Linville Wilderness where canopy openings are largely the result of wildfire. To compensate for this anomaly, several wildfires from the eastern escarpment were removed from the data. Then, approximately 3 to 5 percent of burned area would be high severity throughout the forest and most likely to produce young forest patch.

It was necessary to aggregate information into a decadal figures because the vegetation model (Spectrum) uses decadal timesteps. First, the acreages of wildfires were compiled by year. An estimate of whether the year was more dry or more wet, an average of the seasonal Palmer Drought Index was computed and used to categorize if the year was more drought prone, normal, or more wet. Then, the acreage of wildfire for drought years was calculated by decade. A factor of 5.5 percent was applied to drought years to estimate the amount of young forest patch for each decade. That amount applied forest wide. The assumption is that wildfires that result in high severity patches occur during drought years and that during normal and wet years, fire suppression would be able to contain the fire. The previously excluded fires for the Eastern Escarpment were added back in that increased the amount of young forest patch in the decades of 2000-2019, but focused more for the Eastern Escarpment Geographic Area. The historic amount of young forest patch was applied over the next 50 years.

Another observation of the analysis by Steve Norman was the amount of moderate severity from wildfire. Gaps are created from wildfire, but gaps created and clustered near each other are assumed to create a woodland like structure. This structure is temporary unless wildfire or prescribed fire continues to disturb the area. However, we wanted to account for this in some way. The amount of moderate severity is approximately 10 percent of a burn perimeter. This amount was factored into the vegetation model for tracking those acreages.

Data for Storms

Reconstructing historic frequency, range of severity, and spatial extent of natural disturbances depends in part on availability of records and physical evidence. Weather-severity rankings such as the Fujita scale of tornado severity are often based on the built environment (tornado damage to buildings) with less applicability to forests (Greenberg 2015). Checking the storm event database from NOAA, we found similar circumstances with many anecdotal estimates and mostly damage to the built environment. Therefore, we drew from the literature as much as possible.

The processes with potential high severity from storms are wind and or precipitation events. Winds from remnant hurricanes, tornados, derechos, or mountain waves can cause canopy openings from blowdowns or uprooting of trees. Hurricanes are generally downgraded to tropical storms when they reach the Blue Ridge ecoregion (Peterson, 2015).

Peterson proposes that for secondary forests, low- to moderate intensity wind damage advances succession by removing some of the pre-storm canopy dominants and releasing later-successional subcanopy and sapling stems, whereas high severity damage sets succession back to an earlier stage by sufficiently opening the canopy and removing subcanopy vegetation so that early-successional species can establish. The high-severity component of this model has been demonstrated in several cases (some outside of the Central Hardwood Region), wherein entirely new cohorts of early-successional species establish, rather than simply release of advanced regeneration or regrowth of surviving canopy individuals (Peterson, 2015)

The Central Appalachians have probably the lowest rate of wind disturbance among the Central Hardwood Region. Multiple studies attest that the great majority of patches are quite small (e.g., <1 to 2 ha) even though a few may be much larger (to several tens of hectares); the empirical distribution of sizes is approximated by a negative exponential. This is counter to most observers' visual impressions of wind-disturbed areas (Peterson, 2015).

Canopy opening sizes on the Chattahoochee NF tornado track in 2011, a total of 4,866 disturbed patches (having >10% B.A. loss) were identified, with ~97% of those being 1 ha or less in size (Fig. 5.8); an additional 1.8% were 1-5 ha in size, and the largest single patch was 207.4 ha. (Peterson, 2015).

Larger canopy gaps (>10 windthrown trees) occurred in the Bent Creek watershed from Hurricane Opal (1995) on the average of 1 per 39 ha in the 2,400 ha watershed and occurred on lower elevations with southeasterly slopes (McNab, 2004).

Precipitation can cause high severity impacts in the form of landslides especially when storms occur within the same month. For example, hurricanes Frances and Ivan occurred in August 2004 and caused extensive damage from landslides. Wooten estimates this weather scenario occurs every 29 years in NC. Landslides primarily affect convex slopes and hollows (68%) (Wooten, 2015).

We were informed by literature, but had to estimate the historical amount of young forest patch from severe weather-related events. To do this, we queried the Landscape Change Monitoring System (LCMS) by geographic area to obtain the fast loss and gain of vegetation by year. We obtained records of the amount harvest from 2002-2019. For the years estimated as wet, the estimated amount of harvest was subtracted from the LCMS and averaged. This amount came to approximately 600 acres of young forest patch.

In addition, we obtained landslide records from the NC Geological Survey and estimated approximately 200 – 250 acres of young forest patch would be created on a rotation of 29 years.

Data for Insect and Disease

Three insects are known to have historically (and currently) resulted in the greatest impact, balsam woolly adelgid, hemlock wooly adelgid, and southern pine beetles. Other infestations, such as gypsy moths, and emerald ash borer, beech scale insects or diseases such as oak decline more typically cause small canopy openings, gaps, or result in woodland conditions.

We examined the frequency of disturbance used within the NRV model as a guide for quantifying the size of openings. For spruce-fir, there was variation per decade with greater outbreaks every 15 years. Hemlock woolly adelgids have already decimated the hemlocks on the Nantahala and Pisgah NFs. As a result, we estimated impacts for only the first two decades, since the majority of mid to older age hemlock communities were already impacted. An assessment was completed for pine beetles within shortleaf pine and pitch pine forest types (#3, 4, 6, and 7) for both open and closed states. Based on mature and older age classes, twice the frequency infestations are estimated in the closed versus open state classes.

Decadal increases were assumed during the first 50 years with gradual reductions within the closed classes due to an increase in burning and woodlands. In contrast open state classes gradually increased the entire 200 years. Based on Steve Norman's wildfire analysis, the greatest likelihood of wildfires with patch creation will occur within these 4 forest types (above). To account for the natural disturbance acres already assessed with wildfires, the final acres were reduced. Pine beetle infestation sites with abundant downed wood provides the greatest potential for stand replacement fires and some researchers think this is the natural cycle for these xeric pine communities to regenerate.

Conclusion. Table 9 shows the amount of young forest patch estimated per decade. This is the amount of land that would be impacted by highly severe natural disturbances. It is a fraction of the total amount of natural disturbances distributed throughout the forests, only those with disturbances severe enough to reset succession. Dramatic increases occur in the periods 4 & 5 due mostly to dramatic increases in the 2007 and 2016 fire seasons.

Table 9: Acreage of young forest patch over estimated over 5 decades.

	Decade				
	1	2	3	4	5
Patch (Ac)	1752	1654	1960	2372	3923

Analysis of Future

Several scenarios were considered in developing estimates for future natural disturbance. One scenario (S1) is to use the estimated historic pattern over 5 decades and cycle that pattern over the planning horizon. Another scenario (S2) is to make significant increases in disturbance over the historical pattern due to climate change. A third scenario (S3) would be to decrease the amount of disturbance occurrences in decades 4 and 5 because the fires in those years are anomalies. Another scenario (S4) would compute a four-year moving average and increase fire by 5% per decade, storms by three and one-half percent per decade and insects by 3 percent per decade. The outputs from the vegetation model can be compared for young forests, old forests, amount of regeneration and burning. Another Scenario (S5) used an average of 10 futures from estimates of 5 climate models and two emission scenarios. ST Sim (Apex Resource Management) software was used to sense how seral states might change using background distrurbance rates of HRV and the expected harvest outputs in Alternative E. Refer to the process record, Sensing Project: Seral States using ST Sim (January 2022).

Scenario 1. This scenario was modelled in Alternative E because it is based on the available data or research for the southern Blue Ridge ecoregion. However, scenarios 2,4,5 and the sensing project using ST Sim also provide information that helps frame the uncertainties in estimating disturbance regimes of the future in the face of a changing climate. If the estimates of young forest patch using 2017 Lidar are representative, then the future estimates of natural disturbances in Alternative E are much higher than current.. Table 10 shows an estimated higher percentage of young patch creation compared with the 2017 Lidar for five planning periods.

Table 10 Percent Increase of young patch creations above the 2017 Lidar.

	Planning Period				
	1	2	3	4	5
Patch (Ac)	1752	1654	1960	2372	3923
% Above Lidar	35	27	51	82	202

Scenario 2 (S2). Natural disturbance rates are high in this scenario. To develop this scenario, the first step was to review information related to future climate change specific to Western NC.

The Southern Region monitoring report (Williams, 2020, pp 25-31) provides expected future temperature and precipitation for the southern Blue Ridge Mountains. It shows that mean temperatures are rising higher and faster in the future than rises in mean precipitation. From this, we assume that change in the Blue Ridge ecoregion will lean more toward drought and wildfires. Precipitation amounts may increase slightly but could occur in more severe events.

A study of downscaled climate data for the Blue Ridge ecoregion estimated an increase of lightning fires by 230 percent over 50 years (Prestemon et al, 2016), however, the total amount of wildfire was estimated to decrease over time due to changing social values that would reduce arson and other human caused fires.

One worst case for analysis purposes would have severe drought in the first part of a decade and much wetter or severe precipitation in the last half of the decade. A weather pattern was developed for over eight periods with combinations of dry and wet within each plan period. Periods 9-20 are held constant at the highest rate of disturbance. The Alternative E Tier 2 model formulation was used but updated with the change in natural disturbances. A comparison of a few indicators with Alternative E Tier 2 follows.

The amount of disturbance in S2 varies by plan period, however, the average increase above Alternative E Tier 2 over 50 years is about 92 percent, and in 60-100 years about 86 percent, and then about 138 percent for years 110-200. Wildfire accounts for a high proportion of the change because more droughts are expected due to rising temperatures, as noted above.

