Attachment 14

An Analysis of Important Areas for Salamander Conservation and Connectivity in the Nantahala and Pisgah National Forests

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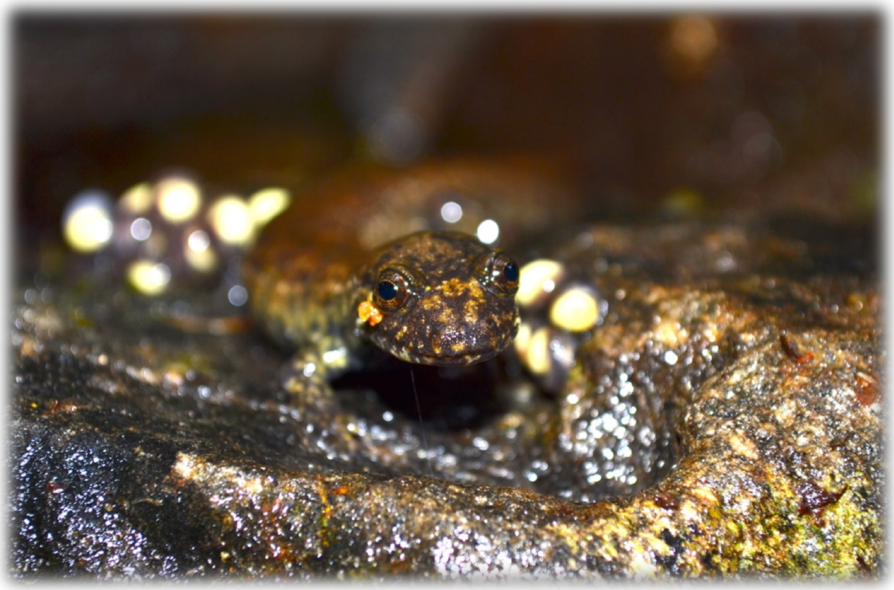

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Introduction and Purpose

Global amphibian declines have been of concern to scientists, conservationists, and land managers since the 1980s (Stuart et al. 2004). The severity of amphibian declines has been shocking, with catastrophic losses occurring across the globe and in a wide variety of habitats (e.g. Sherman and Morton 1993, Drost and Fellers 1996, Pounds et al. 1997, Pounds and Crump 1994, Ron et al. 2003, Young et. al. 2001). More recent assessments have revealed that nearly half of all amphibians are threatened with extinction and nearly all species continue to decline (Stuart et al. 2004, Grant et al. 2016). These trends make amphibians among the most imperiled vertebrate groups in the world.

Within amphibians, there are also clear patterns that have emerged regarding threat level (Stuart et al. 2004, Nowakowski et al. 2018). Notably, salamanders as a group tend to be highly imperiled, with roughly 60% of species considered to be at risk (www. IUCN.org, Apodaca 2010). This is significant for the Southern Appalachians in general and for the Nantahala and Pisgah National Forests, as they are central to what has long been considered the world's hotspot of salamander diversity (Fig. 1). In fact, the region as a whole contains roughly one fifth of the world's salamander diversity and more families and genera than anywhere in the world. Meaning that not only does this area have an incredible diversity of salamanders, but also a high amount of "deep" or phylogenetic diversity in the region.

Unfortunately, the Southern Appalachians have not escaped the trend in worldwide amphibian declines. In fact, within the Pisgah and Nantahala National Forests, there are several species of concern (State listed species, IUCN priority species, US Forest Service (USFS) priority species, and species under review for listing under the Endangered Species Act) and a history of enigmatic declines for some species (e.g. Snyder 1983, Corser and Gaddy 1991, Snyder 1991, Petranka et al. 1993, Corser 2001).

It has also become clear that there is no single cause of amphibian declines, but rather the coalescence of several factors such as habitat loss, disease, climate change, and fragmentation. Consequently, the conservation and management of amphibians, and salamanders in particular, requires a comprehensive approach. While there is no panacea, the long-term persistence of amphibians is highly dependent on healthy metapopulations (Hanski and Gilpin 1991, Hanski and Ovaskainen 2000, Cushman 2006, Apodaca et al. 2012, Cushman et al. 2012). Functioning metapopulations tend to maintain genetic diversity and minimize the effects of inbreeding (Frankham et al. 2002, Apodaca 2010, Apodaca et al. 2012). Genetic diversity provides populations with the ability to adapt to changing conditions (climate fluctuations, disease, invasive species, etc.), and inbreeding diminishes genetic diversity and all-around population health and fitness (Frankham et al. 2002, Pauls et al. 2013). Just as amphibians depend on metapopulation health, metapopulations depend on available habitat patches and an intact and connected landscape.

With over a million acres in total area, the Nantahala and Pisgah National Forests provide the ideal situation to establish large and functioning metapopulations for several species of salamander in the world's center of diversity for them. Currently, salamanders are not factored into forest-wide management decisions. Nor is connectivity considered, even for priority species, in a systematic way. Here, we have attempted to create a tool that identifies USFS stands that are disproportionately important to salamander persistence, connectivity, and metapopulation function within the Nantahala and Pisgah National Forests. By managing the identified stands in a manner beneficial to salamanders, the USFS can help to assure that the Southern Appalachians maintain the rare and endemic salamander diversity found in the region.

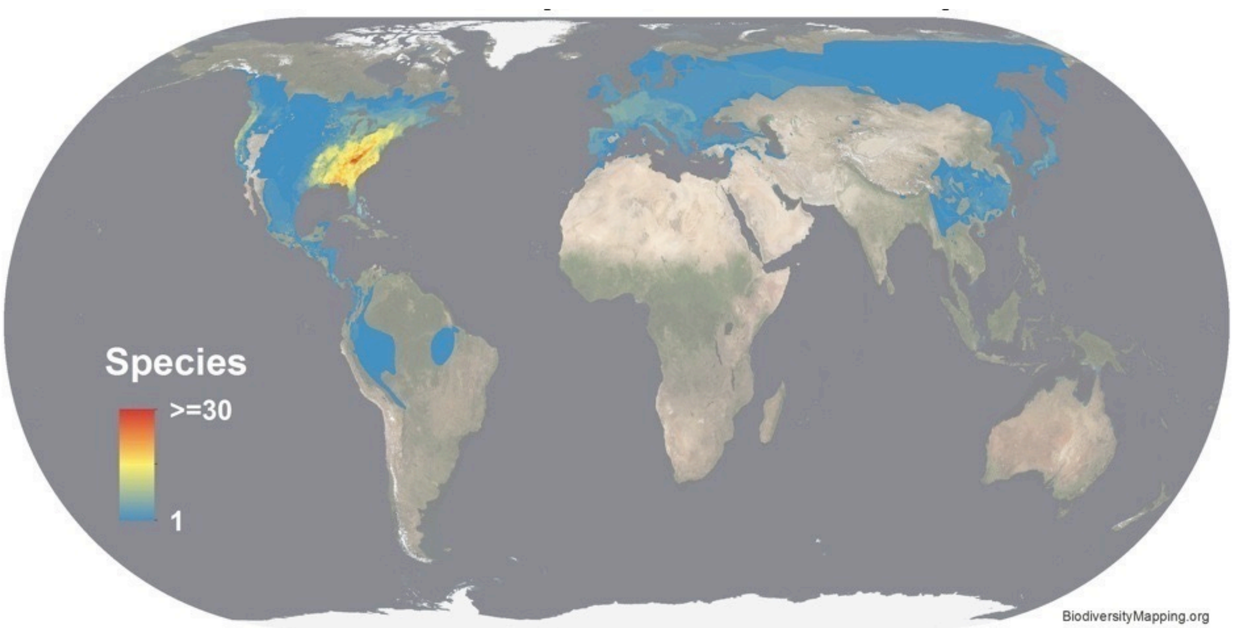

Figure 1. Worldwide salamander diversity.

Methods

Overall Approach

We began by creating environmental niche models (ENMs) for target species. In general, environmental niche models (ENMs) create a prediction of a species' geographic range by relating a species known locality data to environmental parameters. ENMs have been successfully integrated into a diverse set of ecological (e.g., Araújo & Williams, 2000; Ferrier et al., 2002; Mac Nally & Fleishman, 2004, Cunningham et al., 2009), evolutionary (e.g. Graham et al., 2004; Wiens & Graham, 2005; Rissler & Apodaca, 2007), and conservation (e.g. Ferrier, 2002; Raxworthy et al., 2003; Domínguez-Domínguez et al., 2006; Garcia, 2006; Rissler et al., 2006) studies. We then used a tiered threshold to identify 3 levels of habitat and climate space (sub optimal, adequate, and optimal) for each species. From these distribution models, we then created additive distribution models (Apodaca 2010) for each ecological group.

This approach allowed us to identify areas that were of high ecological value for several species without losing the biological reality of the individual species' niche. These maps also provided a basis for identifying core areas for additional analyses.

Running the Maxent Program

23 variables (19 climate variables and 4 habitat variables) were used for niche modeling in Maxent. GIS layers for climate variables were obtained from WorldClim (WorldClim Version 2 BioClimatic Variables bio30s 1970-2000, http://worldclim.org/version2). Climate variables used in the analysis are listed below.

- Annual Mean Temperature
- Mean Diurnal Range (Mean of monthly (max temp - min temp))
- Isothermality
- Temperature Seasonality
- Max Temperature of Warmest Month
- Min Temperature of Coldest Month
- Temperature Annual Range
- Mean Temperature of Wettest Quarter
- Mean Temperature of Driest Quarter
- Mean Temperature of Warmest Quarter

- Mean Temperature of Coldest Quarter
- Annual Precipitation
- Precipitation of Wettest Month
- Precipitation of Driest Month
- Precipitation Seasonality (Coefficient of Variation)
- Precipitation of Wettest Quarter
- Precipitation of Driest Quarter
- Precipitation of Warmest Quarter
- Precipitation of Coldest Quarter

Habitat variable GIS layers used were Canopy Cover (NLCD 2011 USFS Tree Canopy cartographic (CONUS), https://www.mrlc.gov/data?f%5B0%5D=category%3Acanopy), Stream Locations (USGS 24k Hydrography, https://www.usgs.gov/core-science-systems/ngp/national-hydrography/access-national-hydrography-products), Vegetation Cover (North Carolina Land Cover, http://www.basic.ncsu.edu/segap/), and Soil Moisture (Soil Survey Geographic Database (SSURGO)). Each layer was uploaded to ArcGIS Pro 2.2.4 where it was edited to be compatible with the Maxent program. The Stream Locations layer was converted via the Euclidean Distance tool to a layer displaying each cell's distance from a stream. Cell size for each raster was set to 100m.

Species location data was obtained from museums (through the GBIF portal), iNaturalist, and HerpMapper, with supplemental data points provided by local experts. The species included in the niche model were divided into 4 subgroups, listed below.

- Rock Outcrop Specialist Subgroup
  - *Aneides aeneus* (Sample Size 311)
- Streamside Subgroup
  - *Pseudotriton ruber* (Sample Size 72)
  - *Eurycea guttolineata* (Sample Size 20)
  - *Eurycea wilderae* (Sample Size 101)
  - *Eurycea cirrigera* (Sample Size 14)
- Woodland Subgroup
  - *Notophthalmus viridescens* (Sample Size 46)
  - *Plethodon yonahlossee* (Sample Size 34)

- *Plethodon teyahalee* (Sample Size 13)
- *Plethodon shermani* (Sample Size 20)
- *Plethodon serratus* (Sample Size 13)
- *Plethodon montanus* (Sample Size 33)
- *Plethodon metcalfi* (Sample Size 42)
- *Plethodon cylindraceus* (Sample Size 54)
- *Plethodon cinereus* (Sample Size 19)

- High Elevation Subgroup
  - *Desmognathus organi* (Sample Size 11)
  - *Desmognathus wrighti* (Sample Size 33)
  - *Plethodon welleri* (Sample Size 12)

The variable GIS layers and species location data were then used to run a species niche model through Maxent. Each species was run as a separate model.

Processing Maxent Output Rasters

After the Maxent Program model had been run for each species, the output niche rasters were uploaded to ArcGIS Pro. The rasters were reclassified so that the highest value pixel had a score of 2, the second highest 1, and the rest 0. Each species' raster was then added together within their subgroup to create a subgroup-level Additive Distribution Model (ADM) map.

Within each subgroup, the ADM maps were used to create input data for the connectivity analysis tools in the Linkage Mapper Toolbox (version 2.0.0). Reclassifying the ADM raster to reverse the values created the "resistance raster", or a map whose cells have an attributed value reflecting the energetic cost, difficulty, or mortality risk of moving across that cell. The ADM map was also used to create a "core areas" layer, containing regions with the highest suitability score. The number of top values included in the core areas layer depended on the subgroup, with the Rock Outcrop Specialist Subgroup including the top 2 values, the Streamside Subgroup including the top 3, the Woodland Subgroup including the top 5, and the High Elevation Subgroup including the top 3. The number of values to include was determined based on the range of values in each subgroup. For example, the Rock Outcrop Specialist Subgroup's ADM values ranged from 0-2, but the Woodland Subgroup ranged from 0-13. The Core Area layer was aggregated to reduce the number of cores by combining independent, single- cell polygons within close proximity of each other.

Running the Linkage Mapper Toolbox

The Linkage Mapper Toolbox 2.0.0 was used to conduct connectivity analysis. The Linkage Pathways Tool was run in order to identify and map least-cost linkages between core areas. The maximum cost-weighted corridor distance was set to 70,000 meters to prevent extremely remote cores from being connected.

The Linkage Priority tool was then run to quantify the relative conservation priority of each linkage in a landscape. For CAV Calculations, the weight given to Resistance and Size was set to 0.33 and Area/Perimeter was set to 0.34 in order to make the sum 1.0.

The Core Centrality tool was run to calculate current flow centrality, a measure of how important a link or core area is for keeping the overall network connected.

The Barrier Mapper tool was run to detect important barriers that affect the quality and/or location of the corridors. The minimum detection radius, or the minimum search radius for moving window analysis, was set to 250 meters as this is half the minimum length of a strip of land that could be restored. The maximum detection radius, or maximum search radius for moving window analysis, was set to 1000 meters as this is half the maximum length of a strip of land that could be restored. The radius step value was set to 0 so that the program would only search for barriers at a single radius.

Lastly, the Pinchpoint Mapper was run to create current maps that identify and map pinch points (i.e. constrictions, a.k.a. bottlenecks or choke points) in least-cost corridors (Linkage Mapper 2.0.0 User Guide). The CWD Cutoff Distance, or cost-weighted corridor "width", was set to 5,000 meters, a value selected based on information from chapter 2 of WHCWG (2010).

Results and Implications

For each subgroup, we feel that the most important models for salamander management within the Nantahala and Pisgah National Forests are the Core Areas Model (CAM), the Linkage Priority Model (LPM), and the Least Cost Path Model (LCP). Undoubtedly, the stands identified in the CAM (Figs. 2,5,8,9,14, and 15) are the top priority, as they show the areas that have the best current condition for each subgroup. By managing these areas at the stand level for salamander diversity, the USFS can efficiently maintain healthy metapopulations for the identified taxa. We would suggest that harvest in these areas is limited, as research has shown that most Southern Appalachian salamander communities can take a century or more to recover from unnatural disturbance regimes (Herbeck and Larsen 1999, Petranka 1999, Connette and Semlitsch 2013, Hocking et al. 2013).

The stands identified as high priority by the LPM (Figs 3, 6, 10, 11, 16, and 17) and LCP (Figs. 4, 7, 12, 13, 18, and 19) are important to maintain connectivity between the identified core areas. Connectivity is vital to the long-term survival of populations, metapopulations, and ultimately species. These models identify stands that are highly suitable and are high priority for linking populations (LPM) or that represent the biologically shortest path between identified core areas (LCP) that contains habitat that the species are able to disperse through. All of the species analyzed here, save one (*Notophthalmus viridescens),* are Plethodontid or lungless salamanders, which are notoriously poor dispersers (Dowling 1956, Jaeger and Forester 1993, Martin et al. 2016). For many of these species, migration will likely not occur across even relatively small swaths of unsuitable habitat. Therefore, maintaining continuous habitat within high priority stands is recommended. We suggest that timber harvest within these stands is limited to non-adjacent compartments and that streamside BMPs are strictly adhered to and road building/ staging areas are limited. We have provided several other useful tools in the appendix for identifying key areas to consider for salamander persistence and connectivity within the Nantahala and Pisgah National Forests.

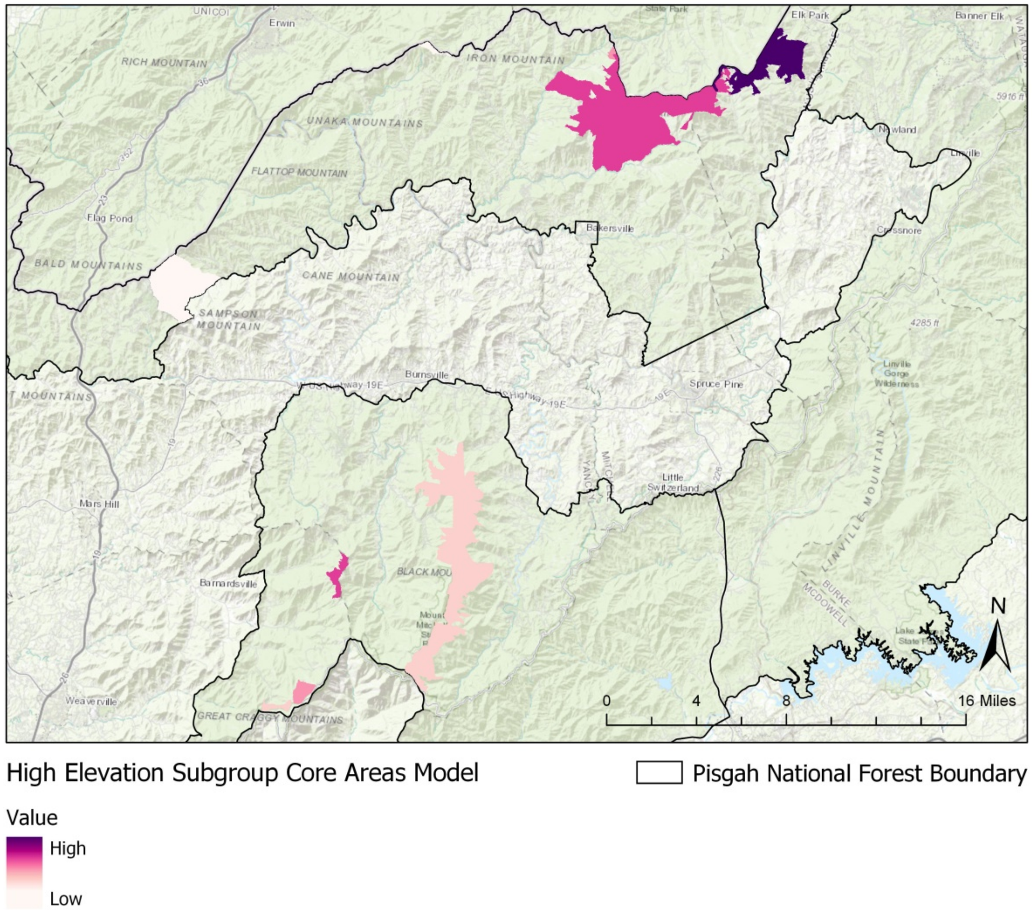

Figure 2. Map showing forest stands within the Pisgah National Forest containing core areas for the High Elevation Subgroup as determined by the Core Area Model. Stands containing core areas with a higher priority value are dark purple while stands containing core areas with a lower priority value are light pink.

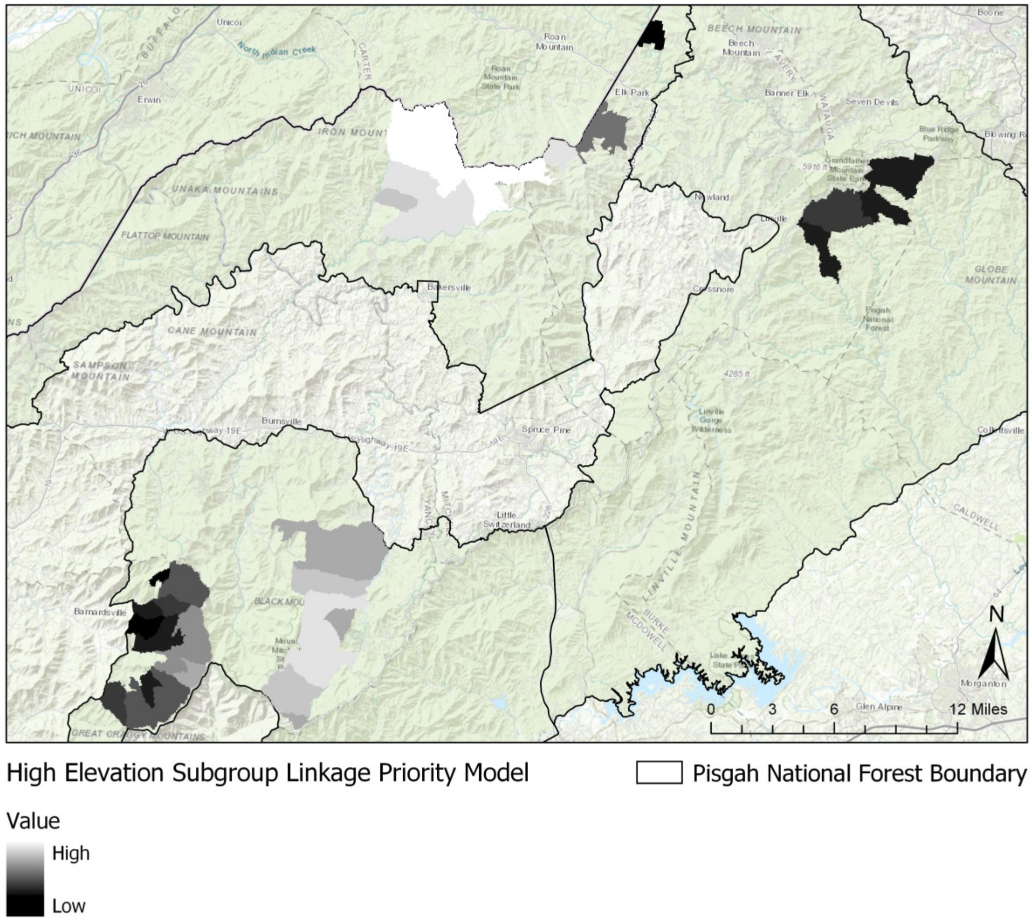

Figure 3. Map showing forest stands within the Pisgah National Forest containing linkages between cores for the High Elevation Subgroup as determined by the Linkage Priority Model. Stands containing linkages with a higher priority value are white while stands containing linkages with a lower priority value are black.

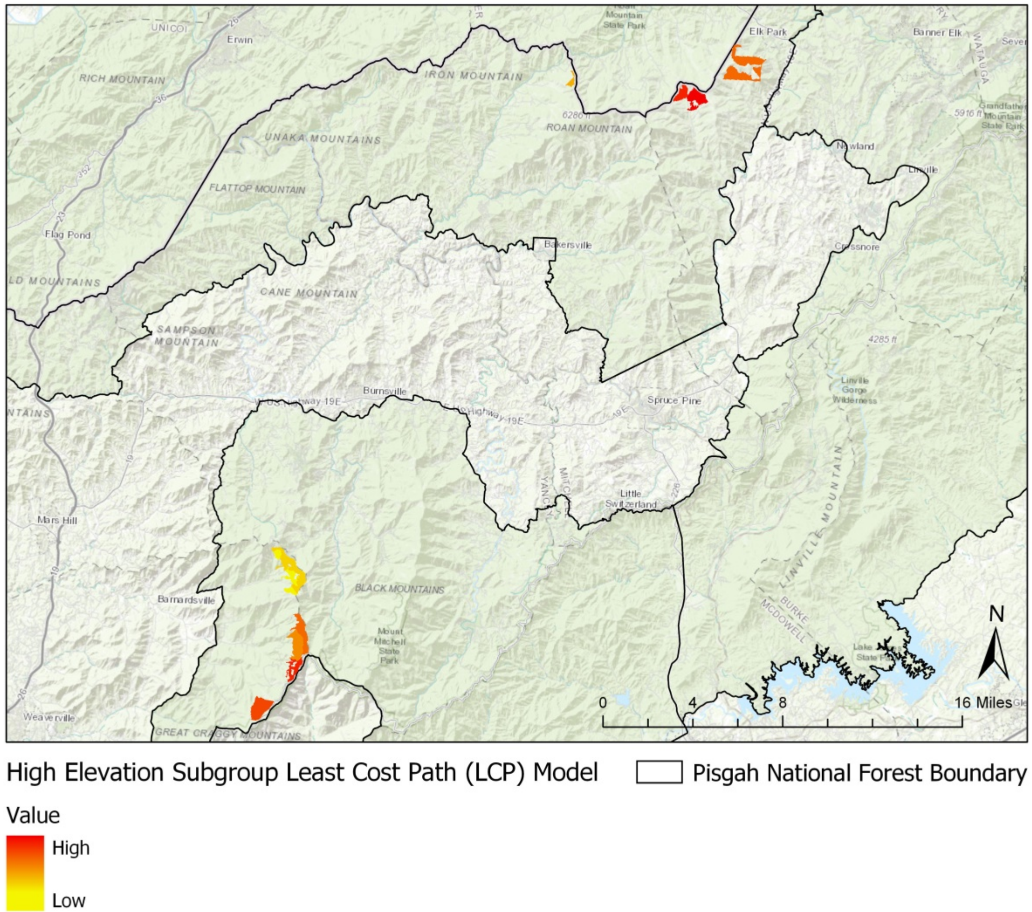

Figure 4. Map showing forest stands within the Pisgah National Forest containing least cost paths between cores for the High Elevation Subgroup as determined by the Least Cost Path (LCP) Model. Stands containing paths with a higher priority value are red while stands containing paths with a lower priority value are yellow.

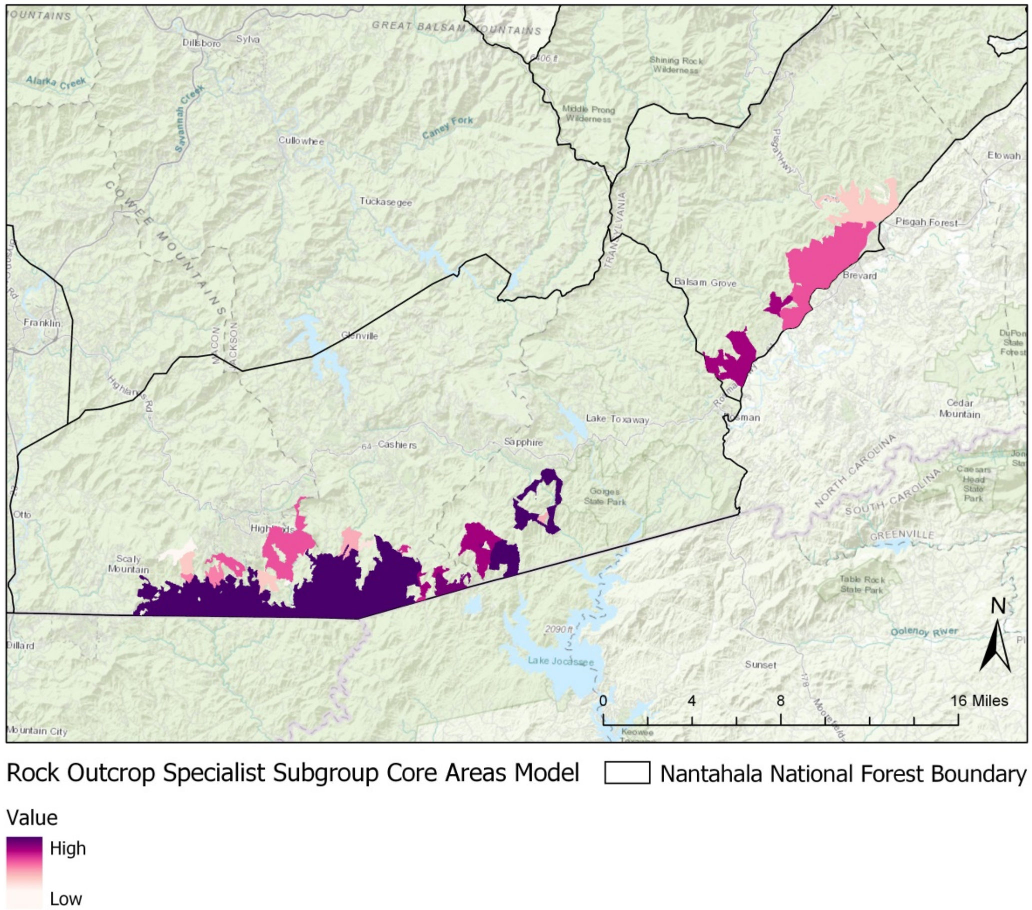

Figure 5. Map showing forest stands within the Nantahala National Forest containing core areas for the Rock Outcrop Specialist Subgroup as determined by the Core Area Model. Stands containing core areas with a higher priority value are dark purple while stands containing core areas with a lower priority value are light pink.

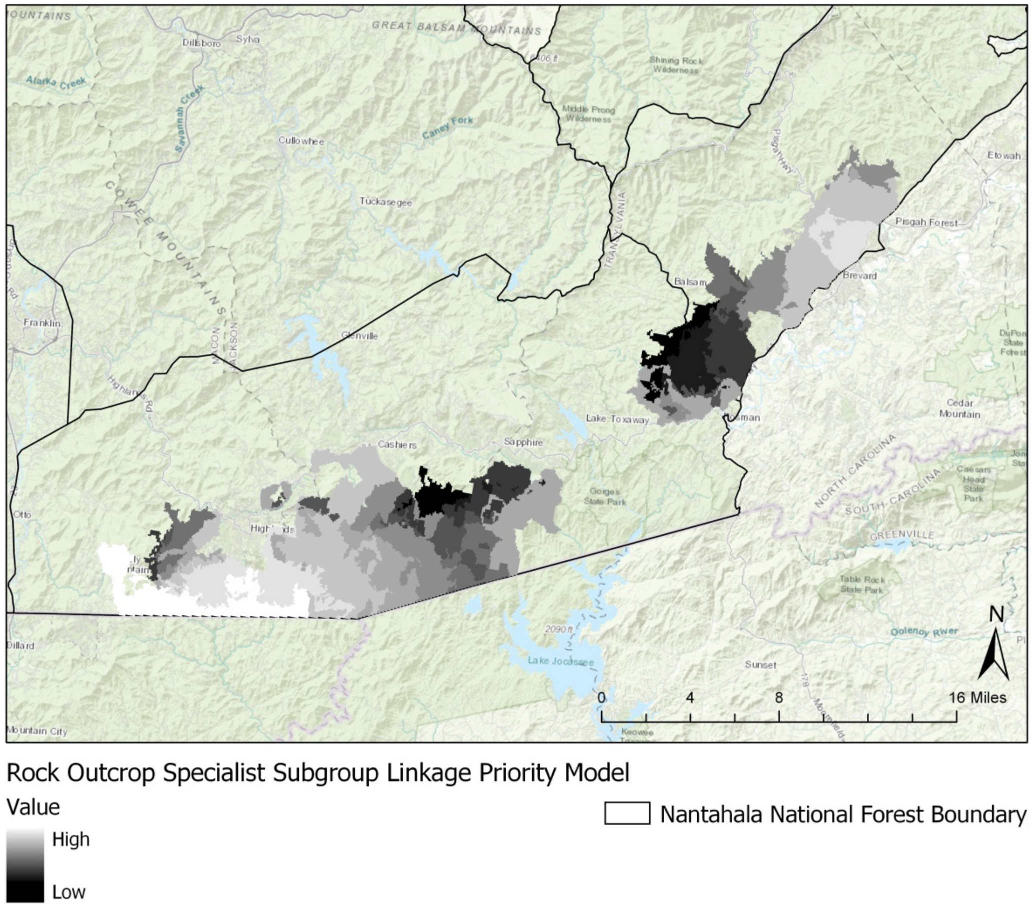

Figure 6. Map showing forest stands within the Nantahala National Forest containing linkages between cores for the Rock Outcrop Specialist Subgroup as determined by the Linkage Priority Model. Stands containing linkages with a higher priority value are white while stands containing linkages with a lower priority value are black.

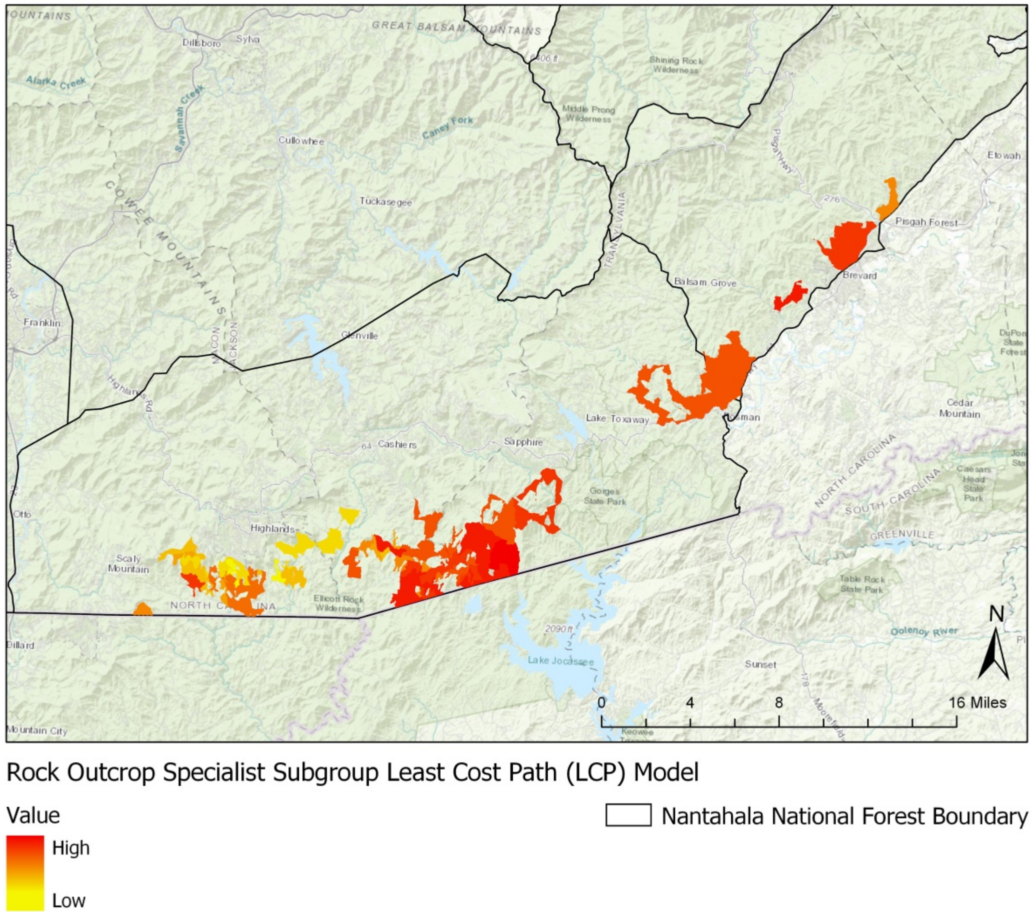

Figure 7. Map showing forest stands within the Nantahala National Forest containing least cost paths between cores for the Rock Outcrop Specialist Subgroup as determined by the Least Cost Path (LCP) Model. Stands containing paths with a higher priority value are red while stands containing paths with a lower priority value are yellow.

