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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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Section 1: Overview of Ecological Analysis Tools and Process

This appendix is used to document the vegetation modeling methods that were used in the terrestrial ecosystem sections of the Environmental Impact Statement. This appendix summarizes extensive information that is available in the project record. *Section 1* describes the primary analysis tools and models that were used and provides a relative timeline of the overall terrestrial ecosystem analysis process.

Primary analysis tools and models

State-and-Transition Simulation (ST-Sim)

ST-Sim modeling software (Apex Resource Management Solutions) was used to develop seral classes for the Natural Range of Variation, which is further described in *Section 2* of this appendix. ST-Sim assigns probabilities to seral classes (states) transitions and stochastically simulates multiple iterations of disturbances. Separate biophysical models (BPS) were developed or revised for the forests' 11 ecozones and each was simulated for a 1000-year period (timesteps) with separate iterations. Additionally, ST-Sim was used to conduct a sensing of the seral states outputs that were derived from Spectrum (more below).

Forest Vegetation Simulator

The Forest Vegetation Simulator was used to grow the Forest Inventory Analysis (FIA) forest type groups to simulate growth, mortality, volumes, and the estimated amount of vegetative conditions on the Forest. (Keyser and Rodrigue, 2014). The 12 FIA forest types used in Spectrum were simulated for growth and mortality and yields over a 150-year period. Both natural growth runs and simulations of vegetation management treatments were modeled. See *Section 3* for more information on how FVS was incorporated into Spectrum.

Spectrum

To analyze the effects of EIS alternatives forest vegetation, Spectrum software was used. Spectrum is a linear programming model that estimates outcomes of applying active or passive management practices to forested stands. Spectrum is better able to model changes to forest structure compared to changes in composition. Spectrum's general process is to

1) stratify the land base by Region 8 forest types,
2) estimate structural changes of forest stands (growth and yield) for active or passive management,
3) identify objectives and constraints in the model based on plan direction, and
4) estimate outcomes for each alternative.

Detailed information about the components that make up the Spectrum model and the processes used to create those components can be found in *Section 3* of this paper.

In addition to estimating outcomes for each alternative, Spectrum was also used to calculate the timber calculations required by the National Forest Management Act. Documentation of how the model was used to calculate the Sustained Yield Limit can be found in *Section 4* of this paper.

Discussion of how the alternatives were developed in Spectrum is the focus of *Section 5*.

Some outcome measures of Spectrum were used as inputs in the Ecological Sustainability Evaluation tool (see just below).

In addition to modeling the EIS alternatives, several climate scenarios were developed in Spectrum using different natural disturbance patterns. These scenarios were used to estimate potential changes to management goals under different levels of natural disturbances. Early in plan development, natural disturbances were estimated for the natural range of variation (NRV) using State and Transition Simulation (ST-SIM) software and were used to develop the seral state ranges of ecozones for NRV. In the Final EIS, it was useful to compare results of Alternative E between Spectrum and ST-SIM. There are noted differences between the model formulations. For example, Spectrum used FIA forest types as an analysis unit whereas ST-SIM used ecozones. It was difficult to generate a clean crosswalk among these different analysis units. ST-SIM uses annual timesteps whereas Spectrum used 10-year decadal planning periods. ST-SIM has 11 models, one for each ecozone, that are modelled and run independent of each other but does not contain for current conditions estimates like Spectrum. Spectrum incorporates all analysis units and potential management actions in one model for each alternative that allows for interactions among the analysis units. Regardless of the differences, it is useful to find where the model results converge or differ for Alternative E. See *Section 6* of this paper for more information on how natural disturbance was incorporated into modeling.

Species analysis: Ecological Sustainability Evaluation

The Ecological Sustainability Evaluation (ESE) tool is a strategic conservation planning tool used by the US Forest Service Southern Region for forest planning. Ecological sustainability in this context is defined as the capability of ecosystems to maintain ecological integrity (36 CFR 219.19). This analysis tool is based on the structure of the *Open Standards for the Practice of Conservation* (CMP 2018) planning tool and utilizes a standardized process that is adaptable to forest specific priorities and needs. The ESE tool employs prioritization algorithms utilizing rank, importance rating, attributes and indicators, stressors and threats, scope and severity ratings, and management opportunities to assist and support management decisions. The tool includes a process record with documentation for assumptions made within the tool. The tool considers current conditions, which are understood based on information about today and the recent past, and also anticipates the future impacts of alternatives.

The general approach to evaluating ecological sustainability and species diversity is to

1) define ecological systems (ecozones and unique habitats), key characteristics, stressors and threats to these systems;
2) identify species for these ecological systems and link them to species groups;
3) link species groups to ecological systems ;
4) identify indicators and values to sustain all ecological systems and species groups;
5) estimate outcomes of the indicators for each alternative;
6) calculate ecological sustainability scores for each ecological systems and species group by alternative; and
7) check plan components for species specific needs.

Additional assumptions regarding the ESE tool analysis are documented in Appendix C of this EIS and in the project record. *Appendix C* provides a list of all the species in the tool, and the species groups, with their associated species. Additionally, it documents the indicators used to analyze each species group, and the values associated with those indicators, by alternative. Parts of this EIS analysis used data and summaries from outside the ESE framework to provide a more complete assessment.

Relative timeline for modeling development and use

A relative timeline describing the use of the above analytical tools is outlined below. This overall process is provided to demonstrate the relationship between different models used in the analysis, including how they build on each other.

Forest Plan Assessment Stage

This first phase of the planning process involved identifying the current condition and trend of forest resources.

- Field Sampled Vegetation (FSVeg): Conducted a current inventory of forest stands used to determine current condition
- Ecozones: Developed a model of ecological types by Simon (2011) compared with FSVeg
- Grouped ecological types into 11 ecozones
- Developed the preliminary list of Species of Conservation Concern

Post Assessment/Pre Draft EIS Stage

Following the assessment, additional data was prepared to inform plan component and alternative development.

- Natural Range of Variation (NRV) was assessed using best practices with Landfire specialists
    - Derived NRV from ST-Sim model for each ecozone
    - Identified a range of seral stages from NRV for each ecozone to inform desired conditions
- Spectrum selected as the analysis tool to meet National Forest Management Act requirements (Southern Region standard approach for forest planning)
    - Prepared growth and yield profiles to use in Spectrum from Forest Vegetation Simulator
        - Used Forest Inventory Analysis (FIA) plot data across Southern Appalachian mountain area
        - Aggregated FIA forest types into Forest type groups (FTG)
        - Developed growth and yield profiles
            - Natural, no-management (include mortality for gaps)
            - Develop silvicultural prescriptions
            - Calculate volumes and other outputs

- Ecological Sustainability Evaluation (ESE) tool selected as the analysis tool to aid in the evaluation of plant components to provide for the persistence of plants and animals Southern Region standard approach for forest planning)
    - Stratified of Ecozones and habitat types
    - Stratified of Species into Species Groups
    - Linked species groups to ecozone and habitat types

Draft EIS

Preparing data to use in the EIS analysis.

- Prepared Spectrum for modeling alternatives
  - Updated FSVeg (2017) following the 2016 fire season
  - Determined FTG amounts using FSVeg inventory
  - Recognized that the integration of ecozones with FSVeg would result in an infeasible model including 400,000-500,000 analysis units. This was beyond limits of software.
  - Integrated Geographic Areas into the model for spatial context
  - Developed preliminary set of analysis units

- Preparing the ESE tool for modeling alternatives
  - Develop indicators for effects by species group and habitat types
  - Develop preliminary scoring method

- Prepared a preliminary estimate of departure
  - Estimate departure from NRV by geographic area using Ecozone/FSVeg Crosswalk
  - Compared this to current forest conditions
  - Used to inform plan direction as well as to serve as a baseline for comparison with future modeling

Conducting the EIS analysis to demonstrate the effects of each alternative on forest resources.

- Brought in plan direction into the analysis tools
  - Integrated forest plan objectives, desired conditions, standards, guidelines, suitability, management approaches in the modeling assumptions
  - Integrated management areas into the analysis units for each alternative
- Completed Initial Spectrum model runs
  - Constrained the model for the plan objectives (same for all alternatives)
  - Ran the models to max young forest, but constrained below desired conditions levels
  - Summarized output streams, especially for underrepresented habitats (young, old and woodland forests)

- Continued of ESE development
  - Associated plan components with Species Groups and habitat linkages

  - Updated scoring techniques
  - Reviewed Spectrum outputs of young, old, woodland seral states for species groups dependent on these seral states and updated scoring for alternatives.
  - Conducted ESE calculations (see Appendix C)

Final EIS development

Changes were made between the draft and final EIS based on public comments. A new alternative, E, was added, that included a different management area configuration and new objectives, including more emphasis on prescribed fire.

