National Forests in North Carolina
Procedure for Estimating the Natural Range of Variation (NRV)
Nantahala and Pisgah National Forests
January 2015

NRV Steps

Completed with Kori Blankenship, Landfire TNC Ecologist

1) **Define an appropriate geographic area** - We included a size large enough to incorporate the 18 county area surrounding the Nantahala and Pisgah NFs. The size was large enough to be statistically significant based on the accuracy of the data for the disturbance frequencies.

2) **Determine appropriate ecozones -** Table 1 identifies the 11 modeled ecological zones that include the majority of the lands across the Nantahala and Pisgah National Forests. 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 modeling completed for these types we met with the botanists and silviculturists from the mountain ranger districts, the southern research station, and state land management agencies 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.

Table 1. Eleven Ecological Zones across Nantahala and Pisgah NFs derived by combining similar ecological types.

EcoZones	Changes	Nantahala and Pisgah Acres	Forest %
Spruce-Fir	Spruce-Fir	16604	2%
Northern Hardwood Slope, Northern Hardwood Cove	Northern Hardwood	53924	5%
High Elevation Red Oak	High Elevation Red Oak	38637	4%
Acidic Cove, Mixed Oak-Rhododendron	Acidic Cove	240938	23%
Rich Cove	Rich Cove	189143	18%
Mesic Oak Slope, Mesic Oak Cove	Mesic Oak	186131	18%
Dry-Mesic Oak Forest	Dry-Mesic Oak	105991	10%
Dry Oak Evergreen, Dry Oak Deciduous	Dry Oak	59677	6%
Pine-Oak/Heath	Pine-Oak/Heath	101275	10%
Low Elevation Pine, Low Elevation Pine-Oak	Shortleaf Pine-Oak	44451	4%
Alluvial, Large Floodplain	Alluvial	2640	0.3%

3) To the extent possible we also examined any correlation with FSVeg types to examine for existing condition. The majority did not have a 1:1 match and typically were incorporated in multiple ecozones. Potentially only the red oak type, ev code 55, closely matched the type. And this type only occurred in 17% of the modeled high elevation red oak forest type. Most FSVeg forest types occurred in mid elevation forests. The same pattern was seen for other FSVeg types and typically occurred across multiple ecozones.

Table 2. Correlation or lack of between Ecozones and FSVeg types.

Ecozones	Forest Type - FSVeg Code
Spruce-Fir	6, 7, 10, 17
Northern Hardwood	70, 81
High Elevation Red Oak	55
Acidic Cove	4, 5, 8, 9, 41, 50, 56, 83
Rich Cove	9, 41, 50, 56, 82, 83
Mesic Oak	10, 42, 48, 53, 54
Dry-Mesic Oak	3, 42, 48, 52, 53, 54
Dry Oak	42, 51, 52, 54, 57, 59, 60
Pine-Oak/Heath	15, 16, 20, 25, 33, 38, 49
Shortleaf Pine-Oak	3, 12, 13, 14, 16, 21, 25, 31, 32, 33, 44, 49
Alluvial	72, 82

4) LANDFIRE (landfire.org) is a nationally created database that in part describes the vegetation dynamics, including structure and disturbance regimes for more than 1,000 ecosystems, called Biophysical Setting (BpS), in the United States (Rollins 2009). Biophysical Settings represents vegetation that may have been dominant on the landscape prior to Euro-American settlement and are based on both the current biophysical environment and an approximation of the historical disturbance regime. Biophysical Settings (BpS) represents vegetation that may have been dominant on the landscape prior to Euro-American settlement and are based on both the current biophysical environment and an approximation of the historical disturbance regime. Map units are defined by Nature Serve (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 quite similar in disturbance regimes and topographic setting. As a result they were correlated as a single unit.

Table 3. Correlation between Ecozones and LANDFIRE Biophysical Setting.

EcoZone	BpS Name	BpS Code
Dry-Mesic Oak	Southern Appalachian Oak Forest	5713150
Dry Oak	Allegheny-Cumberland Dry Oak Forest And Woodland	5713170
Mesic Oak	Montane Red Oak - Chestnut Oak	new provisional (Simon & Croy)
Rich and Acidic Cove	Southern and Central Appalachian Cove Forest	5713180
Pine-Oak/Heath	Southern Appalachian Montane Pine Forest and Woodland	5713520
Shortleaf Pine-Oak	Southern Appalachian Low-Elevation Pine Forest	5713530
Floodplain Forest	Central Interior and Appalachian Floodplain Systems	5714710
Spruce-Fir	Central and Southern Appalachian Spruce-Fir Forest	5713500
Northern Hardwood	Southern Appalachian Northern Hardwood Forest	5713090
High Elevation Red Oak	Central and Southern Appalachian Montane Oak Forest	5713200

5) 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, open vs. closed. An open structure was assumed to represent 40-80% canopy cover and would allow 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 from 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. We examined three local variations within other southern Appalachian reviews of the BpS models. 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. We incorporated the old growth s-class developing our variation for western North Carolina based on the best examples of the three modeling efforts and by detecting inconsistencies across age classes. We were surprised at the lack of young forest when there was so much difference in old growth percentages (Late2 in Table 4). Our goal was to review the systems and learn from previous modeling efforts creating less discrepancies when examining all ten BpS models relative to each other. As a result of detecting differences for the same s-Classes within the same BpS we determined it would be desirable wanted to develop a range for all the S-Classes versus a single fixed percentage.