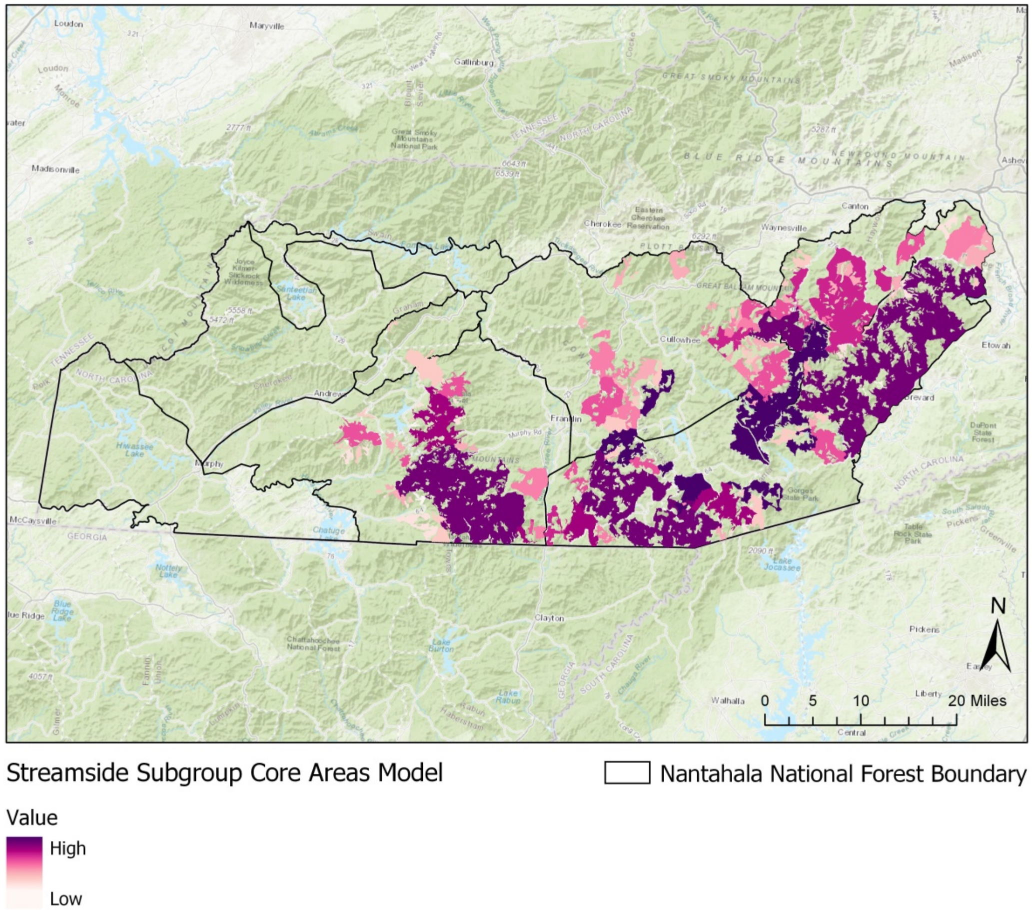

Figure 8. Map showing forest stands within the Nantahala National Forest containing core areas for the Streamside Subgroup as determined by the Core Area Model. Stands containing core areas with a higher priority value are dark purple while stands containing core areas with a lower priority value are light pink.

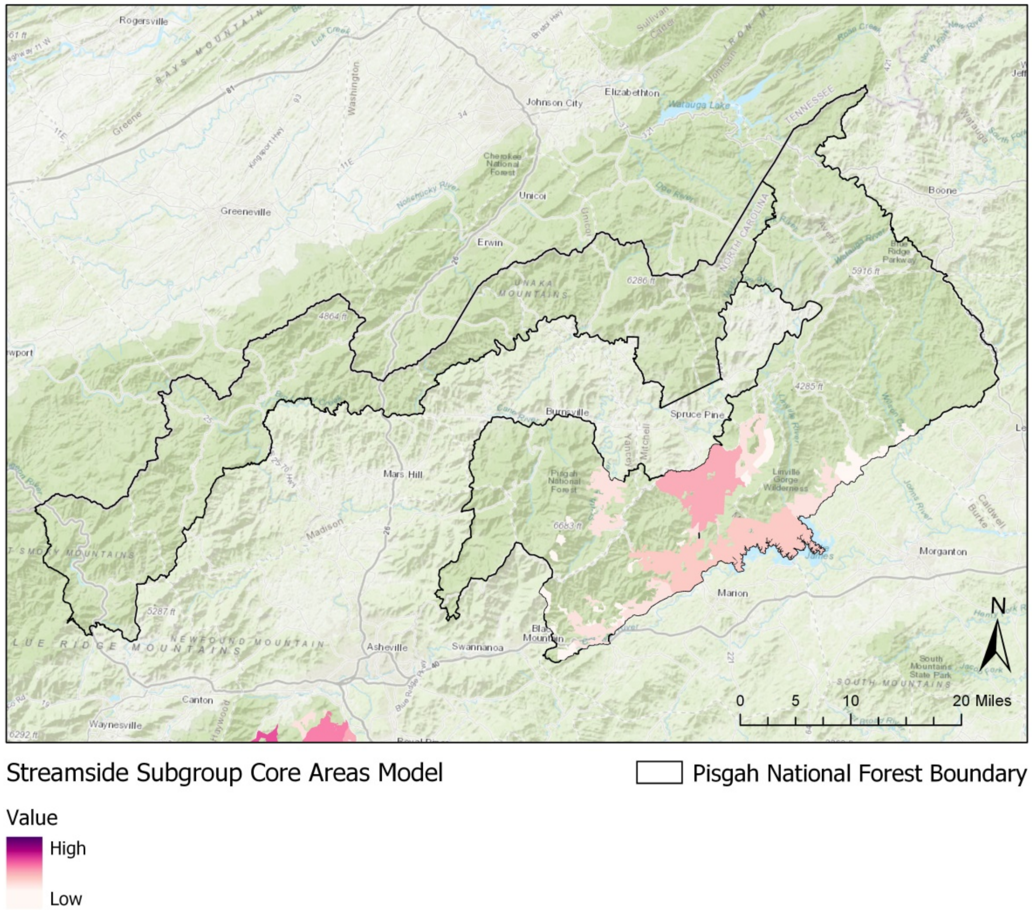

Figure 9. Map showing forest stands within the Pisgah National Forest containing core areas for the Streamside Subgroup as determined by the Core Area Model. Stands containing core areas with a higher priority value are dark purple while stands containing core areas with a lower priority value are light pink.

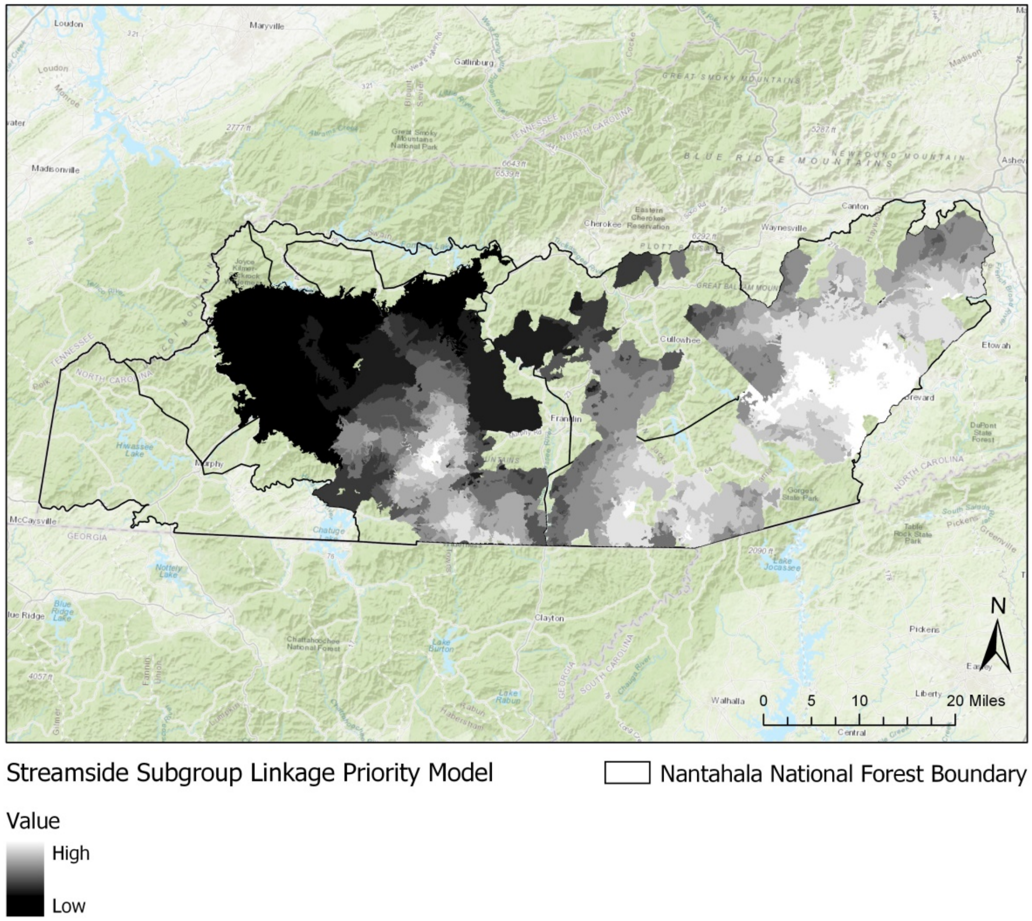

Figure 10. Map showing forest stands within the Nantahala National Forest containing linkages between cores for the Streamside Subgroup as determined by the Linkage Priority Model. Stands containing linkages with a higher priority value are white while stands containing linkages with a lower priority value are black.

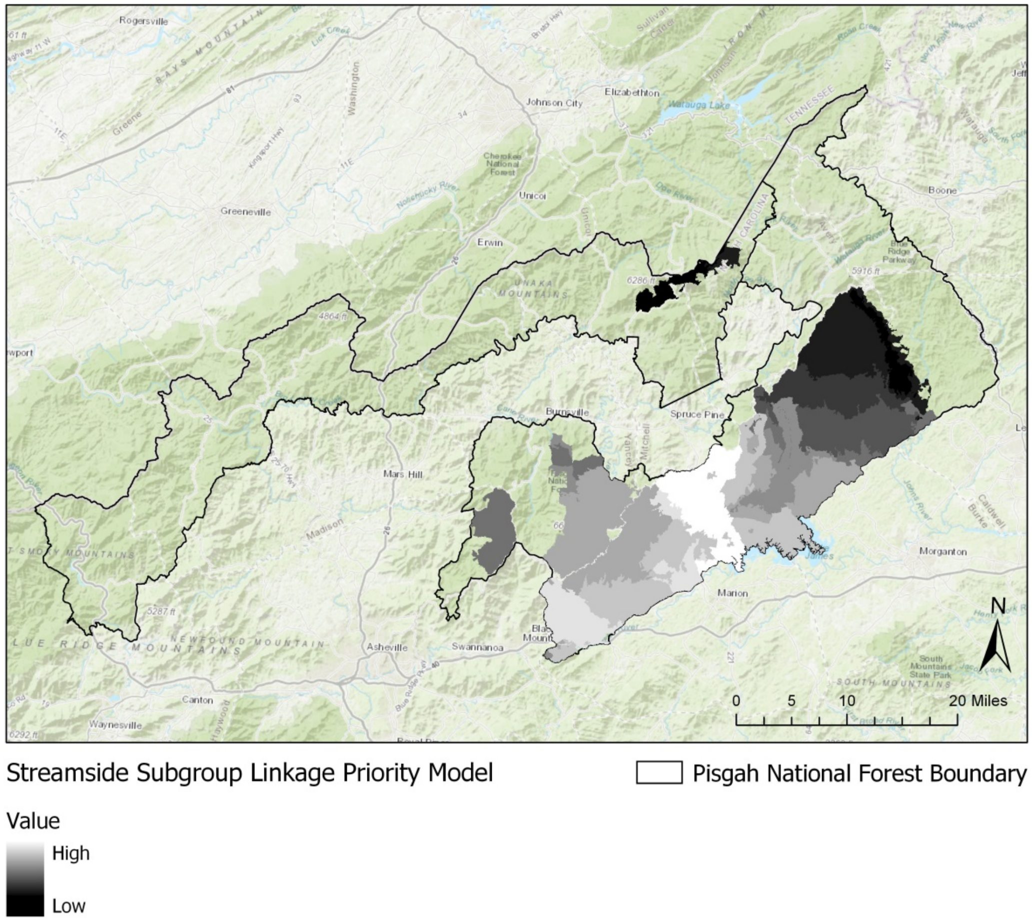

Figure 11. Map showing forest stands within the Pisgah National Forest containing linkages between cores for the Streamside Subgroup as determined by the Linkage Priority Model. Stands containing linkages with a higher priority value are white while stands containing linkages with a lower priority value are black.

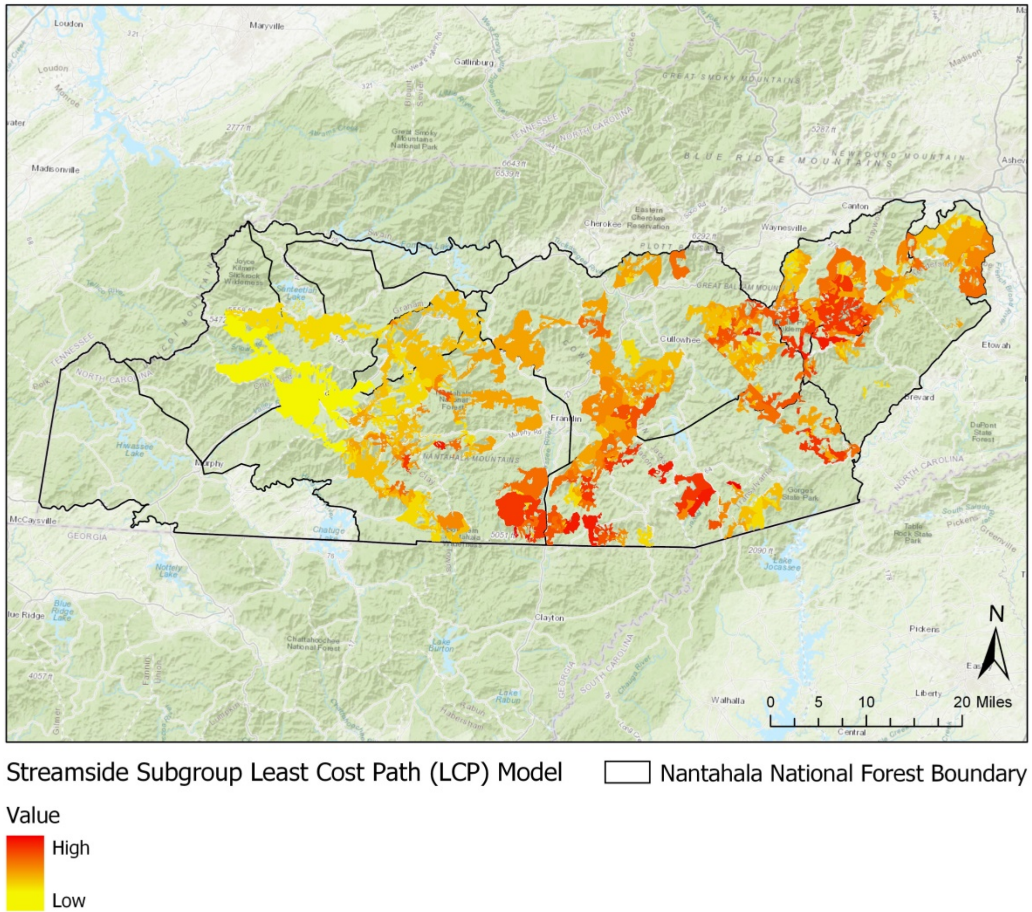

Figure 12. Map showing forest stands within the Nantahala National Forest containing least cost paths between cores for the Streamside Subgroup as determined by the Least Cost Path (LCP) Model. Stands containing paths with a higher priority value are red while stands containing paths with a lower priority value are yellow.

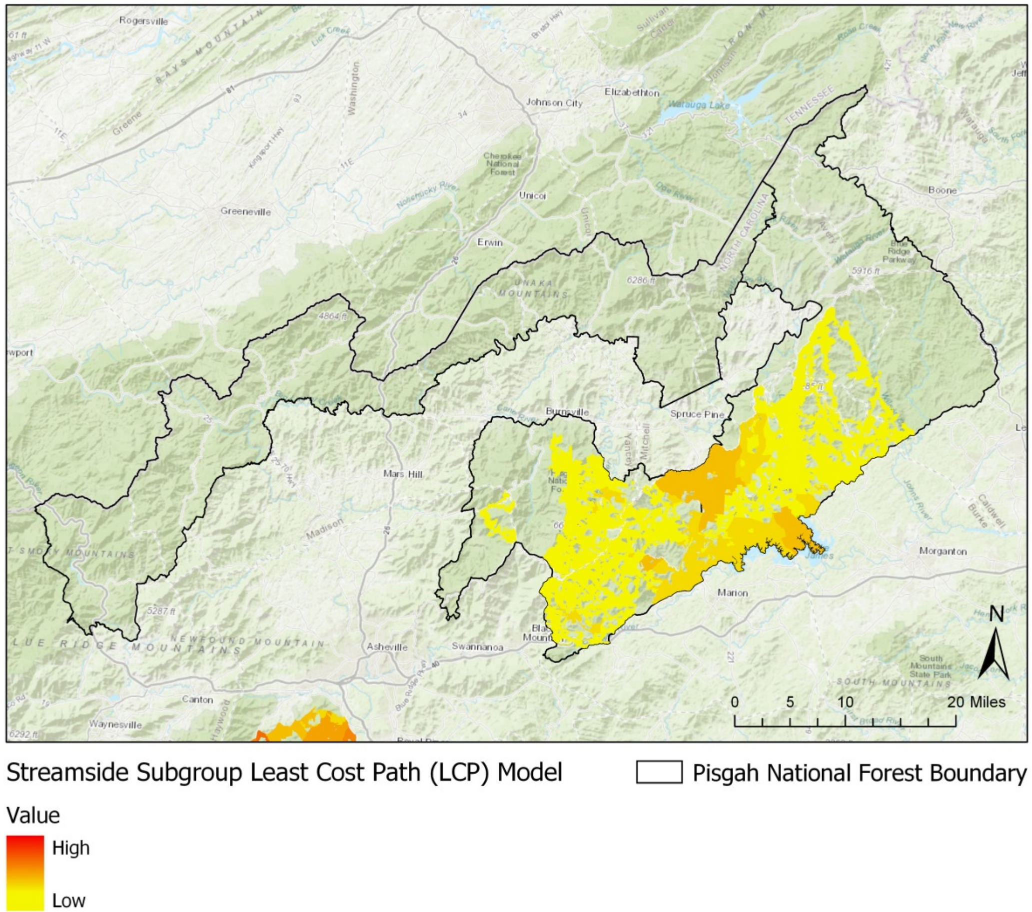

Figure 13. Map showing forest stands within the Pisgah National Forest containing least cost paths between cores for the Streamside Subgroup as determined by the Least Cost Path (LCP) Model. Stands containing paths with a higher priority value are red while stands containing paths with a lower priority value are yellow.

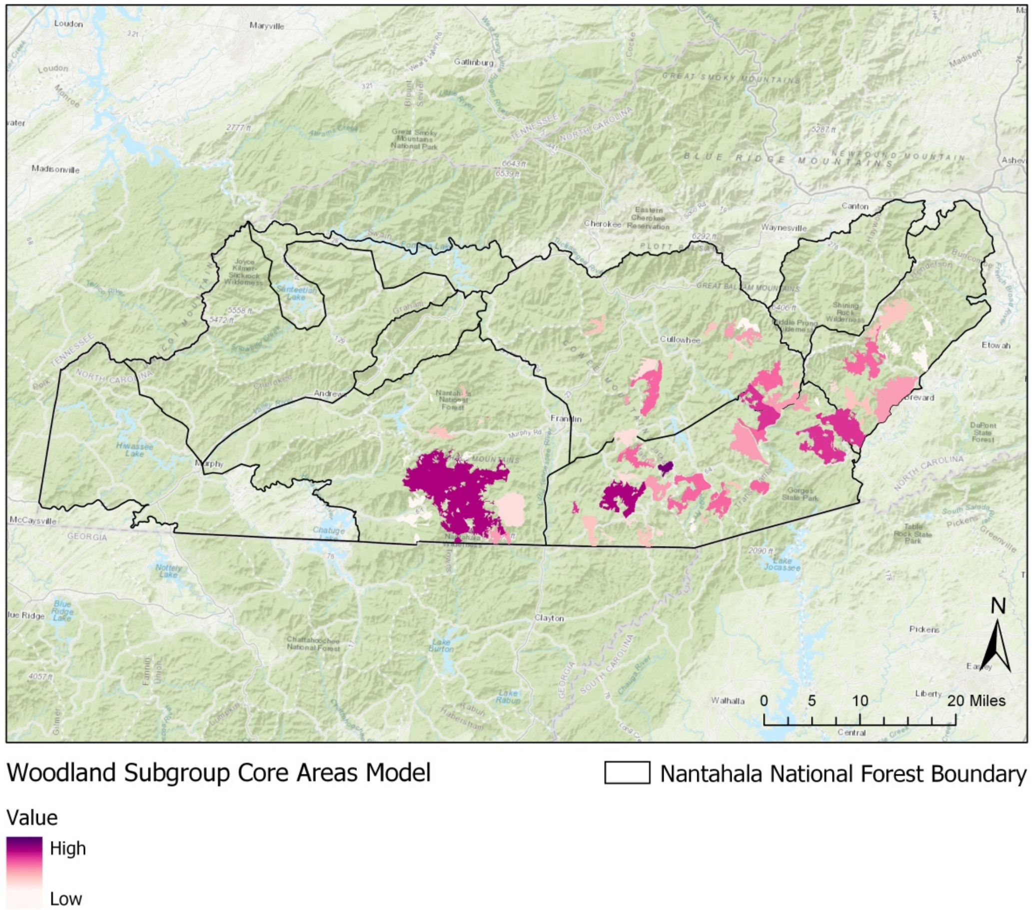

Figure 14. Map showing forest stands within the Nantahala National Forest containing core areas for the Woodland Subgroup as determined by the Core Area Model. Stands containing core areas with a higher priority value are dark purple while stands containing core areas with a lower priority value are light pink.

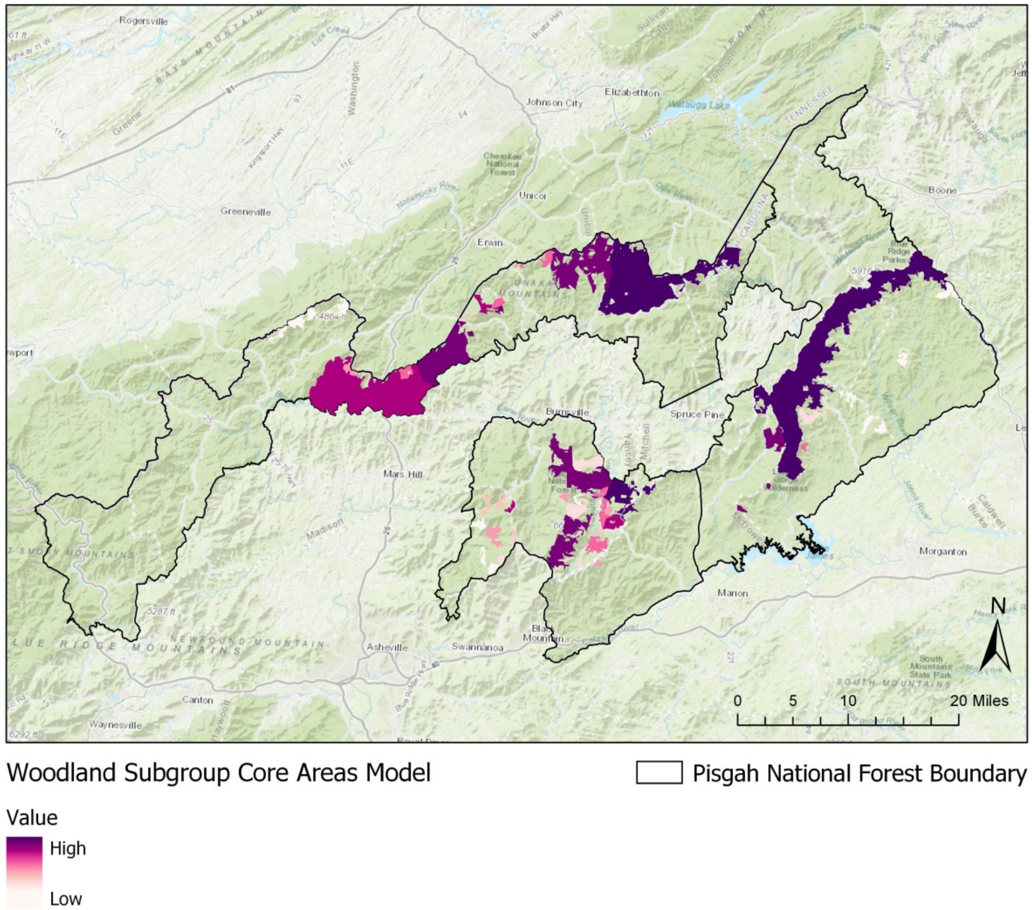

Figure 15. Map showing forest stands within the Pisgah National Forest containing core areas for the Woodland Subgroup as determined by the Core Area Model. Stands containing core areas with a higher priority value are dark purple while stands containing core areas with a lower priority value are light pink.

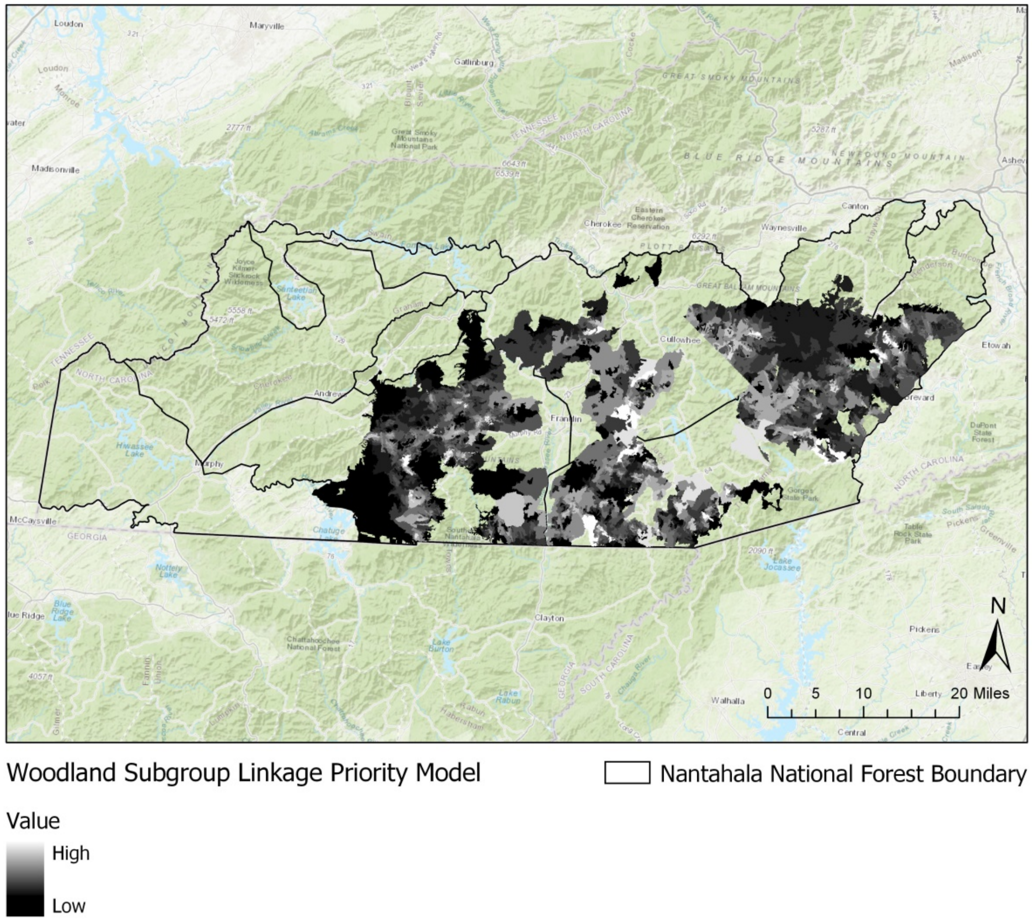

Figure 16. Map showing forest stands within the Nantahala National Forest containing linkages between cores for the Woodland Subgroup as determined by the Linkage Priority Model. Stands containing linkages with a higher priority value are white while stands containing linkages with a lower priority value are black.

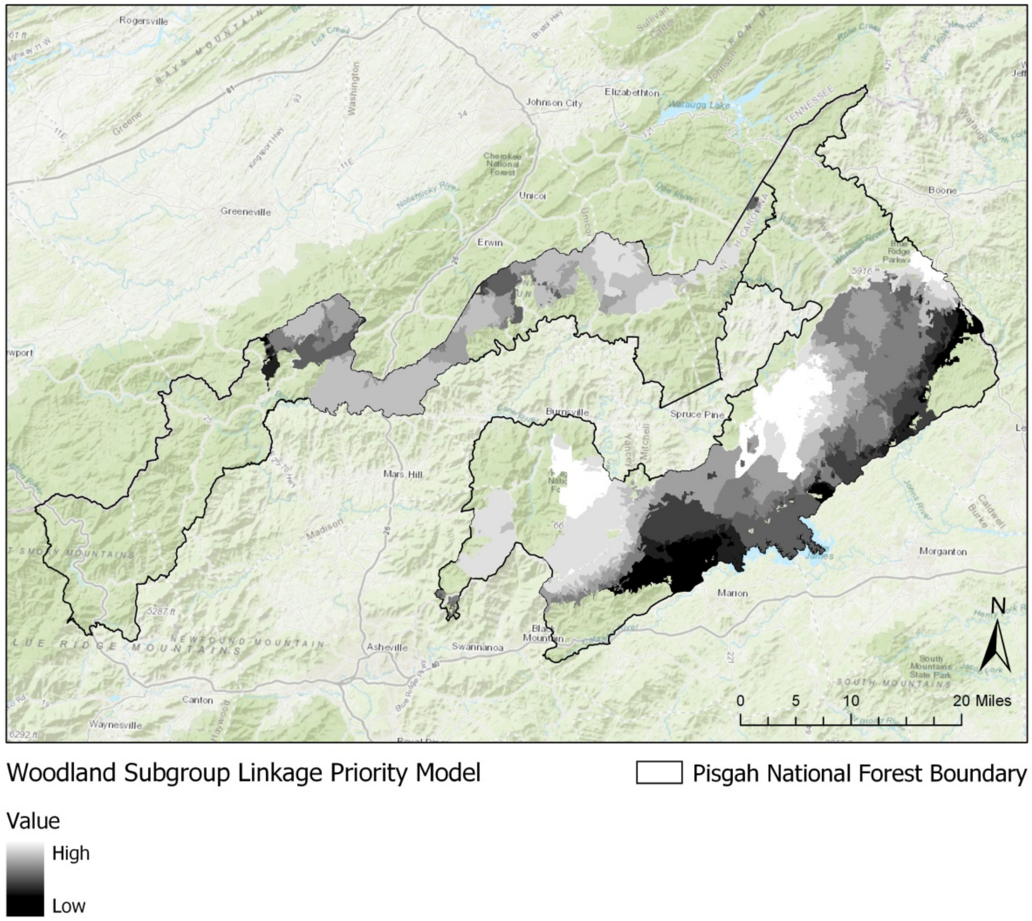

Figure 17. Map showing forest stands within the Pisgah National Forest containing linkages between cores for the Woodland Subgroup as determined by the Linkage Priority Model. Stands containing linkages with a higher priority value are white while stands containing linkages with a lower priority value are black.

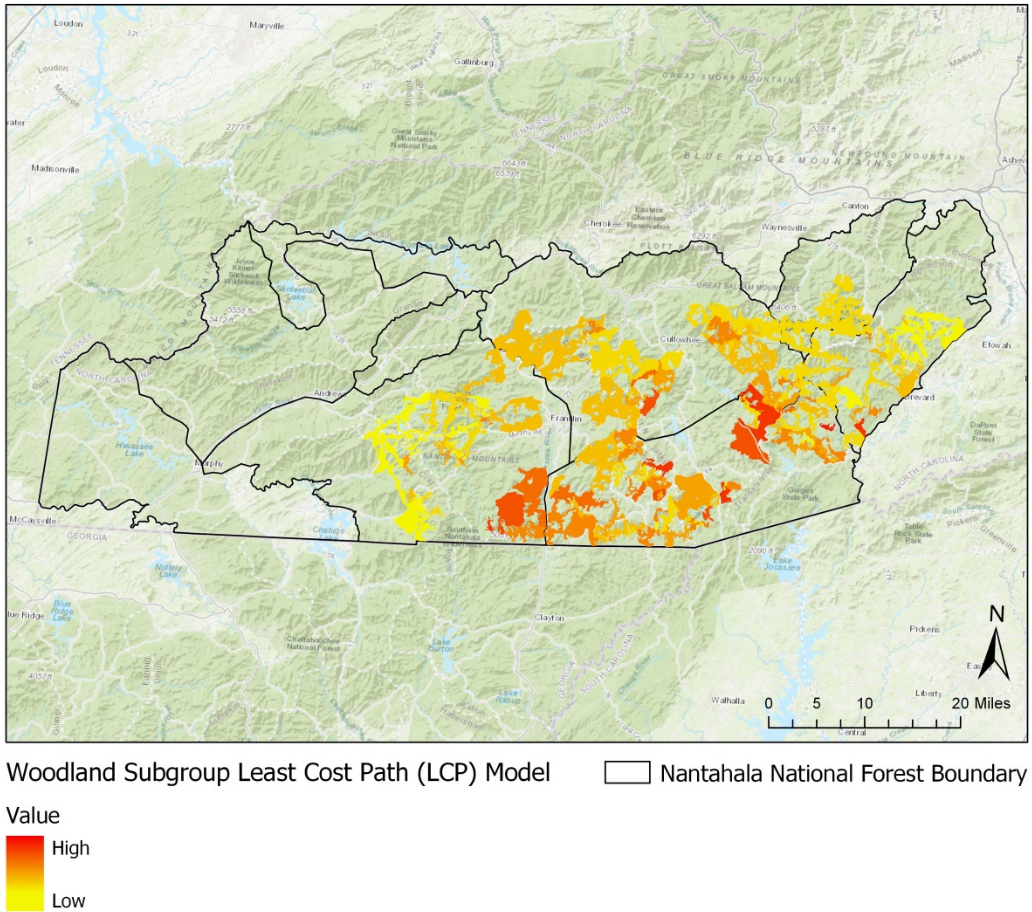

Figure 18. Map showing forest stands within the Nantahala National Forest containing least cost paths between cores for the Woodland Subgroup as determined by the Least Cost Path (LCP) Model. Stands containing paths with a higher priority value are red while stands containing paths with a lower priority value are yellow.