- Updated the model in Spectrum
  - Changed objective function to maximize woodlands
  - Constrained woodland amounts and rollover to maximize young forest
  - Developed a prescription for episodic natural disturbance events that resets succession to young forest conditions.
  - Estimated woodlands created temporarily from wildfire.
  - Integrated management areas into analysis units for Alt E

- Completed Spectrum model runs for Alt E, Tier 1

- Developed different natural disturbance scenarios for Alt E, Tier 2 objectives in the context of climate change
  - Scenario 1. Research the recent past where data are available (50 years, primarily wildfire)
  - Used Scenario 1 as a base for comparison with other scenarios. Quantitative results in Chapter 3.
  - Developed Scenarios 2, 4, and 5. High levels of disturbances. Described effects qualitatively in EIS Ch. 3, with some selected indicators described quantitatively in Appendix D.
  - Conducted ESE calculations for Alternative E (see Appendix C)

Section 2: Developing the Natural Range of Variation

The Natural Range of Variation (NRV) describes the variation in physical and biological conditions exhibited by ecosystems as a consequence of climatic fluctuations and disturbance regimes. An NRV 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 pre-settlement 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.

Procedure for estimating Natural Range of Variation

The following information is a summary of the procedure for estimating the natural range of variation. Details are available in the process record (Process Record, Procedure for Estimating the Natural Range of Variation, Nantahala and Pisgah NFs, January 2015, Kauffman, G. and Blankenship, K.

Define the Analysis Area

The analysis area includes the 18-county area of western North Carolina which is large enough to be statistically significant based on the accuracy of the data for the disturbance frequencies.

Determine the Ecological Types (called Ecozones) and Landfire Biophysical Settings

Ecological Zones are defined as units of land that can support a specific plant community or plant community group based upon environmental factors such as temperature, moisture, fertility, and solar radiation that control vegetation distribution (Simon 2011). Based on the ecological modeling for these types (Simon 2011) a focus group of botanists and silviculturists from the mountain ranger districts, the southern research station, and state land management agencies met and merged types with similar plant diversity, such as acidic cove and oak-rhododendron types, and/or overstory, such as northern hardwood cove or northern hardwood slope. Eleven ecozones were used for the analysis (Table 1).

LANDFIRE (landfire.org) is a nationally created database that describes the vegetation dynamics, including structure and disturbance regimes for more than 1,000 ecosystems) in the United States (Rollins 2009, called Biophysical Setting (BpS). Biophysical Settings descriptions provide information about vegetation that may have been dominant on the landscape prior to Euro-American settlement. Landfire specialists used the current biophysical environment and an approximation of the historical disturbance regime to estimate the vegetation dynamic. Map units are defined by NatureServe (NatureServe.org) Ecological Systems, a nationally consistent set of mid- scale ecological units. BpSs are intended to be dynamic and can be updated with more accurate information, such as disturbance regime frequencies. Potentially new ones can be created for regional variation. In December of 2014 we examined the existing BpS models correlating them with the 11 ecozones to the extent possible. Two ecozones, acidic and rich cove, although quite different in species composition, are similar in disturbance regimes and topographic setting. As a result, they were correlated as a single unit.

Table 1. Eleven ecological zones (ecozones) and associated Landfire Biophysical Settings (Bps)

Ecozone	Acres (%) of N/P	BpS Landfire	BpS Number
Spruce Fir	16,604 (3%)	Central and Southern Appalachian Spruce-Fir Forest	5713150
N. Hardwood	53,924 (5%)	Southern Appalachian Northern Hardwood Forest	5713090
High Elev Red Oak	38,637 (4%)	Central and Southern Appalachian Montane Oak Forest	5713200
Acidic Cove	240,938 (23%)	Southern and Central Appalachian Cove Forest	5713180
Rich Cove	189,143 (18%)	Southern and Central Appalachian Cove Forest	5713180
Mesic Oak	186,131 (18%)	Montane Red Oak - Chestnut Oak	new provisional (Simon & Croy)

Dry-Mesic Oak	105,991 (10%)	Southern Appalachian Oak Forest	5713150
Dry Oak	59,667 (6%)	Allegheny-Cumberland Dry Oak Forest and Woodland`	5713170
Pine-Oak Heath	101,275 (10%)	Southern Appalachian Montane Pine Forest and Woodland	5713520
Shortleaf Pine	44,451 (4%)	Southern Appalachian Low-Elevation Pine Forest	5713530
Alluvial Floodplan	2,640 (0.3%)	Central Interior and Appalachian Floodplain Systems	5714710

Review NRV estimates from adjacent forests

Natural range of variation represents the percent of different succession (s) classes that is found under natural ecological processes with natural disturbance regimes. S-Classes represent differences in age and structure whether it is an open or closed canopy condition. An open structure was assumed to have 40-80% canopy cover, which allows for greater grass and herb diversity, particularly in fire adapted ecozones. It is assumed the drier fire-adapted types, pine-oak/heath, shortleaf-pine, and dry oak, have a lower average woodland canopy, ranging from 40-60%, than dry-mesic oak, which would range from 50-70%, and mesic oak and high elevation red oak, with a range from 60-80%.

BpS models typically develop a 5 class system of successional stages: young (early seral) forest, mid-age open forest, mid-age closed forest, old-age open forest, and old-age closed forest. BpS model variations on the number of s-classes variations have been developed, included the southern Appalachians.

There were three local variations for NRV from other southern Appalachian forests. These included a review of a subset of the southern Appalachian models in Asheville by regional experts in 2012, a variation developed for the north zone of the Cherokee NF, and a local variation developed for the Warwoman watershed on the Chattahoochee NF. Both the later variations included an old growth class that developed seven s-Classes versus five s-Classes. The old growth s-class was used for western North Carolina based on the best examples of the three modeling efforts.

Based on the inconsistencies within the old growth percents in addition to other s-classes across the three modeling efforts, a range rather than a fixed percent was determined to be desirable for the modeled s Class outputs (Table 2)

Table 2. Variation between s-Classes between BpS models across the Southern Appalachians.

Types	Mesic Oak				Dry Mesic Oak				Dry Oak		
S-Classes	**Chatt**	**Cher**	**Sapp**		**Chatt**	**Cher**	**Sapp**		**Chatt**	**Cher**	**Sapp**
Early	5	7	5		7	7	6		7	10	6
Mid -Closed	8	26	6		6	15	10		4	15	4
Mid-Open	7	20	7		13	25	10		13	31	13
Late- Open	6	12	6		14	23	14		18	15	18
Late-Closed	5	18	5		5	13	5		3	8	3
Late2- Open	38	2	39		42	11	49		57	7	57
Late2- Closed	31	14	31		12	6	6		1	14	1
Total Closed	**44**	**58**	**42**		**23**	**34**	**21**		**8**	**37**	**8**

Total Open/Early	56	41	57		76	66	79		95	63	94

Chatt = Warwoman watershed on Chattahoochee NF, Cher = North Zone Cherokee NF, Sapp = Southern Appalachian subset. Numbers represent percent of individual ecozone.

Estimate the age classed for the ecozones

Age classes were determined for each BpS model (Table 3). The early class was determined by silvicultural conditions, such as the growth rate of the major dominate tree species, the density of tree species resulting in canopy closure, and the change in shrub, grass and herbaceous species dominance. Mid ages were assumed to be longer in more mesic systems (cove and floodplain forests) and less within xeric ecozones (dry oak and pine-oak/heath). For the majority of the maximum ages for the late age class and the beginning of the old growth class were based on the region 8 guidelines for old growth (1997). An exception is for dry-mesic oak forest, pine-oak heath forest, northern hardwood forest and floodplain forest. For each of those types the minimum old growth age was increased to 130 years for the first three and 140 years for the later (Table 3).

Table 3: Age classes for the ecozones

	Age Class (years)			
Ecozone	Early	Mid	Late	Old Growth
Spruce Fir	0-35	36-70	71-120	120+
High Elev Red Oak	0-20	21-70	71-130	130+
Northern Hardwood	0-15	16-75	76-130	130+
Acidic & Rich Cove	0-10	11-100	101-140	140+
Mesic Oak	0-10	11-80	81-130	130+
Dry-Mesic Oak	0-15	16-75	76-130	130+
Dry Oak	0-20	21-70	71-100	100+
Pine-Oak Heath	0-20	21-70	71-130	130+
Low Elevation Pine	0-15	16-70	71-130	130+
Floodplain	0-10	11-100	101-140	140+

Estimate the Disturbance Regime for Ecozones

Disturbance regimes (type and frequency) for each separate BpS models were estimated. There is uncertainty on frequencies for many disturbance types given the lack of historical data. A scale of intensity and frequency of any disturbance was used by comparing all 11 ecozones relative to each other. For instance, it was assumed the frequency and intensity of wind and weather events was greater on an exposed landscape, where dry oak or pine-oak heath ecozones are present, in comparison to more protected concave landscape features, typically where rich cove, acidic cove or northern hardwood ecozones occur. Initially disturbance events were run separately, such as ice storms from wind events, but after running a series of models, it did not make any appreciable difference in the outcomes. Based on Kori Blankenship's, Landfire TNC modeler, previous experience with other landscape NRV modeling, several disturbance types were combined. Table 4 shows the disturbance types and frequencies.