Table 4. Variation between s-Classes between BpS models across the Southern Appalachians. Chatt = Warwoman watershed on Chattahoochee NF, Cher = North Zone Cherokee NF, Sapp = Southern Appalachian subset. Numbers represent percent of individual ecozone.

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

6) To begin the modeling process we developed age and successional classes for each of the 11 ecozones for the Nantahala/Pisgah, which will be represented by 10 BpS models. The early class was determined by silvicultural conditions in particular 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 (Table 5). 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 5).

Table 5. Ages of s-Classes for the ten BpS models developed for the Nantahala and Pisgah National Forests.

Ecozones	Age Class			
	Early	Mid	Late	Old Growth
Spruce-Fir	0-35	36-70	71-120	120+
High Elevation Red Oak	0-20	21-70	71-130	130+
Northern Hardwood	0-15	16-75	76-130	130+
Cove (Rich or Acidic)	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	71-100	100+
Floodplain	0-10	11-100	101-140	140+

7) We determined the appropriate disturbance regimes (type and frequency) for each separate BpS model (Table 6). There is uncertainty on frequencies for many disturbance types given the lack of historical data. The analysis was completed on a relative scale of intensity and frequency of any disturbance when comparing all 11 ecozones. 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. We initially separated more disturbance events, such as ice storms from wind events, but after running 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 we simplified the number of disturbances.

Table 6. Frequency (years) of separate disturbance classes for the ten BpS models developed for the Nantahala and Pisgah National Forests.

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

8) 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 the model. For each BpS model we simulated for a 1000-year period 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. This is based on our assumption these are the most protected ecozones in the landscape and would not have an open condition.

9) In order to derive ranges for each s-Class we examined the probability distributions around each average. ST-SIM can be used with either a normal or a beta distribution. We selected beta distribution since one can tie it to a minimum and maximum for disturbances. 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.

Figure 1. Bell-shaped curve for surface fires for Pine-Oak/Heath ecozone.

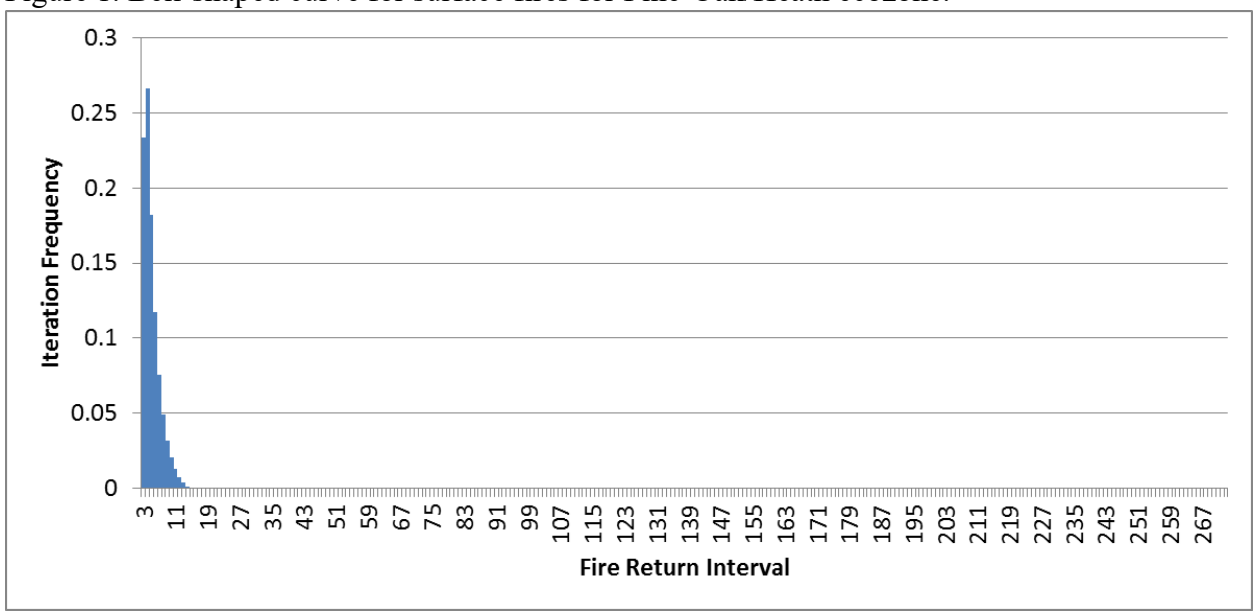


Figure 2. Bell-shaped curve for wind frequencies for Pine-Oak/Heath ecozone.