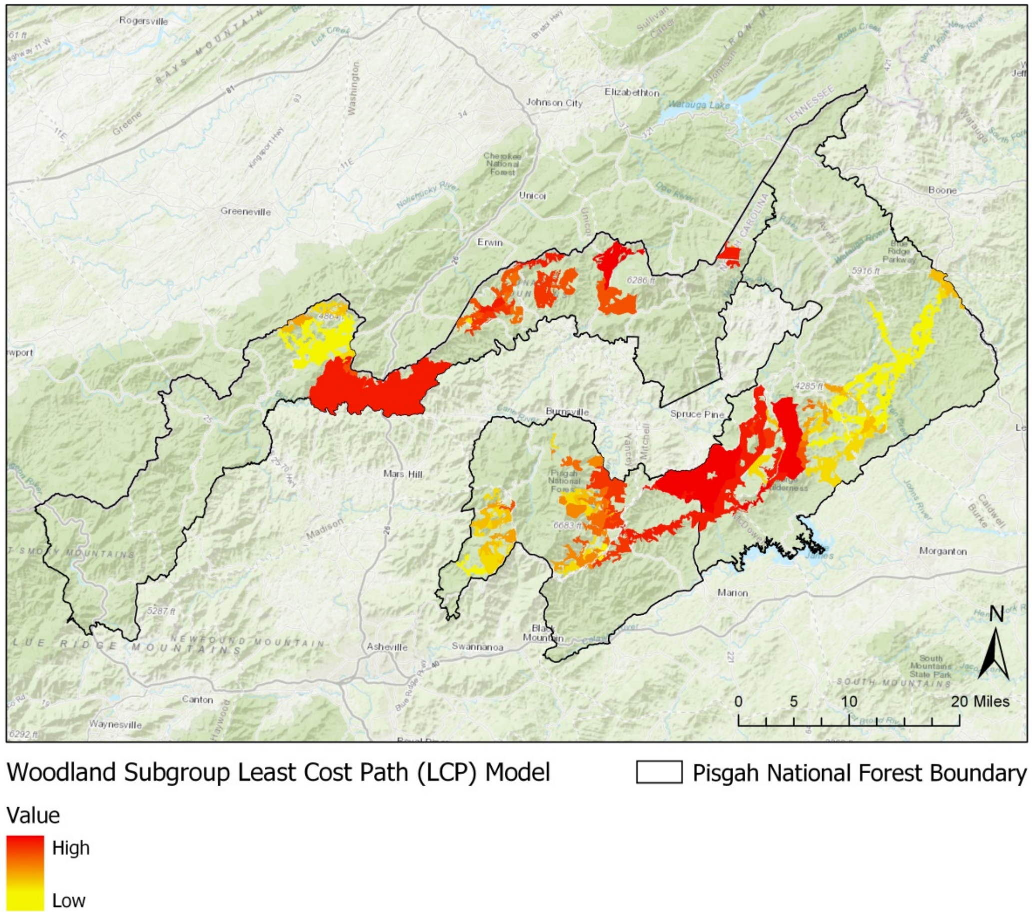

Figure 19. Map showing forest stands within the Pisgah National Forest containing least cost paths between cores for the Woodland Subgroup as determined by the Least Cost Path (LCP) Model. Stands containing paths with a higher priority value are red while stands containing paths with a lower priority value are yellow.

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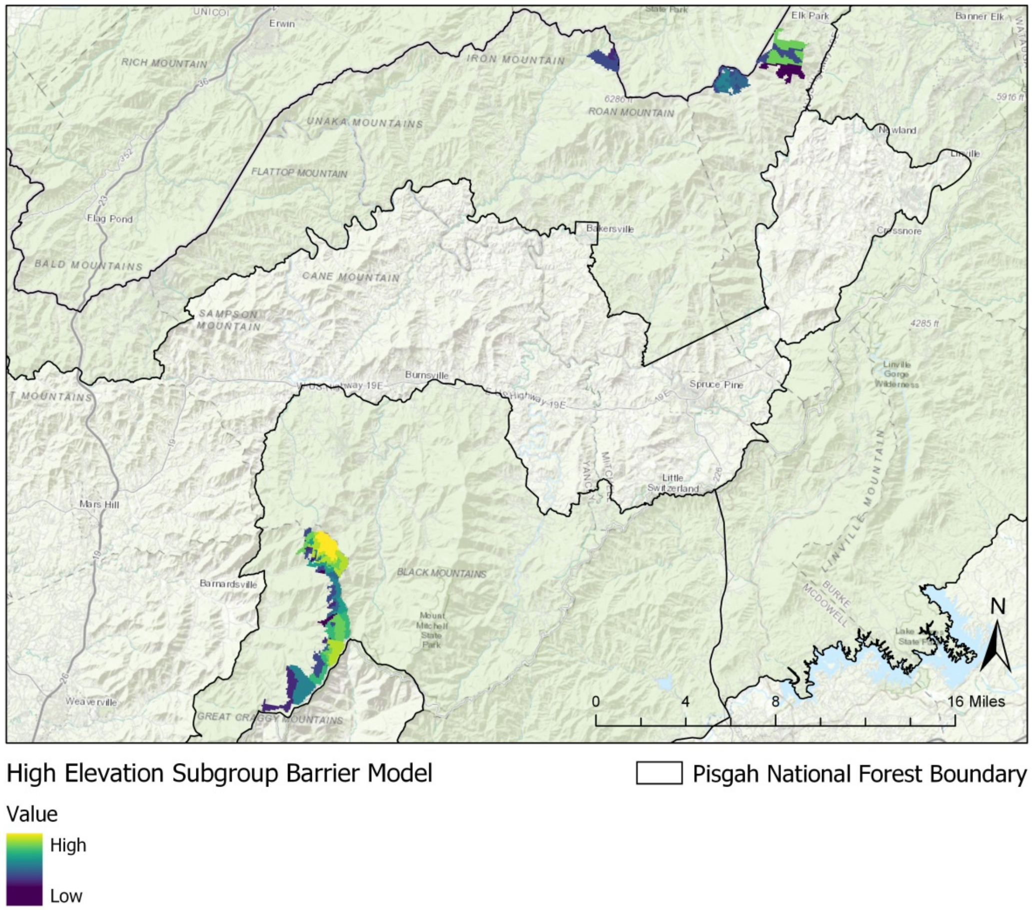
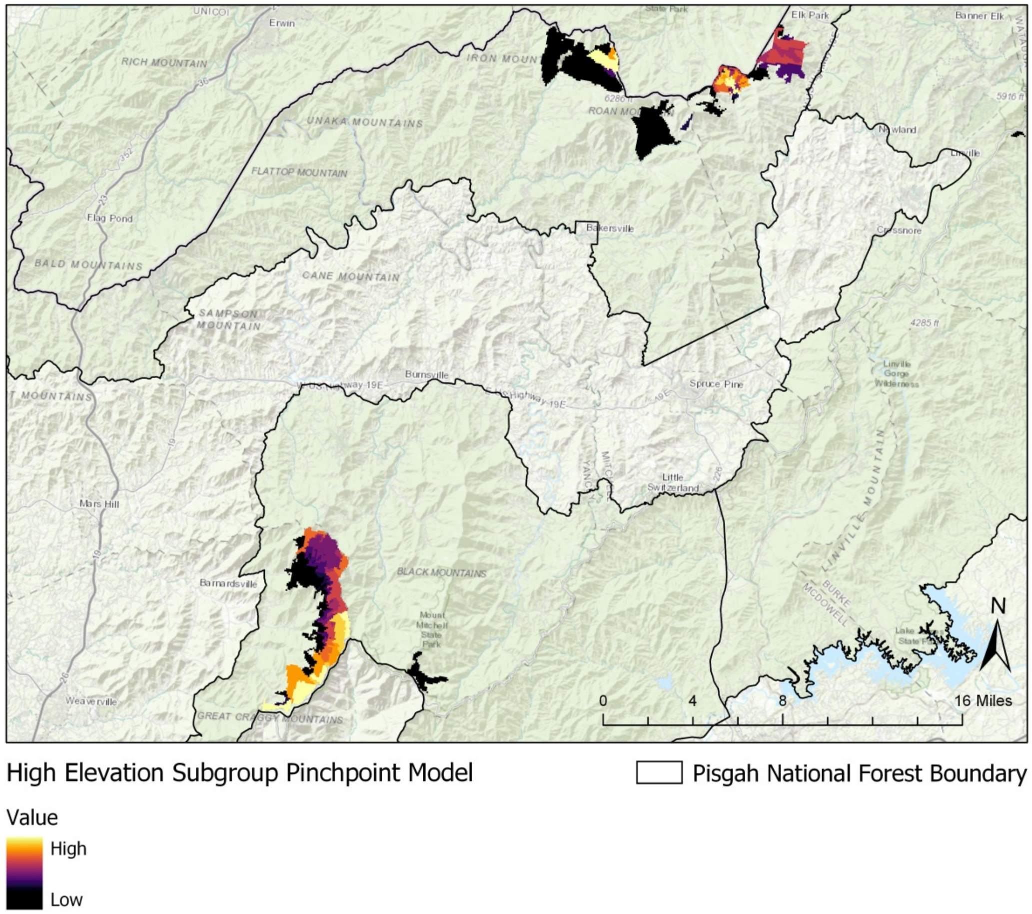
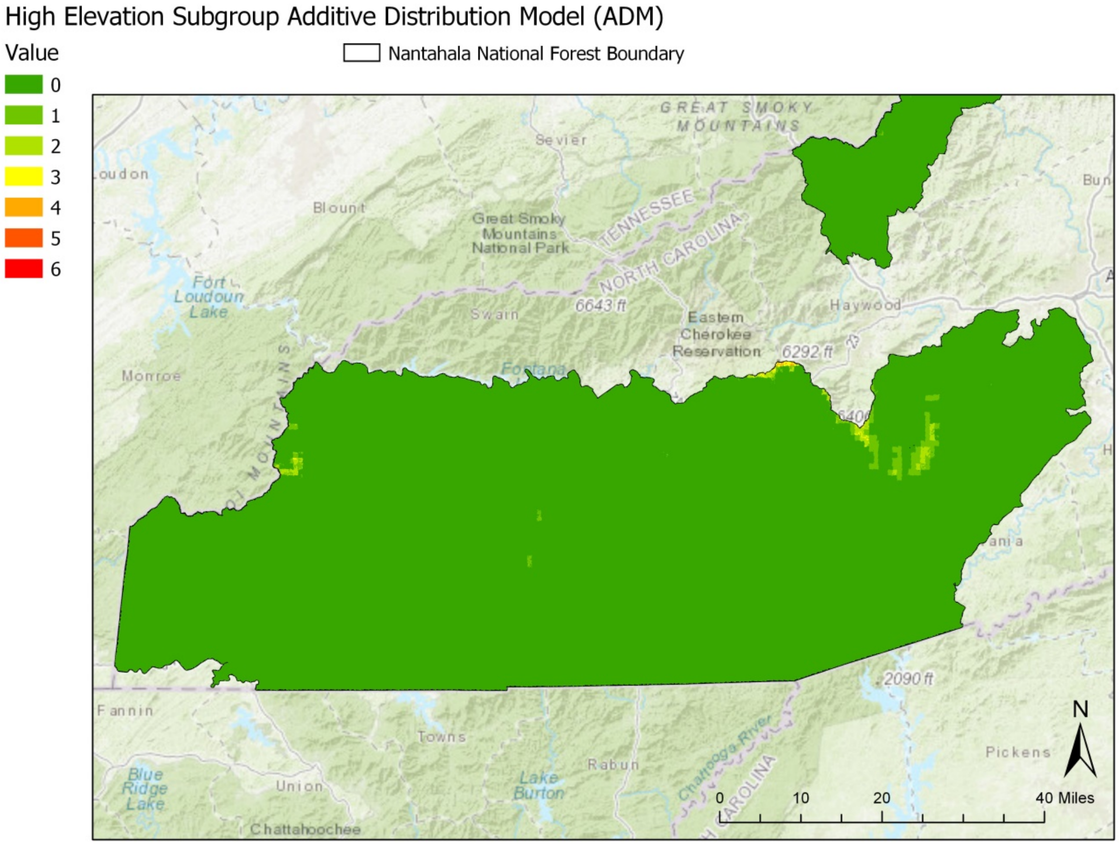
Appendix



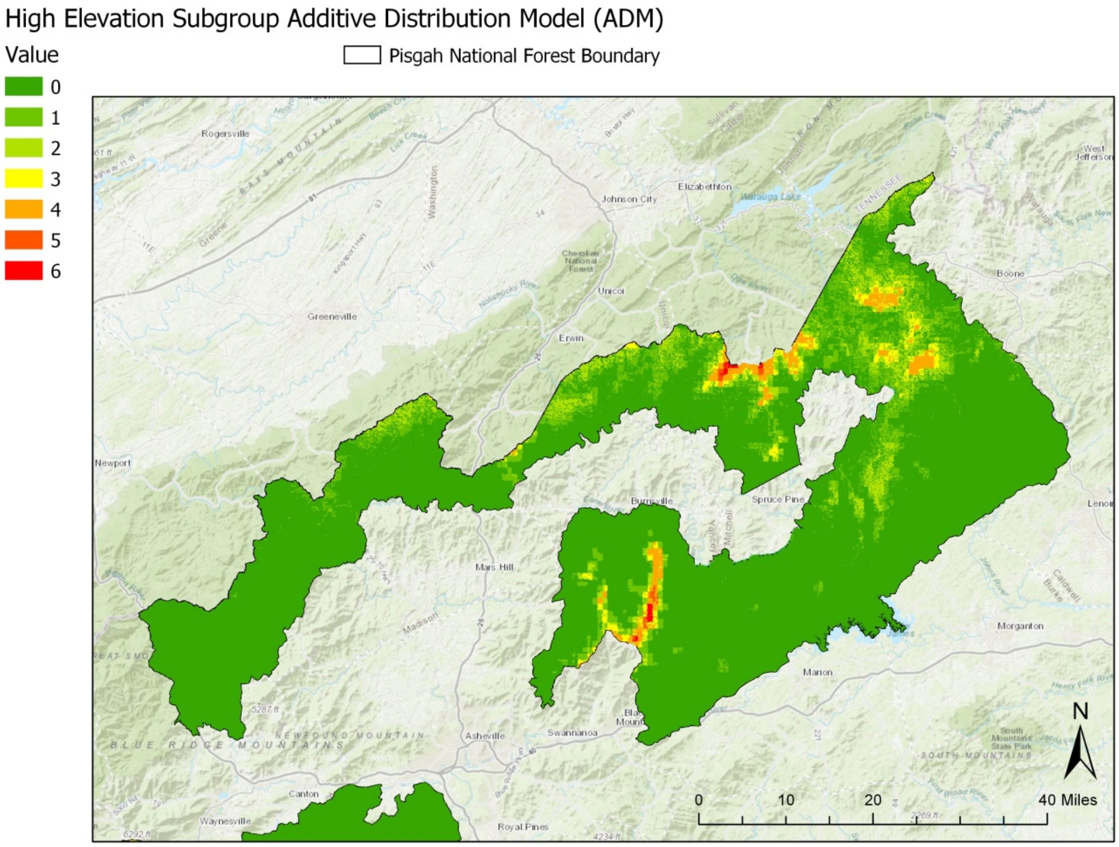
Supplementary Figure 1. Map showing forest stands within the Pisgah National Forest containing barrier centers for the High Elevation Subgroup as determined by the Barrier Model. Stands containing barrier centers with a higher value (corresponding to a higher reduction in least-cost distance per unit distance restored) are yellow while stands containing paths with a lower value (corresponding to a lower reduction in least-cost distance per unit distance restored) are dark blue.



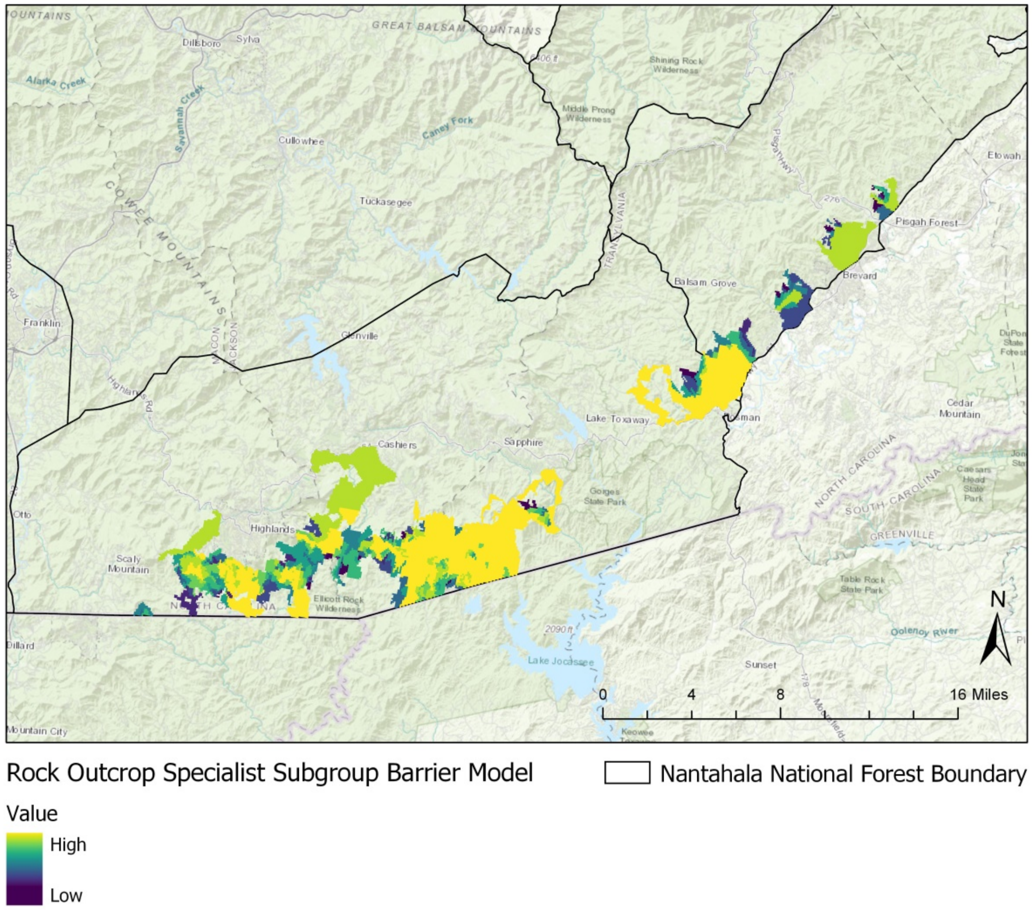
Supplementary Figure 2. Map showing forest stands within the Pisgah National Forest containing routes between cores for the High Elevation Subgroup. The value for these routes was determined using the Pinchpoint Model by running a current between cores and determining the relative resistance value of each route. Stands containing routes with a higher value (corresponding to a low resistance) are yellow while stands with a lower value (corresponding to a high resistance) are black.



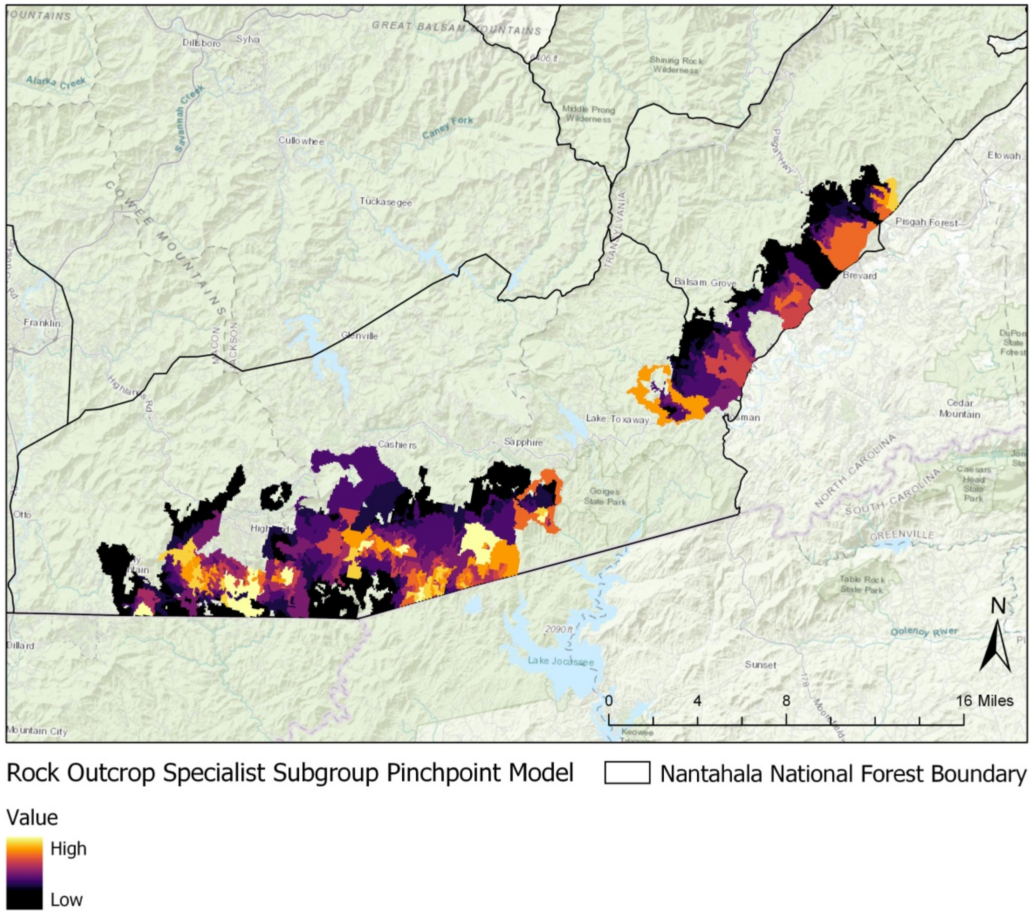
Supplementary Figure 3. Map showing the results of the Additive Distribution Model (ADM) for the High Elevation Subgroup in the Nantahala National Forest. Pixels with high values correspond to more suitable habitat and are red, while pixels with low values correspond to less suitable habitat and are green.



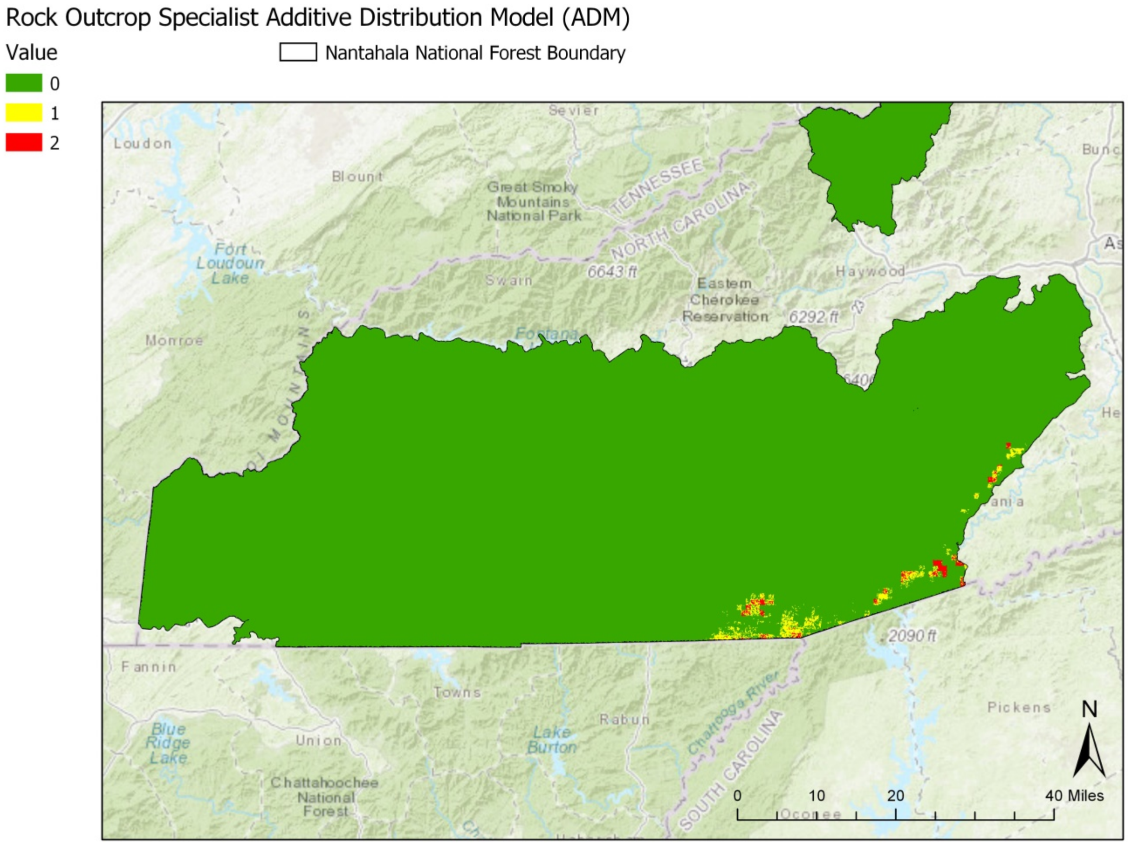
Supplementary Figure 4. Map showing the results of the Additive Distribution Model (ADM) for the High Elevation Subgroup in the Pisgah National Forest. Pixels with high values correspond to more suitable habitat and are red, while pixels with low values correspond to less suitable habitat and are green.



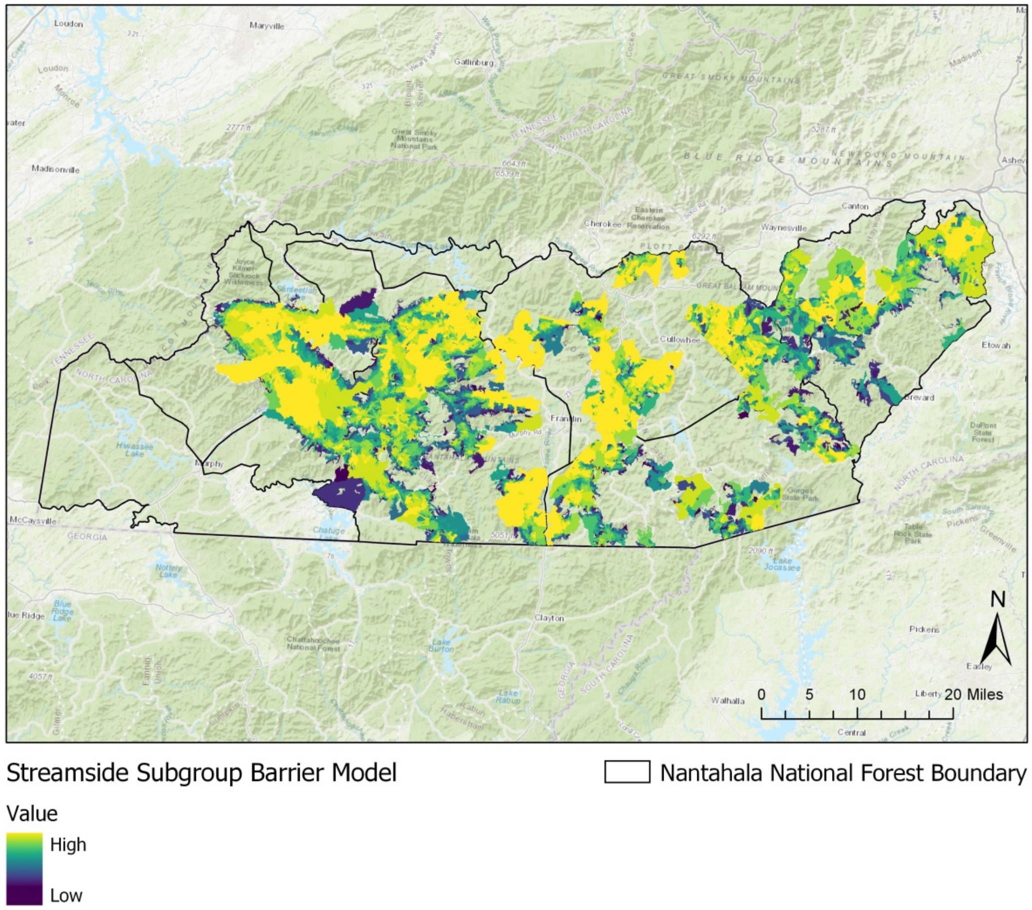
Supplementary Figure 5. Map showing forest stands within the Nantahala National Forest containing barrier centers for the Rock Outcrop Specialist as determined by the Barrier Model. Stands containing barrier centers with a higher value (corresponding to a higher reduction in least-cost distance per unit distance restored) are yellow while stands containing paths with a lower value (corresponding to a lower reduction in least-cost distance per unit distance restored) are dark blue.



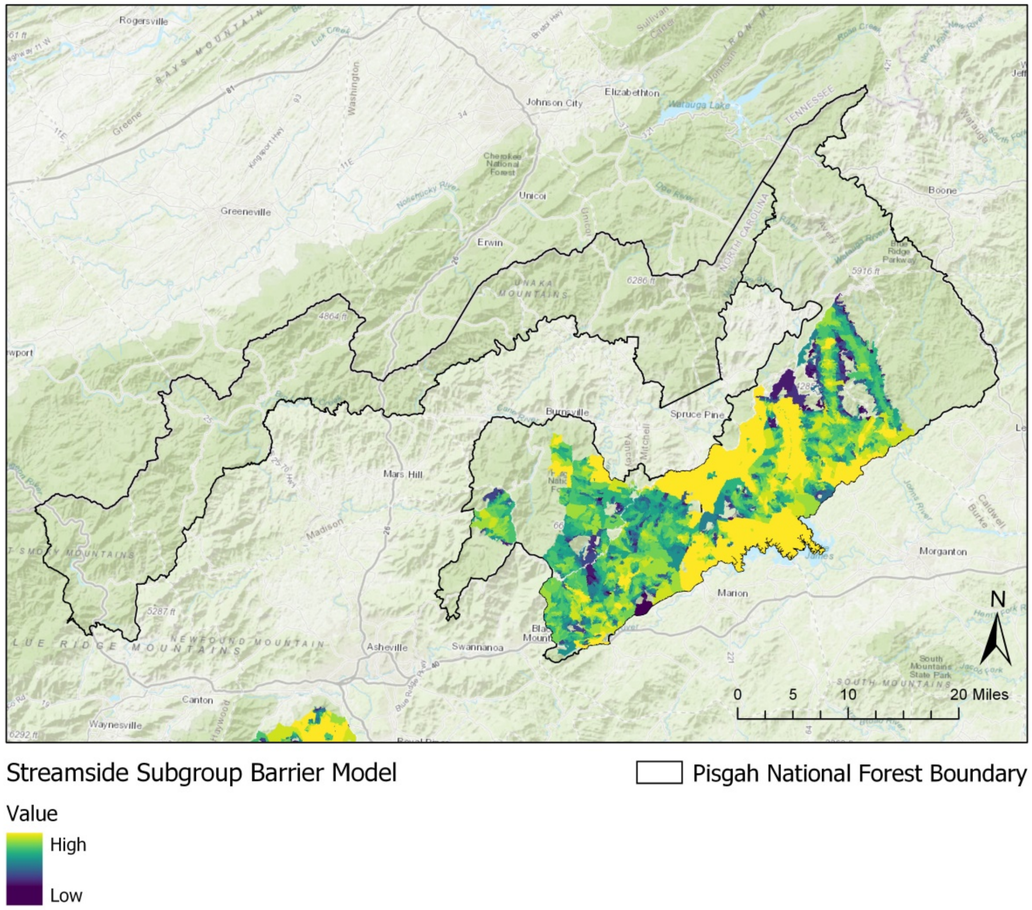
Supplementary Figure 6. Map showing forest stands within the Nantahala National Forest containing routes between cores for the Rock Outcrop Specialist Subgroup. The value for these routes was determined using the Pinchpoint Model by running a current between cores and determining the relative resistance value of each route. Stands containing routes with a higher value (corresponding to a low resistance) are yellow while stands with a lower value (corresponding to a high resistance) are black.



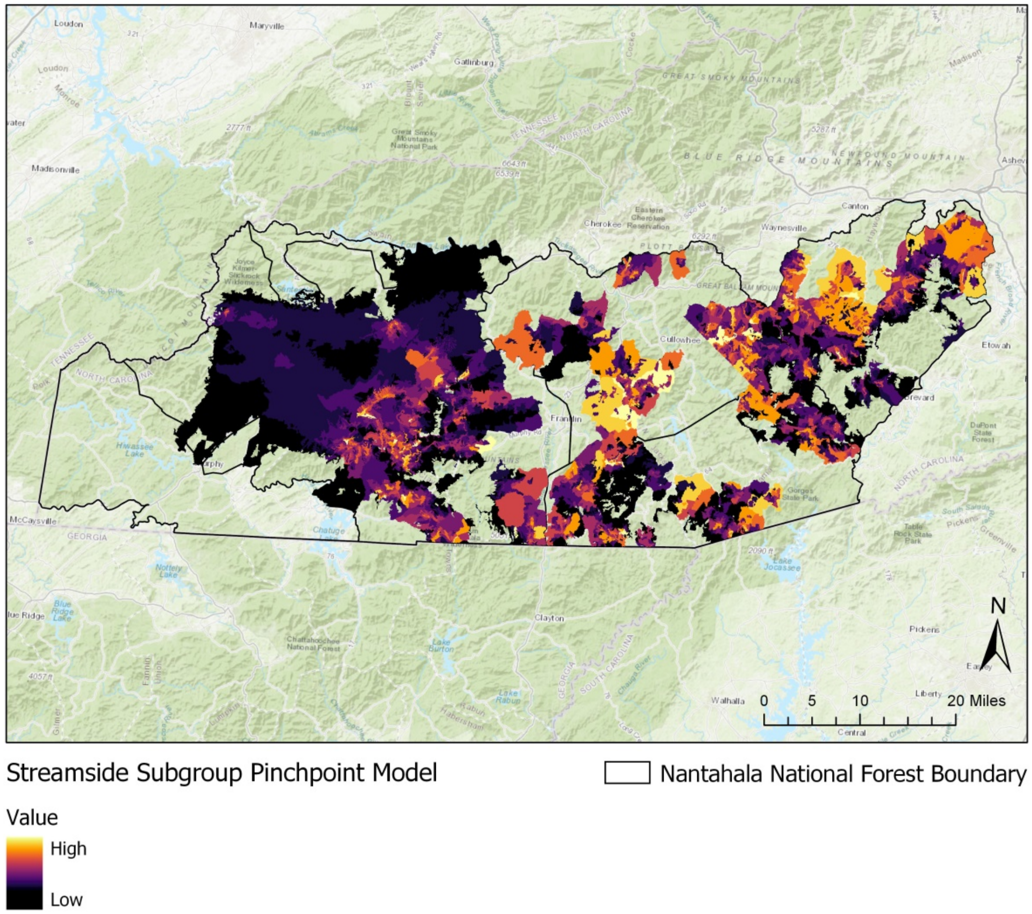
Supplementary Figure 7. Map showing the results of the Additive Distribution Model (ADM) for the Rock Outcrop Specialist Subgroup in the Nantahala National Forest. Pixels with high values correspond to more suitable habitat and are red, while pixels with low values correspond to less suitable habitat and are green.



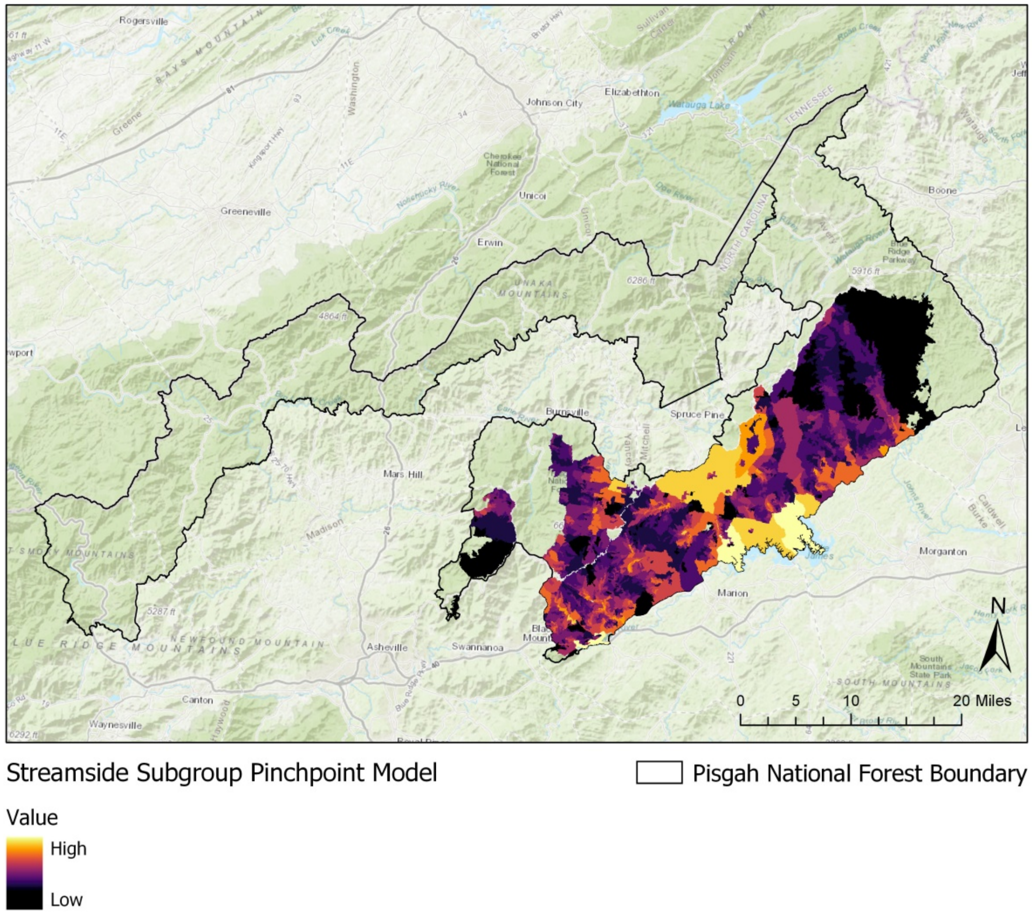
Supplementary Figure 8. Map showing forest stands within the Nantahala National Forest containing barrier centers for the Streamside Subgroup as determined by the Barrier Model. Stands containing barrier centers with a higher value (corresponding to a higher reduction in least-cost distance per unit distance restored) are yellow while stands containing paths with a lower value (corresponding to a lower reduction in least-cost distance per unit distance restored) are dark blue.