Table 4: Disturbance types and frequencies for Ecozones

Disturbances	POH	SLP	Dry Oak	Dry-Mesic Oak	Mesic Oak	HERO	SF	NHwd	Cove	Flood
Min Surface Fire	3	2	5	14	18	11		100	50	50
Max Surface Fire	15	12	20	20	25	20		500	250	350
Average Surface Fire	5	5	10	15	20	15		333	100	200
Min Mixed Fire	20	20	25	80	80	50	600	500	400	400
Max Mixed Fire	100	100	100	250	250	100	2000	1000	1000	1000
Average Mixed Fire	50	50	60	100	100	70	1000	602	500	500
Min Replacement Fire	30	30	25	200	100	100	600	500	500	200
Max Replacement Fire	300	500	500	500	500	500	2000	1000	1500	1000
Average Replacement Fire	150	200	250	300	350	350	1000	602	1000	612
Min Wind/Weather	100	100	70	150	150	40	100	120	200	120
Max Wind/Weather	300	333	333	400	400	300	333	500	500	250
Average Wind/Weather	150	150	100	200	250	100	150	200	300	150
Min Extreme Wind/Ice	100					80		100	100	
Max Extreme Wind/Ice	300					400		500	700	
Average Extreme Wind/Ice	250					250		333	500	
Min Insect/Disease	60	70	70	100	100	70	50	80	100	100
Max Insect/Disease	200	200	200	400	400	300	333	350	400	400
Average Insect/Disease	100	125	125	200	250	125	100	200	250	250
Min Flooding										50
Max Flooding										400
Average Flooding										120

Develop a model for each ecozone in ST-Sim and interpret results

To develop s-Class average means, we used state-and-transition modeling ST-Sim software (Apex Resource Management Solutions), which assigns probabilities to the transitions and stochastically simulates multiple iterations of disturbances. Each BpS model was simulated for a 1000-year period (timesteps) with separate iterations. In order to determine how many iterations would be sufficient before normalization we ran half the models for 300 iterations. However, when there was a negligible difference with the results it was assumed 100 iterations would suffice to derive s-Class separations. For nine models we derived seven s-Classes based on age and open or closed criteria. For cove forest, representing both acidic cove and rich cove ecozones, we only derived a closed old growth s-Class, assuming that these are the most protected ecozones in the landscape and would not have an open condition.

Ranges for each s-Class was derived using a beta distribution that has minimum and maximums. By using a standard deviation of the beta distribution for each disturbance type it is possible to approximate a bell-shaped curve. The bell-shaped curve was visually optimized examining changes in the frequency distribution shape while maintaining the widest possible frequency vales, from which minimum and maximum multipliers were derived. These multipliers were used to provide a range for individual s-Classes for each ecozone.

Conclusion: Estimate Ranges of S-Classes for ecozones

Table 5 shows the ranges of the S-classes for each ecozone. These ranges provided input when deliberating the desired conditions for the forest plan, as to the distribution of composition and structure across the forests. (Note however, these S-class ranges for ecozones were not the only input used for developing desired conditions.)

Table 5. Modeled S-Class ranges (NRV) for Ecozones

	Spruce Fir	Northern Hardwood	High Elevation Red Oak	Acidic Cove	Rich Cove	Mesic Oak	Dry-Mesic Oak	Dry Oak	Pine-Oak Heath	Low Elevation Pine	Floodplain
Young	14-17%	5-7%	14-18%	4-5%	4-5%	4-6%	5-7%	9-22%	11-19%	8-13%	6-8%
Mid-closed	10-11%	17-23%	16-21%	27-32%	27-32%	12-15%	7-9%	2-7%	1-5%	1-4%	30-36%
Mid-open	2-4%	2-3%	11-14%	4-6%	4-6%	12-16%	13-17%	12-19%	34-42%	34-42%	9-14%
Late-closed	9-11%	11-14%	11-13%	9-11%	9-11%	8-10%	7-8%	1-3%	1-5%	1-4%	8-9%
Late-open	5-8%	2-3%	11-13%	1-2%	1-2%	5-7%	7-9%	6-9%	20-27%	22-26%	3-4%
Old growth closed	36-45%	40-50%	6-10%	46-54%	46-54%	27-34%	22-28%	5-16%	1-3%	1-4%	22-30%
Old growth-open	12-16%	11-14%	18-26%	NA	NA	20-25%	28-33%	40-57%	11-26%	16-29%	9-13%

Section 3: Spectrum 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 a 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

A dataset utilizing these attributes was developed for each of the alternatives (tier 1 and tier 2) analyzed during the Nantahala and Pisgah Forest Plan Revision (Alts A – E). 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 6a). 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 and FIA forest types. 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 needed to be cross walked to ecozones for the analysis in the EIS.

Table 6a. 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

Name	Description
12NoHw	12 - Northern hardwood
Other	Other FT, Shrub, or Non-forest
99	99 - Brush

Table 6b. Forest Type and Forest Type Group Cross Walk

Forest Type - FSVeg Code	SPECTRUM FTG Code
6, 7, 10, 17	02SF
70, 81	12NoHw
55	09Ioak
4, 5, 8, 9, 41, 50, 56, 83	10CvHw
9, 41, 50, 56, 82, 83	10CvHw
10, 42, 48, 53, 54	10CvHw
3, 42, 48, 52, 53, 54	09Ioak
42, 51, 52, 54, 57, 59, 60	08Doak
15, 16, 20, 25, 33, 38, 49	04PP, 07PVH
3, 12, 13, 14, 16, 21, 25, 31, 32, 33, 44, 49	03SLP, 06SlpH
72, 82	11MxHw
3, 4, 9, 10,41,42	01WP, 05WpHw

Crosswalk from Spectrum Forest Type Groups to Ecozones

Spectrum forest type groups differ from ecozones, which were used for ESE tool analysis. Mapping sizes between the Spectrum types and ecozones differ. The Spectrum groups are primarily from FSVeg and Forest Inventory Analysis (FIA) forest types. Ecozones tend to be smaller, having been modeled by environmental factors such as topographic positions and underlying geology. They are modeled for the potential vegetation. In contrast, FIA and FSVeg is delineated in the field, looking at existing vegetation based on dominant trees, and could be heavily influenced by prior land use history. Ecozones often are also differentiated with shrub and herb dominants. For instance, cove forest can have similar tree dominates. However, they can differ dramatically with evergreen shrub dominance and herbaceous diversity. Acidic cove and rich cove forests are recognized as separate ecozones while they are not separated as individual forest types.

Given these differences, there is no one to one fit for the majority of the Spectrum forest type groups and the ecozones. A crosswalk was developed between the two types to derive ecozone outputs for use in the EIS analysis including the Ecological Sustainability Evaluation (ESE) tool. The crosswalk paired similar ecological types while maintaining approximate total acreages for the individual ecozones. Tables 7 and 8 list the percentages used for the FIA forest group outputs and the derived output acreage to approximate the ecozone outputs.

Table 7. Crosswalk of percentages comparing the FIA Forest Groups and the Eleven Ecozones.

	Ecozone Percents											
	Spruce Fir	Northern Hardwood	High Elevation Red Oak	Mesic Oak	Dry-mesic Oak	Dry Oak	Pine-Oak Heath	Acidic Cove	Rich Cove	Shortleaf Pine	Floodplain	Total
Spectrum Forest Types												
01 White Pine					0.25	0.25	0.25			0.25		1
02 Spruce-Fir	1											1
03 Shortleaf Pine										1		1
04 Pitch Pine							1					1
05 White Pine Hardwood					0.29			0.71				1
06 Shortleaf Pine Hardwood										1		1
07 Pitch Pine Hardwood					0.2	0.1	0.7					1
08 Dry Oak					0.4	0.3	0.2			0.1		1
09 Intermediate Oak			0.12	0.54	0.01			0.1	0.23			1
10 Cove Hardwood								0.49	0.5		0.01	1
11 Mixed Hardwood								1				1
12 Northern Hardwood		1										1

Table 8. Crosswalk of acreages derived from the FIA Forest Groups for the Eleven Ecozones.