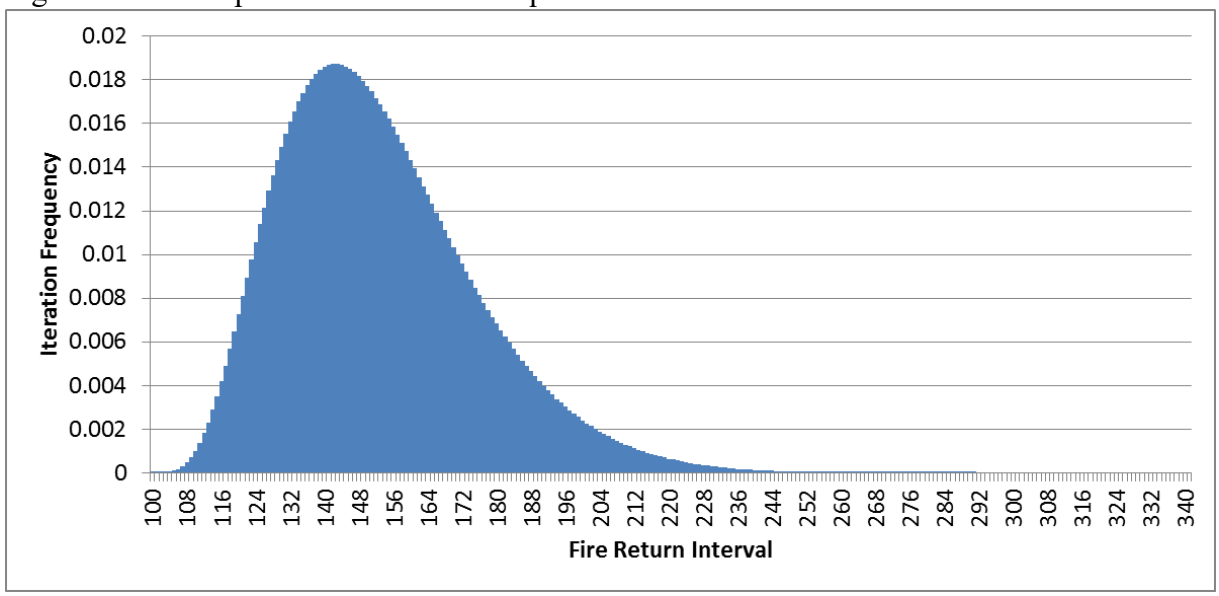
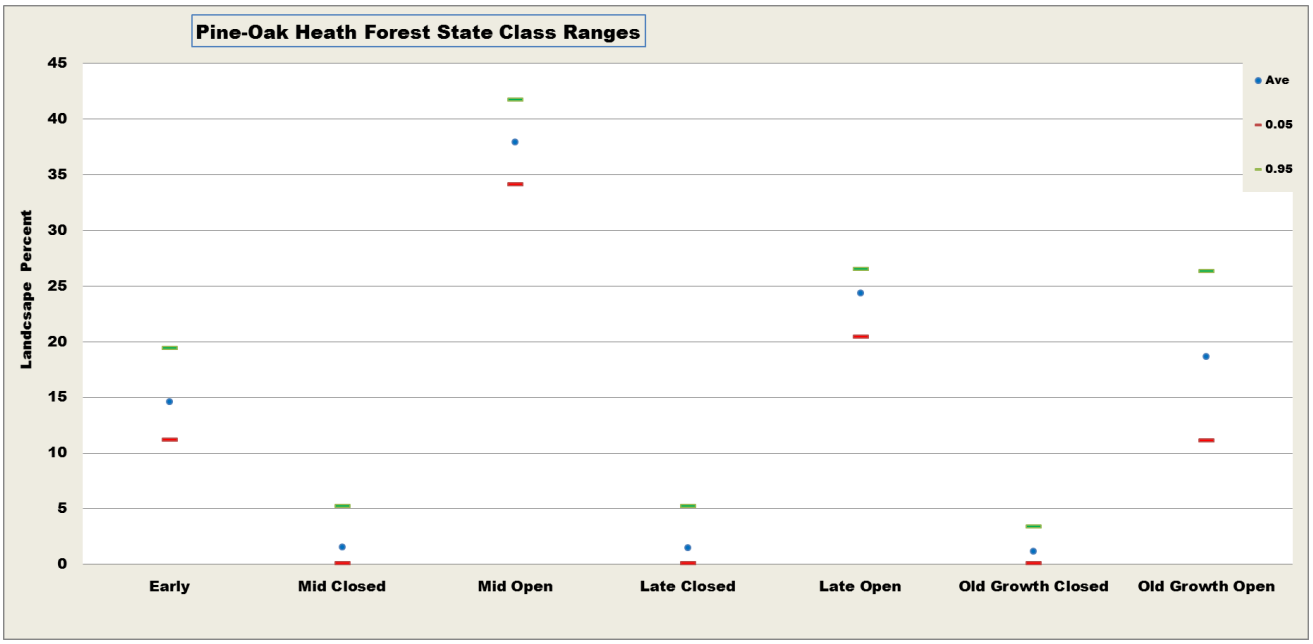


Figure 3. Results of NRV simulations with final ranges within each s-Class for Pine-Oak/Heath ecozone.



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