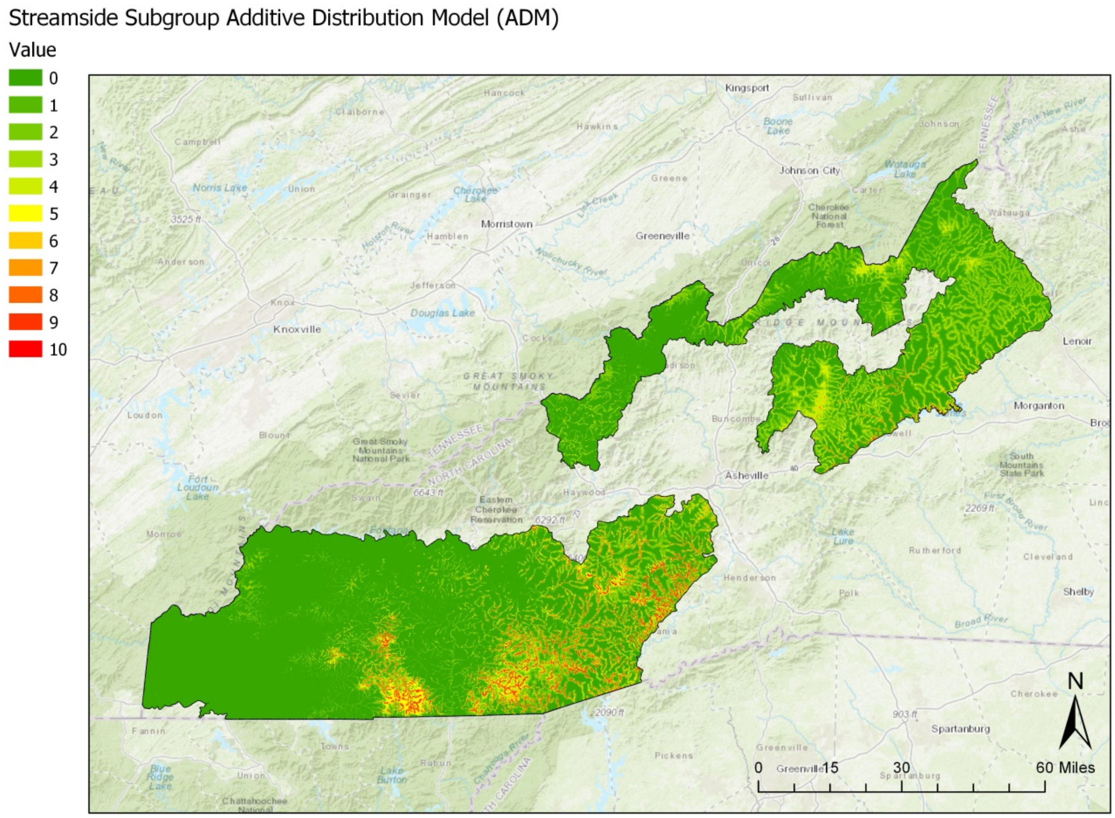
Supplementary Figure 9. Map showing forest stands within the Pisgah National Forest containing barrier centers for the Streamside Subgroup as determined by the Barrier Model. Stands containing barrier centers with a higher value (corresponding to a higher reduction in least-cost distance per unit distance restored) are yellow while stands containing paths with a lower value (corresponding to a lower reduction in least-cost distance per unit distance restored) are dark blue.



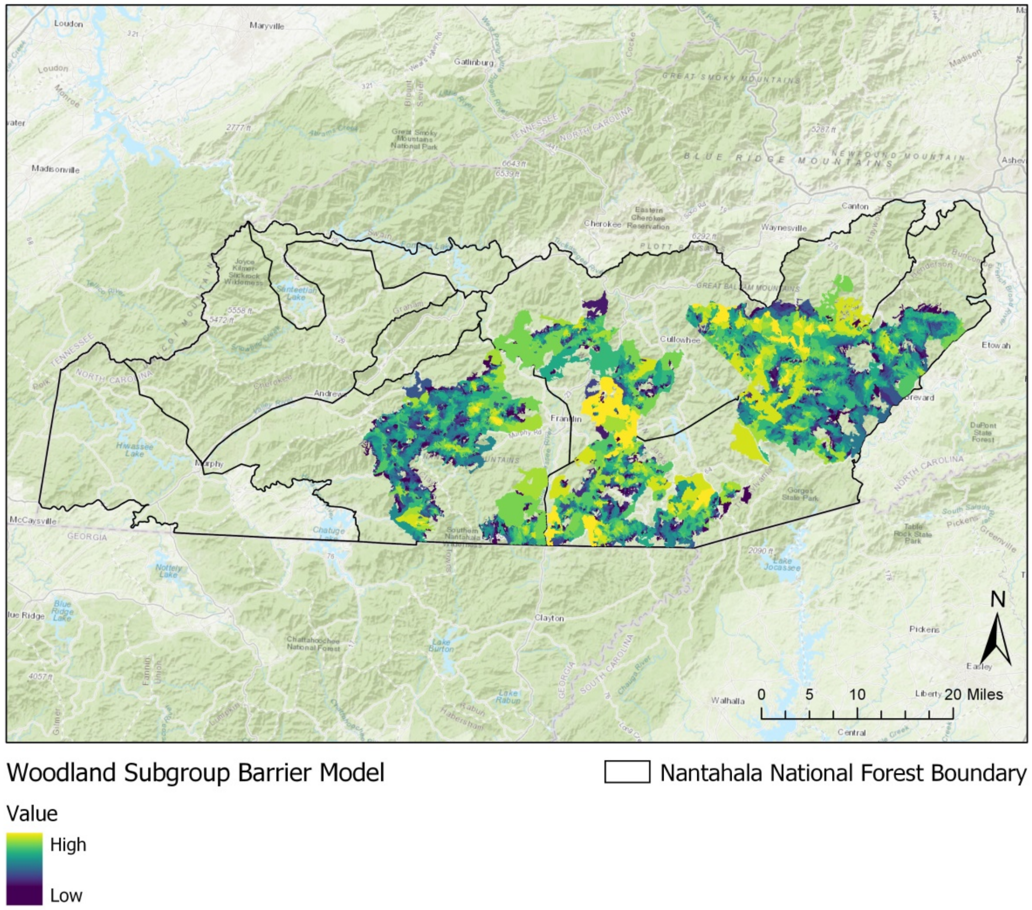
Supplementary Figure 10. Map showing forest stands within the Nantahala National Forest containing routes between cores for the Streamside Subgroup. The value for these routes was determined using the Pinchpoint Model by running a current between cores and determining the relative resistance value of each route. Stands containing routes with a higher value (corresponding to a low resistance) are yellow while stands with a lower value (corresponding to a high resistance) are black.



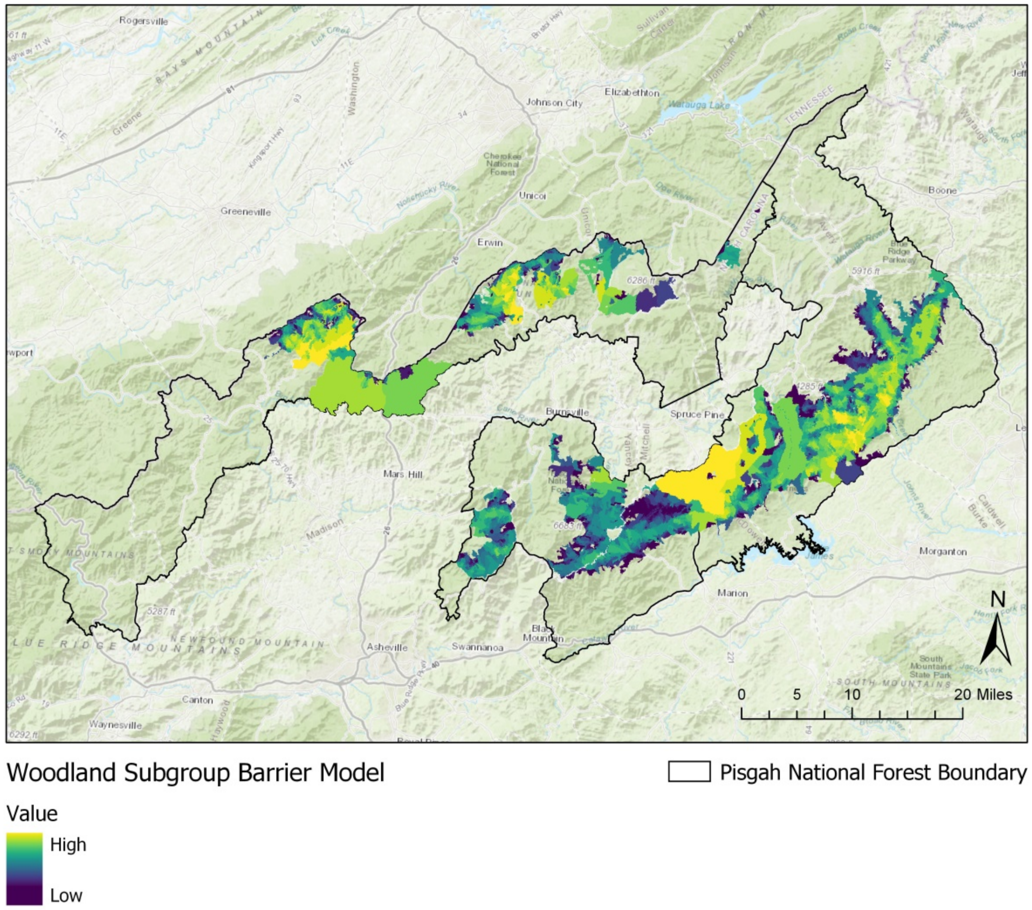
Supplementary Figure 11. Map showing forest stands within the Pisgah National Forest containing routes between cores for the Streamside Subgroup. The value for these routes was determined using the Pinchpoint Model by running a current between cores and determining the relative resistance value of each route. Stands containing routes with a higher value (corresponding to a low resistance) are yellow while stands with a lower value (corresponding to a high resistance) are black.



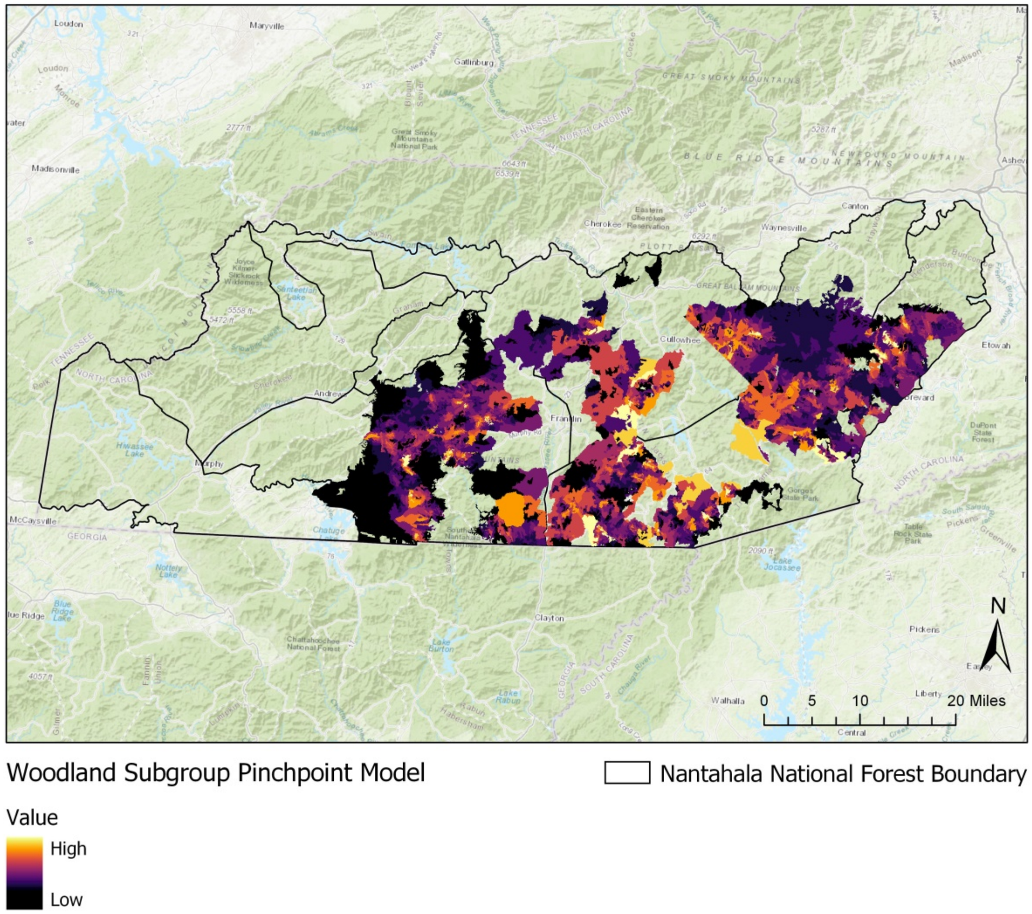
Supplementary Figure 12. Map showing the results of the Additive Distribution Model (ADM) for the Streamside Subgroup in the Nantahala and Pisgah National Forests. Pixels with high values correspond to more suitable habitat and are red, while pixels with low values correspond to less suitable habitat and are green.



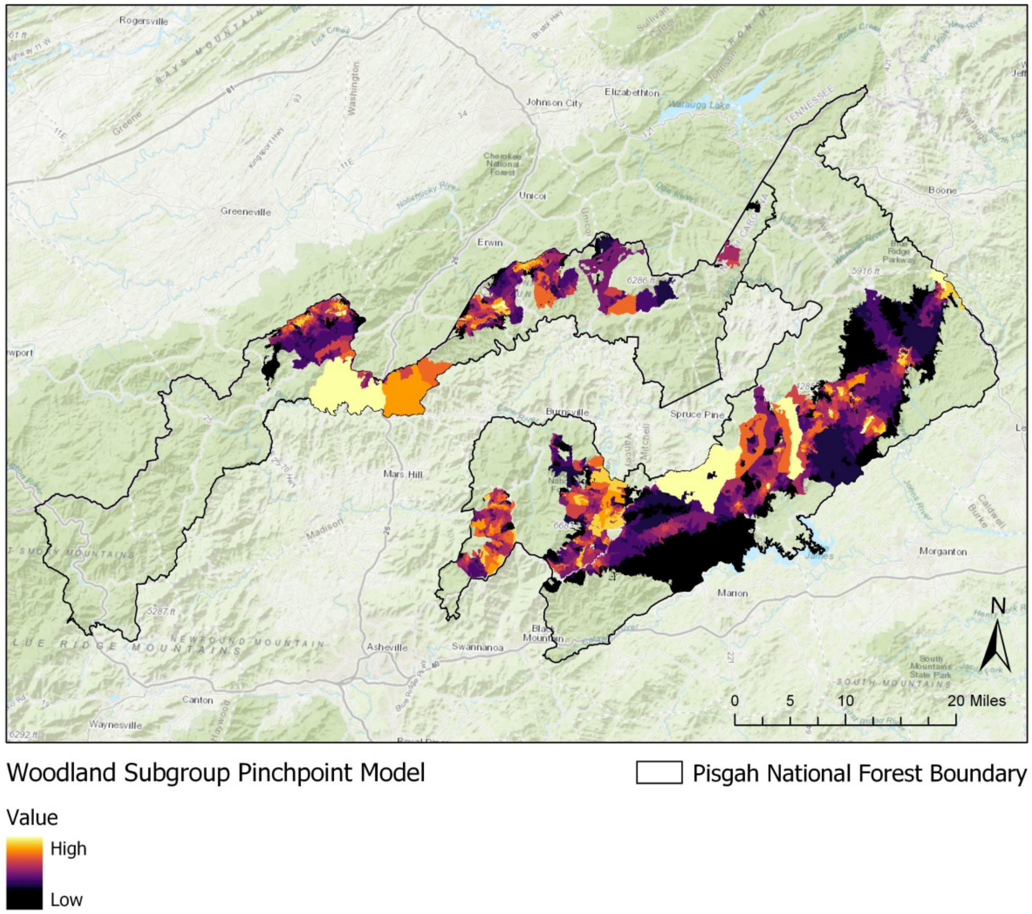
Supplementary Figure 13. Map showing forest stands within the Nantahala National Forest containing barrier centers for the Woodland Subgroup as determined by the Barrier Model. Stands containing barrier centers with a higher value (corresponding to a higher reduction in least-cost distance per unit distance restored) are yellow while stands containing paths with a lower value (corresponding to a lower reduction in least-cost distance per unit distance restored) are dark blue.



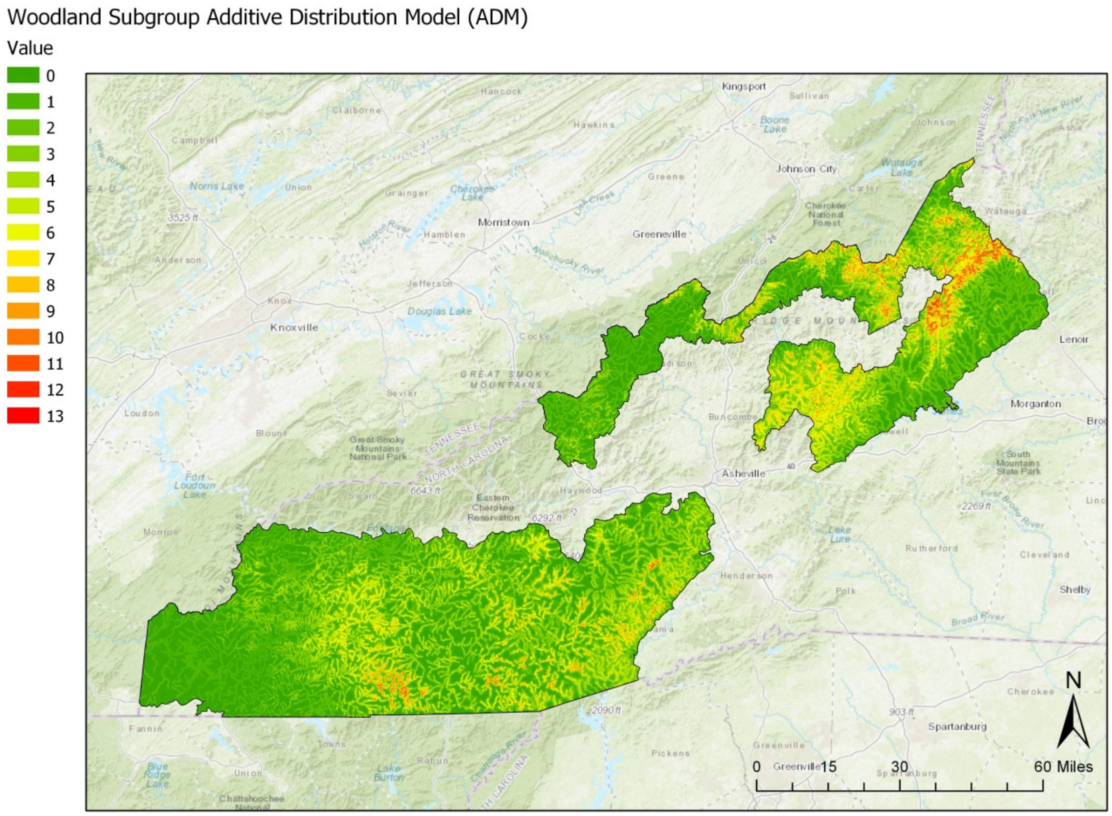
Supplementary Figure 14. Map showing forest stands within the Pisgah National Forest containing barrier centers for the Woodland Subgroup as determined by the Barrier Model. Stands containing barrier centers with a higher value (corresponding to a higher reduction in least-cost distance per unit distance restored) are yellow while stands containing paths with a lower value (corresponding to a lower reduction in least-cost distance per unit distance restored) are dark blue.



Supplementary Figure 15. Map showing forest stands within the Nantahala National Forest containing routes between cores for the Woodland Subgroup. The value for these routes was determined using the Pinchpoint Model by running a current between cores and determining the relative resistance value of each route. Stands containing routes with a higher value (corresponding to a low resistance) are yellow while stands with a lower value (corresponding to a high resistance) are black.



Supplementary Figure 16. Map showing forest stands within the Pisgah National Forest containing routes between cores for the Woodland Subgroup. The value for these routes was determined using the Pinchpoint Model by running a current between cores and determining the relative resistance value of each route. Stands containing routes with a higher value (corresponding to a low resistance) are yellow while stands with a lower value (corresponding to a high resistance) are black.



Supplementary Figure 17. Map showing the results of the Additive Distribution Model (ADM) for the Woodland Subgroup in the Nantahala and Pisgah National Forests. Pixels with high values correspond to more suitable habitat and are red, while pixels with low values correspond to less suitable habitat and are green.

Attachment 15

Forestwide Road Density Summary

Calculating Road Density for ESE *
(miles of road per square mile of forest)

On NP:		NP Density
other miles	448.225265	0.275726628
FS miles	2554.069817	1.571140928
TOTAL:	3002.295082	1.846867557

FS Lands

<------------ FOREST SERVICE ROADS ------------>

Ecozone (EZ)	total acres	total square miles	total road miles	"other" miles**	open, paved road miles	open, unpaved road miles	total seasonal road miles	motorized trail miles	total road density	total road + motorized trail density	open, paved road density	open, unpaved road density	motorized trail density	seasonal road density	seasonal +10%	% EZ ac (FW)
acidic cove	249,253.17	389.46	612.54	179.36	26.72	310.68	92.22	3.55	1.5728	1.5819	0.5292	0.7977	0.0091	0.2368	0.2605	0.239576
dry oak	49,260.19	76.97	63.90	14.99	0.75	30.15	8.65	9.36	0.8302	0.9519	0.2045	0.3917	0.1216	0.1124	0.1236	0.047348
dry-mesic oak	103,187.28	161.23	192.44	43.35	5.61	110.35	30.02	3.11	1.1936	1.2128	0.3037	0.6844	0.0193	0.1862	0.2048	0.099181
floodplain	2,341.95	3.66	17.29	8.72	2.43	3.01	3.13	0.00	4.7258	4.7258	3.0488	0.8229	0.0000	0.8541	0.9395	0.002251
high elevation red oak	40,188.27	62.79	49.54	4.01	4.69	31.02	8.26	1.56	0.7889	0.8138	0.1386	0.4939	0.0249	0.1315	0.1446	0.038628
mesic oak	177,269.69	276.98	278.34	50.63	6.30	162.69	48.59	10.13	1.0049	1.0415	0.2055	0.5874	0.0366	0.1754	0.1930	0.170387
northern hardwood	53,564.16	83.69	282.00	14.61	33.59	157.27	76.50	0.03	3.3695	3.3698	0.5759	1.8791	0.0003	0.9141	1.0055	0.051485
pine-oak heath	103,843.98	162.26	127.93	27.35	0.83	75.74	16.16	7.86	0.7884	0.8369	0.1737	0.4668	0.0484	0.0996	0.1095	0.099812
rich cove	199,477.01	311.68	351.91	73.87	1.59	203.58	60.11	12.75	1.1291	1.1700	0.2421	0.6532	0.0409	0.1929	0.2121	0.191732
shortleaf pine	46,478.77	72.62	109.87	26.39	2.44	58.70	21.61	0.73	1.5129	1.5229	0.3970	0.8083	0.0101	0.2976	0.3273	0.044674
spruce-fir	15,528.95	24.26	10.26	4.24	2.83	1.94	1.25	0.00	0.4230	0.4230	0.2914	0.0799	0.0000	0.0516	0.0568	0.014926
	1,040,393.42	*1,625.61*	*2,096.02*	*447.52*	*87.79*	*1,145.13*	*366.50*	*49.08*	*1.2894*	*1.3196*	*0.3293*	*0.7044*	*0.0302*	*0.2255*		

** Based on 2018 forest roads data and condensed PNV 3rd approximation (Kauffman).*

*** Other roads (State, NPS, etc.): assume all are paved and open year-round*

All Lands

Ecozone (EZ)	total acres	total square miles	total road miles	"other" miles**	open, paved road miles	open, unpaved road miles	total seasonal road miles	motorized trail miles	total road density	total road + motorized trail density	open, paved road density	open, unpaved road density	motorized trail density	seasonal road density
acidic cove		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
dry oak		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
dry-mesic oak		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
floodplain		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
high elevation red oak		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
mesic oak		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
northern hardwood		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
pine-oak heath		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
rich cove		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
shortleaf pine		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
spruce-fir		#VALUE!	0.00						#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

** Based on 2018 forest roads data and condensed PNV 3rd approximation (Kauffman).*

*** Other roads (State, NPS, etc.): assume all are paved and open year-round*

Calculating Road Density for ESE *
(miles of road per square mile of forest)

Alternatives A, B1, C1, and D1

Ecozone (EZ)	open, paved road density*	open, unpaved road density	% miles by ecozone	construct + reconstruct road density	decomm road density	estimated open, unpaved road density	motorized trail density*	seasonal road density	TOTAL OPEN ROAD DENSITY BY ECOZONE	10 years	50 years
acidic cove	0.53	0.80	0.24	0.001906971	0.001291819	0.80	0.01	0.24	1.573412313660	1.578948680858	1.603554757294
dry oak	0.20	0.39	0.05	0.001906971	0.001291819	0.39	0.12	0.11	0.830848785425	0.836385152623	0.860991229059
dry-mesic oak	0.30	0.68	0.10	0.001906971	0.001291819	0.69	0.02	0.19	1.194172700598	1.199709067796	1.224315144232
floodplain	3.05	0.82	0.00	0.001906971	0.001291819	0.82	0.00	0.85	4.726401977558	4.731938344756	4.756544421192
high elevation red oak	0.14	0.49	0.04	0.001906971	0.001291819	0.49	0.02	0.13	0.789555336316	0.795091703514	0.819697779950
mesic oak	0.21	0.59	0.17	0.001906971	0.001291819	0.59	0.04	0.18	1.005503907712	1.011040274910	1.035646351346
northern hardwood	0.58	1.88	0.05	0.001906971	0.001291819	1.88	0.00	0.91	3.370070742586	3.375607109784	3.400213186220
pine-oak heath	0.17	0.47	0.10	0.001906971	0.001291819	0.47	0.05	0.10	0.789056915452	0.794593282650	0.819199359085
rich cove	0.24	0.65	0.19	0.001906971	0.001291819	0.65	0.04	0.19	1.129667005959	1.135203373157	1.159809449593
shortleaf pine	0.40	0.81	0.04	0.001906971	0.001291819	0.81	0.01	0.30	1.513514642144	1.519051009342	1.543657085778
spruce-fir	0.29	0.08	0.01	0.001906971	0.001291819	0.08	0.00	0.05	0.423571453668	0.429107820866	0.453713897302
TOTAL	0.33	0.70	1.00	0.001906971	0.001291819	0.71	0.03	0.23	1.289987765929	1.295524133127	1.320130209563

** Assumes no change in the amount of paved roads or motorized trails over the life of the plan.*

Alternative B, Tier 2

Ecozone (EZ)	open, paved road density*	open, unpaved road density	% miles by ecozone	construct + reconstruct road density	decomm road density***	estimated open, unpaved road density	motorized trail density*	seasonal road density**	TOTAL OPEN ROAD DENSITY BY ECOZONE	10 years	50 years
acidic cove	0.53	0.80	0.24	0.003629396	0.003998487	0.80	0.01	0.24	1.572428070602	1.569106250284	1.554342604422
dry oak	0.20	0.39	0.05	0.003629396	0.003998487	0.39	0.12	0.11	0.829864542368	0.826542722049	0.811779076187
dry-mesic oak	0.30	0.68	0.10	0.003629396	0.003998487	0.68	0.02	0.19	1.193188457541	1.189866637222	1.175102991360
floodplain	3.05	0.82	0.00	0.003629396	0.003998487	0.82	0.00	0.85	4.725417734501	4.722095914182	4.707332268321
high elevation red oak	0.14	0.49	0.04	0.003629396	0.003998487	0.49	0.02	0.13	0.788571093258	0.785249272939	0.770485627078

mesic oak	0.21	0.59	0.17	0.003629396	0.003998487	0.59	0.04	0.18	1.004519664654	1.001197844335	0.986434198474
northern hardwood	0.58	1.88	0.05	0.003629396	0.003998487	1.88	0.00	0.91	3.369086499529	3.365764679210	3.351001033348
pine-oak heath	0.17	0.47	0.10	0.003629396	0.003998487	0.47	0.05	0.10	0.788072672394	0.784750852075	0.769987206214
rich cove	0.24	0.65	0.19	0.003629396	0.003998487	0.65	0.04	0.19	1.128682762902	1.125360942583	1.110597296722
shortleaf pine	0.40	0.81	0.04	0.003629396	0.003998487	0.81	0.01	0.30	1.512530399086	1.509208578767	1.494444932906
spruce-fir	0.29	0.08	0.01	0.003629396	0.003998487	0.08	0.00	0.05	0.422587210611	0.419265390292	0.404501744430
TOTAL	0.33	0.70	1.00	0.003629396	0.003998487	0.70	0.03	0.23	1.289003522872	1.285681702553	1.270918056691

** Assumes no change in the amount of paved roads or motorized trails over the life of the plan.*

***Tier 2 plan components suggest open/close more seasonal roads)*

****Assumes 5% of miles in DEIS Table 52 (page 171)*

Alternative C, Tier 2

Ecozone (EZ)	open, paved road density*	open, unpaved road density	% miles by ecozone	construct road density	decomm road density***	estimated open, unpaved road density	motorized trail density*	seasonal road density**	TOTAL OPEN ROAD DENSITY BY ECOZONE	10 years	50 years
acidic cove	0.53	0.80	0.24	0.003813942	0.004552124	0.80	0.01	0.26	1.595738847960	1.589095207323	1.559567915599
dry oak	0.20	0.39	0.05	0.003813942	0.004552124	0.39	0.12	0.12	0.840733597304	0.834089956666	0.804562664943
dry-mesic oak	0.30	0.68	0.10	0.003813942	0.004552124	0.68	0.02	0.20	1.211436494956	1.204792854319	1.175265562596
floodplain	3.05	0.82	0.00	0.003813942	0.004552124	0.82	0.00	0.94	4.810455726600	4.803812085962	4.774284794239
high elevation red oak	0.14	0.49	0.04	0.003813942	0.004552124	0.49	0.02	0.14	0.801350265201	0.794706624564	0.765179332841
mesic oak	0.21	0.59	0.17	0.003813942	0.004552124	0.59	0.04	0.19	1.021693577472	1.015049936834	0.985522645111
northern hardwood	0.58	1.88	0.05	0.003813942	0.004552124	1.88	0.00	1.01	3.460126518936	3.453482878298	3.423955586575
pine-oak heath	0.17	0.47	0.10	0.003813942	0.004552124	0.47	0.05	0.11	0.797661649905	0.791018009267	0.761490717544
rich cove	0.24	0.65	0.19	0.003813942	0.004552124	0.65	0.04	0.21	1.147599963525	1.140956322887	1.111429031164
shortleaf pine	0.40	0.81	0.04	0.003813942	0.004552124	0.81	0.01	0.33	1.541920387725	1.535276747088	1.505749455365
spruce-fir	0.29	0.08	0.01	0.003813942	0.004552124	0.08	0.00	0.06	0.427378978425	0.420735337787	0.391208046064
TOTAL	0.33	0.70	1.00	0.003813942	0.004552124	0.70	0.03	0.23	1.288634431725	1.281990791088	1.252463499365

** Assumes no change in the amount of paved roads or motorized trails over the life of the plan.*

***Tier 2 plan components suggest open/close more seasonal roads)*

****Assumes 5% of miles in DEIS Table 52 (page 171)*

Alternative D, Tier 2

Ecozone (EZ)	open, paved road density*	open, unpaved road density	% miles by ecozone	construct road density	decomm road density***	estimated open, unpaved road density	motorized trail density*	seasonal road density**	TOTAL OPEN ROAD DENSITY BY ECOZONE	10 years	50 years
acidic cove	0.53	0.80	0.24	0.003567881	0.003321820	0.80	0.01	0.24	1.573043222513	1.575257769392	1.585100199967
dry oak	0.20	0.39	0.05	0.003567881	0.003321820	0.39	0.12	0.11	0.830479694279	0.832694241158	0.842536671732
dry-mesic oak	0.30	0.68	0.10	0.003567881	0.003321820	0.68	0.02	0.19	1.193803609452	1.196018156331	1.205860586905
floodplain	3.05	0.82	0.00	0.003567881	0.003321820	0.82	0.00	0.85	4.726032886412	4.728247433291	4.738089863865
high elevation red oak	0.14	0.49	0.04	0.003567881	0.003321820	0.49	0.02	0.13	0.789186245169	0.791400792048	0.801243222623
mesic oak	0.21	0.59	0.17	0.003567881	0.003321820	0.59	0.04	0.18	1.005134816565	1.007349363444	1.017191794019
northern hardwood	0.58	1.88	0.05	0.003567881	0.003321820	1.88	0.00	0.91	3.369701651440	3.371916198319	3.381758628893
pine-oak heath	0.17	0.47	0.10	0.003567881	0.003321820	0.47	0.05	0.10	0.788687824305	0.790902371184	0.800744801759
rich cove	0.24	0.65	0.19	0.003567881	0.003321820	0.65	0.04	0.19	1.129297914813	1.131512461692	1.141354892266
shortleaf pine	0.40	0.81	0.04	0.003567881	0.003321820	0.81	0.01	0.30	1.513145550997	1.515360097876	1.525202528451
spruce-fir	0.29	0.08	0.01	0.003567881	0.003321820	0.08	0.00	0.05	0.423202362522	0.425416909401	0.435259339975
TOTAL	0.33	0.70	1.00	0.003567881	0.003321820	0.70	0.03	0.23	1.289618674783	1.291833221662	1.301675652236

** Assumes no change in the amount of paved roads or motorized trails over the life of the plan.*

***Tier 2 plan components suggest open/close more seasonal roads)*

****Assumes 5% of miles in DEIS Table 52 (page 171)*

Attachment 16

Email from Michelle Aldridge to Sam Evans regarding roads inputs

Bob Halstead

From: Aldridge, Michelle -FS <michelle.aldridge@usda.gov>
Sent: Tuesday, March 8, 2022 12:59 PM
To: Sam Evans
Subject: Roads inputs

Hi Sam,

As previously mentioned, please route data and information requests through me rather than going to specialists so I can manage the requests. Due to our integrated approach, many questions involve more than a single individual to address. I have asked team members to route any additional information requests back through me as they are taking extensive time and specialists are focused on other priority work.

In talking with Heather, we have provided SELC with about 95 additional plan and analysis files via email, the FTP site and the jump drive. With this email below and another one I will send later today regarding young forest spectrum questions, I believe we will have addressed all SELC's informational requests.

Sheryl worked with others to pull together the responses below to your questions regarding the roads analysis associated with the Ecological Sustainability Evaluation. The road density analysis used in the ESE was just intended for analysis of road sensitive species at the landscape scale and is not intended to be applied as a detailed road density analysis of the forests.