The first observation is that it was not feasible to have dramatic increases in wildfire and the high amount of prescribed fire assumed to occur on the same lands. The model was adjusted to handle large increases in fire by redistributing where it could occur mostly by increasing the proportion of fire that would occur in the moderate moisture class (mesic and dry-mesic oaks). The amount of prescribed fire in pine types had to be lowered compared with Alt E Tier 2 because of wildfire increases. A question from this exercise is whether or not the larger prescribed fire program in Alt E Tier 2 would mitigate the amount of high severe wildfire that could occur from repeated droughts.

There is a shift toward uneven-aged management to reach regeneration goals. The proportion of group selection of total regeneration in S2 scenario is about 11 percent average over 50 years, 20 percent average in 60-100 years and about 18 percent from 110-200 years. For Alternative E Tier 2, about 5% of regeneration would occur by group selection over 50 years, about 8.5 percent average in 60-100 years and 10 percent average from 110-200 years. The amount of even-aged and shelterwood regeneration reduces by an average of about 5% over 50 years and about 11 percent after that timeframe. This is likely due to the increase amounts of forest types (e.g., oaks) that are assigned to natural disturbance prescriptions.

The proportion of natural disturbance patches that contributes to young forest seral state is higher in scenario S2 than Alternative E Tier 2. For S2, an average of about 14 percent over 50 years of young patch and about 22 percent (about) after that timeframe. By comparison, Alternative E Tier 2 averages about 7 percent over 50 years and 12 percent average after that timeframe.

The amount of old forest closed canopy reaches a peak of about 430,000 acres in 110 years for S2, but then decreases to about 418,000 by year 200. Alternative E Tier 2 reaches a peak of about 440,000 acres in 110 years but continues to increase slightly (about 450,000 ac) from years 110 to 200.

Scenario 3 was not run in Spectrum as it would have assumed more flexibility by having less young patch creation. Therefore, the analysis would not have provided any new information about the feasibility of reaching management goals or shifts in potential management actions.

Scenario 4 (S4). The average change in natural disturbances is higher than in Scenario 2 because of the assumption that rate of change will continue throughout the entire planning horizon instead of leveling off at around 100 years. The amount of disturbance in S4 varies by plan period, however, the average increase above Alternative E Tier 2 over 50 years is about 67 average percent, and in 60-100 years about 330 average percent, and then over 700 average percent for years 110-200. Wildfire accounts for a higher proportion of the change because more droughts are expected due to rising temperatures.

There is a shift toward uneven management, similar to Scenario 2. The amount of group selection increases by 7 average percent in 50 years, and about 15 percent after that timeframe. For Alternative E Tier 2, about 5% of regeneration by group selection over 50 years, about 8.5 percent average in 60-100 years and 10 percent average from 110-200 years. Compared with Alternative E Tier 2, the even aged and shelterwood regeneration in S4 held fairly constant over 50 years, but decreased by 9 average percent from 60-100 years and by 18 percent from 110-200 years.

The proportion of young patches that contributes to the total amount of young forest is higher in scenario S4 than Alternative E Tier 2. For S4, an average of about 13 percent over 50 years of young patch and about 24 percent from 60 – 100 years, and about 30 percent after that timeframe. By comparison, Alternative E Tier 2 averages about 7 percent over 50 years and 12 percent average after that timeframe.

The amount of old forest closed canopy follows the same trend as S2. For S4, it reaches a peak of about 430,000 acres in 110 years, but then decreases to about 418,000 by year 200. Alternative E Tier 2 reaches a peak of about 440,000 acres in 110 years but slightly increases from years 110 to 200.

Scenario 5 estimated ten future scenarios for drought conditions using five climate models and two emission scenarios. (Costanza,J. 2021. Working paper in progress: Summary of drought projections for the Nantahala Pisgah landscape). Figure 2 shows the drought projections to 2070 and the median. Projections of drought are relatively stable to mid-century by then rise substantially after that timeframe. The median values were averaged by decade in order to put estimates in the vegetation model (Spectrum using the Alt E Tier 2 model formulation).

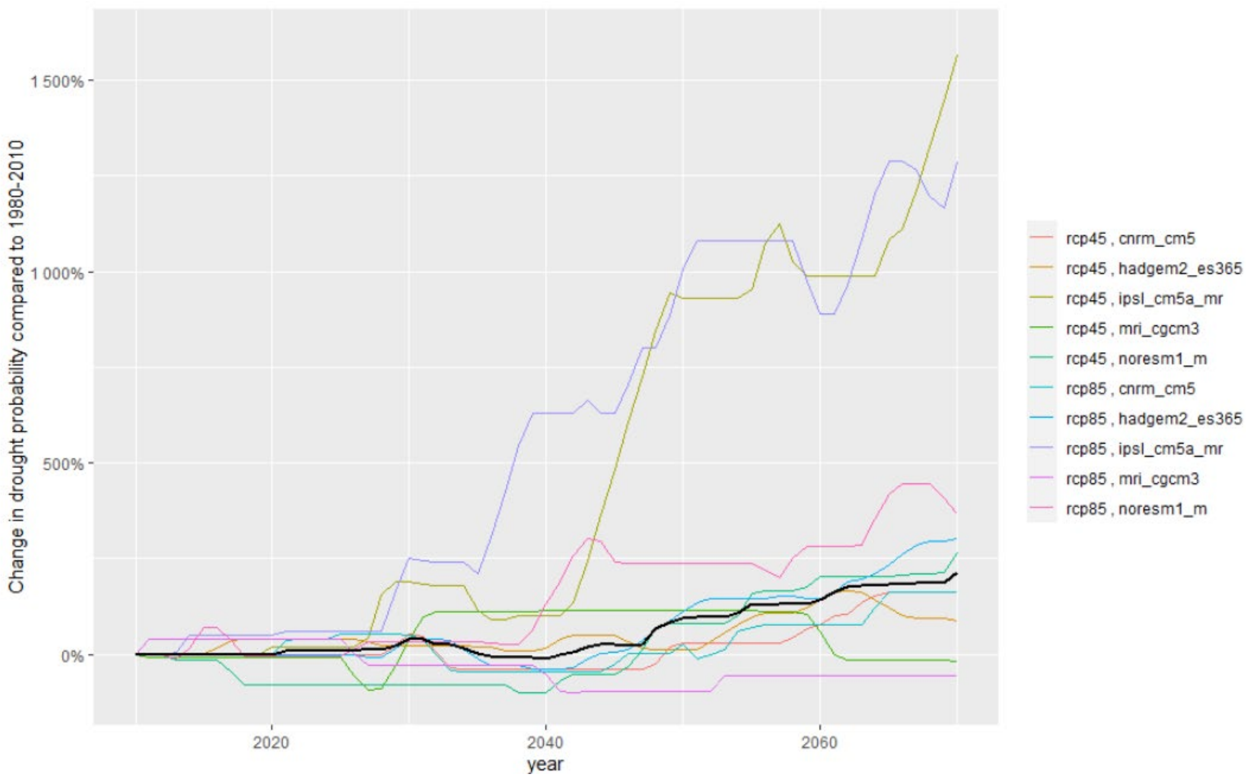

Figure 2. Scenario 5. Change in drought probability under multiple climate scenarios

As with other scenarios, with higher estimates of wildfire in the future, some model adjustments (Tier 2) were required to have a feasible solution as follows:

1) The amount of wildfire assigned to Forest Type 03,04, and 06 (Shortleaf, Pitch, Shortleaf/hardwood) would be lowered because there are not enough acres of those types to accommodate the high increases in projected wildfire;
2) to compensate for lower pine types available for wildfire, higher amount of FT 09 (mesic oak types) would burn from wildfire,
3) the amount of prescribed fire would be lowered in shortleaf pine types because they are affected by wildfire;
4) the overall prescribed fire targets would be lowered to 400,000 acres due to increases in wildfire burning.

The limits on the amount of young forests are reached in plan period 4-7 and 13 -20 (ten year periods). This has an effect of lowering the amount of regeneration in plan periods 11-14 from a range of 23,000 to 25,000 acres, about 20 to 25 percent decrease from the first plan period. As with other higher wildfire scenarios, there is a shift to more uneven-aged management (group selection) for regeneration on mesic sites, since they are less affected by wildfire. There were no limits placed on group selection in mesic sites, but if there were, this could affect the overall regeneration objectives in some planning periods; but not likely within 10-20 years for plan objectives in Alt E.

Closed canopy states are relatively stable over the first 3 planning periods but start to change to more open canopy states after that timeframe more rapidly than in Alt E Tier 2 due to high wildfire projections in later plan periods.   It is uncertain how well an increased prescribed fire program implemented early in the planning horizon (Alt E Tier 2) would mitigate wildfire severity in the future.

Conclusion. Increases in amounts of natural disturbances that create young forest would likely affect management goals in the next couple of planning cycles, but for this planning cycle the desired conditions and objectives are less affected by the climate scenarios. Assumptions about future scenarios are that increases in wildfires that result from droughts brought on by rising temperatures could be the dominant change process of natural disturbances. Acreages impacted from storms and insect & disease could rise but would be less of the driver of change compared with wildfire.

The effect of wildfire on the vegetation model is to assign more land to young forest patch creation from natural disturbances. This reduces the opportunity in the xeric and moderate moisture classes to be assigned to regeneration prescriptions for even-aged and shelterwood management. In order to sustain management goals for regeneration and sustain a high level of young forest, there is a shift to more mesic sites where more uneven management would be applied.

More changes in regeneration by even-aged and shelterwood management occur in the middle of plan horizon 60-140 years. The effect of having more young forest patch created through natural disturbances tend to accumulate as the timeframe progresses, and so, young forest patch by natural disturbances could have a larger share of the total young forest. An unknown is how many natural disturbances would re-occur in the same area and sustain young forest conditions.

A monitoring program is needed to track changes from natural disturbances throughout the planning period. Then, the next planning cycle and beyond would have better information for adjusting (or sustaining) management goals. The remote sensing tools used in this analysis would be useful to continue over time as a check on our assumptions.