	Ecozone Acres											
		Spruce Fir	Northern Hardwood	High Elevation Red Oak	Mesic Oak	Dry-mesic Oak	Dry Oak	Pine-Oak Heath	Acidic Cove	Rich Cove	Shortleaf Pine	Floodpl
Spectrum Forest Types	**Spectrum Acres**											
01 White Pine	40607					10152	10152	10152			10152	
02 Spruce-Fir	17265	17265										
03 Shortleaf Pine	13345										13345	
04 Pitch Pine	17298							17298				
05 White Pine Hardwood	102577					29747			72830			
06 Shortleaf Pine Hardwood	13124										13124	
07 Pitch Pine Hardwood	84321					16864	8432	59025				
08 Dry Oak	104927					41971	31478	20985			10493	
09 Intermediate Oak	320938			38513	173307	3209			32094	73816		
10 Cove Hardwood	248010								121525	124005		2480
11 Mixed Hardwood	910								910			
12 Northern Hardwood	57190		**57190**									

Table 9 compares the modeled ecozone acreage for the Nantahala and Pisgah NFs with the acreage derived from the crosswalk with the FIA forest groups used in the Spectrum analysis. All of the acreages vary between the two models. They vary from less than 1% difference with rich cove to more than 11% for spruce-fir. The majority of the ecozones vary by less than 4%.

Table 9. Comparison of acreages derived for the eleven ecozones from the Spectrum outputs and from the original modeled ecozones.

Derived Type	Spruce Fir	Northern Hardwood	High Elevation Red Oak	Mesic Oak	Dry-mesic Oak	Dry Oak	Pine-Oak Heath	Acidic Cove	Rich Cove	Shortleaf Pine	Floodplain
Ecozone Model	15529	53564	40188	177270	103187	49260	103844	249252	199477	46479	2342
Spectrum Crosswalk Totals	17265	57190	38513	173307	101943	50062	107460	227358	197821	47113	2480

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 10). 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 10. 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 11 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
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 12. For action Alternatives B, C, D and E, a new management area classification was developed, shown in Table 13. See the discussion of the alternatives for details on management areas.

Table 12. 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

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

Table 13. Management Areas, Action Alternatives B, C, and D, and E

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

Management Area Number	Management Emphasis
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. See EIS Appendix B for the step by step documentation associated with the timber suitability process.

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 14 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 14 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. Many of the prescriptions listed contain multiple intermediate treatments that compromise an overall silvicultural system. For example, the shelterwood with conversion 5 period management action within the 03SLP Forest Type Group contains a modeled tending treatment early in the stand's development, prescribed burning throughout, a commercial thinning, an understory/midstory treatment to develop advanced regeneration, a shelterwood establishment harvest, and removal harvest roughly 20 to 30 years later.

Table 14. 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.
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.

Management Action	Description
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 Section 6, 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, D, and E, the same rules were used to construct management action options for analysis units. Assignment of management action options varied primarily by management area. Silvicultural (including 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 15a shows the activities, outputs and states that are tracked in the model.

Table 15a. Activities

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

Table 15b. States

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.

Table 15c. Outputs

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 16). 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 16. 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+

Forest Type Group	Successional Class			
	Young	Mid	Late	Old
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 Section 5. 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, D,and E 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.

Section 4: 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. Spectrum was used to estimate SYL.

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 17.

Table 17. 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.

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 18.

Table 18. 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

[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.

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 19) closely aligning with the number of potentially suitable acres identified during Step 1 of the timber suitability analysis.

Table 19. Annual Sustained Yield

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

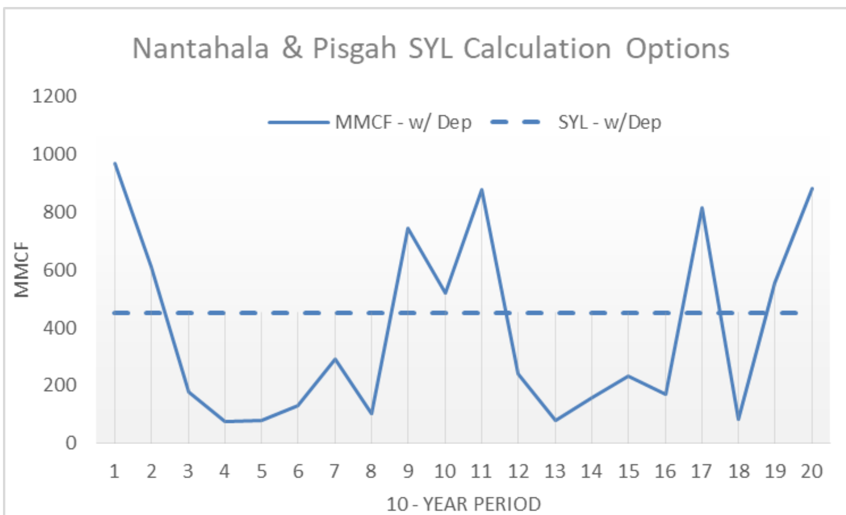

Figure 3. Nantahala and Pisgah Sustained Yield Limit Calculation

Section 5: Development of Alternatives in Spectrum

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 20. 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 14 treatments– standard basal area retention (BAR)
2a	Scenery, Mature Forest, Roaded access	Suited – TP	All T14 Trts - high BAR
2c	Scenery, Mature Forest, Roaded access	Unsuited – TP	All T14 Trts - high BAR
3b	Timber Production, Regulated, Non-motor Rec	Suited – TP	All T14 Trts - st. BAR
4a	Scenery, Mature Forest, Non-motor Rec	Suited – TP	All T14 Trts - high BAR
4c	Scenery, Mature Forest, Non-motor Rec	Unsuited – TP	Just Burning
4d	Mature Forest, Scenery, Non-motor Rec	Suited – TP	All T14 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 21a - f).

Table 21a. 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 21b. 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 21c. 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 21d. 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
Unicoi Mtns	1,688	3
Bald Mtns	1,608	2
Highland Domes	741	1
North Slope	56	0
Total	65,663	100

Table 21e. 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

MA	Acres	%
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 21f. 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 21g 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 21g. 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 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

Target/Constraint (Management Area Controls)	Periods of upper (UL) or lower (LL) limits
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, and E

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 22a. 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 22b. The management area assumptions represented in Tables 22a & b represent the primary inputs to the Spectrum models used for Alternatives B, C, D and E. 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 22a. Alternative B, C, D and E 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
	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 22b. Alternative B, C, D and E 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, D and E. 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 23 shows the full list of Spectrum constraints used to create Tier 1 for Alternatives B, C, and D. The Tier 1 constraints for Alternative E are listed below. 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 23. 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

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 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 in periods 1 to 20	LL 1-4, 11,17	LL 1-6,8-15,17-19	LL 1-20
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			

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 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 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 24. 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 27. 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 25 shows adjustments made to some model Activities/Conditions in order to represent disturbance.

Table 25. 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 26: 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. This methodology is consistent with the definition of group selection as an uneven-aged regeneration method where the intent is to produce young forest within multiple locations within a stand. This allows groups of different age classes to develop over time. When three or more distinct age classes exist, the stand is termed an uneven-aged stand.

Within the Spectrum model Alternative E, when an analysis unit was assigned to the group selection prescription for a period, it was modeled that enough group openings would be created that when combined they would total 1/3 of the analysis unit. Over the full Alternative E model run that analysis unit would be revisited by the group selection regeneration prescription (approximately every 2 periods) adding more groups to again cover another 1/3 of the analysis unit's acres.

With the intent of the group selection harvest to create groups of young forest conditions within the analysis unit, it was desired to account for those conditions when they existed using the following output calculation in Spectrum.

Young Management = RegenAcres + 0.33*OtherHarvAcres

Within Alternative E, Spectrum allocated roughly 20,000 analysis unit acres to the group selection prescription. This accounted for an average of 2,445 acres of young forest conditions being modeled per period contributing to the young management output and being tracked for Objective ECO-O-02.

From a broader perspective, the prescriptions built into FVS[2] in 2014 represented the range of options available to use during subsequent Spectrum model runs (2018 –2021). Ensuring uneven-aged management was represented across the Nantahala and Pisgah landscape was important to address public comments, allow for (where appropriate) closer alignment of disturbance patterns in some community types, restoration of communities, creation of young forest and serving as a place holder for other contemporary silvicultural systems that depict other uneven-aged conditions as discussed in the Timber Section: Common to all Action Alternatives.

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 27. Tier 1 and Tier 2 constraints and targets for Alternative E

[2] The Forest Vegetation Simulator was used to grow the Forest Inventory Analysis (FIA) forest type groups to simulate growth, mortality, volumes, and the estimated amount of vegetative conditions on the Forest. (Keyser and Rodrigue, 2014). The 12 FIA forest types used in Spectrum were simulated for growth and mortality and yields over a 150-year period. Both natural growth runs and simulations of vegetation management treatments were modeled.

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) 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

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 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	
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		

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 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

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
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
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

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 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

Section 6: Natural Disturbances

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 closed canopy forest. Larger canopy openings can create young forest 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.

Two scales of natural disturbances were considered in Spectrum: within stand boundaries of natural growth and mortality from physical and biological processes, and episodic disturbances from weather, fire, or insect/disease outbreaks. Each is scale described in more detail below.

Disturbances of Natural Stand Dynamic Processes in Spectrum

Natural disturbances at small scales are considered in Spectrum by including tree growth, vigor, and mortality in the Forest Vegetation Simulator (FVS) growth and yield profiles. FIA plot data were assigned to one of twelve forest type groups and modeled using FVS for 150 years. The yields were then aggregated by plot age, creating the 12 natural growth and yield profiles.