Michelle

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1. Does road density *anywhere* on the forest matter equally for CWD species? Or does it matter more in the core salamander habitat areas or NHNAs, for example? Road density for dispersal-limited species (including those associated with CWD) is represented by a weighted average of road density estimations for each ecozone. This estimate is not restricted to certain parts of the forest because connectivity is addressed at the landscape scale in this analysis. Road density for smaller areas (i.e., less that forest-wide), can be estimated during project-level analysis using the same process. I think you are reading the table "backwards"-- the gray line for each ecosystem or species group represents the composite score (weighted average) of the indicators identified for each element (white lines above the gray line, number of indicators varies by ecosystem/species group).

2. Can you shed some light on what it means that road density was considered for other species groups (like species persistence and recovery and recreation traffic) but not for road density sensitive species as a whole? Different indicators were used for different species groups. The road and trail indicator in Species Persistence and Recovery and Road Density Sensitive Species is represented by the number of NCNHP element occurrences within a buffered road and trail network to estimate potential threat of this network on rare animal species, to represent the potential threat of recreation and access on rare animals). There are also indicators for things like forest management and climate change, etc. The open road density indicator in Road Density Sensitive Species is as described in #1, at the landscape level.

3. I'm having a hard time understanding which species groups were evaluated for which indicators. (Relevant portion excerpted below.) For the composite score for Road Density Sensitive Species, it looks like the only species considered were snag and den tree associates, with snag density as the indicator. Indicators are used to evaluate species groups and ecosystems. Three indicators were used to estimate composite scores for Road Density Sensitive Species: 1. road and trail density near streams, 2. percent animal EOS within 100 feet of an open road or trail, and 3. open road density. The gray line for each ecosystem or species group represents the composite score (weighted average) of the indicators identified for each element (white lines above the gray line, number of indicators varies by ecosystem/species group).

4. I can't understand why more road miles would be required for Alt. C, which has a smaller suitable base. Where does that assumption come from? I guess I'm asking where the EIS assumptions come from? Is Spectrum spitting out road miles? But that decommissioning number is mainly unauthorized roads, which aren't included in density calculations, right? And if Tier 1 management levels are going to double from historical levels, is that going to be possible without a commensurate increase in roads? No, Spectrum does not output road mileages. Spectrum outputs of suitable acres were used to generate the current accessible acres by MA and determine the potential future access needed to accomplish objectives by alternative. The forest plan intentionally does not include an objective for road construction but rather estimates what would be needed to accomplish objectives based on the existing road system. And yes, achievement of both Tier 1 and Tier 2 objectives assume additional road construction is needed.

5. It looks like y'all used the same numbers for Alternatives D and E? Alternative D was used to estimate Alternative E for the open road and trail density indicator in the ESE analysis because road density calculations didn't differ between alternative D and E, at the landscape scale. Note that road density estimates in the ESE address the topic from an ecological perspective at the landscape scale. Road density for smaller areas (i.e., less that forest-wide), can be estimated during project-level analysis at a relevant scale.

6. I haven't been able to find a table of the thresholds associated with each indicator. Like, what makes a "good" versus a "very good" outcome for road density? This information is contained in the project record, for all indicators and data used in the ESE. Open Road and Trail Density was summarized using: Poor: >2 miles/square mile; Fair: 1.5-2.0 miles/square mile; Good: 1.0-1.5 miles/square mile; Very Good: <1.0 mile/square mile. Note that road density estimates in the ESE address the topic from an ecological perspective at the landscape scale. Road density for smaller areas (i.e., less that forest-wide), can be estimated during project-level analysis at a relevant scale.

From: Sam Evans <sevans@selcnc.org>
Sent: Monday, February 28, 2022 2:05 PM
To: Bryan, Sheryl -FS <sheryl.bryan@usda.gov>
Subject: [External Email]Re: Roads inputs

Apologies for the rapid fire emails, but I can't believe I forgot to ask you my most important ESE question!

I haven't been able to find a table of the thresholds associated with each indicator. Like, what makes a "good" versus a "very good" outcome for road density? Is there a comprehensive table that I'm just not seeing?

Thanks again,

From: Sam Evans
Sent: Monday, February 28, 2022 1:41 PM
To: Bryan, Sheryl -FS <sheryl.bryan@usda.gov>
Subject: Roads inputs

Sheryl, I'm having a hard time following some of the analysis for road density. I've been reviewing your spreadsheet (OpenRoadDensityEstimates_Forestwide). It looks like y'all used the same numbers for Alternatives D and E? Or did you update those assumptions in some other way based on the addition of the Thin & Burn prescription or other changes? Hopefully that's a simple question.

I guess my more complicated question is where do the inputs come from? The table below is in a tab called "plan direction." I can't find any plan direction to construct roads at these levels, although I do see assumptions about how many road miles will be constructed in the EIS. I also don't see any plan direction to decommission 5% of roads, and this is 5% of which roads?

I guess I'm asking where the EIS assumptions come from? Is Spectrum spitting out road miles? I didn't think it could do that. I'm flummoxed, and I need help!

It looks like Tier 1 is based on the historical levels of road construction and decommissioning. But that decommissioning number is mainly unauthorized roads, which aren't included in density calculations, right? And if Tier 1 management levels are going to double from historical levels, is that going to be possible without a commensurate increase in roads?

The scaling question carries over to Tier 2, as well. T2 anticipates about twice as much road construction as T1, but the harvest levels are about 5x as high as the historical levels the road numbers were based on. It seems unduly optimistic to think that we can quintuple harvest acres w

Also, I can't understand why more road miles would be required for Alt. C, which has a smaller suitable base. Where does that assumption come from?

From pages 88-89, 170-171 of DEIS:

	New Construct	Reconstruct	Total Construct	Temp Construct	Deco
A	1.2	1.9	3.1	2.9	
B1	1.2	1.9	3.1	2.9	
B2	2.3	3.6	5.9	5.5	
C1	1.2	1.9	3.1	2.9	
C2	2.4	3.8	6.2	5.8	
D1	1.2	1.9	3.1	2.9	
D2	2.2	3.6	5.8	5.5	

** Assumes 5% decomission*

***Based on total miles of disturbance*

Also related to road denity: In Appendix C, I am looking at the table for "Expected Outcomes for ecosystems, unique habitats, and species groups," and I'm having a hard time understanding which species groups were evaluated for which indicators. (Relevant portion excerpted below.) For the composite score for Road Density Sensitive Species, it looks like the only species considered were snag and den tree associates, with snag density as the indicator.

Road and trail density were considered in other places, such as under the composite of Snag and Den Tree associates, where it "species persistence and recovery" species were looked at in connection with riparian road density. And for the composite of "recreation traffic sensitive species," occurrences near roads and trails and open road density was considered. Can you shed some light on what it means that road density was considered for other species groups (like species persistence and recovery and recreation traffic) but not for road density sensitive species as a whole? I feel like this may just be my misunderstanding of how the table is put together.

Species Group	Interior Forest Associates	60%	NC Audubon
Species Group	**Interior Forest Associates**		**COMPO**
Species Group	Old Forest Associates	CWD density under natural conditions	FVS
Species Group	Old Forest Associates	Percent of each ecozone contributing to old growth forest characteristics	FSVeg, NRV, Spectrum
Species Group	Old Forest Associates	Percent of forest represented by small openings (<0.25 acre)	FS Gap Analysis
Species Group	Recreation Traffic Sensitive Species	Cave/Mine Gate Indicator	FS data, NCWRC data
Species Group	Recreation Traffic Sensitive Species	Roads & Trail Indicator	FS data, SAB summary analysis
Species Group	**Recreation Traffic Sensitive Species**		**COMPO**
Species Group	Road Density Sensitive Species	NHD Density Near Roads and Trails	NHDPlus, INFRA
Species Group	Road Density Sensitive Species	Percent of animal element occurrences (T&E/SCC) within 100 feet of an open road	INFRA; NCNHP EOs
Species Group	Road Density Sensitive Species	Open road density	INFRA
Species Group	**Road Density Sensitive Species**		**COMPO**
Species Group	Snag and Den Tree Associates	Snag Density	FVS
Species Group	**Snag and Den Tree Associates**		**COMPO**
Species Group	Species Persistence and Recovery	Amount of NHNA (top 3 ranks) in MA Group 1 (or density estimate)	NCNHP, FS data
Species Group	Species Persistence and Recovery	Dam and Stream Crossing Density	NP WCF

Element Type	Element Name	Indicator Name*	Data Source(s)*
Species Group	Species Persistence and Recovery	Riparian Road and Trail Density	NP WCF
Species Group	Species Persistence and Recovery	Salamander core habitat and connectivity	Apodaca and Smith (2019)
Species Group	Species Persistence and Recovery	Susceptibility to Climate Change	NCNHP, FS data
Species Group	Species Persistence and Recovery	Susceptibility to Forest Management	NCNHP, FS data
Species Group	Species Persistence and Recovery	Roads & Trail Indicator	NCNHP, FS data

Along the same lines, road density is considered in connection with CWD and Downed Wood species, and so is JJ's modeling, but it's not clear how those relate to each other. Does road density *anywhere* on the forest matter equally for CWD species? Or does it matter more in the core salamander habitat areas or NHNAs, for example? Okay, I think that's all I've got right now. Any help in understanding the ESE process would be appreciated!

Species Group	CWD and Downed Wood Associates		COMPO
Species Group	Dispersal-limited Species	Barriers to Aquatic Species Movement	WCF, ESE WS module (mean CS)
Species Group	Dispersal-limited Species	Barriers to movement of small-ranging species (road density)	ESE ES Road Density (mean ES), INFRA, FSVeg, PNV
Species Group	Dispersal-limited Species	Barriers to movement of small-ranging species (gap size)	FSVeg, Spectrum, disturbance, gap analysis
Species Group	Dispersal-limited Species	Potential effects of forest management on TE/SCC	NCNHP
Species Group	Dispersal-limited Species	Potential effects of forest management on terrestrial salamanders	Apodaca and Smith (2019)

Attachment 17

Nantahala and Pisgah NFs Changes to Plan Components between Draft and Final (4/21/2021)

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Air (AIR)	Air (AIR)	n/a	no changes to air	no changes to air		no public comments rcv'd re: air
AQS	AQS-DC-01	revision	Aquatic ecosystems are diverse with properly functioning streams providing high quality habitat for all native and desired non-native (e.g., brown and rainbow trout) aquatic species, resulting in populations that are robust and resilient. Native brook trout are emphasized when relevant.	Aquatic ecosystems are diverse with properly functioning streams providing high quality habitat for all native and desired non-native (e.g., brown and rainbow trout) aquatic species, resulting in populations that are robust and resilient. In areas where trout populations are present, native Native brook trout are emphasized when possible .		
AQS	AQS-G-04	revision	Aquatic organism passage projects should use channel spanning structures or other stream-simulation techniques on fish-bearing streams whenever possible. Additionally, during forest management activities such as timber harvest or road maintenance, these and other passage techniques (e.g., over-sized, sunken pipes that will collect channel substrate and natural-bottom fords on closed system roads where stream channel gradient and approaches can provide resource protection) should be considered at stream crossings identified for replacement to promote passage of aquatic organisms. And, similarly, use portable bridge decks at temporary crossings whenever practical to support the guideline above.	Aquatic organism passage projects should use channel spanning structures or other stream-simulation techniques on fish-bearing streams unless protection of a native species from encroachment by a non-native species is being provided, and there are no aquatic organism passage benefits (e.g. there is no suitable habitat above the crossing). ~~whenever possible.~~		3/24/21: Heather will follow up w/ Sheryl on this: keep 'should' versus 'shall'? 6/22: Michelle will follow up w/ Sheryl re: rewriting this G/breaking it into 2-3 separate Gs 8/18/21: changes confirmed
AQS	AQS-G-05	new	(formerly AQS=G-04) Aquatic organism passage projects should use channel spanning structures or other stream-simulation techniques on fish-bearing streams whenever possible. Additionally, during forest management activities such as timber harvest or road maintenance, these and other passage techniques (e.g., over-sized, sunken pipes that will collect channel substrate and natural-bottom fords on closed system roads where stream channel gradient and approaches can provide resource protection) should be considered at stream crossings identified for replacement to promote passage of aquatic organisms. And, similarly, use portable bridge decks at temporary crossings whenever practical to support the guideline above.	During forest management activities such as timber harvest or road maintenance, channel-spanning and other passage techniques should be considered to promote passage of aquatic organisms (e.g., over-sized sunken pipes that collect channel substrate, and natural-bottom fords on closed system roads where stream channel gradient and approaches can provide resource protection). Use portable bridge decks at temporary crossings whenever practical to support the guidelines above.		7/15: changes finalized. G-04 was split into 2 G's for final
AQS	AQS-O-01	revision	Tier 1: Maintain or expand the occupied range of native brook trout across the Forests. Additionally, maintain or increase populations within this range over the life of the plan.	Tier 1: Maintain and expand the occupied range of native brook trout across the Forests . Additionally, maintain or increase populations within this range over the life of the plan.		
AQS	AQS-O-02	revision	Tier 1: Maintain or expand the occupied range of freshwater mussels and other aquatic species of conservation concern and federally-listed species across the Forests. Additionally, maintain or increase populations within this range over the life of the plan.	Tier 1: Maintain and expand the occupied range of freshwater mussels and other aquatic species of conservation concern and federally-listed species across the Forests. Additionally, maintain or increase populations within this range over the life of the plan.		
AQS	AQS-O-03	revision	Tier 1: Work with partners to complete the assessment of aquatic organism passage (AOP) needs across the Forests over the life of the plan. Prioritize completion of AOP needs that improves the entire aquatic community and enables reconnection of fragmented populations of native brook trout and other aquatic federally-listed species or species of conservation concern or restoration of these species to suitable unoccupied habitat. Replace a minimum of two impaired stream crossings annually to improve aquatic organism passage and aquatic community connectivity across the planning unit.	Tier 1: Prioritize completion of AOP needs that improves the entire aquatic community and enables reconnection of fragmented populations of native brook trout and other aquatic federally-listed species or species of conservation concern or restoration of these species to suitable unoccupied habitat. a) Work with partners to complete the assessment of aquatic organism passage (AOP) needs across the Forests over the life of the plan. b) Replace a minimum of two impaired stream crossings annually to improve aquatic organism passage and aquatic community connectivity across the planning unit.	Switched first and second sentences and restructured.	8/17/21: changes confirmed
AQS	AQS-S-01	revision	Management activities shall be designed to avoid, minimize, or mitigate negative impacts on aquatic habitats and species unless the management objective is to protect a native species from encroachment by a non-native species. For example, road and trail stream crossings shall not permanently isolate populations of native aquatic species.	Management activities shall be designed to avoid, minimize, or mitigate negative impacts on aquatic habitats and species unless the management objective is to protect a native species from encroachment by a non-native species. For example, road and trail stream crossings shall not permanently isolate populations of native aquatic species, unless it protects them from non-native invasive species Specifically, no activities shall be undertaken to expand the range of non-native trout species into areas that are potentially suitable for or occupied by native brook trout.		

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
AQS	Mgmt Approac	new		Sustain and improve aquatic habitat to benefit native aquatic species, with management actions that support the conservation of key native species, including Brook Trout and Species of Greatest Conservation Need (SGCN) defined in NCWRC's Wildlife Action Plan. Continue to expand the known occupied range of the SGCN aquatic species through increased inventory, improved aquatic organism passage, population augmentations, and species reintroductions.		7/15: change finalized. New MA before "see also" statement
Climate Change (CC)	CC-DC-01	revision	The Nantahala and Pisgah are resilient to disturbance regimes allowing for adaptive capacity of landscape level plant communities to respond to climate.	The Nantahala and Pisgah are resilient to disturbance regimes allowing for adaptive capacity of landscape level plant and animal communities to respond to climate changes.		
Climate Change (CC)	CC-DC-03	revision to footnote	Ecosystem services include supporting services (such as nutrient cycling, soil formation, and primary production), regulating services (carbon, air quality, climate regulation, water regulation, and erosion regulation), cultural services (land use, aesthetic values, spiritual and religions values, and recreation and ecotourism), and provisioning services (forage, forest products, and fresh water).	Ecosystem services include supporting services (such as nutrient cycling, soil formation, and primary production), regulating services (carbon sequestration, air quality, climate regulation, water regulation, and erosion regulation), cultural services (land use, aesthetic values, spiritual and religions values, and recreation and ecotourism), and provisioning services (forage, forest products, energy, fuel, minerals and fresh water).		
Climate Change (CC)	CC-DC-08	revision	Renewable energy opportunities are considered, such as biomass, firewood, hydropower, geothermal, wind, and solar.	Renewable and non-traditional energy opportunities are considered, such as biomass, firewood, hydropower, geothermal, wind, and solar.		
Climate Change (CC)	Mgmt Approac	revision	Managing ecosystems in the face of climate change focuses on maintaining or creating resiliency and adaptability. Maintain a suite of adaptation and mitigation options, focusing on sustaining process and function. Identify and emphasize maintenance and restoration in the microsites most resilient to changing conditions, considering geological settings as well as biological characteristics. Where there are species at risk that are susceptible to the effects of climate change, promote activities that support suitable habitat enhancement. Consider future climate and potential species range shifts when planning restoration projects. Monitor for new invasive species moving into areas where they were traditionally not found, especially in high-elevation communities. Restore native vegetation in streamside zones to help moderate changes in water temperature and stream flow. Anticipate and plan for disturbances from intense storms. Prepare for intense storms using methods that maintain forest health and diversity, including controlling soil erosion, relocating high risk roads and trails, and constructing appropriately sized culverts and stream crossings. To maintain genetic resiliency, consider locally adapted genotypes for use in restoration projects.	Managing ecosystems in the face of climate change focuses on maintaining or creating resiliency and adaptability. In the face of climate uncertainty, maintain a suite of adaptation and mitigation options, focusing on sustaining process and function. Identify and prioritize maintenance and restoration in the microsites most resilient to changing conditions, considering geological settings as well as biological characteristics. Where there are species at risk that are susceptible to the effects of climate change, promote activities that support suitable habitat enhancement. Consider and address future climate and potential species range shifts when planning restoration projects, facilitating species migration and adaptation when possible. Monitor for new invasive species moving into areas where they were traditionally not found, especially in high-elevation communities. Utilize the monitoring information to assess threats and prioritize treating highly invasive infestations. Restore native vegetation in streamside zones to help moderate changes in water temperature and stream flow, and enhance habitat. Anticipate and plan for changes in natural disturbance patterns. Prepare for intense storms and fluctuations in base flow using methods that maintain forest health and diversity, including controlling soil erosion, relocating high risk roads and trails, and constructing appropriately sized culverts and stream crossings while retaining stream connectivity. To maintain genetic resiliency, consider locally adapted genotypes for use in restoration projects.		8/18/21: changes confirmed
Community Connections (COM)	COM-DC-06	revision	Sustainable Forests' settings and opportunities complement regional and local programs and tourism strategies.	Sustainable Forests' settings and opportunities complement regional and local and Tribal programs and tourism strategies, and collaboration with tourism offices is fostered.		
Community Connections (COM)	COM-DC-09	revision	Diversity of visitors, volunteers, and partners continues to grow through existing and new relationships; and, over time, citizen involvement becomes more inclusive of the diversity of the public	All people and communities served by the Forest are engaged, including historically underserved populations. Diversity of visitors, volunteers, and partners continues to grow through existing and new relationships; and,citizen involvement becomes more representative of local community and the nation's demographics and interests.		DC-9 and DC-10 were combined between draft and final
Community Connections (COM)	COM-DC-10	deleted. Include? Yes!	Barriers that reduce underserved populations from connecting with the Forests are reduced.	n/a. DC deleted		DC-9 and DC-10 were combined between draft and final
Community Connections (COM)	COM-O-02	revision	Annually increase volunteer and service program effectiveness by ensuring that volunteers and service participants have the appropriate supervision, coordination, program direction, safety training, certifications, and protective equipment to conduct their work in a safe and efficient manner and are recognized for their time in service, significant accomplishments, and/or exemplary safety records.	Annually ensure that volunteers and service participants have the appropriate supervision, coordination, program direction, safety training, certifications, and protective equipment to conduct their work in a safe and efficient manner and are recognized for their time in service, significant accomplishments, and/or exemplary safety records.		

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Community Connections (COM)	Mgmt Approac	new	n/a	Engage with partners to emphasize expanding the diversity of forest visitors, volunteers, and partners, and increase public land employment pathways across all demographics.		
Conservation Education and Interpretation (CE)	CE-DC-01	revision	Conservation education and interpretation is integrated as a component in all program areas.	Conservation education and interpretation is integrated as a component in all program areas to facilitate public understanding of the resources and their management.		
Conservation Education and Interpretation (CE)	CE-DC-02	revision	Interpretation and conservation education opportunities connect people with nature and enhance the public understanding and appreciation for the natural, cultural, tribal history, and the multiple-use mission of the Forests.	Interpretation and conservation education opportunities connect people with nature and enhance the public understanding and appreciation for the natural, cultural, tribal history, and the multiple-use mission of the Forests. Conservation education programs and activities contribute to connecting people to the land and to each other.		
Conservation Education and Interpretation (CE)	CE-DC-03	new	n/a	Conservation education and interpretation is culturally inclusive, engages diverse audiences and invites diverse visitors to the Forest.		8/18/21: change confirmed
Conservation Education and Interpretation (CE)	CE-DC-05	revision	**(CE-DC-04 in draft plan):** Through a variety of educational and interpretive efforts, people learn about biodiversity, botanical communities, wildlife and aquatic species, ecosystems, geology, and heritage site etiquette, resulting in a motivation to practice careful stewardship. Education themes include sustainability, safety, and user ethics and support national Forest Service education themes. Communication and interpretive message respect diverse backgrounds and needs of visitors.	Through a variety of educational and interpretive efforts, people learn about biodiversity, botanical communities, wildlife and aquatic species, ecosystems, tribal, heritage and other cultural sites, hunting and fishing heritage and geology resulting in a motivation to practice careful stewardship. Education themes include sustainability, safety, and user ethics, and support National Forest Service education themes.	Also last line of original has been deleted	8/18/21: change confirmed
Conservation Education and Interpretation (CE)	Mgmt Approac	many revisions	Educational programs and materials are developed or certified by the Forest Service to incorporate the best scientific knowledge; are interdisciplinary and unbiased; support the Forest Service mission; and are correlated with appropriate national, state, and agency guidelines.// Address visitor safety through education and management actions.// Assure scientific accuracy and unbiased approach in programs.// When promoting conservation education, encourage participation by urban and rural communities, tribes, youth, minority, and low income populations.// Subject matter pertaining to tribes is collaboratively developed and, in appropriate cases, is also in tribal language.// Initiate and facilitate the cooperation of local resources in developing and implementing education relating to use and/or prevention of fire.// Build a working relationship with other Federal and state agencies with a conservation mission; public, private schools, and universities; and non-profit organizations; and maintain professional resource management and educational associations.// Manage the conservation education and interpretive services programs to avoid duplication with other providers whether in public or private sector.// Provide information kiosks that minimize visual clutter by concentrating messages and eliminating the need for multiple signs.// Consider use of both emerging and traditional technologies to reach target audiences efficiently and effectively.// Expand educational programs to reach more youth. For example, in classrooms and at sites across the Forests, ensure that programs provide youth of all ages and backgrounds meaningful educational experiences of the highest quality.// See also: Community Connections, Experimental Forests and Research Natural Areas, Cradle of Forestry	Service to incorporate the best scientific knowledge; are interdisciplinary and unbiased; support the Forest Service mission; and are correlated with appropriate national, state, and agency guidelines.// Education and management actions address visitor safety.// Educational materials addressing project objectives, such as promoting the principles of sustainable timber harvest, wildlife habitat improvement, and ecological restoration, as examples, are provided to the public in coordination with project design and implementation. Working with interested partners, signage will be developed and posted to educate the public about project goals, management approaches and other needed messaging.// Provide information kiosks that include messaging needed for the area while minimizing visual clutter by concentrating messages and eliminating the need for multiple signs. Kiosks will be utilized to educate visitors about nearby projects.// Consider use of both emerging and traditional technologies to reach target audiences efficiently and effectively. // To expand capacity to deliver conservation education, build working relationships with other Federal and state agencies with a conservation mission; public, private schools, and universities; and non-profit organizations; and maintain memberships with professional resource management and educational associations. Manage the conservation education and interpretive services programs to avoid duplication with other providers whether in public or private sector.// Build relationships with community programs that help ensure the delivery of public services reflects the diversity of the American public. When promoting conservation education, encourage participation by urban and rural communities, tribes, youth, minority, and low-income populations.// Expand educational programs to reach more youth. For example, in classrooms and at sites across the Forests, ensure that programs provide youth of all ages and backgrounds meaningful educational experiences of the highest quality.// Subject matter pertaining to tribes is collaboratively developed and, in appropriate cases, is also in tribal language. Opportunities to		3/29: Michelle approves of all changes. 8/18/21: changes confirmed
Cultural Resources (CR)	**no changes**					4/13: no changes to this cultural resources section

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Facilities (FAC)	placeholder	NO CHANGES				6/28/21: cross referenced draft plan to verify no changes were made
Fire and Fuels (FR)	background	new	n/a	○added statement to background: "The ecozone section of the Forest Plan provides more discussion of fire-adapted plant communities." ○ added phrase "and climate change-driven shifts in seasonal burn windows. " ○Removed last sentence of 2nd paragraph		added per public comments.
Fire and Fuels (FR)	FR-DC-05	revision	Prescribed fire is well planned, scheduled and executed to manage vegetation, restore and maintain fire adapted ecosystems and species, create desired wildlife habitat conditions, promote herbaceous ground cover to help control erosion, and modify fuel loads to reduce wildfire intensity. Fire-adapted ecozones are defined in Table 9.	Prescribed fire is well planned, scheduled and executed to manage vegetation, restore and maintain fire adapted ecosystems and species, create desired wildlife habitat conditions, promote herbaceous ground cover to help control erosion, and modify fuel loads to reduce wildfire intensity. Desired fire return intervals associated with fire-adapted ecozones are defined in Table 9.		8/10- changes complete in plan
Fire and Fuels (FR)	FR-G-01	revision	Firelines which expose mineral soil should not be located in streamside zones along lakes, perennial or intermittent springs and streams, wetlands, or water-source seeps, unless tying into waterbodies lakes, streams, or wetlands as firebreaks at designated points with minimal soil disturbance. Low-intensity fires may be allowed to back into the strip along water bodies to utilize natural moisture of extinction	Firelines which expose mineral soil should not be located in streamside zones unless tying into waterbodies as firebreaks at designated points with minimal soil disturbance. Where construction of dozer fireline within streamside and filter zones and across stream channels is required, consult with local resource advisors.		some language from the draft plan was deleted
Fire and Fuels (FR)	FR-S-04	new	n/a	If existing or planned NFS trails are used for access or to create fire lines associated with prescribed burns or wildfire suppression, trails impacted by fire operations shall be repaired to meet agency standards for appropriate Trail Classes and use-types, including restoration of unique recreational values and use of sustainable trail design principles.		3/29: is this still a loose end? No. Michelle is good with proposed change.
Fire and Fuels (FR)	pointer to Rx fire objectives		Updated w/ Brady's edits.	Updated w/ Brady's edits.		3/29: we're going to add a note for the reader to reference back to Terr. Eco for Rx fire objective
Forest Health: Insects and Diseases; Non-Native Invasive Plant Species (FHL)	FHL-G-05	revision	Tools and practices should be utilized to minimize the spread of non-native invasive plants along trails, roads, waterways, and other corridors.	Tools and practices such as minimizing the length of time soil is exposed, mowing before seeds are produce or creating smaller equipment staging areas, should be utilized to minimize the spread of non-native invasive plants along trails, roads, waterways, and other corridors.		7/14: formely ECO-G-17
Forest Health: Insects and Diseases; Non-Native Invasive Plant Species (FHL)	FHL-MA	revision	Education opportunities and signage should encourage lessening the spread of exotics by incorporating key messages such as "don't move firewood."	Education opportunities and signage should encourage lessening the spread of exotics by incorporating key messages such as "don't move firewood," or accepted decontamination protocols.		7/14: formerly an MA in Terr. Eco, Forest Health subsection
Forest Health: Insects and Diseases; Non-Native Invasive Plant Species (FHL)	FHL-O-02 (formerly ECO-O-09)	revision	**Tier 1:** Treat, control or eradicate NNIS plant species on 750 to 1,500 acres. Select sites using the following priorities: unique habitats required for T/E or SCC; key characteristics of ecozones that provide habitat requirements for T/E or SCC. Inventory approximately 1,000 to 2,000 acres for NNIS occurrences. **Tier 2**: Control or eradicate NNIS up to approximately 3,000 acres: to mitigate the spread to or from adjacent lands; where high human uses occur with high risks of NNIS establishment. Inventory up to approximately 4,000 acres for NNIS occurrences. Priority areas are high quality special interest areas, previously treated areas, NC Natural Heritage Program natural areas, and lands where control is completed cooperatively with adjacent state agencies or private landowners.	**Tier 1:** Annually treat, control or eradicate NNIS plant species on **1,500 to 3,000 acres.** Management Approaches: Select sites using the following priorities: unique habitats required for T/E or SCC; key characteristics of ecozones that provide habitat requirements for T/E or SCC. Inventory approximately 1,000 to 2,000 acres for NNIS occurrences. **Tier 2:** Annually treat, control or eradicate NNIS on **3,000 to 5,000 acres**: to mitigate the spread to or from adjacent lands; where high human uses occur with high risks of NNIS establishment. Inventory up to approximately 4,000 acres for NNIS occurrences. Management approaches: Priority areas are high quality special interest areas, previously treated areas, NC Natural Heritage Program natural areas, and lands where control is completed cooperatively with adjacent state agencies or private landowners		Revised acreage for the NNIS objective located in the consolidated objectives for Terrestrial Ecosystems, Table 9. Objectives for Restoring or Maintaining Resiliency 8/17/21: changes confirmed.

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Forest Health: Insects and Diseases; Non-Native Invasive Plant Species (FHL)	FHL-S-04	revision	Use physical barriers to protect federally-listed species or species of conservation concern when using pesticides to protect non-target effects from drift and flow of pesticide use.	Use physical barriers or buffers to protect federally listed species or species of conservation concern when using pesticides to prevent non-target effects from drift and flow of pesticide use.		7/14: formerly ECO-S-36. new Forest Health section has been created.
Forest Health: Insects and Diseases; Non-Native Invasive Plant Species (FHL)	FHL-S-05	new	n/a	Survey for and treat NNIS before and after vegetation management and other ground disturbing activities.		7/14: new standard.
Lands and Special Uses (LSU)	LSU	**no changes in FEIS notebook. 1 new change below**				3/29: no changes being made to this section 7/1: update-new change below
Lands and Special Uses (LSU)	LSU-G-08	revision	Low growing vegetation that does not interfere with overhead lines should be maintained within power line corridors to provide for wildlife habitat and other resource benefits.	Low growing vegetation that does not interfere with overhead lines should be maintained within power line corridors to provide for wildlife habitat and other resource benefits, in accordance with appropriate best management practices.		7/12: change finalized
Lands and Special Uses (LSU)	LSU-S-14	**no change**	Equipment cleaning practices shall be incorporated in special-use authorizations, where needed, to prevent the introduction and spread of non-native invasive plants.	Equipment cleaning practices shall be incorporated in special-use authorizations, where needed, to prevent the introduction and spread of non-native invasive plants.	Last part of Std was deleted. Track change in the spreadsheet	8/10- changes complete in plan
Minerals and Energy (MIN)	background	entire background text replaced		see plan		7/12: change finalized. "all" was deleted from final language, per Tom's feedback that it could give off a negative public impression
Minerals and Energy (MIN)	Mgmt Approac	revision	Plans of operations and reclamation should include a schedule of activities; an estimate of the amount of material to be removed; and measures for stabilizing soil, protecting water quality, restoring vegetation, protecting visual quality, and protecting Native American sites and other cultural resources. A pit development plan should be prepared for large or multiple-entry aggregate sources to ensure efficient use of aggregate resources and avoid adverse environmental effects.	Plans of operations and reclamation would include a schedule of activities; an estimate of the amount of material to be removed; and measures for stabilizing soil, protecting water quality, restoring vegetation and wildlife habitat, protecting visual quality, and protecting Native American sites and other cultural resources. A pit development plan would be prepared for large or multiple-entry aggregate sources to ensure efficient use of aggregate resources and avoid adverse environmental effects.	4/9: outstanding change. Remains in track changes in April version of Plan	6/28: Michelle reviewed and approved. LR accepted track changes. 7/12: changes finalized.
Minerals and Energy (MIN)	Mgmt Approac	new	n/a	When the NPNF receive a BLM request for consent to a BLM authorization for critical minerals, the FS gives the request priority consideration, including due diligence in conducting an environmental analysis in cooperation with BLM in order to make a consent decision in a timely manner.		7/15: Tom proposed new MA, per public comment. M approves. Changes finalized
Minerals and Energy (MIN)	MIN-DC-02	revision	Opportunities are provided for minerals and energy production in an environmentally sound manner to meet current and future needs	Opportunities are provided for minerals and energy production in an environmentally sound manner to meet current and future needs, including critical minerals for renewable energy technology and climate change mitigation infrastructure.		6/28: LR accepted track changes
Minerals and Energy (MIN)	MIN-DC-06	revision	Renewable energy opportunities are considered, such as biomass, firewood, hydropower, geothermal, wind, and solar.	Renewable and non-traditional energy opportunities are considered, such as biomass, firewood, hydropower, geothermal, wind, and solar.	per Chelsea's suggestion to differentiate out biomass	
Minerals and Energy (MIN)	MIN-G-02	new	n/a	Consultation should occur with the North Carolina Geological Survey, the United States Department of the Interior's Geological Survey, the Bureau of Land Management, and the United States Department of Energy on activities impacting minerals and energy resources.		8/17/21: changes finalized
Minerals and Energy (MIN)	MIN-S-02	revision	Staged reclamation shall be accomplished at each stage of mineral activity.	Reclamation should be timely and appropriate to the mining method employed.		7/15: change finalized. Tom and Michelle approved
Non-Timber Forest Products (NTFP)		revision		movement of Guidelines 3 and 4 from tribal section. No changes to the guideline language.		6/28/21: LR accepted track changes 7/12: change finalized

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Old Growth Network (OGN)	OGN-O-01 (for	revision	Tier 2: Enhance or accelerate the development of old growth conditions over time, by actively managing 250 acres for each ten year interval through activities such as increasing downed woody debris within all size classes by felling variable size trees, creating woodlands in appropriate ecozones by thinning and prescribe burning, enhancing the composition of native species, creating snags by girdling trees, and harvesting products as a side benefit of removing uncharacteristic vegetation.	Tier 2: Enhance or accelerate the development of old growth conditions over time, by actively managing 250 acres for each ten year interval through activities. *Management approaches:* Methods for enhancing old growth condition could include increasing downed woody debris within all size classes by felling variable size trees, creating woodlands in appropriate ecozones by thinning and prescribe burning, enhancing the composition of native species, creating snags by girdling trees, and harvesting products as a side benefit of removing uncharacteristic vegetation.		7/23: formerly ECO-O-03. rewritten to make 2nd half of objective into an associated MA, moved out of former Table 9. change finalized
Old Growth Network (OGN)	OGN-S-02	new	n/a	The size and configuration of the designated Old Growth Network that is defined in the Forest Plan shall be maintained through the life of this plan.		7/14: new standard for Alt. E. seperated out into its own Old Growth Network section (rather than ECO)
PAD	background	revision		see plan	Language in background paragraph has been updated with minor edits to reflect comments raised on the plan components.	changes made to NHNA and T&E background paragraphs
PAD	Mgmt Approac	new	n/a	Continue to work with partners to increase the population size, and enhance or restore suitable habitat for federally listed species on the forest and within western North Carolina.		7/14: change added from terr. Eco. Reorganization. This MA is under the sub heading "MAs applicable to all species groups"
PAD	Mgmt Approac	revision	Regularly coordinate with the State Natural Heritage Program regarding newly inventoried locations and proposed changes to the Heritage Program's state registry.	Regularly coordinate with the State Natural Heritage Program regarding newly inventoried locations and proposed changes to the Heritage Program's state registry including refinement of area boundaries to reflect new information about species and rare communities.		7/14: change added from terr. Eco. Reorganization. This MA is under the sub heading "MAs applicable to all species groups"
PAD	Mgmt Approac	revision	Coordinate with the State Natural Heritage Program on out year activities and potential partnership opportunities to improve Natural Area conditions.	Coordinate with the NC Natural Heritage Program early during the development of projects as well as on out year activities and potential partnership opportunities to improve NHNA conditions. Active management techniques may occur within NHNAs, such as but not limited to prescribed burning, vegetation management including commercial timber sales and non-commercial improvement practices, and nonnative invasive species treatments. Prioritize NNIS treatments in NHNAs and emphasize pre-treatment prior to management activities.		7/14: change added from terr. Eco. Reorganization. This MA is under the sub heading "MAs applicable to all species groups"
PAD	Mgmt Approac	new	n/a	Active management techniques may occur within NC Natural Heritage Natural Areas, such as but not limited to prescribed burning, timber management, and nonnative invasive species treatments.	added per FEIS notebook (last modified Oct 2020). Not sure if this is accurate	
PAD	Mgmt Approac	revision	Species management activities are done in coordination with the United States Fish and Wildlife Service (USFWS), North Carolina Wildlife Resources Commission (NCWRC)	Species management activities are done in coordination with the United States Fish and Wildlife Service (USFWS), North Carolina Wildlife Resources Commission (NCWRC), and the NC Heritage Program.		8/10- changes finalized in plan
PAD	PAD-DC-01	revision	see Table 11, pg. 83	Many changes to associated **Table 11**		3/24: changes to table will be grey-highlighted 7/20: Michelle is editing table. The common strategy listed in this table will become a standard.
PAD	PAD-DC-04	revision	Unique ecological characteristics are maintained or enhanced within the North Carolina Natural Heritage Natural Areas.	North Carolina Natural Heritage Natural Areas which support important populations of rare species and high-quality natural communities, contribute to the goal of maintaining and restoring biodiversity across the Forest.		7/14: DC completely revised
PAD	PAD-DC-05	new	n/a	The FS partners with NCNHP, NCWRC, and USFWS in the identification of plant and animal species and their associated habitat needs, proactively working to maintain, enhance, and restore plant and animal diversity.		