Determination of Sustained Yield Limit (SYL)

Determination of the SYL was guided by the requirement in chapter 60 of the 2012 planning Rule. Based on the handbook guidance, timber harvest prescriptions were made available for all lands that were identified as ‘may be suitable for timber production’. For all forest type groups, the prescriptions made available were ones that are silviculturally appropriate for the long-term production of timber. For any harvest regime, that regime (e.g., clearcut with standard retention, or group selection in spruce fir) was modelled to repeat in perpetuity. For each regime modeled on a forest type, the per-acre Long Term Sustained Yield (LTSY) coefficient for that regime was internally calculated. The LTSY coefficient for an acre is the sum of volume harvested over future rotations divided by the rotation age.

Data Validation

Data validation during the SYL calculation was completed to ensure that the per-acre volume production shown in the model was consistent with historical harvest data. In order to do this, a dataset of past timber sales was developed from Timber Information management (TIM) data. This dataset contained timber sale data from 2002 to 2017. This data was checked for errors in the number of acres treated, sales without acre data were removed, sales of Rights of Way were removed, settlement and Wildlife opening clearcuts were also removed.

Forest Activity Tracking System (FACTS) data was joined with Field Sampled Vegetation (FSVeg) data and summarized by ecozone, forest type and sale using GIS for only timber harvest activity records and exported to Excel. This data estimated timber sale harvest units from standard timber sales, salvage units, and some southern pine beetle suppression units. The data was paired with the historical sales data from TIM (see the document "Historical_Sale-Data_for_Validation.xlxs" located in the project record.) and where the sales were present on both datasets the acres in each forest type were matched up, converted to Spectrum FTG and the percentage of the sale in each Forest Type Group (Table 1a) calculated. This could be multiplied by each sales total volume and proportional volume per forest type estimated which was divided by the acres in the FTG for the sale to estimate volume per acre. These were averaged across the forest type groups for comparison to the SPECTRUM yields per FTG. Results from this analysis generated estimates of volume per acre for the Forest Type Groups listed in Table 11.

Table 11. Comparison of TIM/FACTS Database Estimates of CCF/Acre for the SYL Runs (CCF/Acres[1])

Forest Type Group	01	02	03	04	05	06	07	08	09	10	11	12
TIM/FACTS	26	NA	28	28	30	22	26	28	29	31	25	25
SPECTRUM (R-1)	35.5	13.1	41.6	25.6	30.2	23.9	21.6	19.3	26.4	32.5	31.6	NA

Model Adjustments

Based on the results from the first SYL run and comparison to the data validation measures described above, the Spectrum model was adjusted in the following ways:

1. Put in missing harvest options for Forest Type 12
2. Removed option for Spruce Fir harvest on Unsuited lands
3. The yields for Clearcut with Standard Retention were adjusted to more accurately reflect the simulations for that prescription. Initially, yields for this prescription came from FVS natural growth simulations (Keyser and Rodrigue 2015) and showed per-acre yields of 100 percent of the volume present at the age of harvest. This technique was used to allow the model to generate many timing choices for a prescription. Most of these yields were higher than historical harvest levels. To make the model yields closer to historical yields, adjustment proportions were developed for each forest type based on the FVS harvest simulations. These proportions ranged from 0.65 - 0.84.

[1] Limitations to this validation analysis include: (1) The acres between FACTS/FSVeg/TIM data not equating; (2) Volume per acre estimates are inflated because of the inability to remove non-forest conversions like wildlife acres from TIM data; (3) The three tracking systems used may not have all relevant harvest information present especially early in the 2002 to 2017 period.

4. The Spectrum Model was also adjusted to guide selection of regeneration harvests within management areas that were suitable for timber production to the same analysis units (where possible). This adjustment roughly approximated completing management with timber production as a secondary emphasis. It also reduced the model's attempts to assign new analysis units for regeneration treatments minimizing the spread of the regeneration harvest treatment footprint. This had impacts on both the Spectrum model results from a seral progression standpoint but also the level of future roading needed in the timber access analysis. After making these adjustments, the results of "SYL – Run 2" are shown below in Table 12.

Table 12. Comparison of TIM/FACTS Database Estimates of CCF/Acre for SYL Run 2

Forest Type Group	01	02	03	04	05	06	07	08	09	10	11	12
CCF/Acre – TIM/FACTS	26	NA	28	28	30	22	26	28	29	31	25	25
CCF/Acre – SPECTRUM (Run 2)	30.1	13.1	30.8	11.4	25.5	18.7	15.3	13.5	22.1	27.8	23.8	18.1

Note: Data validation and model adjustments were important to the development of all future models for the alternatives because the SYL analysis was the first model run in this overall analysis and provided building blocks for the future alternatives.

Sustained Yield Limit Results

To determine the Sustained Yield Limit, the model was run to maximize the sum of the LTSY coefficients for all acres allocated to timber harvest. The LTSY coefficient for an acre is the sum of volume harvested over future rotations divided by the rotation age. The model was run with departure (no constraint limiting the harvest in any period). This run brought 700,000+ acres into solution (Table 13) closely aligning with the number of potentially suitable acres identified during Step 1 of the timber suitability analysis.

Table 13. Annual Sustained Yield

SPECTRUM Run	Acres	Annual SYL – MMCF (MMBF)
N&P SYL – W/ Departure	700,993	45 (225)

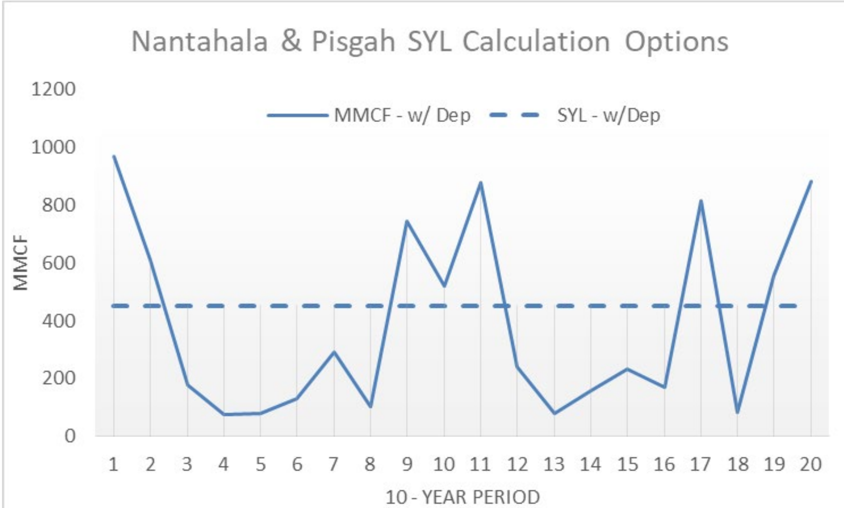

Figure 3. Nantahala and Pisgah Sustained Yield Limit Calculation

Alternative A, the "No Action" Alternative

Management Areas and Permissible Management Actions

The following table describes the management areas assigned under the current plan, the harvest suitability and the range of management prescriptions allowed in those areas. Management action options built for analysis units in the Spectrum model were limited to those listed here.

Table 14. Alternative A Management Areas and Their Characteristics

Mgmt. Area	Description	Admin. Suitability Design	Harvest Treatments Permitted
1b	Timber Production, Regulated, Motorized Rec	Suited – Timber Production (TP)	All Table 6 treatments– standard basal area retention (BAR)
2a	Scenery, Mature Forest, Roaded access	Suited – TP	All T6 Trts - high BAR
2c	Scenery, Mature Forest, Roaded access	Unsuited – TP	All T6 Trts - high BAR
3b	Timber Production, Regulated, Non-motor Rec	Suited – TP	All T6 Trts - st. BAR
4a	Scenery, Mature Forest, Non-motor Rec	Suited – TP	All T6 Trts - high BAR
4c	Scenery, Mature Forest, Non-motor Rec	Unsuited – TP	Just Burning
4d	Mature Forest, Scenery, Non-motor Rec	Suited – TP	All T6 Trts - st. BAR with 25 acre max limit
5	Backcountry, Mature, Non-motor Rec	Unsuited – TP	Just Burning
6	Wilderness Study Areas	Unsuited – TP	------
7	Wilderness	Unsuited – TP	------
8	Experimental Forests	Unsuited – TP	All Treatments
9	Roan Mountain	Unsuited – TP	------

10	Research Natural Areas	Unsuited – TP	------
11	Cradle of Forestry in America	Unsuited – TP	All Treatments
12	Developed Recreation Sites	Unsuited – TP	------
13	Special Interest Areas	Unsuited – TP	------
14	Appalachian Trail Corridor	Unsuited – TP	------
15	Wild and Scenic River Corridors	Unsuited – TP	------
16	Admin Sites	Unsuited – TP	------
17	Balds	Unsuited – TP	------
18	Riparian Areas	Unsuited – TP	Embedded in other MAs
U	Old acquisitions unassigned MA	Unsuited – TP	------
U-New	New acquisitions unassigned MA*	Unsuited – TP	------

* Several small areas of the forest were acquired under the existing forest plan but were not assigned a management area. These areas were not assigned a management area in this analysis and were analyzed as unassigned.

Objectives for Alternative A

The planning team determined that the no-action/current condition for Alternative A is work that has happened in the last five years. To generate the objectives for Spectrum, historical data was compiled for activity types including harvest and prescribed fire. Forestwide targets for activity levels were determined from these data and applied as targets to attain in the model. A subset of the management area and geographic area distribution data, expressed as percentages, was translated into Spectrum constraints in order to distribute the target activity levels in a manner similar to the past (Tables 15 a - f).