FVS simulations modeled stand development of each plot utilizing locally-modified growth, mortality, and regeneration routines to produce outputs for every growth cycle across the modeling timeframe (Keyser and Rodrigue, 2014). While modeling stand development on each plot involves complex interactions among trees, the mortality patterns commonly found in natural stands were simulated utilizing three mortality processes in FVS: background mortality, density-related mortality, and tree senescence.

Background mortality represented individual tree mortality that occurs in young, low-moderately dense stands. Growth during this development phase offset the small amount of mortality being estimated. Density-related mortality represented tree mortality of trees being outcompeted for resources in moderate – highly dense stands. This mortality was most often focused on intermediate and suppressed trees as stand differentiation occurred. Finally, tree senescence was included by increasing the rate of mortality on canopy-level trees that grew beyond their upper size limits found in the FIA data and literature. For instance, scarlet oak mortality increased ~14%, once a tree was over 22.0 inches DBH, while a longer-lived species, white oak, increased mortality only 3% past that size range. Adjustments to these simulated types of mortality are described in the FVS Modeling Techniques paper (cited above).

The natural growth profiles produced from these FVS simulations are used in Spectrum when “minlevel” (no human management) applies. There are more than 100 variables computed in the natural growth runs, some of which were included in the Spectrum analysis (See Process Record, FVS Modeling Techniques, Section 8).

Conclusion: The effect of including the three types of tree mortality included in the underlying FVS yield profiles result in myriad conditions where some openings from tree death are small and quickly closed by expansion of the surrounding trees, usually occurring in younger stands as simulated by background and density-related mortality, while other openings from larger trees may take some time to close, usually occurring in older stands where simulated tree senescence creates larger gaps that take longer to close.

On a landscape scale, these simulated openings are small, representing gaps usually less than ¼ acre in size. These simulated openings have been verified using the 2005 and the 2017 LiDAR analyses that found more than 80 percent of openings are small in size. By using the natural growth and yield profiles from FVS in Spectrum, it is reasonable to assume that the model accounts for a majority of these smaller canopy openings. For analyses purposes, these small canopy openings are called “gaps,” and due to their relatively small size while being embedded within the closed canopy structure of the larger stand area, these gaps do not change the age structure of an analysis unit in Spectrum.

Accounting for Disturbances from Episodic Events

To account for episodic events that create canopy openings larger than gaps, a new prescription between the Draft and Final EIS was developed called Natural Disturbance Young patch. A patch is an area of homogeneous vegetative conditions, while gaps are inclusions within the dominant structure of forest vegetation. A young forest “patch” would be of a size sufficient enough to re-classify the age of vegetation to zero. In order to estimate acreages of a change in age class from older to young forest to use in Spectrum, this required an area estimate of a patch size.

NRV approach vs Spectrum approach to episodic natural disturbances

Different approaches were used to frame episodic natural disturbances in ST-Sim vs Spectrum. NRV uses a simulation algorithm (ST-Sim) to derive broad succession classes by ecological type. To do this, western NC was reviewed for the ecozones that occur. Return intervals were estimated for the more severe disturbances that would cause stand replacement within the Western NC spatial context. Acreages of ecozones were the same, meaning that the start of the simulations had all the same acres for each ecozone. This allowed for the s-classes to be separated over time by ecozone based on the return intervals of disturbances. So, the spatial context is limited for the derived NRV. However an initial “sensing” of the Spectrum outputs was completed with ST-Sim where current s-classes were used for the initial starting analysis. This is further described on page 39. As well as in the process record, Sensing Project: Seral States using ST Sim (January 2022).

There is greater spatial context in Spectrum compared with NRV analysis. Spectrum uses an optimization algorithm that makes it a deterministic model approach rather than a stochastic simulation approach. As such, spatial units (FSVEG stands) are aggregated into a series of analysis units that includes forest type, age, and other values, including the unit's geographic area. Actual inventories (FIA plots; FSVEG stand level data) were used in Spectrum. With more specificity of inputs into Spectrum, it seemed reasonable to explore a spatial context for episodic natural disturbances. To do so, reliable, on-the-ground data was needed, or, in absence of data then the best scientific research applicable to the NP forests has been used.

Defining young forest

An investigation of the definition of young forest was conducted between Draft and Final EIS in order to quantify the amounts of episodic natural disturbances that contribute to young forests for use in the Spectrum model. A natural disturbance prescription for episodic natural disturbances was modeled in Spectrum and it required acreage amounts in 10-year timesteps.

During the assessment phase of the planning process, the ecological ID team reviewed the BpS settings descriptions and models. It was assumed that BpS settings were developed for "forests." The term in the descriptions was "Early." That term among forest managers is usually interpreted as early successional habitat, which is a concept more broad than young forests. The term "early" was changed to "young forests" during the assessment to help clarify the intent of how that s-class applies to forests, which does not include grass openings. For example, a large county park with mostly grass and few scattered trees could be considered early successional habitat, but would not be classified as a "forest." Young forests, however, are considered early successional habitat. One difference is the tree component necessary for young forests. Some excerpts from the literature follow.

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 a 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 patch 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 a 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.

For purposes of analysis, 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 allowing 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) to determine current conditions and expected conditions with implementation of plan components. 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.

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 (Light Detection and Ranging), 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 to 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.

Procedure. The 2017 LiDAR data was processed to determine canopy density and heights by the Geometronic Service Center of the USDA Forest Service. The canopy density was separated into two classes, 0-25% , and greater than 25%. Greater than 25% was considered closed canopy and not a canopy opening or gap. Canopy height is classed as 0-15 feet and greater than 15 feet. Canopy heights greater than 15 feet were considered closed canopies., not providing enough light to the forest floor to be considered a gap. Acreages of openings were calculated for NP ownership lands. There are seven classes as follows: 0-0.25 acres = small Gap; 0.25-0.50 acres = Gap; 0.5-2.0 acres = small Patch; 2-5 acres = medium patch; 5-10 acres =large Patch; 10-20 acres = extra large patch; and greater than 20 acres = extra,extra large Patch.

The canopy openings were reviewed and further classified into 3 categories: 1) Human caused 2) natural feature of the landscape and 3) natural disturbance. The following features were used to classify the origin of the canopy openings.

- Human Caused: Agricultural old fields, constructed feature, harvest unit, open pit mine, vehicle parking area, powerline, prescribed burn area, railway, recreational facility, roadway, shoreline.
- Natural Features of the Landscape: Grassy Balds, bogs, glades, rock outcrops, water.
- Natural Disturbances: Blowdowns, deadfalls, disease, tornado, wildfire, unknown.

Approximately 189,570 canopy openings were found that totaled about 9,300 acres. The total amount of young forest patches 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 openings 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 28 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 28 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 the Southern Appalachians. 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 (above) for Linville Gorge 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. With this change 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 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.

Table 29. Proportional distribution of High Severity Wildfire among Forest Type Groups

Ac	40607	13345	17298	13124	84321	104927	102577	320938	910	17265	57190	248010
FT	01WP	03SLP	04PP	06SlpH	07PvH	08D0	05WpHw	09Ioak	11MixHwD	02SF	12NHwD	10CHwD
Proportion	0.123	0.17	0.25	0.17	0.25	0.123	0.05	0.05	0.05	0	0.019	0.014

The amount of high severity wildfire acreages would affect xeric forest type groups much greater than mesic types. Table 29 shows the assumed proportional amounts of how high severity wildfire would be distributed among forest type groups. Highlighted colors denote the moisture classes: Yellow=Xeric, Green=Moderate, Blue= mesic. Xeric moisture classes are more likely to have high severity fires (12 to 25%) among those types compared with mesic moisture classes with less than 2%.

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 Spectrum 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 Spectrum 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 shows the amount of young forest patch estimated per decade using the episodic, historic disturbance regime over the past 50 years. This is the amount of land that would be impacted by high severity 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. The amount of young patch are not intended to be annually scheduled to be used in Spectrum, but instead, a decadal amount that could have occurred in one or more events. Dramatic increases occur in the periods 4 & 5 due mostly to dramatic increases in the 2007 and 2016 fire seasons. If the estimates of young forest patch using 2017 Lidar are representative, then the historic estimates of natural disturbances are higher than current. For example, the amount of young patch creation would range from 1654 ac to 3923 acres over a 50-year period, which is 27 to 200 percent higher than shown using Lidar. This includes only the amount of canopy openings ½ acre or greater in size due to larger scale, episodic disturbances. Gaps are accounted for in the growth and yield profiles.

Table 30: Acreage of young forest patch estimated over 5 decades.