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PAD	PAD-DC-06 and	revision	**See Table 12, "Desired Conditions of Unique Habitats" pg. 85. DC:** Desired conditions for canopy cover and shrub and herbaceous cover of unique habitats are shown in Table 12. These conditions may also be enhanced by active management techniques. **Table 12:** *Rocky bar and shore: Occur along naturally functioning floodplains. *Caves/mines: Not trampled or impacted by recreationists, habitat free from white nose syndrome for a diversity of bats.	Changes to **table 12 "Desired Conditions of Unique Habitats" and Table 13 "Plant and Animal Diversity Objectives"** associated w/ DC, cave habitats: Caves/mines retain characteristics important to bats (E.g., microclimate, airflow) and are surrounded by healthy forests providing quality spring staging and fall swarming habitat. *Rocky bar and shore: Occur along naturally functioning floodplains, typically *Caves/mines: Not trampled or impacted by recreationists, habitat free from white nose syndrome for a diversity of bats. Caves/mines retain characteristics important to bats (E.g., microclimate, airflow) and are surrounded by healthy forests providing quality spring staging and fall swarming habitat.		3/24/21: changes to Table 13 "Plant and Animal Diversity Objectives" being made . 7/15: formerly DC-05 in draft plan. Multiple changes to associated Table 12. see Table/at left
PAD	PAD-G-01	revision	USFWS Recovery Plan and relevant Biological Opinion guidance for federally-listed species should be incorporated into project design and implementation.	Work directly with USFWS to ensure that Recovery Plan, 5-Year Reviews, and relevant Biological Opinion guidance for federally listed species is incorporated into project design and implementation.	This guideline was updated in response to comment from USFWS	3/24: flagged for Matt Tilden's (OGC) review. 11/2/2021 OGC recommended not referencing 5-year reviews in the guideline.
PAD	PAD-G-02	new	**PAD-O-05**: Tier 1: Coordinate annually with the NC Natural Heritage program to identify Natural Areas in potential project areas. Discuss unique values that are present in the area and management opportunities to enhance or maintain those values, including, but not limited to, the use of prescribed burning, thinning, regeneration and non-native invasive treatments. Based on latest information about the values present, review the boundaries of Natural Areas and discuss potential updates. The intent is to complete the review prior to initiating projects. Tier 2: Coordinate with the NC Natural Heritage program to review all Natural Areas on the Forests to discuss unique values and potential boundary adjustments and opportunities to enhance or maintain unique values. Where resources are limited, prioritize those areas that have higher State Natural Heritage Area rankings	When State Natural Heritage Natural Areas are present within an analysis area, coordination should occur with the NC Natural Heritage Program early during project development to discuss the unique ecological values present, the representativeness and quality of these values, and potential management. Project proposal development should consider opportunities to maintain or restore unique values. Field review may be necessary.	this language is to replace PAD-O-05	
PAD	PAD-O-03	revision	Tier 1: Restore and/or maintain at least 12 Southern Appalachian bogs by reducing woody plant production.	Tier 1: Restore and/or maintain at least 12 Southern Appalachian **bogs** by reducing woody plant encroachment .	Suggested word edit	
PAD	PAD-O-04	revision	Maintain existing **balds** across the Nantahala and Pisgah (Timeframe: 10 yrs)	Tier 1: Maintain or restore 10-20 acres of existing grassy balds across the Nantahala and Pisgah, outside of Roan Mountain. Across these habitat boundaries, maintain a variable size shrub or heath bald. (See also the separate bald objective for Roan Mountain: RM-O-01).		**7/12:** change finalized in plan. There is no longer a 10 yr timeframe stated.
PAD	PAD-O-05	new	**Tier 1:** Coordinate annually with the NC Natural Heritage program to identify Natural Areas in potential project areas. Discuss unique values that are present in the area and management opportunities to enhance or maintain those values, including, but not limited to, the use of prescribed burning, thinning, regeneration and non-native invasive treatments. Based on latest information about the values present, review the boundaries of Natural Areas and discuss potential updates. The intent is to complete the review prior to initiating projects. **Tier 2:** Coordinate with the NC Natural Heritage program to review all Natural Areas on the Forests to discuss unique values and potential boundary adjustments and opportunities to enhance or maintain unique values. Where resources are limited, prioritize those areas that have higher State Natural Heritage Area rankings. (Timeframe: annually)	Tier 1: Manage and restore *Hudsonia montana* and *Liatris helleri* populations to ensure competing woody plants do not overtop and impact either species.		7/12: change finalized in plan.Objective is entirely new, per FWS consultation discussions. Objective is no longer in Table 13. see 2 rows below for revised PAD-O-05 language (which is now a guideline) **9/23/2021 objective was revised further to remove specificity regarding Linville wilderness and Rx Fire.**
PAD	PAD-S-01	new	n/a	Continue to work with the USFWS to expand known range, increase the population size, and enhance/restore suitable habitat for federally listed species on the NP and within western North Carolina. to increase the population size and enhance/restore suitable habitat for federally listed species on the Nantahala and Pisgah and within western North Carolina.		7/23: change finalized. New S added by M, per FWS consultation discussions. All subsequent Standard #'s for PAD now go up by 1
PAD	PAD-S-02 (form	revision	Do not issue permits for collection of federally-listed species or species of conservation concern except for approved scientific purposes.	Do not issue permits for collection of federally-listed species or species of conservation concern except for approved scientific purposes and after coordinating with the USFSW.		7/23: formeraly PAD-S-01

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PAD	PAD-S-03	revision- deleted and rewritten entirely	In areas occupied by federally-listed species and species of conservation concern, management shall maintain characteristics required by these species.	Manage recreational impacts to Hudsonia montana and Liatris helleri within Linville Gorge Wilderness to protect the species. (See also REC-S-19)	This standard was moved to background because this is law/reg/policy.	**3/24:** further discussion w/ Gary needed to finalize **Loose end from Gary:** While I agree with this, we do not currently always do this. For instance if we have a relatively large healthy population of a SCC species, we may potentially affect a portion of the occupied habitat, thereby not maintaining characteristics. **7/12:** deletion of standard accepted and finalized. former (draft) PAD-S-03 deleted and moved to PAD background
PAD	PAD-S-03 (form	revision	*When Project-level field surveys for population and habitat of federally listed species or Species of Conservation Concern shall be commensurate with the risk of potential activities, using the following consistent and efficient approach: Field surveys may not be required if any of the following are true and are documented in the project record: * Field surveys shall be conducted when all of the following conditions are met: The proposed treatment area has a high potential for occupancy, and •Project activities may affect the population or habitat of a federally-listed species or Species of Conservation Concern, and •Adequate population inventory information is unavailable, and •Information on number and location of individuals and habitat conditions would improve project design, the application of mitigations to reduce adverse effects, or the assessment of effects of the population.	*When Project-level field surveys for population and habitat of federally listed species or Species of Conservation Concern shall be commensurate with the risk of potential activities, using the following consistent and efficient approach: Field surveys may not be conducted if any of the following are true and are documented in the project record: * Field surveys shall be conducted when all of the following conditions are met: The proposed treatment area has a (deleted 'high') potential for occupancy, and •Project activities may affect the population or habitat of a federally-listed species or Species of Conservation Concern, and •Adequate population inventory information is unavailable, and •Information on number and location of individuals and habitat conditions would improve project design, the application of mitigations to reduce adverse effects, or the assessment of effects of the population.	bullet previously added, then deleted: Measures implemented into project plans from consultation with USFWS will result in a project level determination of "may affect, not likely to adversely affect" when effects on listed species are expected to be discountable or insignificant.	3/24: Gary will review 4th bullet to confirm it's being added 7/12: deletion of "high" per 7/7/21 FWS consultation discussions. LR asked Michelle- was new proposed bullet point (at right) deleted? 7/13: Yes it was 7/23: change finalized. Standard was PAD-S-02 in draft plan.
PAD	PAD-S-04	revision	Prohibit rock climbing, rappelling, hang gliding, the use of drones, and other nest disturbing activities in the vicinity of active peregrine falcon nesting sites from January 15th to August 15th to control human disturbance and encourage successful nesting and fledging	Manage [rock- delete "rock"] climbing, rappelling, hang gliding, the use of drones, and other nest disturbing activities in the vicinity of active peregrine falcon nesting sites from January 15th to August 15th to control human disturbance and encourage successful nesting and fledging. (See also REC-S-19)		7/14: formerly PAD-S-05. nested under Standards-Rocky Habitats. 8/10- "rock climbing" changed to "climbing" throughout.
PAD	PAD-S-05	revision	Remove or relocate travelways from boulderfields known to support species such as the Allegheny woodrat and timber rattlesnake to minimize disturbance of suitable habitat features. Do not construct new trails across these features unless these species are confirmed to be absent.	Remove or relocate travelways from boulder fields known to support species such as the Allegheny woodrat and timber rattlesnake to minimize disturbance of suitable habitat features. Do not construct new trails across these features unless species at risk are confirmed to be absent.		7/14: formerly PAD-S-06. nested under Standards-Rocky Habitats
PAD	PAD-S-08	new	n/a	Coordinate with the USFWS to ensure that protection of potential and known hibernacula, and maternity habitat is consistent with the most recent conservation measures, recovery plans, biological opinions or USFS bat conservation strategy. This includes delineating appropriate fall swarming and spring emergence buffers and applying appropriate conservation measures (e.g. activity type, timing, etc.).		7/23: new S, per FWS consultation discussions. Changes finalized. All subsequent Standard #s increase by 1
PAD	PAD-S-09	revision	Post and enforce the regional cave and abandoned mine closure order at all biologically significant caves and other known bat hibernacula (e.g., abandoned mines, large rock shelters) to control human disturbance and prevent the spread of white-nose syndrome in cave-associated bats, including, but not limited to, the federally-endangered Indiana bat and threatened northern long-eared bat.	Post and enforce the regional cave and abandoned mine closure order at all biologically significant caves and other known bat hibernacula (e.g., abandoned mines, large rock shelters, talus slopes, cliff faces) to control human disturbance and prevent the spread of white-nose syndrome in cave-associated bats, including, but not limited to, the federally-endangered Indiana bat and threatened northern long-eared bat.		

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PAD	PAD-S-10 (form	revision	Post and enforce the regional cave and abandoned mine closure order at all biologically significant caves and other known bat hibernacula (e.g., abandoned mines, large rock shelters) to control human disturbance and prevent the spread of white-nose syndrome in cave-associated bats, including, but not limited to, the federally-endangered Indiana bat and threatened northern long-eared bat.	Post and enforce the regional cave and abandoned mine closure order at all biologically significant caves and other known bat hibernacula (e.g., abandoned mines, large rock shelters, talus slopes, cliff faces) to control human disturbance and prevent the spread of white-nose syndrome in cave-associated bats, including, but not limited to, the federally-endangered Indiana bat and threatened northern long-eared bat.		7/14: formerly PAD-S-09. nested under "standards-caves, abandoned mines and other bat hibernacula" subheading. 7/23: change finalized
PAD	PAD-S-11 (form	no changes, except #	no changes to text			7/23: changes finalized. Formerly PAD-S-10
PAD	PAD-S-12 (form	no changes, except #	no changes to text			7/23: changes finalized. Formerly PAD-S-11
PAD	PAD-S-14	revision	Within spruce-fir and northern hardwood forests, maintain a 100' canopy tree buffer around rock outcrops greater than 300 square feet in size to protect spruce-fir moss spider and rock gnome lichen habitat. If structural or compositional restoration needs are identified within this area, appropriate field surveys and consultation with the USFWS to design and implement projects to meet multiple objectives shall be conducted.	Within spruce-fir and northern hardwood forests, maintain a 100' canopy tree buffer around rock outcrops and boulders in appropriate habitat for spruce-fir moss spider and rock gnome lichen . If structural or compositional restoration needs are identified within this area, appropriate field surveys and consultation with the USFWS to design and implement projects to meet multiple objectives shall be conducted.	This std was edited to be more general in response to USFWS	3/24: M approves changes
PAD	PAD-S-14 (form	revision	Within the documented range of green salamanders, shaded rocks greater than 36 square feet in size shall be surveyed for species' presence. If present, project activities shall be designed to avoid direct and indirect disturbance of the species and habitat, to protect thermal and moisture characteristics of the rocks (e.g., when appropriate, identification of a 300 foot no canopy tree removal buffer or other mitigations) and provide for habitat connectivity and dispersal. If the rocks are determined to be unoccupied, design activities to maintain suitable habitat.	Within the documented range of green salamanders, shaded rocks greater than 36 square feet in size shall be surveyed for species' presence during project-level planning. These surveys shall occur prior to project design to inform project implementation. If present, project activities shall be designed to avoid direct and indirect disturbance of the species and habitat, to protect thermal and moisture characteristics of the rocks (e.g., when appropriate, identification of a 300 foot no canopy tree removal buffer or other mitigations) and provide for habitat connectivity and dispersal. If the rocks are determined to be unoccupied, design activities to maintain suitable habitat.		7/14: formerly PAD-S-13. nested under "standards-green salamander" subheading
PAD	PAD-S-15 (form	revision	Within spruce-fir and northern hardwood forests, maintain a 100' canopy tree buffer around rock outcrops greater than 300 square feet in size to protect spruce-fir moss spider and rock gnome lichen habitat. If structural or compositional restoration needs are identified within this area, appropriate field surveys and consultation with the USFWS to design and implement projects to meet multiple objectives shall be conducted.	Within spruce-fir and northern hardwood forests, maintain a 100' canopy tree buffer around rock outcrops and boulders in appropriate habitat for spruce-fir moss spider and rock gnome lichen. If structural or compositional restoration needs are identified within this area, appropriate field surveys and consultation with the USFWS to design and implement projects to meet multiple objectives shall be conducted.		7/14: formerly PAD-S-14. nested under "standards-spruce fir moss spider and rock gnome lichen" subheading
PAD	Threatened or Endangered Species, Status, and Contributions	revision	White Fringless Orchid (*Platanthera integrilabia*); T; Maintain bogs and wetlands for potential occupancy.	this final row/species of Table 11 has been deleted. Other significant changes/reformatting anticipated		**7/12:** species has been removed by request of USFWS. Change finalized in plan **7/14:** there may be other changes/reorg. To this table
Public Involvement (PI)	Mgmt Approac	revision	Forest Service employees provide high quality customer service, striving to create a management environment characterized by collaboration, communication, and cooperation.	Forest Service employees provide high quality customer service, striving to create a management environment characterized by inclusivity, collaboration, communication, and cooperation.		
Public Involvement (PI)	Mgmt Approac	new	n/a	As needed, review and update group volunteer agreements, favoring to develop Forest or multi-district group volunteer agreements where appropriate.		per 3/24 discussion w/ M and H. 7/27: change finalized
Public Involvement (PI)	Mgmt Approac	revision	Encourage the formation of broadly-based user groups to assist, communicate, and support forest resources activities. Work with interested individuals and user groups to promote responsible, safe, and sustainable public use practices and to help the Forest Service communicate with the public and interested organizations.	Encourage the formation of broadly-based user groups to assist, communicate, and support forest resource management activities. Work with interested individuals and user groups to promote responsible, safe, and sustainable public use practices and to help the Forest Service communicate with the public and interested organizations.		
Public Involvement (PI)	PI-DC-03	revision	Forest managers work with state and local governments, tribes, and partners across boundaries to achieve shared goals.	Forest managers work with state and local governments, tribes, and partners across boundaries to achieve shared goals, to enhance our capacity for restoration, including the control of pests, non-native invasive species, and use of prescribed fire.		

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
REC	background	revision	Dispersed recreation occurs in all management areas and geographic areas and is managed to provide for a variety of opportunities and activities across all recreation settings. The combination of activity and setting allows for a broad range of user experiences, from backcountry angling in designated Wilderness to riding off-highway vehicle (OHV) trails. Access to dispersed recreation opportunities can be from Federal, state, or National Forest System (NFS) roads and trails, as well as waterways, climbing routes, or by cross-country foot-travel. With hundreds of miles of NFS trails for hiking, bicycling, horseback riding, and OHV use, access for dispersed recreation is provided to most management areas. In addition to trails, the network of NFS roads open to vehicular use allows motorized access to many parts of the Forests, while administratively closed, or "gated", NFS roads often serve as connectors to equestrian and bicycle trails. Many of these "gated" roads are also managed as linear wildlife openings that enhance access and opportunities for hunting and wildlife viewing. Distributed throughout the Forests are numerous opportunities for other types of recreation, like rock climbing, whitewater boating, swimming, long-distance trail backpacking, hunting, fishing, nature study, photography, bush crafting, primitive camping, car-camping at designated dispersed campsites, and many other activities.	Dispersed recreation occurs in all management areas and geographic areas and is managed to provide for a variety of opportunities and activities across all recreation settings. The combination of activity and setting allows for a broad range of user experiences, from backcountry angling in designated Wilderness to riding off-highway vehicle (OHV) trails. Access to dispersed recreation opportunities can be from Federal, state, or National Forest System (NFS) roads and trails, as well as waterways, climbing routes, or by cross-country foot-travel. With hundreds of miles of NFS trails for hiking, bicycling, horseback riding, and OHV use, access for dispersed recreation is provided to most management areas. In addition to trails, the network of NFS roads open to vehicular use allows motorized access to many parts of the Forests, while administratively closed, or "gated", NFS roads often serve as connectors to equestrian and bicycle trails. Many of these "gated" roads are also managed as linear wildlife openings that enhance access and opportunities for hunting and wildlife viewing. Distributed throughout the Forests are numerous opportunities for other types of dispersed recreation, like climbing and similar activities, whitewater boating, swimming, long distance trail backpacking, hunting, fishing, nature study, photography, primitive camping, car-camping at designated dispersed campsites, and many other activities.		7/15: changes accepted
REC	Mgmt Approac	new	n/a	Replaces REC-S-15 language from draft plan entirely, per Erik's 6/16/21 finalized revisions: Collaborative trail planning at a Geographic Area or Ranger District scale should address deferred maintenance needs, structure repair or replacement, new trail construction or decommissioning, connectors and loop trail opportunities, unauthorized route adoption or closure, resource damage, user conflicts, user education and trail etiquette, effective utilization of volunteers and partnerships, and procurement of grants or other non-allocated funding for trail construction and maintenance; this should be done for each trail complex. Planning discussions could take multiple forms. They could consist of public meetings for each Geographic Area or Ranger District every 5-7 years, a series of ongoing stakeholder meetings, or public engagement in conjunction with other project or landscape level planning efforts where sustainable management of hiking, bicycle, and/or equestrian trails is the focus. Collaborative trail planning may include key representatives of stakeholder groups, volunteer or partner organizations, user councils, community organizations, special use permit holders, and/or state or local governments with an interest in sustainable trail management.	REC-S-14 New trail construction, or adoption of unauthorized routes as system trails, must meet conditions 1-3 below. See exceptions for trail relocation and connectors in REC-S-15. 1. Proposed trails have been identified through collaborative trail planning between the Forest Service and interested stakeholders, such as recreation users, volunteer or partner organizations, user councils, community organizations, special use permit holders, state or local governments, etc. Etc...	4/28: new MA added from the document "Equestrian Bicycle Trail Objectives Standard - Draft 3.25.2021". This MA may be revised further. Revisit. 6/22: changes approved, per Erik's finalized changes 7/15: confirming w/ M-are we moving this MA? 1/17/22- move from S-15 to S-14 and edited language include.
REC	Mgmt Approac	revision	iv. Mountain bike, equestrian, and backcountry hiking trails as further prioritized by collaborative trail planning.	revision to the 2nd to last MA, bullet iv.: Mountain bike, equestrian, and (backcountry deleted) hiking trails as further prioritized by collaborative trail planning.		7/15: change finalized
REC	Mgmt Approac	deletion	Where trail use and climbing routes are impacting unique habitats, trails will be closed, relocated, or other protection measures will be implemented.	n/a. MA deleted		7/15: change finalized
REC	Mgmt Approac	revision	Bear-proof trash or food storage containers are available at sites where bears are known to frequent, as funding is available according to the area ROS class. Practices such as pack it in pack it out are also encouraged to reduce the potential to attract bears.	Bear-proof trash receptacles and/or food storage devices should be installed at sites where bears are known to frequent and as funding is available. Decisions on the need for such devices and the type installed should consider the desired ROS setting. Where bear-proof trash receptacles are not provided, pack-it-in-pack-it-out practices should be encouraged through visitor education, and signage where appropriate, to reduce the potential to attract bears.		8/10- this was included in Rec comments spreadsheet, but not yet documented here. Changes are in the current Plan draft. arc
REC	Mgmt Approac	new		The identification of non-commercial mineral collection sites and techniques (REC-O-02) will involve collaboration with mineral and rock collecting groups, volunteer or partner organizations, and/or state or local governments with an interest in minerals and geology.		8/17/21: approved by Michelle. Changes finalized

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
REC	objective. Placeholder	new	n/a	**TA-O-01 Tier 1: Unauthorized road and trail miles within priority watersheds and Inventoried Roadless Areas will be identified and prioritized for obliteration to minimize erosion and sedimentation. A minimum of 20 miles of unauthorized roads and 30 miles of unauthorized trails will be restored to natural contours during the life of the plan.**		**4/12/21:** The following note was transferred from the old FEIS notebook "Detailed list of plan components changing": Add objective for obliterating unauthorized trails in IRAs and priority watersheds (previously in TA-O-04). Mileage for trails would be 30 miles. LR not sure if this change has been finalized. need to revisit. 1/17/22- change confirmed
REC	REC-DC-01	revision	Forest settings reflect healthy and resilient landscapes, provide a diverse sense of place for community residents and visitors and connect people to the land through high-quality and safe sustainable recreation opportunities and valuable outdoor experiences. The Forests' recreation niches include sightseeing; water-based recreation (motorized and non-motorized boating, swimming, and other aquatic recreation activities); non-motorized trails for hiking, mountain biking, and pack-and-saddle; motorized trails; climbing; remote backcountry experiences; hunting, fishing, and wildlife viewing; and conservation education.	Forest settings reflect healthy and resilient landscapes, provide a diverse sense of place for community residents and visitors and connect people to the land through high-quality and safe sustainable recreation opportunities and valuable outdoor experiences. The Forests' recreation niches include sightseeing; water-based recreation (motorized and non-motorized boating, swimming, and other aquatic recreation activities); non-motorized trails for hiking, mountain biking, and pack-and-saddle; motorized trails; climbing and similar activities; remote backcountry experiences; hunting, fishing, and wildlife viewing; and conservation education.		8/10- changes complete in plan
REC	REC-DC-21	revision	Sustainable trail use occurs within the ability of the land to support it, with high visitor satisfaction, minimal conflict between users, and without impacts to ecologically and culturally sensitive areas.	Sustainable dispersed recreation use occurs within the ability of the land to support it, with high visitor satisfaction, minimal conflict between users, and without impacts to ecologically and culturally sensitive areas.		7/15: changes accepted. Formally REC-DC-22 in draft plan. We're switching the order of the 2 DCs.
REC	REC-DC-22	revision	An ecologically, socially, and financially sustainable system of trails provides high quality recreation experiences across a range of settings for each use-type.	An ecologically, socially, and financially sustainable system of trails provides high quality recreation experiences across a range of settings for each use-type.		7/15: no changes to text of this DC. Just noting it here as it switched order w/ REC-DC-21 from draft.
REC	REC-O-01	revision	Tier 1: Move toward a more ecologically, socially, and economically sustainable recreation program by: i. Implementing collaborative recreation planning with stakeholders and local communities to develop a strategic guidance and a shared vision for sustainable recreation for the future within five years. ii. Improve visitor satisfaction by maintaining and operating priority developed recreation sites to a facility condition index of at least 90 percent and to National Quality Standards within 10 years.	Tier 1: Move toward a more ecologically, socially, and economically sustainable recreation program by: i. Implementing collaborative recreation planning with stakeholders and local communities to develop a strategic guidance and a shared vision for sustainable developed recreation for the future within five years. ii. Improve visitor satisfaction by maintaining and operating priority developed recreation sites to a facility condition index of at least 90 percent and to National Quality Standards within 10 years.		7/1/21: edit suggested by Alice and Erik per public comment; addition of "developed" approved by Michelle and Heather, 7/20: change finalized

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
REC	REC-O-07	new	Note: This objective differs by alternative. This objective only exists in Alternative D and is not considered in Alternatives A, B or C. The effects of including this objective in Alt D is discussed in the accompanying draft Environmental Impact Statement. Alternative D: Tier 1: Within three years, establish a "Trail Bank" that can be used to add new sustainable trail miles to the trail system for hiking, cycling, and pack and saddle uses. The Trail Bank will begin with a seed of 30 miles. Additional miles will be credited to the Trail Bank when existing NFS trails are decommissioned and/or rehabilitated. Trail Bank credits can then be used, but not exceeded, when constructing new sustainable trails or adopting unauthorized routes as NFS trails. The Trail Bank system will also have provisions for the forest supervisor to increase or decrease trail mile credits based on periodic reviews of trail program needs and limitations and changing trail-use trends within a Geographic Area. Use of Trail Bank credits will focus on improving ecological, social, and financial sustainability of the Nantahala and Pisgah NF trail system by conducting critical analysis of new trail proposals, increasing the percentage of NFS trails meeting National Quality Standards, reducing the occurrence of unauthorized routes, and providing desired user experiences.	*** A trail bank O does not exist in Alt. E* New O is below** (a) Tier 1: Within 5 years, begin collaborative trail planning to address equestrian and/or bicycle trail supply/demand issues in Bald Mountains, Black Mountains, Eastern Escarpment, and Highland Domes Geographic Areas. (b) Tier 1: To help move the trail system to a more sustainable condition forestwide, conduct collaborative trail and trailhead planning across all Geographic Areas every 5-7 years, building on the Nantahala and Pisgah National Forest Trail Strategy.	It's labeled in the document (one mentioned to the right) as REC-O-07. Is it replacing the trail bank objective above?	**4/28**: new objective added from the document "Equestrian Bicycle Trail Objectives Standard - Draft 3.25.2021". This may be revised further. Revisit. Currently REC-O-11 in April version of plan in Teams. 7/15: complete rewrite of this objective. Changes finalized.
REC	REC-O-09	revision	Tier 2: Through a collaborative process, develop a Nantahala and Pisgah National Forest climbing strategy that provides guidance on rock climbing, bouldering, and slack lining; guidance shall address climbing in general forest and designated areas.	Tier 2: Over the life of the Land Management Plan, develop a Nantahala and Pisgah National Forest climbing management plan in collaboration with representatives of the climbing community. The climbing management plan should utilize inventories of climbing routes, access trails, staging areas, and other information provided by users to develop area-specific management direction following the latest agency policy on climbing and similar activities. The climbing management plan should consider user desires to improve the climber experience, identify access trails suitable for addition to the system, explore climber education opportunities, identify site-specific resource protection measures and potential closures, and develop monitoring protocol.		7/15: change finalized
REC	REC-O-09/12 (?) This is REC-O-07	new	n/a	Tier 1: Within 5-years, collaboratively plan for new trails to address equestrian and/or bicycle trail supply/demand issues in Bald Mountains, Black Mountains, Eastern Escarpment, and Highland Domes Geographic Areas. Once planning and analysis of proposed trails is completed in these Geographic Areas, implement REC S-11 through a Forest Supervisor order. Included in current Plan draft, arc 8/10: REC-O-07(a) Tier 1: Within 5 years, begin collaborative trail planning to address equestrian and/or bicycle trail supply/demand issues in Bald Mountains, Black Mountains, Eastern Escarpment, and Highland Domes Geographic Areas. (b) Tier 1: To help move the trail system to a more sustainable condition forestwide, conduct collaborative trail and trailhead planning across all Geographic Areas every 5-7 years, building on the Nantahala and Pisgah National Forest Trail Strategy.	4/28: in April version of plan, currently REC-O-12. may need to align numbering w/ REC-S-11. which REC objective is this ultimately?	4/27: has this objective been finalized and approved as is? added from the document "Equestrian Bicycle Trail Objectives Standard - Draft 3.25.2021". This may be revised further. Revisit. 8/10-See updated objective in Red. Already included above.
REC	REC-S-11	revision	Equestrian (horse, stock, pack and saddle) and bicycle use is only allowed on NFS trails designated for those uses, and on open or gated NFS roads; unless the road is closed to those uses by forest supervisor order. Equestrian use is allowed for big game retrieval in hunting seasons identified by the State	*standard remains the same, footnote added:* footnote 16: * Standard REC-S-11 will be implemented forestwide through a Forest Supervisor order after Objective REC-O-07(a) has been achieved		4/28: revision added from the document "Equestrian Bicycle Trail Objectives Standard - Draft 3.25.2021". This S may be revised further. Revisit. 6/22: standard remains the same, with a footnote added footnote :

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
REC	REC-S-14	revision, entire component replacement	different wording for Alternatives B, C and D. Given that this proposed plan does not indicate a preferred alternative, and all options are shown below. The effects of this difference in language by alternative is discussed in the accompanying draft Environmental Impact Statement. Alternative B: New trail construction or adoption of unauthorized routes as NFS trails, shall only be allowed if all of the following conditions are met: 1. Trail layout incorporates the most current design principals, minimizes adverse impacts to natural and cultural resources, and does not increase user conflict. 2. The proposed trail is found to be ecologically, socially, and financially sustainable; and the project has been approved by the forest supervisor. Alternative C: New trail construction or adoption of unauthorized routes as NFS trails, shall only be allowed if all of the following conditions are met: 1. same as 1 above in Alternative B… 2. same as 2 above in Alternative B… 3. The need for a new trail has been identified through a Forest Service-lead collaborative planning process or trail strategy. 4. Within the Geographic Area, new trail mileage will be offset by a comparable length of existing NFS trail decommissioning. Alternative D: New trail construction or adoption of unauthorized routes as NFS trails, shall only be allowed if all of the following conditions 1 through 4 are met, and at least one of the conditions in 5a through 5c is met: 1. same as 1 above in Alternatives B and C… 2. same as 2 above in Alternatives B and C… 3. same as 3 above in Alternative C…	**REC-S-14** New trail construction, or adoption of unauthorized routes as system trails, must meet conditions 1-3. See exceptions for trail relocation and connectors in REC-S-15. 1. Proposed trails have been identified through collaborative trail planning between the Forest Service and interested stakeholders, such as recreation users, volunteer or partner organizations, user councils, community organizations, special use permit holders, state or local governments, etc. 2. (a) One or more volunteer or partner organizations commit to long-term maintenance of proposed trails through an agreement; OR… (b) Proposed trails resolve critical health and safety needs, or supply/demand issues identified in Geographic Area Goals; OR… (c) New trail mileage will be offset by a comparable length of existing system trail decommissioning, or unauthorized route closure of at least twice the length. 3. Proposed trails are found to be ecologically, socially and financially sustainable; and must utilize current trail design principles, avoid adverse impacts to natural and cultural resources, and not create user conflicts. **footnote 18**: Financial sustainability should consider available resources for initial construction and long-term maintenance, such as agency allocated funding, fee or permit revenue, grants, endowments, contributions from volunteer or partner organizations, etc.		6/22: changes approved
REC	REC-S-15	revision, entire component replacement	Relocation of unsustainable NFS trails to mitigate resource damage, safety issues, or user conflicts does not require a match in decommissioned trail miles, understanding the length of relocated and decommissioned trail segments may differ. Abandoned trail segments shall be decommissioned and rehabilitated to prevent continued resource damage, and the relocated trail segment shall adhere to conditions of REC-S-14 items 1 and 2.	Relocation of unsustainable system trails regardless of length, or construction of new connector trails of less than 0.5 miles to create loop opportunities, are not subject to REC-S-14 conditions 1 and 2 but must conform to condition 3. Relocated trails or trail segments may be longer than those being replaced, potentially resulting in a net increase of system trail miles. Abandoned trail segments shall be decommissioned to prevent continued resource damage and discourage use, unless sustainability can be addressed by repairs and changing designated use to hike-only.		7/15: changes finalized
REC	REC-S-19	revision	New trails or climbing routes shall not traverse unique habitats in rocky areas, such as high and low elevation rocky summits, high and low elevation granitic domes, or basic and acidic cliffs.	Until completion of a climbing management plan per REC-O-09, implement the following: (a) New trails or climbing routes shall not traverse unique habitats or NRHP eligible, unevaluated, or sacred cultural resource sites on rocky summits, granitic domes, cliffs, or waterfall spray zones. (b) Where existing trail use or climbing routes are impacting unique habitats or NRHP eligible, unevaluated, or sacred cultural resource sites, climbing routes shall be closed, unauthorized trails shall be obliterated, NFS trails shall be decommissioned or relocated, or other protective measures must be implemented to mitigate resource impacts.		7/15: changes accepted. Complete re-write of S.The last dispersed recreation MA was deleted and incorporated into this S
REC	TBD	new		FR-S-01 If existing or planned NFS trails are used for access or to create fire lines associated with prescribed burns or wildfire suppression, trails impacted by fire operations shall be repaired to meet agency standards for appropriate trail classes and use-types, including restoration of unique recreational values and use of sustainable trail design principles.		1/17/22- changes confirmed