Table 15a. Historic Distribution of Harvest Types within the Nantahala & Pisgah Management Areas*

Alt. A MA	EA Regen	Salvage	Thinning	UEA Regen	% of Total Harvest
5 - 18	--	--	--	--	0.8
% in MA 1b	73	7	20	--	4.4
% in MA 2a	43	18	36	3	10.5
% in MA 2c	80	11	9	--	2.1
% in MA 3b	67	24	8	1	48.2
% in MA 4a	56	26	4	15	7.9
% in MA 4c	46	52	--	2	3.2
% in MA 4d	74	4	14	8	22.4
% in New Aq	76	14	10	--	0.5

*Based on Forest Activity Tracking System (FACTS) and Timber Information Management (TIM).

Table 15b. Historic Distribution of Harvest Types within the Nantahala and Pisgah Geographic Areas*

Geographic Area	EA Regen %	Salvage %	Thinning %	UEA Regen %	GA Harvest %
Nantahala Mtns	75	8	16	--	22.1
Unicoi Mtns	85	4	3	8	17.5
Fontana Lake	15	53	32	--	14.9
Eastern Escarpment	63	37	--	--	12.3
Pisgah Ledge	51	--	34	15	8.0
Highland Domes	83	--	1	17	7.8
Great Balsam	95	--	5	--	7.4
Hiwassee	35	65	--	--	4.6
Nantahala Gorge	69	8	23	--	3.1
Black Mtns	91	9	--	--	2.1
Bald Mtns	100	--	--	--	0.1

*Based on Forest Activity Tracking System (FACTS) and Timber Information Management (TIM).

Table 15c. Timber Harvest Over the Last Five Years on the Nantahala and Pisgah

Fiscal Year	(Vol Cut/acres trt)
2017	16,311 CCF/ 767 acres
2016	26,818 CCF/ 1,271 acres
2015	19,793 CCF/ 756 acres
2014	12,136 CCF/ 649 acres
2013	17,043CCF/ 633 acres

Table 15d. Acres and Percent Prescribed Fire by Geographic Area

Geographic Area	Acres	%
Eastern Escarpment	13,629	21
Hiwassee	13,391	20
Nantahala Mtns	13,154	20
Black Mtns	6,771	10
Pisgah Ledge	6,030	9
Fontana Lake	3,567	5
Great Balsam	2,821	4
Nantahala Gorge	2,207	3

Geographic Area	Acres	%
Unicoi Mtns	1,688	3
Bald Mtns	1,608	2
Highland Domes	741	1
North Slope	56	0
Total	65,663	100

Table 15e. Acres and Percent Prescribed Fire by Alternative A Management Area

MA	Acres	%
6	3	0
16	47	0
7	54	0
8	73	0
13	104	0
12	297	0
14	412	1
17	566	1
11	1,145	2
2c	2,311	4
2a	2,468	4
U-New	3,198	5
1b	4,603	7
4a	6,246	10
4c	7,652	12
4d	9,686	15
5	10,672	16
3b	16,125	25
Total	65,663	100

Table 15f. Nantahala and Pisgah Burn Accomplishments CY 14 to 17

Calendar Year	Acres
2017	3,300
2016	11,673
2015	4,384

2014	9,257
4-Year Average	7,154

Two other objectives for Alternative A were based on data that was not present in the model, and therefore could not be modelled directly. The first was to have no harvest in riparian areas, and the second was to allow no harvesting in existing old growth patches. To make sure that these two objectives could be met, the solution harvest acres by management area were compared to the number of acres in each management area that were not in riparian and old growth patches. In no case did the harvest level exceed what was available, indicating that these objectives could be met.

The harvest of previously treated stands before additional second growth stands was decided to be an overall criteria to guide Alternative A. To model this, the objective function chosen to drive the model was to maximize the acres harvested in the first 100 years from stands that are currently 60 years old or younger, subject to meeting the other targets, limits, and constraints in the model.

Table 15g shows the full list of Spectrum constraints used to create Alternative A. See the explanation in "Interpretation of Objective and Constraint Tables for Alternatives," above, for interpretation of this table. Constraints were adjusted iteratively as the model was refined. Additional explanation of certain constraints is available in the project record.

Table 15g. Spectrum Constraints on Alternative A

Target/Constraint (Category)	Periods of upper (UL) or lower (LL) limits
Acres burned forest-wide (BG1) cannot be more than 80000 in periods 1 to 10	UL 3
Acres burned forest-wide (BG1) must be at least 70000 in periods 1 to 10	LL 1-2
Acres receiving regeneration cuts (HV3) cannot be more than 7000 in periods 1 to 10	UL 1-10
Acres thinned (HV4) must be at least 1500 in periods 1 to 10	LL 2-4
Acres receiving regeneration cuts (HV3) must be at least 6500 in periods 1 to 10	

Target/Constraint (Geographic Area Controls)	Periods of upper (UL) or lower (LL) limits
Acres harvested in MA 2a (Hm2) in periods 1 to 5 must be at least 10.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 5	LL 2-5
Acres harvested in MA 3b (Hm3) in periods 1 to 5 must be at least 48.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 5	LL 4-5
Acres harvested in MA 4d (Hm4) in periods 1 to 5 must be at least 22.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 5	LL 1-4
Young forest acres in MA 1b (YM1) in periods 1 to 10 must be at least 5.00 percent of Total acres in MA 1b (AM1) in periods 1 to 10	LL 7
Acres BURNED in MA 4c (BM2) in periods 1 to 10 must be at least 12.00 percent	

Target/Constraint (Geographic Area Controls)	Periods of upper (UL) or lower (LL) limits
of Acres burned forest-wide (BG1) in periods 1 to 10	
Acres BURNED in MA 4d (BM3) in periods 1 to 10 must be at least 15.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	
Acres BURNED in MA 5 (BM4) in periods 1 to 10 must be at least 16.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	
Acres BURNED in MA 3b (BM5) in periods 1 to 10 must be at least 25.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	
Young forest acres in MA 1b (YM1) in periods 1 to 10 cannot be more than 10.00 percent of Total acres in MA 1b (AM1) in periods 1 to 10	UL 1,3

Target/Constraint (Management Area Controls)	Periods of upper (UL) or lower (LL) limits
Acres harvested in Eastern Escarpment GA (HG4) in periods 1 to 7 cannot be more than 14.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	UL 2-5
Acres harvested in Nantahala Mtns (HG1) in periods 1 to 7 must be at least 19.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	LL 1-6
Acres harvested in Nantahala Mtns (HG1) in periods 1 to 7 cannot be more than 23.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	UL 7
Acres harvested in Unicoi Mtns (HG2) in periods 1 to 7 must be at least 16.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	LL 1-6
Acres harvested in Unicoi Mtns (HG2) in periods 1 to 7 cannot be more than 20.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	
Acres harvested in Fontana Lake GA (HG3) in periods 1 to 7 must be at least 13.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	LL 1-7
Uneven age acres harvested in Unicoi Mtns. (Hg2) in periods 1 to 5 must be at least 8.00 percent of Acres harvested in Unicoi Mtns (HG2) in periods 1 to 5	LL 1-5
Acres harvested in Eastern Escarpment GA (HG4) in periods 1 to 7 must be at least 10.00 percent of Acres harvested forestwide (Hv1) in periods 1 to 7	LL 7
Uneven age acres harvested in Highland Domes (Hg5) in periods 1 to 5 must be at least 15.00 percent of Acres harvested in Highland Domes (HG5) in periods 1 to 5	LL 1-3
Uneven age harvest acres in Pisgah ledge (Hg6) in periods 1 to 5 must be at least 17.00 percent of Acres harvested in Pisgah Ledge (HG6) in periods 1 to 5	LL 1-5

Alternatives B, C, D, the Action Alternatives

The action alternatives are differentiated primarily by the number of acres assigned to the different management areas. For each alternative, the relevant management area map for that alternative was overlayed on the other land attribute layers to construct a unique analysis unit set for that Alternative as well as the addition of step 2 of the timber suitability analysis. As mentioned above, the starting point for the development of each dataset was the sustained yield limit dataset.

Management Areas and Permissible Management Actions

Assumptions related to management actions were synthesized based on forest plan ID team discussions. These assumptions were incorporated into the model for each action alternative and described Table 16a. Along with the actions permissible within each management area, assumptions addressing the intensity of harvest across the management areas for both Tier 1 and Tier 2 were development using the terrestrial ID team subset. These proportional assumptions are included in Table 16b. The management area assumptions represented in Tables 16a & b represent the primary inputs to the Spectrum models used for Alternatives B, C, and D. Secondary inputs related to GA and forest type group were developed but were not used as broadly. They were used where model actions could not easily be guided by the management area level assumptions. The geographic area assumptions are located in the project record.

Table 16a. Alternative B, C, and D Management Areas and Their Permissible Management Actions

Forest Plan Management Area Direction	
Management Area and Code	**Permissible Management Actions**
Interface (2)	Use high BA retention treatments
Matrix (1)	Standard BA retention
	Regeneration treatments more even-aged
Backcountry (3)	Higher amount of group selection and woodland habitat creation
	Use High BA retention when regenerating using even-aged treatments
	Increased use of fire in comparison to Matrix
EIA/SIA (5a, 5b)	Use Fire and Thinning primarily
	In cove forest type (10CVHw) use Group Selection and thinning only
	In WP Types (01WP, 05WpHw) use regeneration only treatments
AT (4a)	Use Fire and Thinning primarily
	In cove forest type (10CVHw) use Group Selection and thinning only
	WP Types (01WP, 05WpHw) use regeneration only treatments (High BA)
Byways (4b)	Use Fire and Thinning primarily
	In cove forest type (10CVHw) use Group Selection and thinning only
	WP Types (01WP, 05WpHw) use regeneration only treatments (High BA)
	Don’t use CC management options
Heritage Corridors (4c)	Use Fire and Thinning primarily
	In cove forest type (10CVHw) use Group Selection and thinning only

Forest Plan Management Area Direction	
Management Area and Code	**Permissible Management Actions**
	WP Types (01WP, 05WpHw) use regeneration only treatments (High BA)
	Don’t use CC management options
Wild and Scenic Rivers (4d)	Wild – Fire Only
	Scenic – Fire and Thinning
	Recreational – All types but with high BA retention on regeneration
RNA (5R)	No Management
Wilderness/ WSA (7, 6)	No Management
Experimental Forests (8)	Open to all management (low intensity 1% of harvest)
Roan Mtn (9)	Individual tree and group selection in 02SF and 12NoHw
Cradle of Forestry (11)	Open to all management (low intensity 1% of harvest)

Table 16b. Alternative B, C, and D Management Areas and Their Estimated Relative Proportion of Activity

Management Area	Tier 1 MA Activity Distribution (%)	Tier 2^ MA Activity Distribution (%)
Matrix	92%	60%
Interface	3%	5%
EIAs*	3%	10%
Backcountry % other MAs	2%	25%

*Where the MA is present in Alternatives C and D. Within Alternative B the proportion of activity distribution was within the appropriate management are assignment that the EIA would have derived from.