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

Analysis of Alternative E – Tier 2 Scenarios

This section provides a package of information about Alternative E-Tier 2 that responds to comments on the Draft EIS. The purpose is to inform the decision maker the assumptions and uncertainties inherent in the analyses of Alternative E-Tier 2, especially the uncertainties with a changing climate. In order to address uncertainties, several scenarios were developed to explore future possibilities. The focus of the investigation was to respond to comments about how the amount of natural disturbances would account for young forests. Specifically, how Tier 2 objectives would be affected by increases of natural disturbances. For clarification, the Spectrum model was not used to determine objectives, but instead, the plan objectives were determined through collaborative discussions with stakeholders. The primary use of the model formulation in Spectrum has been to determine the PTSQ and WTSQ in the plan in order to conform with NFMA and the 2012 planning regulations.

To conduct the investigation of possible effects of climate change on Tier 2 objectives, several scenarios were considered for potential future disturbances. The intent is to provide a package of information to highlight uncertainties, and to identify potential alerts while monitoring natural disturbances. 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 were considered highly unlikely in the future by some stakeholders. However, this scenario would not have provided new information, and therefore, was not investigated further. 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, objectives, the amount of natural disturbances, and older forests. 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 disturbance rates of NRV and the expected harvest outputs in Alternative E. Refer to the process record, Sensing Project: Seral States using ST Sim (January 2022).

Table 31 displays output streams from the model over the 200 -year period. It shows the amounts of even-aged regeneration (Regen Even), uneven-aged regeneration (GS), total amount of silvicultural regeneration (Total Regen), the acreages of high severity natural disturbance (Natural), and the amounts of young forest (Total young forest). The scenarios are labeled S1, S2, S4, S5. General and specific observations as follow.

General Observations.

1). For total regeneration, the model was constrained to about 30,000 acres (instead of 32,000 acres for plan objectives) per 10-year planning period. It was assumed that some amount (about 2,000-3,000 acres per decade) of prescribed fire would be used to create young forest conditions.

2). The total amount of young forest is slightly higher than 90,000 acres in order to allow for feasible solutions. The model has thousands of calculations and some amount of slack was allowed for solution space.

3). The amount of natural disturbances fluctuates over time, but generally rises over the planning horizon. This is partially due to the differences in the timing of 10-year planning periods (Spectrum) vs. young forest creation where some forest types have longer timeframes than 10 years as young forest. Another reason for fluctuation is to allow for variation of natural disturbances to occur over time.

4) The acreages of high severity natural disturbances are a small portion of the lands affected by episodic disturbances. These acreages provide an estimate of amount of a patch of at least ½ acre with disturbance severe enough that becomes young forest. The amount of natural disturbed land would be higher. For example, it is assumed that total wildfire disturbance is 3 times higher than young patch creation by wildfire.

5) The critical timing of this decision is this planning cycle, which is about 10-20 years. Future planning cycles would consider new information and develop new desired conditions based on the conditions then. The purpose of looking forward beyond 10-20 years is to estimate potential future tradeoffs from the decisions made in this planning cycle.

Table 31. Selected output amounts using Spectrum for Scenarios 1,2,4 and 5

	Year																			
	0-10		21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-150	151-160	161-170	171-180	181-190	191-200
Disturbance Type																				
S1-Regen (Even)	29000	27301	26616	26381	26092	25746	25357	25750	25826	27701	27298	26816	26671	26826	26665	26816	26662	26818	27667	27991
S1-GS	996	1174	1380	1624	1910	2248	2644	2248	2644	2297	2701	3179	3330	3179	3330	3179	3330	3179	2334	2005
S1-Total regen	29996	28475	27996	28005	28002	27994	28001	27998	28470	29998	29999	29995	30001	30005	29995	29995	29992	29997	30001	29996
S1-Natural	1483	3625	5583	8966	11758	10821	11875	10553	8668	12953	11818	12908	10727	8491	13108	11909	12692	10825	8701	12930
S1- Total young forest	44666	69557	88426	91980	91981	91985	91977	86415	87251	85477	91975	89323	91983	91989	91992	91983	91975	91978	91986	91972
S2 -Regen (Even)	27723	27323	24565	24292	25357	24869	21677	22262	21462	22261	23155	19757	23156	19761	23158	24254	23319	19762	21215	26939
S2-GS	2274	2675	3147	3702	4357	5124	6030	5735	6256	5735	6556	5735	6556	5735	6556	5735	6556	5735	4282	3060
S2-Total regen	29997	29998	27712	27994	29714	29993	27707	27997	27718	27996	29711	25492	29712	25496	29714	29989	29875	25497	25497	29999
S2 Natural	3839	7688	12370	17356	19401	20361	20481	19620	18857	19252	19521	20588	20587	20647	20650	20656	19246	17811	16979	16582
S2- Total young Forest	50348	75020	91976	91979	91987	91982	91975	91972	91984	91985	86547	81824	85293	84348	85378	87244	90894	91987	81356	89669
S4-Regen (Even)	28585	28338	25759	25698	26979	24812	23934	23584	23016	23589	20255	17862	19989	24969	24614	20743	19718	21088	26715	27242
S4-GS	1413	1660	1955	2299	2705	3182	3745	4405	4662	4405	4662	4405	4662	4405	4662	4405	4662	4405	3249	2751
S4-Total regen	29998	29998	27714	27997	29684	27994	27679	27989	27678	27994	24917	22267	24651	29374	29276	25148	24380	25493	29964	29993
S4-Natural	3115	7131	10580	14930	18091	19893	23116	22464	21722	23021	23674	27832	26935	25770	27245	27800	31379	29737	27111	24846
S4- Total young forest	49607	75021	91977	91973	91981	91969	91972	91962	91976	91972	91972	91965	91965	91971	91971	91975	91967	91961	91959	91961
S5-Regen (Even)	27007	26476	23696	22989	22075	21116	19868	18524	17078	18526	12875	13709	13558	16024	19073	20526	14730	20000	22230	24175
S5-GS	2996	3521	4146	4875	5738	6750	7941	9343	10734	9343	10734	9343	10734	9343	10734	9343	10734	9343	7738	5822
S5-Total regen	30003	29997	27842	27864	27813	27866	27809	27867	27812	27869	23609	23052	24292	25367	29807	29869	25464	29343	29968	29997
S5-Natural	3838	7966	12352	16781	20467	25342	30554	35488	37277	37392	37547	37742	37748	37747	37747	37946	36130	33286	30799	27202
S5-Total young forest	48980	74319	91987	91975	91991	91986	91981	91979	91989	91989	91975	91969	91974	91975	91976	91977	91978	91984	91988	91983

Scenario 1. This scenario is based on the recent historical pattern of natural disturbances over the last 50 years. A cycle of dry and wet periods are assumed to occur in the near future. The cycle shows the drought and wet periods of the recent past using the Palmer Drought Index. The figure below shows the variation of dry (negative numbers) and wet periods (positive numbers). The natural disturbance prescription that was developed in Spectrum intended to mimic this variation.

For this scenario, the episodic disturbances replicates the entire 50 year cycle. It was assumed that: 1). a wet period develops (2017 was the start date for analysis in Spectrum) and would extend through much of the first planning period. 2) While floods are considered a disturbance driver in western NC, the effect from flood damage to forest vegetation on the NP is less than the surrounding lands due to the topographic mid to high elevation range of most NP lands. For example, floodplain forests comprise about 0.3% of the NP ,and so, most floodplain forests in western NC are beyond the borders of the NP. Instead, extreme rainfall on the NP tends to cause landslides (which are accounted for in this analysis) and damage to roads and other human infrastructure, 3) The widespread fires of 2016 are accounted for late in the 50-year cycle. It is assumed that widespread, severe wildfires are less likely to occur during wet periods over the next 10 years. 4). The effects of climate change would be gradual over time in western North Carolina. For example, hurricanes often severely affect coastal forests, but are usually remnant tropical depressions when reaching western NC. Also, the complex topography of dissected slopes and aspects of the mountains in NC may shield lands from direct sun and help mitigate the effects of drought to some extent. 5) This scenario cycles the historic pattern of disturbances into the future to use as a base level for comparison with other scenarios. Estimates beyond this planning cycle are speculative, but could inform monitoring of disturbances.

Referring to Table 31 for Scenario 1, the total amount of regeneration hovers around the 28-30K amount throughout the planning horizon. However, the amount of even-aged regeneration dips downward as natural disturbances accumulate over the planning horizon. To compensate for this, the amount of uneven-aged (GS) regeneration increases over time. The likely reason is that wildland fire affects the xeric and moderate moisture classes of forest types and renders those as being affected by natural disturbances rather than even aged regeneration.

Observations common to Scenarios 2,4, and 5. These scenarios boosted the amount of young forest creation within this planning cycle and steadily increased disturbances in the further in the future. Due to expected higher temperature, increases in drought and wildfires were estimated as driving change more than increased precipitation. The changes in disturbance patterns required model adjustments in order to make feasible solutions. The primary model changes are with the fire-adapted forest types, which are most affected by wildfire 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.
5) The amount of old forest closed canopy generally trend as follows. Old closed canopy generally reaches a peak of about 430,000 acres in 110 years, but then decreases to about 418,000 by

year 200. This is the trend in Scenario 4, but S2 and S5 are similar. Scenario 1 - Tier 2 reaches a peak of about 440,000 acres in 110 years but slightly increases from years 110 to 200.