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Scenery (SC)	background	revision	Combined, the two National Forests receive approximately 4.6 million visits annually. National Visitor Use Monitoring has shown that 55 percent of visitors to the Forests (approximately 2.5 million annually) engage in viewing scenery.	Combined, the two National Forests receive approximately 5.1 million visits annually. National Visitor Use Monitoring has shown that 53 percent of visitors to the Forests (approximately 2.5 million annually) engage in viewing scenery.		4/13: no changes to scenery section of the plan, except for updated NVUM #s in the background, thus far. This row is a placeholder to keep the spreadsheet order consistent with Plan Table of Contents. Revisit later to confirm. 6/28.21: changes to NVUM #s remains the only change to this section 7/15: change finalized
Scenery (SC)	SC-S-03	revision	Desired Scenic Integrity Objectives must be met in the following timeframes:	change to lead in statement: For vegetation management actions, desired Scenic Integrity Objectives must be met in the following timeframes:....(remaining text remains unchanged)		7/15: change finalized
Soils (SLS)	SLS-G-01	revision	During planning of roads, trails, and other infrastructure, avoid hydric soils or mitigate adverse impacts to protect the function of these soils when no alternative is available.	During planning of roads, trails, and other infrastructure, avoid hydric soils or mitigate adverse impacts to protect the function of these soils when no reasonable or practical alternative is available.		
Soils (SLS)	SLS-G-02	revision	During construction of roads, trails, and other infrastructure, the risk of soil erosion should be reduced by implementing mitigation measures such as erosion control matting, slash (tree branches, etc.) placement, seeding, and mulching. The minimum amount of soil should be exposed at any given time during project execution.	During construction of roads, trails, and other infrastructure, the risk of soil erosion should be reduced by implementing mitigation measures such as erosion control matting, slash (tree branches, etc.) placement, seeding, and mulching. The minimum amount of soil should be exposed at any given time during project implementation.		6/28/21: minor change, word replacement
Soils (SLS)	SLS-S-01	revision	Lannette please note the change in plan component number (used to be ECO-O-10). (This was moved here from Terrestrial Ecosystems). Same words as before.	Vegetation management activities, road and trail design, and other proposed infrastructure projects shall be screened for the presence of highly erodible soils. If present, then location and design measures shall be provided to reduce erosion potential and effects to natural resources.		4/12: added as a placeholder to keep order consistent w/ Plan table of contents. There may be a change to SLS-S-01. need to revisit **6/28/21:** emailed Barry Jones to get final approval to change SLS-S-01 **7/12:** LR finalized change, deleted comment thread in plan
Streamside Zones (SZ	background	revision	n/a	Follow up with Sheryl on rewriting this guideline, possibly separating into 2 or 3 Gs		
Streamside Zones (SZ	Mgmt Approac	new	n/a	**added 2 new MAs**: The NPNF monitors the implementation and effectiveness of Forestry Best Management Practices annually to document our status for meeting Forest Plan standards, North Carolina State water quality standards and ultimately the Clean Water Act. Review of forest practices effectiveness occurs annually as part of our program of work and a summary of monitoring findings is drafted. In response to monitoring results, less than effective practices are diligently corrected to meet management direction. A summary of monitoring results is presented bi-annually in the Forest Plan Monitoring and Evaluation Report. Manage ephemeral stream channels and their areas of impact to reduce the risk of erosion and sedimentation by minimizing disturbance during management. For example, temporary road and skid trail crossings are allowed but minimized and timber is managed while minimizing soil disturbance and retaining vegetation for slope stability.		
Streamside Zones (SZ	SZ-DC-01	revision	Areas along streams and rivers and around ponds, and reservoirs are healthy, functioning, and contain a variety of forest compositions and structures representative of the existing forest community. Streamside zones may vary based on site-specific conditions that consider geology, soils, vegetation, and water flows.	Updated as shown.		6/28: revised grey highligting in plan to account only for the changed text

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Streamside Zones (SZ	SZ-G-01	revision	When stream crossing is needed, new road and trail construction, including skid trails should minimize potential effects of management (e.g., sedimentation of habitats, increased water temperature, etc.) on aquatic habitat and populations, and follow ECO-S-07 to meet soil and water quality standards. Additionally, existing roads and trails should be a priority for maintenance, relocation or decommissioning as appropriate in this zone. (See Terrestrial Ecosystems: Timber Guidelines)	When stream crossing is needed by new road, trail and other management activities, minimize potential effects of management (e.g., sedimentation of habitats, increased water temperature, etc.) on aquatic habitat and populations, and follow ECO-S-07 and TA-S-04 to meet soil and water quality standards. Additionally, existing roads and trails should be a priority for maintenance, relocation or decommissioning as appropriate in this zone.		
Streamside Zones (SZ	SZ-O-02	revision	Tier 1: Implement three and five stream channel improvement projects annually, using natural channel concepts, focusing on restoring floodplain connectivity, stream bank stability, and enhancement of aquatic habitat diversity. Tier 2: Implement between six to ten stream channel improvement projects annually, using natural channel concepts, focusing on restoring floodplain connectivity, stream bank stability, and enhancement of aquatic habitat diversity.	Tier 1: Implement at least three stream channel improvement projects annually, using natural channel concepts, focusing on restoring floodplain connectivity, stream bank stability, and enhancement of aquatic habitat diversity. Tier 2: Implement at least six stream channel improvement projects annually, using natural channel concepts, focusing on restoring floodplain connectivity, stream bank stability, and enhancement of aquatic habitat diversity		
Streamside Zones (SZ	SZ-S-01	revision	SZ-S-01 Vegetation management activities within streamside zones (as defined in figure below) of perennial and intermittently flowing streams must contribute to ecosystem restoration and not compromise aquatic system and riparian structure and function with the exception of short term impacts for long-term improvements. For example, water temperature regulation, sediment transport, streambank stability, and recruitment of large woody debris must exhibit natural dynamics after treatment. In these areas other objectives must be secondary to ecosystem restoration. Streamside zones are delineated as: •Within 100 feet of either side of (or perimeter around) perennial waterbodies (streams, ponds, and reservoirs); •Within 100 feet of perennial springs, bogs, and other wetlands; •Within 50 feet of either side of (or perimeter around) intermittent streams Narrowing of the above widths are allowed in special circumstances when the project IDT determines that within "shallow valleys", where a break in topography occurs within the SMZ, water flow is directed away from the protected waterbody. The IDT shall also consider potential changes in shading , subsequent stream temperature changes, and wildlife habitat connectivity. Any alteration to SMZs shall be documented in the project record. Additionally, all activities must be in compliance with NC Best Management Practices and Forest Practice Guidelines related to water quality. While vegetation management is allowed within streamside zones, as described above, this area is not suitable for timber production.	Vegetation management activities within streamside zones (as defined in figure below) of perennial and intermittently flowing streams must contribute to ecosystem restoration and not compromise aquatic system and riparian structure and function with the exception of short term impacts for long-term improvements. For example, water temperature regulation, sediment transport, streambank stability, and recruitment of large woody debris must exhibit natural dynamics after treatment. In these areas other objectives must be secondary to ecosystem restoration. Streamside zones are delineated as: •Within 100 feet of either side of (or perimeter around) perennial waterbodies (streams, ponds, and reservoirs); •Within 100 feet of perennial springs, bogs, and other wetlands; •Within 50 feet of either side of (or perimeter around) intermittent streams Narrowing of the above widths are allowed in special circumstances when the project IDT determines that within "shallow valleys", where a break in topography occurs within the SMZ, water flow is directed away from the protected waterbody. The IDT shall also consider potential changes in shading , subsequent stream temperature changes, and wildlife habitat connectivity. Any alteration to SMZs shall be documented in the project record. Additionally, all activities must be in compliance with NC Best Management Practices and Forest Practice Guidelines related to water quality. While vegetation management is allowed within streamside zones, as described above, this area is not suitable for timber production.		footnote 10 added to clarify that standard's restrictions is in addition to NC BMPs
Streamside Zones (SZ	SZ-S-02	revision	Avoid ground disturbing activities, such as skid roads and trails, temporary or permanent roads, log landings and loading areas, and waste disposal areas within streamside zones unless satisfactory mitigation measures have been designed. When soils sensitive to erosion, steep slopes and other factors identified by the analysis dictate, consider site specific mitigations, including wider exclusion zones for logging equipment. (See Terrestrial Ecosystems: Timber Standards)	Avoid ground disturbing activities, such as skid roads and trails, temporary or permanent roads, log landings and loading areas, firelines, concentrated recreational use and waste disposal areas within streamside zones except for designated stream crossings or when placement of disturbance-prone activities outside of the streamside zone would result in more environmental disturbance than placing such activities within the streamside management zone. Satisfactory mitigation measures shall be designed. (See Terrestrial Ecosystems: Ecosystem Restoration through Silviculture or Timber Management Practices and Fire and Fuels)		8/17/21: changes finalized Additional edit made on 9/21/2021 per Brady's review
Streamside Zones (SZ	SZ-S-03	new	n/a	Do not remove down large woody debris from streamside zones , unless it poses a significant risk to stream flow, water quality, aquatic or riparian habitat, or downstream infrastructure (e.g. bridges or other stream crossings). Need for removal of large woody debris in these zones is determined on a project-specific basis by a hydrologist or other aquatic specialist.		

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Streamside Zones (SZ	SZ-S-05	revision	Within identified streamside zones, allow chemical treatment to improve native plant composition and growth; and for non-native invasive plant species, control with aquatic-labeled herbicides and/or adjuvants. Applicators will use guards on the end of sprayer wands when applying along stream edges and banks. All herbicide will be sprayed away from any water source.	Within identified streamside zones, allow chemical treatment to improve native plant composition and growth; and for non-native invasive plant species, control with aquatic-labeled herbicides and/or adjuvants sprayed away from the water source. Applicators will use guards on the end of sprayer wands when applying along stream edges and banks.	**From Jason Farmer:** would there ever be a time when we would consider treating NNIS plants IN a stream (like hydrilla in the Cheoah River or didymo)?? If so, would we just handle it with a one-time forest plan amendment? I'm not advocating adding anything to the forest plan… **From Michelle:** Need to see how the new NNIS EA is looking at this and ensure consistency. When treatment is needed in water, need to ensure this is covered in aquatic, water or NNIS sections. But some of these might not be NNIS, just woody encroachment.	3/28/21: This is still a loose end. 3/29: Heather confirmed that the edits look good.
Terrestrial Ecosystems (ECO)	background	significant reorganization; many changes made		*see plan for changes. *Changes made under the "wildlife habitat across terrestrial ecozones" heading * changes to this paragraph: Across multiple above objectives, vegetation management activities, including, but not limited to, timber harvest and fire management, will emphasize ecosystem restoration (as reflected in forest-wide desired conditions) and maintaining existing silvicultural investments. Use geographic area goals, compositional and structural departure results, and monitoring reports to aid in the identification of vegetation management opportunities.	From Michelle: Need to see how the new NNIS EA is looking at this and ensure consistency. When treatment is needed in water, need to ensure this is covered in aquatic, water or NNIS sections. But some of these might not be NNIS, just woody encroachment.	3/24/21: Michelle is reorganizing this section, unintegrating 7/13: changes accepted. Entire background text highlighted in grey due to significant changes
Terrestrial Ecosystems (ECO)	ECO-DC-01	revision	The ecological integrity of the landscape pattern and connectivity is enhanced and maintained broadly across the Forests. Landscape patches and connectors sustain a diversity of ecosystems and habitat types, enhancing conditions for native species. The landscape sustains an evolving network of structural classes (from young to old) within the natural range of variation for each ecological zone.	Across the forest, patches and connectors of National Forest System land sustain a diversity of ecosystems and habitat types, providing ecological integrity and enhancing conditions for native species.		7/13: changes added. Significant rewrite
Terrestrial Ecosystems (ECO)	ECO-DC-02	revision	Some landscape patches evolve mostly through natural succession and natural disturbance regimes, which are less frequently managed than other patches because of their location on the landscape or because their desired management is relatively light. Due to the number and size of these patches, the areas are large enough for natural systems to evolve. High quality old growth characteristics develop over time and dominate these patches. A relatively small amount of management would continue in these lands, such as where the forest has uncharacteristic conditions that need to be restored	Some landscape patches develop mostly through natural succession and natural disturbance regimes. These patches are less frequently managed than other patches because of their location or because their desired management is relatively light. Due to the number and size of these patches, the areas are large enough for natural systems to evolve. High quality old growth characteristics develop over time and dominate these patches. A relatively small amount of management would continue in these lands, such as where the forest has uncharacteristic conditions that need to be restored.		7/13: change added, per Michelle's re-org/edits
Terrestrial Ecosystems (ECO)	ECO-DC-03	revision	Other landscape patches evolve through a combination of natural succession and natural and human-caused disturbances. These patches contain the most actively managed landscapes where management contributes to the landscape's overall natural range of variation. These patches provide a mix of habitat types for a wide variety of species that depend on young forests as well as old. Young forests are provided in a patch size and arrangement to provide high quality habitat for species dependent on these forest conditions.	Other landscape patches evolve through a combination of natural succession with both natural and human-caused disturbances. These patches contain the most actively managed landscapes where management contributes to the landscape's overall natural range of variation. These patches provide a mix of habitat types for a wide variety of species that depend on young forests as well as old. Young forests are provided in a patch size and arrangement to provide high quality habitat for species dependent on these forest conditions. Locally, young forest patch size will frequently exceed average natural disturbance gap size to provide for habitat diversity and benefit wildlife, and to facilitate restoration operations and financial considerations, but will not contribute to exceeding the Natural Range of Variation at the landscape scale.		7/13: change added, per Michelle's re-org/edits

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Terrestrial Ecosystems (ECO)	ECO-DC-07	revision	Across the landscape, departure from potential natural vegetation composition by ecozone improves over time through both active and passive restoration, leading to an increase in healthy forest functions, resiliency, and adaptiveness.	Across the landscape, ecozone composition improves over time through both active and passive restoration, leading to an increase in forest functions, resiliency and adaptiveness.		7/13: formerly DC-09 in draft. Changes incorporated
Terrestrial Ecosystems (ECO)	ECO-DC-08	revision	Across the landscape, the amount of age class and structural departure from the natural range of variation reduces over time, increasing multi-scale community complexity, stability, and connectedness through a combination of natural disturbances and silvicultural practices, including fire	Across the landscape, ecozone structure improves over time, increasing multi-scale community complexity, stability, and connectedness through a combination of natural disturbances and silvilcultural practices, including fire.		7/13: formerly DC-10 in Draft. Changes incorporated.
Terrestrial Ecosystems (ECO)	ECO-DC-09	revision	Restoring ecozone composition and structure has multiple outcomes: enhanced forest health and resiliency; restored fire-adapted ecozones that have been degraded due to fire suppression; contribution to the local economy by providing forest products in a cost efficient manner, ranging from high quality logs for veneer and dimensional lumber to small diameter logs for pulp, firewood, or emerging products; and research support by maintaining plots as well as future research needs.	Restoring ecozone composition and structure has multiple outcomes: enhanced forest health and resiliency; restored fire-adapted ecozones that have been degraded due to fire suppression; contributions to the local economy by providing forest products in a cost efficient manner, ranging from high quality logs for veneer and dimensional lumber to small diameter logs for pulp, firewood, or emerging products; and research plots support by maintaining plots as well as future research needs.		7/13: formerly DC-07 in draft. Changes incorporated
Terrestrial Ecosystems (ECO)	ECO-DC-10	reorganization	Ecological restoration emphasizes both restoring species composition when it is departed from desired conditions and restoring structural classes.	n/a. text remains the same		7/13: no change to the text. Re-organized. Formerly DC-08
Terrestrial Ecosystems (ECO)	ECO-DC-25	revision	Old growth forests provide optimal habitat conditions for species such as black bear, wild turkey, white tailed deer, cerulean warbler, wood thrush, other species of migratory and resident birds, terrestrial salamanders, bats, and reptiles. (See the desired conditions in the “Old Growth Forest” section for more.)	Old growth forests provide habitat and forage for species such as black bear, cerulean warbler, wood thrush, other species of migratory and resident birds, terrestrial salamanders, bats, and reptiles. (See the desired conditions in the “Old Growth Forest” section for more.)	removed "optimal" "conditions" wild turkey" and "white tailed deer"	
Terrestrial Ecosystems (ECO)	ECO-DC-30	revision	Populations of game species are at levels that support harvest consistent with goals and objectives of the NCWRC.	Habitats across the forest are diverse and support populations of game species such as ruffed grouse, black bear, white-tailed deer, and wild turkey. Habitats are distributed across the forest to provide opportunities for hunters to harvest game species at sustainable levels.	DC rewritten. Original language removed	
Terrestrial Ecosystems (ECO)	ECO-DC-31	new	n/a	Suitable habitat conditions for North Carolina's expanding elk herd are provided within NCWRC's Elk Management Zone	This is a new DC added in response to NCWRC comment	
Terrestrial Ecosystems (ECO)	ECO-G-03	revision	To minimize hybridization between golden-winged warbler (GWWA) and blue-winged warblers (BWWA), management activities between 2,500' and 3,000' elevation should be designed to avoid colonization by BWWA.	To minimize hybridization between golden-winged warbler (GWWA) and blue-winged warblers (BWWA), management activities between 2,500' and 3,000' elevation should be designed to avoid colonization by BWWA. Coordination with the NCWRC and USFWS should be a part of this process during project implementation.		7/13: formerly ECO-G-10 in draft plan
Terrestrial Ecosystems (ECO)	ECO-O-01	revision	Tier 1: Maintain 3,750 acres of existing grass, forb and shrub openings. Tier 2: Restore 1,450 acres of grass, forb and shrub openings that are not currently present on the forest.	Tier 1: Over the life of the plan, maintain 3,750 acres of **existing grass, forb and shrub** openings. Tier 2: Over the life of the plan, restore 1,450 acres of grass, forb and shrub openings that are not currently present on the forest.		8/17/21: changes finalized
Terrestrial Ecosystems (ECO)	ECO-O-02	revision	Tier 1: Provide 11,000-17,000 acres of young forest conditions,17 by steadily increasing new young forest conditions from 6,500 acres up to 12,000 acres through silvicultural practices with at least 70% above 2,500 feet elevation and 50% in oak-dominated, northern hardwood, and rich coves. Additionally, ensure at least 50% of these conditions are within NCWRC Wildlife Habitat Active Management focal areas. Tier 2: Provide up to 37,000 acres of young forest conditions by increasing new young forest conditions up to 32,000 acres through silvicultural practices with similar elevation and spatial arrangements described above. This tier includes more focused use of prescribed fire to generate young forest conditions.	Tier 1: Increase **new young forest** conditions by using silvicultural practices on between 650 to 1,200 acres annually. Tier 2: Increase new young forest conditions by using silvicultural practices on between 1,200 to 3,200 acres annually. Management approach: Young forest creation will be accomplished using both timber harvest and prescribed fire. Timber harvest will account for most (approximately 80% or more) of young forest creation during the life of the plan.		8/17/21: changes finalized

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Terrestrial Ecosystems (ECO)	ECO-O-03 (formerly ECO-O-05)	revision	Tier 1: Conduct stand and forest community improvement practices, increasing from a minimum of 3,800 acres to approximately 6,000 acres.	Tier 1: Conduct **stand and forest community improvement practices** on between 3,800 acres to approximately 6,000 acres annually. Tier 2: Conduct stand and forest community improvement practices, on between 6,000 acres to approximately 12,000 acres annually. Management approach: This objective includes mechanical and chemical site preparation and release treatments in seedling and sapling stands across all disturbance types. It also includes midstory treatments to assist with developing advanced competitive regeneration, and treatments to improve ecosystem composition and density.		8/17/21: changes finalized
Terrestrial Ecosystems (ECO)	ECO-O-04 (formerly ECO-O-08)	revised	Tier 1: Provide stable or improved forest health conditions on at least 250 acres where current or newly established threats are present. Prioritize actions on (1) maintaining effectiveness of existing treatment areas, (2) new threats and new areas when species viability is at risk and (3) expanding treatments for species impacted by known threats. Tier 2: Improve at least 500 acres with cooperator involvement.	Tier 1: Annually apply intermediate thinning treatments on 150 to 400 acres to address forest health, future composition, and structure desired conditions. Tier 2: Annually apply intermediate thinning treatments on 400 to 600 acres to address forest health, future composition, and structure desired conditions.		8/17/21: changes finalized
Terrestrial Ecosystems (ECO)	ECO-O-05	revised	**formerly ECO-O-04**: Tier 1: Provide 1,500 to 4,000 acres of open forest woodland conditions that do not currently exist on the forest, by restoring and then maintaining sites for open conditions. Priorities will be given to pine types and oak dominated stands such as dry and mesic oaks. Additionally, ensure at least 50% of these conditions are within NCWRC Wildlife Habitat Active Management focal areas, and ensure these conditions provide for elk habitat when activities are within its currently occupied range or within the NCWRC elk focal area. Tier 2: Provide 4,000 to 6,000 acres of open forest woodland conditions that do not currently exist on the forest, by restoring and then maintaining sites for open conditions. Priorities will match those in Tier 1.	Tier 1: Annually thin and burn 300 to 600 acres to advance **open forest woodland conditions**. Tier 2: Annually thin and burn 600 to 900 acres to advance open forest woodland conditions. Management approach: Open forest woodland conditions are restored and maintained using a combination of both timber harvest and prescribed fire, and both commercial and non-commercial treatments. This will include regeneration in a portion of the woodland during the maintenance phase. The maintenance phase requires repeated prescribed fire treatments.		7/27: change finalized. There is an outstanding highlight in Tier 2 objective. Revisit? 8/17/21: changes finalized
Terrestrial Ecosystems (ECO)	ECO-O-06	revision	Tier 1: Prioritize prescribe burns to restore the most fire-adapted ecozones and across ecozones where reducing fuel loads will improve public safety on adjacent private lands. Annually prescribe burn for 6,500 to 10,000 acres. Prioritize 50% of the annual burns within the following four types, consisting of the following desired acre ranges: Shortleaf Pine :1000-1500 acres Pine-Oak/Heath: 1000-1500 acres Dry-Mesic Oak: 850-1300 acres Dry Oak: 400-600 acres In order to maximize restoration, include approximately 10% as growing season burns. Tier 2: Expand the extent of prescribed fire up to approximately 20,000 acres (annually) with emphasis on restoring the fire-adapted ecozones and across ecozones where reducing fuel loads will improve public safety on adjacent private lands. Include approximately 10% growing season burns, designed to ensure compatibility with federally threatened and endangered species needs	Tier 1: Apply prescribed fire on 10,000 – 20,000 acres annually to restore and maintain priority fire adapted ecozones, create woodlands, and reduce hazardous fuels. Tier 2: Apply prescribed fire on 20,000 – 45,000 acres annually to restore and maintain priority fire adapted ecozones, create woodlands, and reduce hazardous fuels. Management approach: Annually, determine a planned level of prescribed fire based on resource availability, weather conditions, and other factors. The priority fire adapted ecozones include shortleaf pine, pine-oak/heath, dry oak, and dry mesic oak ecozones. Prescribed fire would be prioritized where federally listed and SCC species habitat require frequent burning.		7/27: changes finalized 8/17/21: changes adjusted and finalized.
Terrestrial Ecosystems (ECO)	ECO-O-07	revision	Tier 1: Restore 50 acres of spruce fir ecozones per year in order to restore 500 acres of the 3,900 acres departed from its characteristic vegetative composition.	Tier 1: Restore 50 acres of **spruce fir ecozones** annually to improve ecozone composition. See also: Objectives in Plant and Animal Diversity, Old Growth Network, and Forest Health		8/17/21: changes finalized

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Terrestrial Ecosystems (ECO)	ECO-S-31	revision	Tier 2: Control or eradicate NNIS on 3,000 to 5,000 acres: to mitigate the spread to or from adjacent lands; where high human uses occur with high risks of NNIS establishment. Inventory up to approximately 4,000 acres for NNIS occurrences. Priority areas are high quality special interest areas, previously treated areas, NC Natural Heritage Program natural areas, and lands where control is completed cooperatively with adjacent state agencies or private landowners.	ii. Emphasize hard and soft mast producing species, including mast-bearing trees, berries, and fruit trees, to enhance foraging opportunities for species such as white-tailed deer, wild turkey, ruffed grouse, black bear, song birds, and small mammals. iii.When identifying trees for retention during vegetation management, emphasize: •Native trees with exfoliating bark and natural crevices, including, but not limited to, shagbark hickory, white oaks, yellow pines, yellow birch and black locust, to provide roosting and denning habitat for bats and Carolina northern flying squirrels. Consider current research, such as USFWS, NCWRC, North Carolina Bat Working Group (NCBWG), or other relevant guidance to determine appropriate roost and den tree species and condition for retention during project implementation.	entire S not listed here due to it's length. Changes were only made to bullets ii. and iii.	
Terrestrial Ecosystems (ECO)	ECO-S-33	revision	Do not remove beavers or beaver dams except when needed to protect critical values such as existing infrastructure or public health and safety. Trapping, as defined and regulated by the North Carolina Wildlife Resources Commission, is permitted.	Do not remove beavers or beaver dams except when needed to protect critical values such as existing infrastructure or public health and safety. Trapping, as defined and regulated by the North Carolina Wildlife Resources Commission, is allowed.	changed "permitted" to "allowed"	
Terrestrial Ecosystems (ECO)	Forestwide Desired Amounts of	many revisions	see plan for Table	see plan. Language (additional species) added to the 1st 3 rows of table		
TIM	TIM-DC-06	revision	Lands identified as suitable for timber production have a regularly scheduled timber harvest program that contributes to forestwide desired conditions. Rotation ages needed to meet restoration and habitat objectives for young forest habitat are also compatible with the production of sawtimber and pulpwood products.	Lands identified as suitable for timber production have a regularly scheduled timber harvest program that contributes to forestwide desired conditions. Rotation ages needed to meet restoration and habitat objectives for young forest and future middle-aged mast producing forests are also compatible with the production of sawtimber and pulpwood products.		7/14: formerly ECO-DC-17. Timber is now its own plan section
TIM	TIM-G-05	revision	Where management objectives include regeneration of advance growth dependent species, (such as oaks, hickories, sugar maple, black walnut, buckeye, black cherry), the desired future stocking of these species should be supported through use of pre-harvest site preparation, planting, and shelter wood treatments that establish and promote individuals of a competitive stature.	Where management objectives include regeneration of advance growth dependent species (AGDS), (such as oaks, hickories, sugar maple, black walnut, buckeye, black cherry), the desired future stocking of these species should be supported through use of pre-harvest site preparation, planting, and shelter wood treatments that establish and promote individuals of a competitive stature. Managers should track the development of AGDS using surveys and determine their competitiveness prior to regeneration treatments		7/14: formerly ECO-G-05
TIM	TIM-G-06	revision	Stand improvement practices should be used to manage stages of intermediate stand development and support desired species on the site or within the ecozone across all site types and communities where desired species composition and growth needs to be promoted.	Stand improvement practices should be used to manage stages of intermediate stand development and support desired species on the site or within the ecozone across all site types and communities where desired species composition and growth needs to be promoted. Use national database tools and surveys to track the development of young and mid aged stands after the regeneration phase to ensure desired species composition is maintained.		7/14: formerly ECO-G-06
TIM	TIM-S-02	revision	While timber harvest can occur on lands both suitable and not suitable for timber production, unless otherwise specified in management area direction, it can only occur on lands not suitable for timber production when it is determined that timber harvesting activities are needed to protect multiple use values other than timber production, such as, but not limited to: ...	While timber harvest can occur on lands both suitable and not suitable for timber production, unless otherwise specified in management area direction, it can only occur on lands not suitable for timber production when it is determined that timber harvesting activities are needed for salvage or to protect multiple use values other than timber production, such as, but not limited to: ...		8/10- changes complete in plan

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TIM	TIM-S-07	revision	see draft plan. Very lengthy standard	changes to bullets a, d, and k. All other text remains the same from draft: a. Follow North Carolina performance standards as outlined in Forest Practices Guidelines Related to Water Quality (NC FPGs) by implementing effective soil and water Best Management Practices, such as those outlined by North Carolina Forest Service. d.To cross established stream channels during logging: i.Use temporary bridges when feasible. Alternatively, select the type of crossing (bridge mat, culvert, ford, or pole crossing) based on site characteristics and the ability to best protect water quality while providing safe and efficient access. When these crossings are removed, natural hydrology and soil stabilization must be restored. k.The project or activity authorizing the temporary road or trail shall decommission the temporary access when no longer needed, using techniques such as but not limited to removing drainage structures, re-contouring, and stabilizing the final slope. (See also TA-S-08)		7/14: formerly ECO-S-07
TIM	TIM-S-14	revision	Limit the size of openings created in one harvest operation under even-aged (including two-aged) regeneration objectives to 40 acres in all hardwood communities. Within the shortleaf pine ecozone or on appropriate shortleaf pine sites11 even-aged opening sizes are limited to a maximum of 80 acres in size (36 CFR 219.11(d)). The following exceptions apply: i.Where pine forest types exist in an offsite condition, they may be removed through even-aged regeneration methods (up to 80 acres per harvest unit); where ecologic objectives require restoration to another more appropriate forest community such as dry oak, dry mesic oak, mesic oak, shortleaf, cove, or high elevation red oak communities (36CFR 219.11(d)(4)) (Sec 64.21 2012 Planning Rule). ii.Proposals for larger openings (than above), on an individual timber sale basis, are subject to a 60-day public notification and review by the regional forester;	Limit the size of openings created in one harvest operation under even-aged (including two-aged) regeneration objectives to 40 acres in all hardwood communities. Within the shortleaf pine, shortleaf pine-oak, and pine oak heath ecozone or on appropriate shortleaf pine and pine oak heath sites 11 even-aged opening sizes are limited to a maximum of 80 acres in size (36 CFR 219.11(d)). The following exceptions apply: i.Where pine forest types exist in an offsite condition, they may be removed through even-aged regeneration methods (up to 80 acres per harvest unit); where ecologic objectives require restoration to another more appropriate forest community such as dry oak, dry mesic oak, mesic oak, shortleaf, shortleaf pine-oak, pine oak heath, cove, or high elevation red oak communities (36CFR 219.11(d)(4)) (Sec 64.21 2012 Planning Rule). ii.Proposals for larger even-aged openings (than above), on an individual timber sale basis, are subject to a 60-day public notification and review by the regional forester; iii.The maximum size for openings to be cut in one harvest operation shall not apply to the size of openings harvested as a result of natural catastrophic conditions such as fire, insect and disease attack, or windstorm (16 U.S.C. 1604(g)(3)(F)(iv)). (36 CFR 219.11(d)(4)).		8/10- changes complete in plan
TIM	TIM-S-15	revision	Limit the size of openings created in one harvest operation under even-aged (including two-aged) regeneration objectives to 40 acres in all hardwood and spruce-fir ecozones. Within the shortleaf pine ecozone or on appropriate shortleaf pine sites even-aged opening sizes are limited to a maximum of 80 acres in size (36 CFR 219.11(d)). The following exceptions apply:	Edits only to 1st paragraph. Subsequent bullets remain the same (not included here): Limit the size of openings created in one harvest operation under even-aged (including two-aged) regeneration objectives to 40 acres in all hardwood communities. Within the shortleaf pine and pine oak heath ecozone or on appropriate shortleaf pine and pine oak heath sites even-aged opening sizes are limited to a maximum of 80 acres in size (36 CFR 219.11(d)). The following exceptions apply:		7/14: formerly ECO-S-16. edits were only made to the 1st paragraph
Transportation and Access (TA)	Mgmt Approac	revision	i. Minimize the number of perennial and intermittent, stream crossings	i. Minimize the number of perennial, and intermittent, and ephemeral stream crossings		3/29: M approved change, per Brady's feedback
Transportation and Access (TA)	TA-O-04	revision	Tier 1: Unauthorized road and trail miles within priority watersheds and Inventoried Roadless Areas will be identified and prioritized for obliteration to minimize erosion and sedimentation. A minimum of 50 miles of unauthorized roads and trails will be restored to natural contours during the life of the plan.	Tier 1: Unauthorized road and trail miles within priority watersheds and Inventoried Roadless Areas will be identified and prioritized for obliteration to minimize erosion and sedimentation. A minimum of 50 miles of unauthorized roads and trails will be restored to natural contours during the life of the plan. A minimum of 20 miles of unauthorized roads and 30 miles of unauthorized trails will be restored to natural contours during the life of the plan.	LR added language to Plan per the note in the FEIS notebook. Emailed Heather to follow up- is there finalized language? 3/29: aligned language with April version of Plan	

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Transportation and Access (TA)	TA-S-04 (bullet	revision	iv. Stream crossings shall be designed to allow passage for native aquatic organisms, including amphibians, where needed by the species and shall be designed to minimize impacts, including erosion and sedimentation from the road; vi. Revegetation of areas disturbed due to road construction or maitenance activities shall be accomplished. vii. Road work shall be timed to reduce impacts to resources and infrastructure; and	iv.Stream crossings shall be designed to allow passage for native aquatic organisms, including amphibians, where needed by the species and shall be designed to minimize impacts, including erosion and sedimentation from the road; vi. Areas disturbed due to road construction or maintenance activities shall be revegetated; vii. Road work shall be timed to reduce impacts to resources and infrastructure, including recreational access; and	LR added language to Plan per the note in the FEIS notebook. Emailed Heather to follow up- is this component actually changing?	3/29: add bullet ii grammatical edit. 6/28/21: Change to bullet iv. Remains pending 7/20: changes finalized
Tribal (TR)	Mgmt Approac	new	n/a	During tribal coordination involve both natural resources staff as well as the tribal historic preservation office with an intent to support regular interdisciplinary involvement in project design		
Tribal (TR)	Mgmt Approac	revision	When requested by tribes, translate Forest interpretation and education materials and maps into native languages.	Engage with tribes on the opportunity to translate Forest interpretation and education materials and maps into native languages.		
Tribal (TR)	Mgmt Approac	new	n/a	Utilize collaborative and shared stewardship authorities to conduct work that benefits both tribal and National Forest System lands.		
Tribal (TR)	TR-DC-03	new	n/a	Lands are guided by shared stewardship, including tribal and Forest Service lands and resources, to support healthy and resilient forests that benefit tribal communities and the public.		Draft plan language derived from document titled: "Proposed Forest Plan Feb6 2020 hll" 6/28/21: LR accepted track changes, per M's approval
Tribal (TR)	TR-G-03	new	n/a	Development of integrated landscape projects should seek early input from Federally Recognized Tribes and explore opportunities to reflect Traditional Ecological Knowledge in project design	add "often" to this G. left comment in Plan	
Tribal (TR)	TR-G-03/04	moved		guidelines moved to non-timber forest products section		6/28: move of Gs approved and track changes accepted
Tribal (TR)	TR-O-03	new	n/a	During the planning period, work with tribes and the Southern Research Station to identify research locations and collaboratively study sustainable plant harvesting, artisan resource management, and the use of traditional ecological knowledge.		6/28: LR accepted track changes. Michelle approved change
Watersheds (WSD)	Mgmt Approac	revision		Participate with NGO partners, tribes, state and federal agencies in promoting high quality water resources.		
Watersheds (WSD)	WSD-O-01, ii.	revision to bullet ii.	ii. Restore a minimum of 15 to a maximum of 20 acres of stream, focusing on restoring floodplain connectivity, stream channel function (for example, large woody debris), and native riparian vegetation.	Restore a minimum of 15 to a maximum of 20 acres of stream and other wetland ecosystems, focusing on restoring floodplain connectivity, stream channel function (for example, large woody debris), and native riparian vegetation.		
Watersheds (WSD)	WSD-O-02, iii.	revision to bullet iii.	iii. Perform road maintenance activities on 15 miles of roads that are known to be hydrologically connected to the stream network, (see also Transportation and Access, TA-O-03).	iii. Perform road maintenance activities on 15 miles of roads that are known to be hydrologically connected to the stream network, focusing on those causing degradation of aquatic ecosystems (see also Transportation and Access, TA-O-03).		
Watersheds (WSD)	WSD-O-03	revision	Tier 1: Annually, conduct a site-specific analysis of base cations in 1 to 2 project locations where there is a concern for base cation depletion. Develop mitigation or restoration strategies when these strategies are necessary to restore or protect at-risk water, soils, flora and fauna.	no change to text. Formerly ECO-O-10		7/15: no changes to the text made. Formerly ECO-O-10 in draft. 7/23: change finalized
		revision		the draft terrestrial ecosystems section was reorganized, and in some cases renumbered into the following sections: Terrestrial Ecosystems; Forest Landscape Pattern and Connectivity; Ecological Restoration Priorities; Ecosystem Management; Wildlife Habitat Across Terrestrial Ecozones; Integrated Ecosystem and Wildlife Habitat Objectives; Integrated Ecosystem and Wildlife Habitat Management Approaches; Plant and Animal Diversity; Old Growth Network; Forest Health: Insects and Diseases; Non-Native Invasive Plant Species; Timber Management Practices	What changed here was the number of the objective as it moved from an ECO objective to the watershed section. I want to keep the change noting the objective number changed but we don't need to track all the other ECO components line by line.	1/17/22- change confirmed
Wildlife (WLF)	Table 7	many editorial revisions	Table 7	renumbered to Table 3: Terrestrial Wildlife Habitat Conditions Across Ecozones		1/17/22- change confirmed
Wildlife (WLF)	Table 8	editorial revisions	Table 8	renumbered to Table 4: Finer-Scale Habitat Desired Conditions for Young Forests		1/17/22- change confirmed