^This is the allocation of the extra acres from Tier 2, NOT the total acres. Tier 1 related activities would still use the tier one activity distribution.

Management Objectives

For all the action alternatives, two sets of objectives, represented in the model as constraints, were developed: Tier 1 and Tier 2 objectives. For each tier, constraint levels were the same for all the alternatives. These were developed based on the forest plan objectives published in the consolidated terrestrial objectives section. They were transformed to represent a decagonal number as needed.

Table 17 shows the full list of Spectrum constraints used to create Tier 1 for Alternatives B, C, and D. See the explanation in “Interpretation of Objective and Constraint Tables for Alternatives,” above, for interpretation of this table. Additional explanation of certain constraints is available in the project record.

Table 17. Tier 1 Objectives and Constraints for Alternatives B, C, and D

Tier 1 Target/Constraint (Targets)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres harvested (all treatments) forest wide (HA2) cannot be more than 30000 in periods 1 to 20	UL 1-6,11,15-17,19	UL 1-6,15-17,19	UL 1-6,15-17,19
Acres burned forest-wide (BG1) must be at least 65000 in periods 1 to 2	LL 1	LL 1	LL 1
Acres burned forest-wide (BG1) cannot be more than 100000 in periods 1 to 10	UL 3,7,8	UL 3,7,8	UL 3,7,8
Acres receiving regeneration cuts (HV3) cannot be more than 12000 in periods 1 to 20	UL 2-20	UL 1-20	UL 2-20
YOUNG FOREST acres created by all mgmt (yng) must be at least 11000 in periods 1 to 2			
Regen Acre harvest in MA 2 (Hm6) must be at least 500 in periods 1 to 1	LL 1	LL 1	LL 1

Tier 1 Target/Constraint (Prohibitions)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres Allocated to Management in MA 5R, RNA (AMe) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Management in MAs 6, 7 (AMd) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Burn for Young Forest Creation in MA 8 (AMh) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1

Tier 1 Target/Constraint (Open Forest)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
YOUNG FOREST on Types 08,09,10,11,12 produced with regen cuts (YT1) in periods 1 to 4 must be at least 50.00 percent of YOUNG FOREST acres created by regen cuts (YP1) in periods 1 to 4	LL 1	LL 1	LL 1
OPEN FOREST condition acres on Types 03,04,06,07,08,09,11 (OT1) in periods 2 to 10 must be at least 90.00 percent of OPEN FOREST condition acres forestwide (OF1) in periods 2 to 10	LL 2,3		LL 2,3
OPEN FOREST condition acres forest-wide (OF1) must be at least 4000 in periods 2 to 10	LL 2	LL 2	LL 2

Tier 1 Target/Constraint (Management Controls)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres of For Type 10 allocated to GrpSel or MinLvl on MAs 4a-5b (AT3) in periods 1 to 1 must be equal to Acres of Forest Type 10 in MAs 4a,4b,4c,5a,5b (AT2) in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Group Selection on Admin. Unsuit lands (SM6) in periods 1 to 1 cannot be more than 10.00 percent of All acres Allocated to Group Selection (SM5) in periods 1 to 1			
Acres Allocated to Thin&Burn or Sanit. Thin on Admin Unsuit land (SM4) in periods 1 to 1 cannot be more than 10.00 percent of All acres Allocated to Thin and Burn or Sanitation Thinning (SM3) in periods 1 to 1	UL 1	UL 1	UL 1
Acres allocated to Regeneration Rxs on Admin Unsuit lands (SM2) in periods 1 to 1 cannot be more than 10.00 percent of Acres Allocated to Regeneration Rxs forestwide (SM1) in periods 1 to 1	UL 1	UL 1	UL 1
Acres allocated to Group Selection in Forest Types 10, 12 (GS2) in periods 1 to 1 must be at least 25.00 percent of Acres allocated to active management on Forest Types 10 & 12 (AT4) in periods 1 to 1	LL 1	LL 1	LL 1

Tier 1 Target/Constraint (Management Area Control)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres Allocated to Thin and Burn in MA 1 (BM6) in periods 1 to 1 cannot be more than 50.00 percent of Acres Allocated to Thin and Burn forestwide (BA1) in periods 1 to 1	UL 1	UL 1	UL 1
Acres Allocated to Prescribed Burn and Thin and Burn in MA 5a (BM9) in periods 1 to 1 must be at least 80.00 percent of Acres allocated to active management in MA 5a (AMj) in periods 1 to 1			
Acres Allocated to CC w High Retention in MAs 1&3 (AMg) in periods 1 to 1 cannot be more than 5.00 percent of Acres Allocated to Management, MAs 1&3 (AMf) in periods 1 to 1	UL 1	UL 1	UL 1
Acres Burned in MA 5a (BMA) must be at least 5000	LL 1-4, 11,17	LL 1-6,8-15,17-	LL 1-20

Tier 1 Target/Constraint (Management Area Control)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
in periods 1 to 20		19	
Acres Allocated to CCRR or CCRH in MAs 3,5b,4a-d,8 (Hm5) in periods 1 to 1 must be at least 5.00 percent of Acres Allocated to CC HiRet or CC StdRet Forestwide (HV5) in periods 1 to 1	LL 1	LL 1	LL 1
Acres Allocated to Management in MA 2, Interface (AMa) in periods 1 to 1 cannot be more than 3.00 percent of Acres Allocated to Management (AA2) in periods 1 to 1			
Acres Allocated to Burn for Young Forest in MA 1 (BA4) in periods 1 to 1 cannot be more than 90.00 percent of Acres allocated to Burning for Young forest (BA2) in periods 1 to 1			
Acres Allocated to Management in MA 1, Matrix (AMb) in periods 1 to 1 must be equal to 92.00 percent of Acres Allocated to Management (AA2) in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Burn for Young Forest in MAs 3,5b,4a-d,8 (BM8) in periods 1 to 1 must be at least 25.00 percent of Acres allocated to Burning for Young forest (BA2) in periods 1 to 1	LL 1	LL 1	LL 1
Acres Alloc to Thin&Burn, Prescribed burn, Sanit.Thin in MA 5a (BMa) in periods 1 to 1 must be equal to Acres allocated to active management in MA 5a (AMj) in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Clearcut Hi Retention in GeoArea HD, MAs 1&3 (AMi) in periods 1 to 1 cannot be more than 40.00 percent of Acres Allocated to CC w High Retention in MAs 1&3 (AMg) in periods 1 to 1			
Acres allocated to Thin and Burn in GeoArea HI, MA 1 (BG5) in periods 1 to 1 cannot be more than 40.00 percent of Acres Allocated to Thin and Burn in MA 1 (BM6) in periods 1 to 1			

Tier 1 Target/Constraint (Flow Control)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres receiving regeneration cuts (HV3) must not increase more that 17.65 percent. in periods 2 to 21			
Acres receiving regeneration cuts (HV3) must not decrease more than 15.00 percent. in periods 1 to 20			
Young Forest + Young Gaps (YNG) must not increase more that 15.00 percent. in periods 6 to 20	LL 8,9,10,16-18	LL 8,9,10,14-18	LL 8,9,10,14,16-18
Young Forest + Young Gaps (YNG) must not decrease more than 15.00 percent. in periods 6 to 20	LL 6,12,13	LL 6,12,13	LL 6,12,13
Acres harvested from Group Selection (GS1) must not increase more that 17.65 percent. in periods 2 to 21	LL 1,3,5,7,9,11,19	LL 3,5,7,9,11, 13,19	LL 1,3,5,7,11,19

Tier 1 Target/Constraint (Burning)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
BURNING acres on Types 04,07,08 (BT5) in periods 1 to 10 must be at least 5.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10			
Acres Allocated to Thin and Burn forestwide (BA1) in periods 1 to 1 must be at least 8.00 percent of Acres allocated to burning Rxs forestwide (BA5) in periods 1 to 1	LL 1	LL 1	LL 1
BURNING acres on Forest Type 09 (BT4) in periods 1 to 10 must be at least 13.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	LL 1-7,9	LL 3-7,9	LL 1,3,4,6,7,9
Acres Allocated to Burn1 (prescribed burning) (BA3) in periods 1 to 1 must be at least 60.00 percent of Acres allocated to Burning for Young forest (BA2) in periods 1 to 1			
Acres burned forest-wide (BG1) must be at least 60000 in periods 3 to 10			
Acres Burned on ForTypes 03,04,06,07,08,09 (BT9) in periods 1 to 10 cannot be more than 75.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	UL 2,5,7-9	UL 1,2,7	UL 2,3,5,7,9
BURNING acres on Types 03,06 (BT3) in periods 1 to 10 must be at least 16.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	LL 1-5,7,9,10	1,2,4-10	LL 1-7,9,10
Acres allocated to Burning on For Type 02 (BT6) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1
Burning on ForTypes 04,07 (BT7) in periods 1 to 10 must be at least 15.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10			
Burning of Forest Type 08 (BT8) in periods 1 to 10 must be at least 6.00 percent of Acres burned forest-wide (BG1) in periods 1 to 10	LL 1,5,9,10	LL 1,5,6,8,9	LL 1,5,6,8-10

Table 18 shows the full list of Spectrum constraints used to create Tier 2 for Alternatives B, C, and D. See the explanation in “Interpretation of Objective and Constraint Tables for Alternatives,” above, for interpretation of this table.