Scenario 2. This scenario changes the disturbance patterns by estimating higher levels in this planning cycle and increasing disturbances over time. 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.

For this scenario, it is assumed that there would be variation of disturbances from decade to decade for 80 years, but the starting amounts over the next 10 years would increase and continue to increase over the following 80 years. This assumes that the effects of climate change are more abrupt than Scenario 1 over the next 10 years. To build out this scenario, it is assumed that both extreme drought and precipitation would occur within the same decade, and this would increase episodic disturbances substantially.

Referring to Table 31 for Scenario 2, the amount of natural disturbances are much higher in 10 years than Scenario 1, and continues to increase greatly over the next 50 years. While the total regeneration amount hovers around 28-30 k-acres per decade, the amount of even-aged regeneration starts to dip down in the 3rd decade and then substantially more over time. This is most likely due to the effect of wildland fire on xeric sites, where the more fire-adapted forest types are not able to contribute to even aged regeneration because, in the model, they are allocated to natural disturbance.

However, the uneven-aged regeneration (S2-GS) increases substantially over time, and in some decades more than twice the amount of Scenario 1. In future planning cycles, the amount of natural disturbances would create as much as percent of the young forest using assumptions in this scenario. In order to meet objectives, the model would access more mesic sites which require group selection rather than even-aged regeneration. This shift to more uneven-aged management may deviate from desired conditions for rich and acidic cove forests. Monitoring the timing and frequency of severe natural disturbances (more than 2 per decade) that cause young forest creation within short timeframes (less than 10 years) may lead to an assessment of objectives.

Scenario 4. This scenario assumes a much higher amount of natural disturbances in this planning cycle. It starts lower than Scenario 2, but instead of leveling off after 80 years, it continues to rise throughout the planning horizon. The effects on objectives are similar to Scenario 2, where the uneven-aged management (group selection) that would occur in cove forests increase substantially in order to reach objectives. Again, this might depart from desired conditions (depending on what desired conditions might be in future planning cycles) and, as in the other scenarios, if the onset of the effects of climate change are determined to be occurring within the next 10 to 15 years due to severe, larger scale disturbances, it may trigger a reassessment of objectives. Similar with Scenario 2, the amount of natural disturbances account for about one-third of the desired amount of young forest in future planning cycles.

Scenario 5. The estimates in Scenario 5 are based on 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).

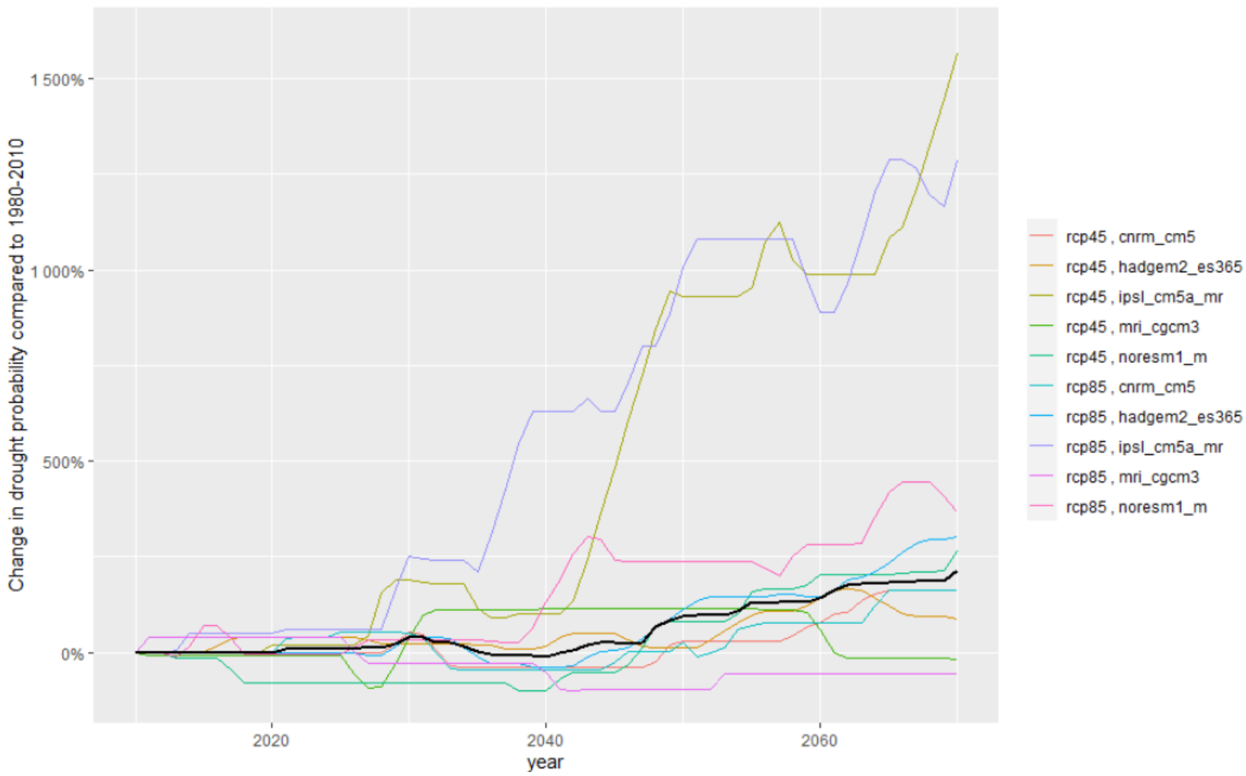

Figure 2. Scenario 5. Change in drought probability under multiple climate scenarios

This scenario deviates somewhat from the graphic above by estimating higher levels of disturbances in this planning cycle, and then a more gradual increase of disturbance until 30-80 years in the future before leveling off. Therefore, the effects on objectives are similar to Scenario's 2, and 4, where even-aged regeneration begins to dip earlier in the planning horizon forcing more uneven-aged regeneration on mesic sites.

Conclusion: Several scenarios were developed to evaluate Alternative E- Tier 2 objectives. A recent historic pattern of episodic natural disturbances was developed (Scenario 1) and projected into the future to provide a basis for comparison with other scenarios and highlight uncertainties of assumptions. This scenario assumes a more gradual onset of effects of climate change in this planning cycle. The gradual change would be due to the NP'S position within the Southern Appalachians and Blue Ridge mountains, its diverse topography of intersecting slopes and aspects, and having mid to high elevation ranges. As a basis for comparison, this scenario did not speculate changes in disturbance patterns from the recent past into the far future.

Scenarios 2, 4, and 5 were developed to have more abrupt changes in disturbance patterns during this planning cycle and increases into the future. These assumptions would affect objectives in future planning cycles, but the desired conditions and objectives are less affected in this planning cycle. As the timeframe progresses in future planning cycles, the amount of young forests created by natural disturbances accumulate and increases the share of the total desired amounts. Even-aged regeneration dips in the future planning cycles and more uneven-aged management in mesic types would be needed to meet objectives.

Other scenarios could be developed that are between the gradual vs abrupt change in disturbance patterns in this planning cycle and the near future. However, the net effect on Tier 2 objectives are likely to occur through a change in silvicultural practices that would emerge in this planning cycle. As noted in FEIS, Chapter 3 Timber, silviculturists would use other methods than even-aged regeneration modeled in Spectrum. Among the treatments listed are: retention harvests, gap based, variable density thinning, irregular shelterwood, and unbalanced uneven-aged systems. These methods could be used to respond to changes in disturbance patterns.

Monitoring natural disturbances is an important component in the monitoring program. If more severe, larger scale, episodic disturbances are detected on the NP over the next 5 to 10 years, then this might trigger an assessment of objectives. Other important indicators could be developed in a monitoring guide to detect the timing of changes in disturbances. For example, the conditions of spruce-fir ecozone require cooler temperatures, and the status of this species may provide alerts about the timing of climate change effects.

ST-Sim: Sensing project using NRV disturbance rates

To further address concerns about modeling, the team took an initial step to review the pattern of seral states using ST-Sim and the disturbance probabilities assumed for the natural range of variability (NRV) for ecozones. This exercise is an initial step rather than a full, comprehensive model. The team took an incremental approach to building out ecozone models with objectives using ST-Sim over time, as such, this is a preliminary estimate or a “sensing” for model behaviors of ST-Sim.