Table 18. Tier 2 Objectives for Alternatives B, C, and D

Tier 2 Target/Constraint (Target)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres receiving regeneration cuts (HV3) cannot be more than 35000 in periods 1 to 20	UL 1	UL 1	UL 1
Young Forest + Young Gaps (YNG) must be at least 60000 in periods 2 to 20			
Young Forest + Young Gaps (YNG) must be at least 57000 in periods 1 to 1			
Regen Acre harvest in MA 2 (Hm6) cannot be more than 500 in periods 1 to 10	UL 3-10	UL 1-10	UL 2-10
Young Forest + Young Gaps (YNG) cannot be more than 90000 in periods 1 to 20	UL 2-20	UL 3-20	UL 3-20
All Harvest acres forestwide (HA2) cannot be more than 65000 in periods 1 to 20	UL 1,2,5,6,14	UL 1	UL 1,2,5,6
Acres receiving regeneration cuts (HV3) must be at least 31000 in periods 1 to 20	LL 2-20	LL 2-20	LL 2-14, 16-20
Regen Acre harvest in MA 2 (Hm6) must be at least 300 in periods 1 to 10	LL 1-2		LL 1

Tier 2 Target/Constraint (Target)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
YOUNG FOREST on Types 08,09,10,11,12 produced with regen cuts (YT1) in periods 1 to 4 must be at least 50.00 percent of YOUNG FOREST acres created by regen cuts (YP1) in periods 1 to 4			

Tier 2 Target/Constraint (Proportional Controls)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Of the acres managed in Tier 2 in excess of the Tier 1 managed acres, 60 percent of those should be in MA 1	EQ 1	EQ 1	EQ 1
Of the acres managed in Tier 2 in excess of the Tier 1 managed acres, 25 percent of those should be allocated to Burning prescriptions	Had to do 60%	Had to do 48%	Had to do 60%
Of the acres managed in Tier 2 in excess of the Tier 1 managed acres, 75 percent of those should be allocated to regeneration harvest prescriptions	Could only reach 34%	Could only reach 45%	Could only reach 35%

Tier 2 Target/Constraint (Prohibitions)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres Allocated to Management in MA 5R, RNA (AMe) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Management in MAs 6.7 (AMd) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres allocated to Burning on For Type 02 (BT6) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1

Tier 2 Target/Constraint (Open Forest)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
OPEN FOREST condition acres forest-wide (OF1) must be at least 33000 in periods 4 to 10			
OPEN FOREST condition acres on Types 03,04,06,07,08,09,11 (OT1) in periods 2 to 10 must be at least 90.00 percent of OPEN FOREST condition acres forestwide (OF1) in periods 2 to 10	LL 5,6,10	LL 4-7, 10	LL 4-6, 9,10
OPEN FOREST condition acres forest-wide (OF1) must be at least 20000 in periods 3 to 3		LL 3	LL 3
OPEN FOREST condition acres forest-wide (OF1) must be at least 15000 in periods 2 to 2	LL 2	LL 2	LL 2

Tier 2 Target/Constraint (Management Controls)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres Allocated to Group Selection on Admin. Unsuit lands (SM6) in periods 1 to 1 cannot be more than 10.00 percent of All acres Allocated to Group Selection (SM5) in periods 1 to 1	UL 1	UL 1	
Acres Allocated to Thin&Burn or Sanit. Thin on Admin Unsuit land (SM4) in periods 1 to 1 cannot be more than 10.00 percent of All acres Allocated to Thin and Burn or Sanitation Thinning (SM3) in periods 1 to 1	UL 1	UL 1	UL 1
Acres allocated to Regeneration Rxs on Admin Unsuit lands (SM2) in periods 1 to 1 cannot be more than 10.00 percent of Acres Allocated to	UL 1	UL 1	UL 1

Tier 2 Target/Constraint (Management Controls)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Regeneration Rxs forestwide (SM1) in periods 1 to 1			
Acres allocated to Group Selection in Forest Types 10, 12 (GS2) in periods 1 to 1 must be at least 25.00 percent of Acres allocated to active management on Forest Types 10 & 12 (AT4) in periods 1 to 1	LL 1	LL 1	LL 1
Acres allocated to GROUP SELECTION (AMs) in periods 1 to 1 cannot be more than 15.00 percent of Acres Allocated to Management (AA2) in periods 1 to 1			
Acres of For Type 10 allocated to GrpSel or MinLvl on Mas 4a-5b (AT3) in periods 1 to 1 must be equal to Acres of Forest Type 10 in MAs 4a,4b,4c,5a,5b (AT2) in periods 1 to 1	EQ 1	EQ 1	EQ 1

Tier 2 Target/Constraint (MA Controls)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres Alloc to Thin&Burn, Prescribed burn, Sanit.Thin in MA 5a (BMa) in periods 1 to 1 must be equal to Acres allocated to active management in MA 5a (AMj) in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to Prescribed Burn and Thin and Burn in MA 5a (BM9) in periods 1 to 1 must be at least 80.00 percent of Acres allocated to active management in MA 5a (AMj) in periods 1 to 1			
Acres Allocated to CCRR or CCRH in MAs 3,5b,4a-d,8 (Hm5) in periods 1 to 1 must be at least 5.00 percent of Acres Allocated to CC HiRet or CC StdRet Forestwide (HV5) in periods 1 to 1	LL 1		LL 1
Acres Allocated to Thin and Burn in MA 1 (BM6) in periods 1 to 1 cannot be more than 78.00 percent of Acres Allocated to Thin and Burn forestwide (BA1) in periods 1 to 1	UL 1		UL 1
Acres allocated to Burn for Young Forest creation in MA 8 (AMh) must be equal to 0 in periods 1 to 1	EQ 1	EQ 1	EQ 1
Acres Allocated to CC w High Retention in MAs 1&2 (AMg) in periods 1 to 1 cannot be more than 8.00 percent of Acres Allocated to Management, MAs 1&2 (AMf) in periods 1 to 1	UL 1	UL 1	UL 1

Tier 2 Target/Constraint (GA Control)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres allocated to Thin and Burn in GeoArea HI, MA 1 (BG5) in periods 1 to 1 cannot be more than 40.00 percent of Acres Allocated to Thin and Burn in MA 1 (BM6) in periods 1 to 1			
Acres Allocated to Clearcut Hi Retention in GeoArea HD, MAs 1&3 (AMi) in periods 1 to 1 cannot be more than 40.00 percent of Acres Allocated to CC w High Retention in MAs 1&2 (AMg) in periods 1 to 1			

Tier 2 Target/Constraint (Flow Control)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Young Forest + Young Gaps (YNG) must not decrease more than 13.04 percent. in periods 2 to 21			
Acres harvested from Group Selection (GS1) must not increase more that 17.65 percent. in periods 2 to 21	LL 2-11,13,19		
Young Forest + Young Gaps (YNG) must not increase more that 33.33 percent. in periods 2 to 21	LL 2	LL 2	LL 2

Tier 2 Target/Constraint (Burning)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres burned forest-wide (BG1) must be at least 95000 in periods 3 to 10			
Acres Allocated to Burn1 (prescribed burning) (BA3) in periods 1 to 1 must be at least 60.00 percent of Acres Allocated to Burning for Young Forest forestwide (BA2) in periods 1 to 1			
Acres Allocated to Burn for Young Forest in MA 1 (BA4) in periods 1 to 1 cannot be more than 90.00 percent of Acres Allocated to Burning for Young Forest forestwide (BA2) in periods 1 to 1			
Acres Burned in MA 5a (BMA) must be at least 5000 in periods 1 to 20		LL 1,2,4,6,8,10, 12,14,16,18, 20	

Tier 2 Target/Constraint (Burning)	Alt B, Periods of Upper (UL) or Lower (LL) Limits	Alt C, Periods of Upper (UL) or Lower (LL) Limits	Alt D, Periods of Upper (UL) or Lower (LL) Limits
Acres Allocated to Thin and Burn forestwide (BA1) in periods 1 to 1 must be at least 8.00 percent of acres allocated to burning Rxs forestwide (BA5) in periods 1 to 1	LL 1	LL 1	LL 1
Acres Allocated to Burn for Young Forest in MAs 3,5b,4a-d,8 (BM8) in periods 1 to 1 must be at least 25.00 percent of Acres Allocated to Burning for Young Forest forestwide (BA2) in periods 1 to 1	LL 1	LL 1	LL 1
Acres burned forest-wide (BG1) must be at least 85000 in periods 1 to 2			
BURNING acres on Forest Type 09 (BT4) in periods 1 to 10 must be at least 13.00 percent of acres burned forestwide (BG1) in periods 1 to 10			
Acres burned forestwide (BG1) must be at least 200000 in periods 1 to 10	LL 1-2	LL 1-2	LL 1-2
BURNING acres on Types 03,06 (BT3) in periods 1 to 10 must be at least 16.00 percent of acres burned forestwide (BG1) in periods 1 to 10		LL 1,3,4,7	LL 3,4
Burning of Forest Type 08 (BT8) in periods 1 to 10 must be at least 6.00 percent of acres burned forestwide (BG1) in periods 1 to 10	LL 1,4,8		LL 1,5,9
Burning on Forest Types 04,07 (BT7) in periods 1 to 10 must be at least 15.00 percent of acres burned forest-wide (BG1) in periods 1 to 10	LL 2,10		
Acres Burned on Forest Types 03,04,06,07,08,09 (BT9) in periods 1 to 10 cannot be more than 80.00 percent of acres burned forestwide (BG1) in periods 1 to 10	UL 1,3,4,7	UL 1,4,7	UL 1,3,4

Alternative E:

Modelling Alternative E

Most of the adjustments made in the creation of Alternative E had some representation in the Spectrum model. This allowed us to explore the effects of changing management objectives. The changes in the model to represent Alternative E fall into four categories: changes to the delineation of Management Areas, changes to the solution technique and target levels of management activities and outcomes, a representation of natural disturbance in the model and changes to the application of prescribed burning activities.

Management Areas

Changes to the delineation of Management Areas were represented in the Spectrum model with the Analysis Unit stratification. With a new Management Area map, numbers of acres in most Analysis Units changed. Changes to the designated old growth network, timber suitability, acres for wilderness, the matrix management area and ecologic interest management area were all represented in the Management Area attribute assigned to Analysis Units. The delineations based on forest type, age class, and geographic area remained the same as the other Alternatives. The rules for what management activities were permissible on each Management Area were also the same as in the other Alternatives.

Targets and Solution Technique

Many of the important management objectives were represented as targets in the model. Desired ranges of prescribed burning, regeneration harvest and young forest conditions are shown in Table 21. To accommodate the simultaneous objectives of creating both open woodland conditions and young forest conditions, a different set of objective functions was used in Alternative E. First, the model was solved to meet all the management objectives and maximize the sum of acres in open woodland state over the planning period. Next, we ask the model to meet all the management objectives, produce at least 95% of the open woodland achieved in the first step and maximize the sum of young forest acres over the planning period. This solution technique is called preemptive goal programming, and in the Forest Service it is informally referred to as the rollover technique.

Disturbance

The Spectrum model for Alternative E incorporates the effects of disturbance more explicitly. Table 19 shows adjustments made to some model Activities/Conditions in order to represent disturbance.

Table 19. Outputs used to represent disturbance in Alternative E.

Activity/Condition Name	Description	Units
Young Mgmt	Young forest, created with management by harvest or prescribed burning; same as Young Forest in Alts B,C,D	Acre
Young Patch	Young forest created from large scale natural disturbance; not modeled in Alts B,C,D	Acre
Gaps	Small areas of young forest created by small scale natural disturbance; same as Young Gaps in Alts B,C,D	Acre
Disturbance	A large stand-altering disturbance caused by storms, insects and disease or fire	Acre

Natural disturbances are random events, and their future occurrences can only be estimated. In the modelling of Alternative E, different scenarios of disturbance levels were explored. In each scenario an estimate of the total number of acres disturbed in each time period was hardwired into the model. The model was forced to apply the Disturbance “prescription” to that number of acres. The application of disturbance was also guided by proportions for each forest type group. For example, 12 percent of the estimated acres disturbed by wildfire are assumed to occur on forest type 08, dry oak. Proportions were input for each forest type group based on historical data and research on disturbance probabilities.

Another modelling technique was employed to more accurately represent the variability of stand conditions after a disturbance. After wildfire it is estimated that some of the burned area will be completely burned while other parts of the burned area will be transformed into a woodland state with some surviving trees. The technique used to model this is referred to as a multiple outcome Model II structure (Davis, 2001).

Moisture Class Outputs:

Based on the comments we received during the draft plan and DEIS review we developed an additional category in Spectrum that allowed us to report outputs by moisture class. This grouping strategy simplified parts of the FEIS and the forest plan timber appendices.

Table 20: Description of Moisture Class Output Categories added to Alternative E

ForType	Forest Type Name	Moisture
01WP	White Pine	Xeric
02SF	Spruce-Fir	Moist
03SLP	Shortleaf Pine	Xeric
04PP	Pitch Pine	Xeric
05WpHw	White Pine-Hardwood	Moderate
06SlpH	Shortleaf Pine Hardwood	Moderate
07PVH	Pitch Pine Hardwood	Moderate
08Doak	Dry Oak	Xeric
09Ioak	Intermediate	Moderate
10CvHw	Cove Hardwood	Moist
11MxHw	Mixed Hardwood	Moderate
12NoHw	Northern Hardwood	Moist

Prescribed burning

Alternative E places an increased emphasis on prescribed burning. In the model, some changes were made to the representation of prescribed burning prescriptions. For the primary burning prescription, detail was added to more accurately represent the sequence of burning activity that would take place on pine versus oak timber types. For pine types, two burns occur every 10-year period and the stand reaches an open, woodland state one period after the burning begins. For oak types, two burns occur each period for four periods, followed by one burn per period; and the open, woodland state is achieved two periods (20 years) after the burning begins. The Thin and Burn prescription was also changed. The timing of the burning was moved to happen in the same period as the thinning instead of two periods later. A prescribed burning prescription was also linked to create young forest conditions.

Group Selection

Further clarification of the group selection acres that contribute to young forest was made in Alternative E. When young management was calculated as an output of the model the acres of group selection (represented by the OtherHarvestAcres output) was multiplied by 0.33 to approximate those acres with the group selection analysis unit that were converted to young forest in the entry.

New Openings = RegenAcres + 0.33*OtherHarvAcres

Model Check

1) A check was run on Alternative E data and results to determine that there were enough acres available that were also considered accessible based on the Land Potentially Impacted by Timber Operations. Results indicated that lands available for timber operations would not be limiting to the estimates being produced by Spectrum for wither Tier 1 or Tier 2 of Alternative E. (Refer to the FEIS timber resources section for further information covering the lands available for timber operations.)

Table 21. Tier 1 and Tier 2 constraints and targets for Alternative E

Alternative E, Target/Constraint (Targets)	Tier 1, Periods of Upper (UL) or Lower (LL) Limits	Tier 2, Periods of Upper (UL) or Lower (LL) Limits
OPEN FOREST condition acres forest-wide (OF1) must be at least 4000 in periods 2 to 10		
Acres burned by management forest-wide (BG1) must be at least [Tier1: 190000/Tier2: 430000] in periods 1 to 10		LL 1,5,9,10
Acres burned by management forest-wide (BG1) cannot be more than [Tier1: 200000 / Tier2: 450000] in periods 1 to 10	UL 1-7, 9	UL 2-4, 6
Young Mgmt + Young Patch (YNG) cannot be more than 95000 in periods 1 to 20	NA	UL 4-7, 13-20
Young Mgmt acres created by all mgmt (yng) must be at least 11000 in periods 1 to 2		
Regen Acre harvest in MA 2 (Hm6) must be at least 500 in periods 1 to 10	LL 1-10	LL 1-4, 10
Acres thinned with Thin and Burn plus Sanitation management (HV6) cannot be more than 10000 in periods 1 to 3		UL 1-2
Acres receiving regeneration cuts (HV3) must be at least [Tier1: 10000 / Tier2: 28000] in periods 1 to 10	LL 1-2	LL 3-8
Acres BURNED by management acres on Types 03,06 (BT3) must be at least 27000 in periods 1 to 10	NA	LL 1-10
Acres receiving regeneration cuts (HV3) cannot be more than [Tier1: 12000 / Tier2: 30000] in periods 1 to 20	UL 4-20	UL 1, 10-20
All Harvest acres forestwide (HA2) cannot be more than 30000 in periods 1-20	UL 5-9, 15, 16	NA

Alternative E, Target/Constraint (Prohibitions)	Tier 1, Periods of Upper (UL) or Lower (LL) Limits	Tier 2, Periods of Upper (UL) or Lower (LL) Limits
Acres allocated to Burn for YoungForest creation in MA 8 (AMh) must be equal to 0 in periods 1 to 1		
Acres Allocated to Management in MAs 6.7 (AMd) must be equal to 0 in periods 1 to 1		
Acres allocated to Burning Rx's on For Type 02 (BT6) must be equal to 0 in periods 1 to 1		
Acres of FTG 01 & 05 allocated to shelterwood or Grp Sel (AT5) must be equal to 0 in periods 1 to 1		
Acres Allocated to Management in MA 5R, RNA (AMe) must be equal to 0 in periods 1 to 1		
Acres Allocated to burning on FTG 10 (BA6) must be equal to 0 in periods 1 to 1	NA	

Alternative E, Target/Constraint (Mgmt Area Control)	Tier 1, Periods of Upper (UL) or Lower (LL) Limits	Tier 2, Periods of Upper (UL) or Lower (LL) Limits
Acres of FTG 10 allocated to non-CC harv or MinLvl on MAs 4a-5b (AT3) in periods 1 to 1 must be equal to Acres of Forest Type 10 in MAs 4a,4b,4c,5a,5b (AT2) in periods 1 to 1		
Acres Allocated to CC w High Retention in MAs 1&2 (AMg) in periods 1 to 1 cannot be more than 5.00 percent of Acres Allocated to Management, MAs 1&2 (AMf) in periods 1 to 1	UL 1	UL 1
Acres Allocated to CCRR or CCRH in MAs 3,5b,4a-d,8 (Hm5) in periods 1 to 1 must be at least 5.00 percent of Acres Allocated to CC HiRet or CC StdRet Forestwide (HV5) in periods 1 to 1	LL 1	LL 1
Acres allocated to Thin and Burn in GeoArea HI, MA 1 (BG5) in periods 1 to 1 cannot be more than 40.00 percent of Acres Allocated to Thin and Burn in MA 1 (BM6) in periods 1 to 1		
Acres Allocated to Clearcut Hi Retention in GeoArea HD, MAs 1&3 (AMi) in periods 1 to 1 cannot be more than 40.00 percent of Acres Allocated to CC w High Retention in MAs 1&2 (AMg) in periods 1 to 1		