The initial conditions in the NRV model needed to be updated to reflect the conditions of the NP lands. The original NRV assessment used the entire western NC region with equal proportions of the 7 seral states for each ecozone model. The estimated amount of each seral state for each ecozone was updated for the initial conditions on the NP

The next step was how to modify the existing models to include management activity. To do this, additional information about model behavior was needed. Assistance was provided by Jim Smith (TNC, Landfire), Kori Blankenship (TNC, Landfire), Leonardo Fried (Apex RMS), and Jennifer Costanza (SRS). At this stage, it was decided to keep the models as non-spatial, keep it simple, and learn how to include harvests in the model. We decided to take the Alternative E runs of Spectrum harvest outputs and attempt to crossover into ecozone models using ST Sim.

The crossover from Spectrum outputs to ST-Sim inputs was difficult because there is no direct link to the land stratifications used for each model, and therefore assumptions about a crosswalk were necessary. Spectrum modelling used FIA forest type groups because reliable plot data from FIA was used to generate tree growth and yields for outputs. ST-Sim modelling uses ecozones that rely on a 3rd approximation model. A crosswalk was used to estimate of FIA forest type groups to Ecozones (see p. D-14). As such, an exact match of Alternative E Spectrum harvest outputs using the ecozones in ST-Sim is not possible.

The amount of harvest was computed from the Spectrum Alt E (Tier 1 & Tier 2) for the forest types and distributed across the ecozones. The harvest amount was assumed to be the objective acreages, including the openings created by group selection. The harvest amount was divided by 200 and set as an annual transition target in ST-Sim with a probability of 1. The 200 timesteps in ST-Sim was used to be consistent with the planning horizon used in Spectrum. This is another deviation from how Alt E is modelled in ST-Sim vs. Spectrum, which has a set of timing combinations and schedules that is selected by the algorithm to meet the objectives and constraints in the model, rather than, an annual even-flow used in ST-Sim.

The next step was developing a method to confine harvests to a portion of the land base. Most of the harvests in Spectrum are constrained for the matrix and interface management areas. These management areas are grouped into what is called Management Area Group 1. A description of the management area groups is documented in the FEIS, Terrestrial Ecosystem Section.

Table 32 displays the assumptions about where harvests are likely to occur as well as burning for young forest. These assumptions were applied as transition targets in ST-Sim. Most harvests are confined to management area group 1, along with a much lower amount in management area group 2. No harvesting was estimated for management area groups 3 & 4. In addition, no harvesting was estimated in the designated old growth network, portions which occur within all the management groups

Tables 33 through 35 show the estimated probabilities that harvesting would occur in different age groups. The first row shows our initial estimates, and the modified row is our revised estimates of the likelihood of tree ages that would be harvested. The tables that follow have used the modified probabilities. The transition pathways in ST-Sim were updated with these age groups and probabilities.

Table 32. Assumed amounts of harvest amounts occurring by Management Area Group

	Harvest	Burning for Young Forest
Management Group 1	85-90%	0
Management Group 2	10-15%	33-40%
Management Group 3	0	60-66%
Management Group 4	0	0

Table 33. Probability of harvest occurring by age group for 7 ecozones.

	50-70	71-120	121-140	140+
Rich Cove, Acidic Cove, Northern Hardwood, Mesic Oak, Dry-Mesic Oak, High Elevation Red Oak, Shortleaf Pine	0.1	1	0.5	0.1
Modified	0	1	0.1	0

Table 34. Probability of harvest occurring by age group for Pine-Oak/Heath Ecozone

	60-70	71-120	121-130	111-130	131+
Pine-Oak/Heath	0.1	1	0.5	0.1	0
Pine-Oak/Heath Modified	0	1	0.1	0	0

Table 35. Probability of harvest occurring by age group for Dry Oak ecozone

	60-70	71-100	101-110	111-140	141+
Dry Oak Typical	0.1	1	0.5	0.1	0
Dry Oak Modified	0	1	0.1	0	0

Preliminary Observations: The models in the NRV assessment were revived using updated software in SyncroSim. The NRV models used 1000 years (timesteps), so they are adjusted to use 200 timesteps that is comparable to the planning horizon used in Spectrum. The regeneration harvest amounts that reset the age to zero for Alt E were estimated for the ecozones, but as noted earlier, there is not a direct crossover of forest types to ecozones. The regeneration amounts were estimated annually over the 200 timesteps. This is not a likely management mode, but this assumption allowed for a way to get the models up and running.

Each ecozone has its own model, and regeneration harvests were allocated to nine of the 11 ecozones (Spruce Fir and Floodplains were excluded since there were no proposed harvest or prescribe burning activities). The initial conditions in each model had to be adjusted to estimate current conditions by intersecting the ecozone model and FSVeg database age classes. And, the cove model, that had both rich and acidic cove, had to be split into two models. Given that more activities occur in rich cove forest compared to acidic cove forest, the harvest runs utilized 80% of the Spectrum cove harvest outputs for the rich cove model and 20% for the acidic cove model. For Alt E with 2 tiers, there were 18 harvest model runs. The NRV runs tend to have some wide swings early in the timeline but stabilize quickly. For the harvest scenarios given the even-flows, the seral states tend to stabilize quickly as well.

The results from 2 models are show below: one for mesic types (Table 36, rich cove) and one for xeric types (Table 37, dry oak). The NRV disturbance regime affects the xeric ecozones as there is a relatively high proportion of young seral states, and then, with harvests the young seral states can be as much as 15 percent. Young forest is higher within these types with more historic replacement fires compared to current rates of stand replacement fires. This tends to modulate the mid and older seral states of xeric ecozone models.

The mesic ecozones also have a moderate proportion of young seral states, which also tends to modulate the mid and older seral states. The rich cove and mesic oak harvest scenarios tend to have higher proportions of young forest in comparison with NRV runs.

Table 36. Rich cove forest model state class percentages in selected years under different scenarios from the natural range of variation (NRV) to management under Tier1 or Tier2 objectives.

MODEL: Rich Cove														
	HRV, even start, Scenario 12598	HRV, existing conditions, Scenario 13010	No Harvest, Scenario 12996				Tier1, Scenario 13003				Tier2, Scenario 13004			
	Year		Year				Year				Year			
State Class	200	200	10	50	100	200	10	50	100	200	10	50	100	200
Early1:ALL	4.7%	5.0%	4.3%	4.6%	5.1%	5.1%	5.3%	5.9%	5.6%	6.0%	8.3%	8.3%	7.8%	7.5%
Late1:CLS	9.7%	10.0%	24.5%	22.6%	13.5%	10.0%	23.6%	19.1%	10.3%	9.4%	23.5%	13.9%	6.0%	7.4%
Late1:OPN	1.4%	0.7%	1.8%	1.8%	1.4%	0.9%	1.9%	1.7%	1.0%	0.8%	2.3%	1.0%	0.7%	0.6%
Late2:ALL	50.0%	50.1%	9.6%	28.9%	46.5%	48.6%	9.7%	28.5%	42.0%	43.4%	9.0%	26.7%	33.2%	32.9%
Mid1:CLS	29.0%	31.7%	54.8%	38.2%	30.8%	32.3%	54.3%	40.8%	37.4%	37.2%	51.8%	45.4%	47.6%	47.1%
Mid1:OPN	5.3%	2.6%	5.1%	3.9%	2.8%	3.1%	5.2%	4.0%	3.6%	3.3%	5.1%	4.7%	4.7%	4.6%

Table 37. Dry oak forest model state class percentages in selected years under different scenarios from the natural range of variation (NRV) to management under Tier1 or Tier2 objectives.

MODEL: Dry Oak														
	HRV, even start, Scenario 12647	HRV, existing conditions, Scenario 12814	No Harvest, Scenario 12842				Tier1, Scenario 12823				Tier2, Scenario 12822			
	Year		Year				Year				Year			
State Class	200	200	10	50	100	200	10	50	100	200	10	50	100	200
Early1:ALL	12.9%	13.3%	6.4%	13.3%	12.7%	12.3%	6.6%	13.6%	11.3%	13.9%	8.5%	17.5%	16.0%	15.9%
Late1:CLS	2.2%	1.6%	20.5%	1.9%	2.3%	2.2%	19.7%	1.5%	2.0%	1.9%	21.2%	1.5%	2.0%	1.9%
Late1:OPN	7.7%	7.6%	10.8%	5.0%	6.4%	8.1%	10.5%	4.0%	7.9%	7.7%	10.4%	3.6%	8.5%	8.7%
Late2:CLS	9.5%	8.4%	33.0%	14.8%	10.9%	9.6%	35.0%	13.2%	8.5%	9.7%	31.9%	10.8%	7.9%	8.4%
Late2:OPN	49.0%	50.2%	17.5%	54.4%	48.5%	48.7%	17.7%	54.5%	47.3%	47.7%	17.0%	50.3%	42.0%	41.2%
Mid1:CLS	3.6%	2.7%	9.2%	1.9%	3.4%	3.6%	8.4%	2.4%	4.6%	3.6%	8.6%	3.5%	4.7%	5.0%
Mid1:OPN	15.2%	16.1%	2.6%	8.8%	15.8%	15.4%	2.1%	10.8%	18.5%	15.5%	2.4%	12.8%	19.1%	18.9%