Alternative E, Target/Constraint (Management Control)	Tier 1, Periods of Upper (UL) or Lower (LL) Limits	Tier 2, Periods of Upper (UL) or Lower (LL) Limits
Acres Allocated to Group Selection on Admin. Unsuit lands (SM6) in periods 1 to 1 cannot be more than 10.00 percent of All acres Allocated to Group Selection (SM5) in periods 1 to 1		
Acres of FTG 08 allocated to regen harvest treatments (AA5)		

Alternative E, Target/Constraint (Management Control)	Tier 1, Periods of Upper (UL) or Lower (LL) Limits	Tier 2, Periods of Upper (UL) or Lower (LL) Limits
in periods 1 to 1 cannot be more than 20.00 percent of Acres Allocated to regen treatments on FTG 08, 09, 10 (AA6) in periods 1 to 1		
OPEN FOREST condition acres on Types 03,04,06,07,08,09,11 (OT1) in periods 2 to 10 must be at least 90.00 percent of OPEN FOREST condition acres forest-wide (OF1) in periods 2 to 10		LL 9, 10
Acres allocated to Regeneration Rxs on Admin Unsuit lands (SM2) in periods 1 to 1 cannot be more than 10.00 percent of Acres Allocated to Regeneration Rxs forestwide (SM1) in periods 1 to 1		
Acres allocated to Group Selection in Forest Types 10, 12 (GS2) in periods 1 to 1 must be at least 25.00 percent of Acres allocated to active management on Forest Types 10 & 12 (AT4) in periods 1 to 1		LL 1
Acres Allocated to management on FTG 02 (AT6) in periods 1 to 1 cannot be more than 10.00 percent of Acres Allocated to Management (AA2) in periods 1 to 1		
Young Mgmt on Types 08,09,10,11,12 produced with regen cuts (YT1) in periods 1 to 4 must be at least 50.00 percent of Young Mgmt acres created by regen cuts (YP1) in periods 1 to 4		
Regen Acres on FTG 08, Dry Oak (HTd) in periods 1 to 10 must be at least 2.00 percent of Acres receiving regeneration cuts (HV3) in periods 1 to 10	LL 4-7, 9,10	LL 1-10
Acres Regenerated on FTG 10 using clearcut with High Retention (HTc) in periods 1 to 10 cannot be more than 30.00 percent of Regen Acres and Other Harvest acres on FTG 10 (HTb) in periods 1 to 10	UL 1,10	UL 3,9
Regen Acres and Other Harvest acres on FTG 10 (HTb) in periods 1 to 10 cannot be more than 30.00 percent of Acres receiving regeneration cuts (HV3) in periods 1 to 10		
Regen Acres on FTGs 03 & 06 (HTe) in periods 1 to 10 must be at least 2.00 percent of Acres receiving regeneration cuts (HV3) in periods 1 to 10	LL 1-10	LL 1-10
Regen Acres on FTGs 03 & 06 (HTe) in periods 1 to 10 cannot be more than 3.00 percent of Acres receiving regeneration cuts (HV3) in periods 1 to 10		
Acres of FTG 12 allocated to active management (AT7) in periods 1 to 1 cannot be more than 10.00 percent of Acres Allocated to Management (AA2) in periods 1 to 1		
Regen Acres on FTG 08, Dry Oak (HTd) in periods 1 to 10 cannot be more than 3.00 percent of Acres receiving regeneration cuts (HV3) in periods 1 to 10	UL 1-3, 8	

Alternative E, Target/Constraint **(Management Control)**	**Tier 1, Periods of Upper (UL) or Lower (LL) Limits**	**Tier 2, Periods of Upper (UL) or Lower (LL) Limits**
Acres Regenerated on FTG 10 using clearcut with High Retention (HTc) in periods 1 to 10 must be at least 27.00 percent of Regen Acres and Other Harvest acres on FTG 10 (HTb) in periods 1 to 10	LL 2-9	LL 1,2,4-8, 10
Regen Acres and Other Harvest acres on FTG 10 (HTb) in periods 1 to 10 must be at least 27.00 percent of Acres receiving regeneration cuts (HV3) in periods 1 to 10	LL 1-10	LL 1-10
Acres Allocated to Shelterwood mgmt in FTG 10 (AT8) in periods 1 to 1 must be at least 5.00 percent of Acres Allocated to Shelterwood mgmt. forest-wide (AT9) in periods 1 to 1		
Acres Allocated to timber management on MAs 2,3,4a-d,5b (AMm) in periods 1 to 1 must be at least 5.00 percent of Acres allocated to Timber management forest-wide (AA7) in periods 1 to 1		
Acres allocated to timber management in MA 1 (AMk) in periods 1 to 1 must be at least 92.00 percent of Acres allocated to Timber management forest-wide (AA7) in periods 1 to 1	LL 1	LL 1
Acres thinned under Thin and Burn mgmt (HV7) in periods 1 to 3 must be equal to 75.00 percent of Acres thinned with Thin and Burn plus Sanitation management (HV6) in periods 1 to 3	LL&UL 1-3	LL&UL 1-3

Alternative E, Target/Constraint **(Flow Control)**	**Tier 1, Periods of Upper (UL) or Lower (LL) Limits**	**Tier 2, Periods of Upper (UL) or Lower (LL) Limits**
Young Mgmt + Young Patch (YNG) must not decrease more than 15.00 percent. in periods 6 to 20		
Young Mgmt + Young Patch (YNG) must not increase more that 15.00 percent. in periods 6 to 20	LL 6, 8, 14-18	LL 12
Acres receiving regeneration cuts (HV3) must not decrease more than 15.00 percent. in periods 1 to 20		
Acres receiving regeneration cuts (HV3) must not increase more that 17.65 percent. in periods 2 to 21	LL 3	
Acres harvested from Group Selection (GS1) must not increase more that 17.65 percent. in periods 2 to 21	LL 14, 19	LL 1-5, 8, 10, 11

Alternative E, Target/Constraint (Burning)	Tier 1, Periods of Upper (UL) or Lower (LL) Limits	Tier 2, Periods of Upper (UL) or Lower (LL) Limits
Burning with Burning for Young Forest on FTG 07 (BTg) in periods 1 to 20 must be at least 10.00 percent of Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20		
Burning with Burning for Young Forest on FTG 08 (BTh) in periods 1 to 20 must be at least 10.00 percent of Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20	LL 1-3, 13	
Acres Allocated to Prescribed Burn and Thin and Burn in MA 5a (BM9) in periods 1 to 1 must be at least 80.00 percent of Acres allocated to active management in MA 5a (AMj) in periods 1 to 1		
Burning with Burning for Young Forest on FTG 06 (BTf) in periods 1 to 20 must be at least 10.00 percent of Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20	LL 1-6	LL 6
Acres Allocated to Thin&Burn or Sanit. Thin on Admin Unsuit land (SM4) in periods 1 to 1 cannot be more than 10.00 percent of All acres Allocated to Thin and Burn or Sanitation Thinning (SM3) in periods 1 to 1	UL 1	UL 1
Acres BURNED by management on ForTypes 04,07 (BT7) in periods 1 to 10 must be at least 25.00 percent of Acres burned by management forest-wide (BG1) in periods 1 to 10	LL 1-3	LL 2-4
Acres BURNED by management acres on Forest Type 09 (BT4) in periods 1 to 10 must be at least 13.00 percent of Acres burned by management forest-wide (BG1) in periods 1 to 10		
Acres Allocated to Thin and Burn forestwide (BA1) in periods 1 to 1 must be at least 6.00 percent of Acres allocated to burning Rxs forestwide (BA5) in periods 1 to 1		LL 1
Acres Allocated to Burn1 (prescribed burning) (BA3) in periods 1 to 1 must be at least 60.00 percent of Acres Allocated to Burning for Young Forest forestwide (BA2) in periods 1 to 1		
Acres Alloc to Thin&Burn, Prescribed burn, Sanit.Thin in MA 5a (BMa) in periods 1 to 1 must be equal to Acres allocated to active management in MA 5a (AMj) in periods 1 to 1	LL & UL 1	LL&UL 1
Burning with Burning for Young Forest on FTG 05 (BTe) in periods 1 to 20 must be at least 10.00 percent of Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20	LL 1-5, 7	LL 2, 4-6, 8
Burning with Burning for Young Forest on FTG 04 (BTd) in periods 1 to 20 must be at least 10.00 percent of Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20	LL 1-5, 10	LL 6-8
Acres Allocated to Burning on Xeric types(01,03,04,06,07,08) (BTa) in periods 1 to 1 must be at least 50.00 percent of Acres allocated to burning Rxs forestwide (BA5) in periods 1 to 1		LL 1

Alternative E, Target/Constraint (Burning)	**Tier 1, Periods of Upper (UL) or Lower (LL) Limits**	**Tier 2, Periods of Upper (UL) or Lower (LL) Limits**
Burning with Burning for Young Forest on FTG 03 (BTc) in periods 1 to 20 must be at least 10.00 percent of Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20	LL 5, 6	LL 5
Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20 must be at least 7.00 percent of Acres burned by management forest-wide (BG1) in periods 1 to 20	LL 1-5, 9	
Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20 cannot be more than 10.00 percent of Acres burned by management forest-wide (BG1) in periods 1 to 20		UL 15
Acres Allocated to Burn for Young Forest in MAs 3,5b,4a-d,8 (BM8) in periods 1 to 1 must be at least 75.00 percent of Acres Allocated to Burning for Young Forest forestwide (BA2) in periods 1 to 1	LL 1	LL 1
Burning under Burn for Young Forest Creation (BMb) in periods 1 to 20 cannot be more than 15.00 percent of Acres burned by management forest-wide in periods 1-20		NA
Acres Burned by management of ForTypes 03, 06 (BT3) in periods 1 to 10 must be at least 15.00 percent of Acres burned by management forest-wide (BG1) in periods 1-10	LL 1-4, 7	NA