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Wildlife (WLF)	WLF-DC-02	revision	Permanent grass, forb, and shrub openings are positioned within forested habitats to ensure nesting and foraging areas are within proximity of each other for many animals. These openings are located to minimize conflict with recreationists and to ensure streams and native plant communities near these openings are not affected (i.e., stream temperature and channel integrity are not negatively affected). These areas are important to the life histories of many wildlife species but especially to ruffed grouse, white-tailed deer, elk, black bear, golden-winged warblers, and many other birds, bats, and pollinators. (See Table 3)	Permanent grass, forb, and shrub openings are positioned within young forested habitats to ensure nesting and foraging areas are within proximity of each other for many animals. These openings are located to minimize conflict with recreationists and to ensure streams and native plant communities near these openings are not affected (i.e., stream temperature and channel integrity are not negatively affected). These areas are important to the life histories of many wildlife species but especially to bobwhite quail, wild turkey, white-tailed deer, elk, black bear, golden-winged warblers, and many other birds, bats, and pollinators.		7/13: fomerly ECO-DC-22 in draft plan. Component code changed due to section re-organization
Wildlife (WLF)	WLF-DC-03	revision/reorg.	no text change. Plan component relabeled. Formeraly ECO-DC-24 in draft plan	n/a		7/13: no text change. Plan component relabeled. Formeraly ECO-DC-24 in draft plan
Wildlife (WLF)	WLF-DC-04	revision/reorg.	Old growth forests provide optimal habitat conditions for species such as black bear, wild turkey, white-tailed deer, cerulean warbler, wood thrush, other species of migratory and resident birds, terrestrial salamanders, bats, and reptiles. (See the desired conditions in the “Old Growth Forest” section for more.)	Mature forests, including late seral stages and old growth conditions, provides habitat and forage for species such as black bear, wild turkey, white-tailed deer, cerulean warbler, wood thrush, other species of migratory and resident birds, terrestrial salamanders, bats, and reptiles.		7/13: formerly ECO-DC-25 in draft plan. Changed per section re-org.
Wildlife (WLF)	WLF-DC-06	revision/reorg.	Habitat components at finer scales provide for wildlife occupancy, are present in sufficient amounts, and distributed across all ecozones. For example, snags provide roosting and nesting habitat for bats and cavity nesting birds, especially along the edge of openings, and foraging habitat for insectivores such as woodpeckers. Larger diameter live or dead trees provide habitat for black bear and other species requiring cavity or denning conditions, while smaller live or dead trees with crevices provide critical nesting and roosting habitat for flying squirrels and bats. Coarse wood on the forest floor, in a variety of sizes and shapes, provides habitat for salamanders and other cover and moisture-associated wildlife, as well as drumming logs for ruffed grouse. These habitat components that are retained during young forest restoration perpetuate to later successional stage, either through natural succession or through forest stand improvement practices. Over time, they contribute to the development of old growth characteristics such as large downed woody debris, abundant snags, variable gap sizes, and tip up mounds. Table 8 provides desired amounts of finer scale habitat components retained during young forest restoration.	Habitat components at finer scales provide for wildlife occupancy, are present in sufficient amounts, and distributed across all ecozones. For example, snags provide roosting and nesting habitat for bats and cavity nesting birds, especially along the edge of openings, and foraging habitat for insectivores such as woodpeckers. Larger diameter live or dead trees provide habitat for black bear and other species requiring cavity or denning conditions, while smaller live or dead trees with crevices provide critical nesting and roosting habitat for flying squirrels and bats. Coarse wood on the forest floor, in a variety of sizes and shapes, provides habitat for salamanders and other cover and moisture-associated wildlife, nesting areas for some migratory birds (e.g. black and white warbler), as well as drumming logs for ruffed grouse.		7/13: formerly ECO-DC-27.
Wildlife (WLF)	WLF-DC-08	revision/reorg.	Adjacent habitat types are provided in arrangements to support species’ complete life histories. For example, wild turkey require open grassy areas for nesting and foraging, shrubby areas for cover and forested areas for roosting. White-tailed deer require open or grassy areas for grazing and mature forest for mast production critical to foraging success. Golden-winged warblers require open grassy and herbaceous areas with shrubby inclusions adjacent to mature forest. Desired conditions for a hard mast component are identified as a key characteristic in appropriate ecozones (See Table 2Table 2). Additionally, soft mast, in the form of fruit and berries, is available in sufficient quantities across all ecozones. Hard and soft mast quality and quantity is vital to many animal species, including wild turkey, white-tailed deer, black bear, and migratory birds, such as cedar waxwings.	Adjacent habitat types are provided in arrangements to support species’ complete life histories. For example, wild turkey require open grassy areas for nesting and foraging, shrubby areas for cover and forested areas for roosting. White-tailed deer require open or grassy areas for browsing and mature forest for mast production critical to foraging success. Golden-winged warblers require open grassy and herbaceous areas with shrubby inclusions adjacent to mature forest. Desired conditions for a hard mast component are identified as a key characteristic in appropriate ecozones (See Table 2). Additionally, soft mast, in the form of fruit and berries, is available in sufficient quantities across all ecozones. Hard and soft mast quality and quantity is vital to many animal species, including wild turkey, white-tailed deer, black bear, and migratory birds, such as cedar waxwings and thrushes.		7/13: fomerly ECO-DC-29 in draft plan.

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Wildlife (WLF)	WLF-DC-09	revision	**ECO-DC-29:** Adjacent habitat types are provided in arrangements to support species' complete life histories. For example, wild turkey require open grassy areas for nesting and foraging, shrubby areas for cover and forested areas for roosting. White-tailed deer require open or grassy areas for grazing and mature forest for mast production critical to foraging success. Golden-winged warblers require open grassy and herbaceous areas with shrubby inclusions adjacent to mature forest. Desired conditions for a hard mast component are identified as a key characteristic in appropriate ecozones (See Table 2Table 2). Additionally, soft mast, in the form of fruit and berries, is available in sufficient quantities across all ecozones. Hard and soft mast quality and quantity is vital to many animal species, including wild turkey, white-tailed deer, black bear, and migratory birds, such as cedar waxwings. **ECO-DC-30:** Populations of game species are at levels that support harvest consistent with goals and objectives of the NCWRC.	Habitats across the forest are diverse and support populations of game species such as ruffed grouse, black bear, white-tailed deer, and wild turkey. Habitats are distributed across the forest to provide opportunities for hunters to harvest game species at sustainable levels.		7/14: this is a new DC that is a result of combining former ECO-DC-29 and 30 from the draft plan
Wildlife (WLF)	WLF-DC-10	revision	**ECO-DC-29:** Adjacent habitat types are provided in arrangements to support species' complete life histories. For example, wild turkey require open grassy areas for nesting and foraging, shrubby areas for cover and forested areas for roosting. White-tailed deer require open or grassy areas for grazing and mature forest for mast production critical to foraging success. Golden-winged warblers require open grassy and herbaceous areas with shrubby inclusions adjacent to mature forest. Desired conditions for a hard mast component are identified as a key characteristic in appropriate ecozones (See Table 2Table 2). Additionally, soft mast, in the form of fruit and berries, is available in sufficient quantities across all ecozones. Hard and soft mast quality and quantity is vital to many animal species, including wild turkey, white-tailed deer, black bear, and migratory birds, such as cedar waxwings. **ECO-DC-30:** Populations of game species are at levels that support harvest consistent with goals and objectives of the NCWRC.	Elk habitat conditions for North Carolina's expanding elk herd are provided within NCWRC's Elk Management Zone.		7/14: this is a new DC that is a result of combining former ECO-DC-29 and 30 from the draft plan

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Wildlife (WLF)	WLF-S-01	revision	vegetation management activities: i. Maintain an average of four snags (>/= 15" DBH) per acre across the project area to contribute to landscape scale wildlife habitat diversity for species such as bats, woodpeckers, and other cavity nesting birds, except where such snags pose a threat to human health or safety. Retain snags exhibiting suitable wildlife habitat characteristics (e.g., exfoliating or sloughing bark, cavities or crevices) along the edge of openings or combined with other leaf trees to extend the life of ephemeral wildlife habitat elements in the project area and reduce threats to human health and safety during vegetation management activities. ii. Emphasize hard and soft mast producing species, including mast-bearing trees, berries, and fruit trees, to enhance foraging opportunities for species such as white-tailed deer, wild turkey, black bear, song birds, and small mammals. iii. When identifying trees for retention during vegetation management, emphasize: • Native trees with exfoliating bark and natural crevices, including, but not limited to, shagbark hickory or black locust, to provide roosting and denning habitat for bats and Carolina northern flying squirrels. Consider current research, such as USFWS, NCWRC, North Carolina Bat Working Group (NCBWG), or other relevant guidance to determine appropriate roost and den tree species and condition for retention during project implementation. • Standing live and dead trees >22" DBH that exhibit cavities and other denning conditions, except where human safety is of concern. • Live eastern hemlock where possible to preserve the gene pool and food source for birds and small mammals. iv. Downed woody debris of various sizes should be emphasized for	vegetation management activities:Maintain an average of four snags (≥ 9" DBH) per acre across the project area to contribute to landscape scale wildlife habitat diversity for species such as bats, woodpeckers, and other cavity nesting birds, except where such snags pose a threat to human health or safety. Retain snags exhibiting suitable wildlife habitat characteristics (e.g., exfoliating or sloughing bark, cavities, or crevices) along the edge of openings or combined with other leave trees to extend the life of ephemeral wildlife habitat elements in the project area and reduce threats to human health and safety during vegetation management activities. To minimize the risk of incidental take, in areas known to be or potentially occupied by federally listed bats, snag recruitment and retention should also include snags or live trees with more than 25% exfoliating bark ≥3" DBH. ii. Emphasize hard and soft mast producing species, including mast-bearing trees, berries, and fruit trees, to enhance foraging opportunities for species such as white-tailed deer, wild turkey, ruffed grouse, black bear, song birds, and small mammals. iii. Emphasize the following: NativeNative trees with exfoliating bark and natural crevices, including, but not limited to, shagbark hickory, white oaks, yellow pines, yellow birch, and black locust, to provide roosting and denning habitat for bats and Carolina northern flying squirrels. Consider current research, such as United States Fish and Wildlife Service (USFWS), NCWRC, North Carolina Bat Working Group (NCBWG), the USFS bat conservation strategy, or other relevant guidance to determine appropriate roost and den tree species and condition for retention during project implementation. • Whenever possible, snags susceptible to windthrow should be identified in clumps and/or buffered by live trees. • Standing live and dead trees >9" DBH that exhibit cavities and other denning conditions, except where human safety is of concern.		final edits to this std were made through conversations with USFWS in January 2022
Wildlife (WLF)	WLF-S-02	reorganization	no changes to text. Formarly ECO-S-31			
Wildlife (WLF)	WLF-S-02	revision	Use native plant material in wildlife openings and other wildlife habitat enhancements unless the non-native material is desired for a historical, wildlife, or other identified resource benefit	Use native plant material in wildlife openings and other wildlife habitat enhancements unless the non-native material is not invasive and is desired for a historical, wildlife, or other identified resource benefit.	Added to be consistent w/ FHL std.	
Wildlife (WLF)	WLF-S-03	revision/reorg.	Do not remove beavers or beaver dams except when needed to protect critical values such as existing infrastructure or public health and safety. Trapping, as defined and regulated by the North Carolina Wildlife Resources Commission, is permitted.	Do not remove beavers or beaver dams except when needed to protect critical values such as existing infrastructure or public health and safety. Trapping, as defined and regulated by the North Carolina Wildlife Resources Commission, is allowed.		7/13: formerly ECO-S-32
WTR	WTR-DC-02	revision	**(listed as a G in draft plan)**: Water quality meets state and federal water quality standards, including those in the Clean Water Act, and supports designated beneficial uses and native and desired nonnative aquatic species. Short-term exceedance of water quality standards (i.e., temporary period of declining water quality) due to management activity occurs only in the anticipation of long-term improvement of watershed condition and water quality.	WTR-DC-02 Water quality meets state and federal water quality standards , including those in the Clean Water Act, and supports designated protected uses and native and desired nonnative aquatic species. Short-term exceedance of water quality standards (i.e., temporary period of declining water quality) due to management activity occurs only in the anticipation of long-term improvement of watershed condition and water quality.	Talk with Brady about adding 'tribal' to the list of water quality standards .	6/22/21: Michelle to follow up on adding "tribal". revisit. The Gs were edited to DCs. 1/17/22- confirmed revised language as listed in column E.
WTR	WTR-DC-13	revision	Changes in the streamflow regime should not be permitted where they would adversely impact stream function, except where short term impacts result in long-term improvement.,	Changes in the streamflow regime should not be permitted where they would adversely impact stream function, except where short term impacts result in long-term improvement, or where other public benefits are provided such as through special use authorizations.		7/15: changes accepted
WTR	WTR-G-01	revision	Minimize the number of stream crossings in the design of roads and trails	Minimize the number of stream crossings in the design of roads and trails. (See also, ECO-S-7b and TA-S-04iii).	Added from Brady's August version base text. We need to ensure added component numbering aligns	
WTR	WTR-S-01	revision	Prevent visible sediment from reaching perennial and intermittent stream channel and perennial water bodies in accordance with North Carolina Forest Practice Guidelines Related to Water Quality (NC FPGs or latest). Minimize the visible sediment reaching ephemeral stream channels (NC FPGs).	Prevent visible sediment from reaching perennial and intermittent stream channel and perennial water bodies in accordance with North Carolina Forest Practice Guidelines Related to Water Quality (NC FPGs or latest). (last sentence removed)	removed last sentence per Brady's August version	

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Bald Mountains (BAM)	background	revision		*added statement to background: "The Cherokee National Forest manages lands adjacent to this geographic area in Tennessee. "		7/13: changes accepted
Bald Mountains (BAM)	BAM-GLS-02	revision	Increase and maintain grassy balds and other open habitats at high elevations between Roan Mountain and Max Patch. Management approaches will focus on improving habitat for open area-associated species such as golden-winged warbler, ruffed grouse, elk, and rare plant communities.	BAM-GLS-02 Increase and maintain grassy balds and other open habitats at high elevations between Roan Mountain and Max Patch. Management approaches will focus on improving habitat for open area-associated species such as golden-winged warbler, Appalachian cottontail, elk, and rare plant communities (also deleted ruffed grouse)		7/13: changes accepted
Bald Mountains (BAM)	BAM-GLS-05	new	n/a	Emphasize restoration of spruce-fir habitat for the Carolina northern flying squirrel, and maintain the health and resiliency of this forest type in the face of climate change.		7/15: change finalized. New goal, added per Sheryl and M's approval
Bald Mountains (BAM)	BAM-GLS-09	moved		moved goal 9 to goal 13, and consolidated to remove redudancy		
Bald Mountains (BAM)	BAM-GLS-10	new	n/a	Address supply/demand issues for equestrian and/or bicycle trail opportunities within the Geographic Area through collaborative trail planning to identify appropriate trail mileage, new trail locations utilizing sustainable trail design principles, potential adoption of unauthorized routes, sources of construction funding, and long-term maintenance commitments by volunteer and/or partner organizations		7/13: changes accepted. LR moved goal from "Partnering with others" subheading to "connecting people with the land" per Michelle's guidance
Bald Mountains (BAM)	BAM-GLS-15	moved. No changes to text	Partner with Cherokee Tribes to preserve community identity and traditional and ceremonial areas and to restore high elevation balds to enhance traditional special uses. Protect and preserve Paint Rock using tribal and community partnerships	Partner with Cherokee Tribes to preserve community identity and traditional and ceremonial areas and to restore high elevation balds to enhance traditional special uses. Protect and preserve Paint Rock using tribal and community partnerships		7/15: just noting that this goal was moved "connecting people to the land" to "partnering with others"
Black Mountains (BLM)	BLM-GLS-02	revision	Emphasize restoration along Iron Mountain and areas below 2,500 ft. and mid and old woodland habitat for species requiring young and open forest conditions, such as deer, turkey, pine warblers, and several species of bat.	Emphasize restoration along Iron Mountain and areas below 2,500 ft. and mid and old woodland habitat for species requiring young and open forest conditions, such as deer, turkey, pine warblers, whip-poor-will, and several species of bat.		7/13: changes accepted, per Michelle's approval
Black Mountains (BLM)	BLM-GLS-03	revision	At mid elevations accessible by existing roads, emphasize restoration of structural and compositional diversity within rich cove ecozones for species such as ruffed grouse, American woodcock, bats, and many salamander species.	At mid elevations accessible by existing roads, emphasize restoration of structural and compositional diversity within rich cove ecozones for species such as warbler, ruffed grouse, American woodcock, bats, and many salamander species.		7/13: changes accepted, per Michelle's approval
Black Mountains (BLM)	BLM-GLS-06	revision	Respond to increased demand for access by a growing public interest in mountain biking and rock climbing, as well as hunting and fishing experiences.	Respond to increased demand for access by a growing public interest in mountain biking and [rock- deleted "rock"] climbing, hunting, fishing, and other recreation opportunities.		7/13: changes accepted, per Michelle's approval. 8/10- "rock climbing" changed to "climbing" throughout.
Black Mountains (BLM)	BLM-GLS-08	new	n/a	Address supply/demand issues for equestrian and/or bicycle trail opportunities in this Geographic Area through a collaborative Trail Strategy to plan appropriate trail mileage, new trail locations utilizing sustainable trail design principles, potential adoption of unauthorized routes, sources of construction funding, and long-term maintenance by volunteer and/or partner organizations.		4/28: new goal added from the document "Equestrian Bicycle Trail Objectives Standard - Draft 3.25.2021". This goal may be revised further. Revisit. 7/15: change finalized
Black Mountains (BLM)	BLM-GLS-08	new	n/a	Address supply/demand issues for equestrian and/or bicycle trail opportunities within the Geographic Area through collaborative trail planning to identify appropriate trail mileage, new trail locations utilizing sustainable trail design principles, potential adoption of unauthorized routes, sources of construction funding, and long-term maintenance commitments by volunteer and/or partner organizations.		7/13: changes accepted, per Michelle's approval. Moved to "connecting people to the land" subheading
Black Mountains (BLM)	BLM-GLS-17	new	n/a	Partner with wilderness and outdoor recreation groups to assist in managing Craggy Mountain Wilderness Study Area and in educating visitors about Wilderness values and ethics and low impact camping and climbing techniques.		7/13: changes accepted, per Michelle's approval

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Eastern Escarpment (EE)	background	revision		added the phrase "horseback riding in the Boone Fork complex; " in the 3rd paragrpah of Connecting People with the Land background		7/13: changes accepted, per Michelle's guidance
Eastern Escarpment (EE)	EE-GLS-09	new	n/a	Address supply/demand issues for equestrian and/or bicycle trail opportunities within the Geographic Area through collaborative trail planning to identify appropriate trail mileage, new trail locations utilizing sustainable trail design principles, potential adoption of unauthorized routes, sources of construction funding, and long-term maintenance commitments by volunteer and/or partner organizations		7/13: changes accepted, per Michelle's guidance. Moved to "connecting people with the land" sub heading
Eastern Escarpment (EE)	EE-GLS-11	revision	iii. Emphasize treatment of non-native invasive species in Linville Gorge Wilderness.	iii. Emphasize treatment of non-native invasive species in and around Linville Gorge Wilderness.		7/13: formally GLS-10. changes accepted, per Michelle's guidance
Eastern Escarpment (EE)	EE-GLS-14	revision	Partner with diverse recreation groups to assist in maintaining and enhancing the quality of recreation opportunities	Partner with diverse recreation groups to assist in maintaining and enhancing the quality of recreation opportunities including collaborative efforts to increase multi-use trails.		7/13: formally GLS-13. changes accepted, per Michelle's guidance
Fontana Lake GA (FL)	background	revision		**2 additions:** *The low elevation and abundant water of the region primarily support shortleaf pine, dry-mesic oak, rich cove, and acidic cove forests that provide habitat for larger mammals, such as deer and bear, as well as bird species including turkey, golden cerulean warbler, eastern whip-poor-will, ruffed grouse, and other non-game species. *Restoration efforts will focus on increasing the resilience of the forest to southern pine beetle infestations and outbreaks, conducting timber stand improvement projects on degraded forest types, and increasing the amount of habitat for cerulean warblers, eastern whip-poor-wills, and other songbirds. Rare habitats in the region include patches of rocky bar and shore and montane alluvial forest along the lakes and low elevation basic glades on scattered upper slopes. Bald eagles nest along reservoir shorelines in this geographic area		7/13/21: changes accepted, per Michelle's guidance
Fontana Lake GA (FL)	FL-GLS-03	revision	Increasing the amount of habitat for golden-winged warblers.	Increasing the amount of habitat for warblers and eastern whip-poor-will.		7/13/21: changes accepted, per Michelle's guidance
Great Balsam GA (GB)	background	revision		*addition to end of this sentence: The Blue Ridge Parkway borders most of the upper reaches of the Great Balsam Mountains, and the geographic area includes the Parkway's highest point at Richland Balsam (6,053 feet), as well as the Mountains-to-Sea National Recreation Trail. * deleted Mountains -to-Sea National Recreation Trail from list of MAs within this GA		7/13/21: changes accepted, per Michelle's guidance

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Great Balsam GA (GB)	GB-GLS-01	revision	Conserve and restore high elevation red oak forests, northern hardwood forests, spruce-fir forests.	Conserve and restore high elevation red oak forests, northern hardwood forests, spruce-fir forests, and mesic oak forests. Emphasize restoration of spruce-fir habitat for the Carolina northern flying squirrel, and maintain health and resiliency of this forest type in the face of climate change.		7/15: changes finalized
Great Balsam GA (GB)	GB-GLS-03	revision	Restore degraded lands and conduct mid- and late-seral composition, structural, and habitat management at Roy Taylor.	Restore degraded lands and conduct mid- and late-seral composition, structural, and habitat management in the Roy Taylor area.		7/13/21: changes accepted, per Michelle's guidance
Great Balsam GA (GB)	GB-GLS-04	revision	Red spruce bog preservation in Alarka Laurel and Roy Taylor.	Restore or maintain the red spruce bogs in Alarka Laurel and Roy Taylor areas to ensure a red spruce and sphagnum moss component is present.		7/13/21: changes accepted, per Michelle's guidance
Great Balsam GA (GB)	GB-GLS-15	revision	Partner with North Carolina Wildlife Resources Commission.	Partner with North Carolina Wildlife Resources Commission to manage for healthy wildlife and aquatic habitats and populations.		7/13/21: changes accepted, per Michelle's guidance
Great Balsam GA (GB)	GB-GLS-22	revision	Trail and hiking associations and groups. Continue to participate in the Sicklefin Redhorse Conservation Committee and the Little Tennessee River Native Fish Conservation Partnership to achieve goals tied to clean and abundant water.	(deletion of 1st sentence) Continue to participate in the Sicklefin Redhorse Conservation Committee and the Little Tennessee River Native Fish Conservation Partnership to achieve goals tied to clean and abundant water.		7/13/21: changes accepted, per Michelle's guidance
Great Balsam GA (GB)	GB-GLS-23	new	n/a	Partner with trail conservation and maintenance groups, hiking associations, and hiking clubs.		7/13/21: changes accepted, per Michelle's guidance
Highland Domes (HD)	background	revision	The region's rivers provide visitors with access to fishing, with anglers seeking brook trout especially attracted to the headwaters of the Cullasaja, Chattooga, Tuckasegee, and Whitewater Rivers.	The region's rivers provide visitors with access to fishing, with anglers seeking brook trout especially attracted to the headwaters of the Cullasaja, (deleted Chattooga) Tuckasegee, and Whitewater Rivers.		7/13/21: changes accepted, per Michelle's guidance
Highland Domes (HD)	HD-GLS-07	revision	Maintain and enhance unique tannic, sandy bottom stream habitat within Panthertown Creek, upper Chattooga River, and Savannah River watersheds to provide quality habitat for native brook trout and other native aquatic species.	Maintain and enhance unique tannic, sandy bottom stream habitat within Panthertown Creek, upper Chattooga River, and Savannah River watersheds to provide quality habitat for (native brook trout deleted) native aquatic species.	deleted "native brook trout"	7/13/21: changes accepted, per Michelle's guidance
Highland Domes (HD)	HD-GLS-10	revision	Emphasize interpretive means to convey unique values at Whitewater Falls, Whiteside Mountain, Dry Falls, and the Cullasaja and Whitewater rivers, as they are some of the most highly visited sites in the Forests.	Emphasize interpretive means to convey unique values at Mountain Waters Scenic Byway , Whitewater Falls, Whiteside Mountain, Dry Falls, and the Cullasaja and Whitewater rivers, as they are some of the most highly visited sites in the Forests.	Added per loose end tracking in Onenote.	
Highland Domes (HD)	HD-GLS-13	new	n/a	Address supply/demand issues for equestrian and/or bicycle trail opportunities within the Geographic Area through collaborative trail planning to identify appropriate trail mileage, new trail locations utilizing sustainable trail design principles, potential adoption of unauthorized routes, sources of construction funding, and long-term maintenance commitments by volunteer and/or partner organizations.		7/13/21: changes accepted, per Michelle's guidance. Moved to "connecting people with the land" subheading. Offsets subsequent goal #s
Highland Domes (HD)	HD-GLS-25	new	n/a	Work with recreation groups to maintain and enhance recreation opportunities in the Panthertown Valley while also reducing user-created trails.		
Highland Domes (HD)	HD-GLS-26	new	n/a	Partner with wilderness and outdoor recreation groups to assist in managing Ellicot Rock Wilderness and the geographic area's Wilderness Study Areas and in educating visitors about Wilderness values and ethics and low impact camping and climbing techniques.		7/13/21: changes accepted, per Michelle's guidance
Hiwasee GA (HW)	background	revision		**changes:** * The less developed portions of the geographic area provide habitats supporting populations of game, especially deer, turkey, and bear, and non-game wildlife such as blue-winged warblers, eastern whip-poor-will, and Chuck-will's-widow, which is popular with hunters and bird watchers.		7/13/21: changes accepted, per Michelle's guidance

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Hiwasee GA (HW)	HW-GLS-12	revision	Respond to demand for hunting opportunities for ruffed grouse, wild turkey, white- tailed deer, and black bear by maintaining and enhancing habitat, both alone and in partnership with the North Carolina Wildlife Resources Commission.	HW-GLS-01 Respond to demand for hunting opportunities for (deleted grouse) wild turkey, white- tailed deer, and black bear by maintaining and enhancing habitat, both alone and in partnership with the North Carolina Wildlife Resources Commission.		7/13/21: changes accepted, per Michelle's guidance
Minerals and Energy (MIN)	MIN-G-02	new	n/a	Consultation should occur with the North Carolina Geological Survey, the United States Department of the Interior's Geological Survey, the Bureau of Land Management, and the United States Department of Energy on activities impacting minerals and energy resources.		7/15: change finalized. Originally porposed as a new MA by Tom, in response to public comment. Michelle and Tom approve of it becoming a G instead. 7/27: this may become a Standard after all. Revisit. Tom added language on what we would consult with external partners on. flagged for Michelle to finalize
Nantahala Mountains GA (NM)	background	revision		deleted "south fork mills river" from Clean and Abundant Water subheading		7/13/21: changes accepted, per Michelle's guidance
Nantahala Mountains GA (NM)	NM-GLS-18	revision	Partner with trail conservation and maintenance groups, hiking associations, and hiking clubs.	Continue strengthening partnerships with volunteer organizations to reduce deferred maintenance and increase sustainability of trail and developed and dispersed recreation infrastructure .		8/16/21: this new goal replaces the old NM-GLS-18 and 20 per Erik and Michelle approval.
Nantahala Mountains GA (NM)	NM-GLS-20	deleted	Partner with equestrian organizations, trail riding club, and Wilderness advocacy and management groups .	na		8/16/21: this goal was replaced with GLS-18 per Erik and Michelle approval
Nantahala Mountains GA (NM)	NM-GLS-24	new	n/a	Partner with wilderness and outdoor recreation groups to assist in managing Southern Nantahala Wilderness and in educating visitors about Wilderness values and ethics and low impact camping and climbing techniques.		
North Slope GA (NS)	NS-GLS-02	revision	Restore and maintain select high elevation openings to increase needed wildlife habitat for golden winged warblers and ruffed grouse.	Restore and maintain select high elevation openings to increase needed wildlife habitat for Appalachian cottontail, elk, and ruffed grouse. (also deleted GWW)		7/13/21: changes accepted, per Michelle's guidance
North Slope GA (NS)	NS-GLS-03	revision	Maintain resilient habitat conditions, particularly in spruce-fir and northern hardwood forests, for the endangered Carolina northern flying squirrel and rock gnome lichen.	Emphasize restoration of spruce-fir and northern hardwood forests for the northern flying squirrel and rock gnome lichen, and maintain health and resiliency of these critical forest types in the face of climate change.		7/13/21: changes accepted, per Michelle's guidance
North Slope GA (NS)	NS-GLS-07	revision	Maintain healthy populations of hellbenders in East Fork and West Fork Pigeon River.	Restore and/or maintain healthy populations of hellbenders in East Fork and West Fork Pigeon River.		7/13/21: changes accepted, per Michelle's guidance
North Slope GA (NS)	NS-GLS-10	new	n/a	Partner with wilderness and outdoor recreation groups to assist in managing Shining Rock and Middle Prong Wilderness and in educating visitors about Wilderness values and ethics andincluding low impact camping and climbing techniques.[		7/15: revisit. Need to combine w/ NS-GLS-08 7/27: change finalized
Pisgah Ledge GA (PL)	background	revision		*addition of "The Mountains-to-Sea Trail traverses the northern boundary of this* Geographic Area, adjacent to the Blue Ridge Parkway." under area description * revision of : "The area also supports important habitat for the Appalachian Cottontail and is also a popular fishing destination, especially for anglers seeking to fish its cold water trout streams."		7/13: changes accepted, per Michelle's guidance
Pisgah Ledge GA (PL)	PL-GLS-02	revision	Reduce the abundance of white pine in the North Mills River and Davidson River watersheds while enhancing oak regeneration.	Reduce the abundance of white pine in the North Mills River and Davidson River watersheds while enhancing oak regeneration and hunting opportunities.	Revised per Sheryl's feedback on public comment: you can weave in the words 'hunting opportunities' into PL-GLS-02. It does emphasize that we heard the local collaborators that are already active in that GA.	4/19: need to revisit and confirm change w/ Michelle and Heather 7/12: changes accepted, per Michelle's guidance
Pisgah Ledge GA (PL)	PL-GLS-03	deletion	Maintain and restore Southern Appalachian bog habitats within geographic area. Management actions will focus on reducing woody plant encroachment and eliminating non-native invasive plant populations.	n/a: goal deleted		7/13/21: changes accepted, per Michelle's guidance

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Pisgah Ledge GA (PL)	PL-GLS-06	new		Enhance structural conditions for ruffed grouse, deer, and turkey by providing more young forest		added goal in response to a comment requesting to do so
Roan Mountain (RM)	RM-DC-05	revision	The desired recreation setting is predominantly Semi-Primitive Non-Motorized and Roaded Natural along and around tha access roads and developed recreation areas.	The desired recreation settings range from Semi-Primitive Non-Motorized and Semi-Primitive Motorized, to Roaded Natural and Rural		
Roan Mountain (RM)	RM-DC-10	revision	Desired Landscape Character is Natural Evolving, Natural-Appearing, Rural Pastoral, or Cultural/Historic	Desired Scenic Character is Natural-Appearing or Pastoral, or Cultural/Historic		
Roan Mountain (RM)	RM-O-01	revision	Tier 1: Over the life of the plan, maintain grassy and heath balds on approximately 320 acres across six separate balds. (This is approximately 60-80 acres per year over a four-to-five year cycle.)	Tier 1: Over the life of the plan, maintain grassy balds, both grass or alder dominated, on approximately 350 acres across Round Bald, Jane Bald, Grassy Bald, Bradley Gap, Little Hump, and Big Hump; and restore an additional 10-20 acres of grassy balds. Tier 2: Over the life of the plan, restore an additional 20-40 acres of grassy balds.	Tier 2 was RM-O-02 in draft plan. Now combined in RM-O-01. Objectives numbering shifted up one.	8/6/21: changes finalized
Roan Mountain (RM)	RM-O-02		Tier 1: Over the life of the plan period, restore and maintain an additional 10-20 acres of grassy and heath balds on Roan Mountain .	Tier 1: Within 5 years, an ecosystem management plan for Roan Mountain will be completed incorporating interests from adjacent landowners, conservation groups, and associated state and Federal agencies.	RM-O-03 became RM-O-02 with no edits/changes.	8/6/21: changes finalized
Roan Mountain (RM)	RM-O-3		Tier 1: Within 5 years, designate campsites in Roan Mountain areas subject to impact from heavy use.	Tier 2: Within 5 years, work with partners to develop a visitor use plan for the Roan Mountain management area, including designating campsites in areas subject to impact from heavy use.	This had been RM-O-04 in draft plan.	8/6/21: changes finalized
Roan Mountain (RM)	RM-S-01	revision	Scenery management of the ANST and OMVNHT foreground....	Management of lands within the Appalachian National Scenic Trail and Overmountain Victory National Historic Trail foreground (up to ½ mile) shall be consistent with direction found in the respective ANST and NHT management areas. Where management direction differs, the more restrictive direction applies		
Roan Mountain (RM)	RM-S-10	new	n/a	Do not allow commercial collection of Fraser fir seedlings.		8/6/21: changes finalized
Unicoi Mountains GA (UM)	UM-GLS-23	revision	Continue partnerships with trail clubs, friends groups, and Wilderness advocacy groups to help manage the hike-only trail systems, and maintain or enhance Wilderness character in Wilderness and Wilderness Study Areas.	Continue partnerships with trail clubs, friends groups, outdoor recreation groups, and Wilderness advocacy groups to help manage the hike-only trail systems, and manage, maintain or enhance Wilderness character in Wilderness and Wilderness Study Areas, including Joyce Kilmer-Slick Rock Wilderness, as well as educating visitors about Wilderness values and ethics.		7/22: changes proposed 7/27: change finalized
Administrative Sites (AS)	AS-DC-01	revision	Facilities reflect the natural and cultural landscape and provide optimal service to Forest Service personnel and visitors of the Forests. They are maintained in good working condition, safe, clean, structurally sound, energy efficient, and accessible to all users.	Facilities reflect the natural and cultural landscape and provide optimal service to Forest Service personnel and visitors of the Forests. They are maintained in good working condition, safe, clean, structurally sound, energy efficient, and accessible to all users. Where recreational amenities are provided, the desired recreation setting is rural.		
Administrative Sites (AS)	AS-DC-02	revision	Desired landscape character is natural-appearing, rural pastoral or cultural/historic.	Desired scenic character is rural forested, pastoral, or cultural/historic.		
AT	"see also" state	revision	Coordinate with the ATC to monitor visitor use and develop and implement visitor use management strategies to maintain ANST values and desired visitor experiences. Such strategies may include visitor capacity studies.	last paragraph revised: Coordinate with the ATC to monitor visitor use and develop and implement visitor use management strategies to maintain ANST values and desired visitor experiences. Such strategies may include visitor capacity studies and assignment of visitor capacities if warranted		7/19: changes recorded
AT	AT-DC-03	revision	The footpath itself is designed, constructed, and maintained for foot travel only and to wear lightly on the land. Associated structures are in harmony with the surrounding environment.	ANST facilities include the footpath itself, shelters approximately one day's hike apart, designated overnight sites, privies, trailhead parking areas, spur trails, and information boards at road crossings. The footpath is designed, constructed, and maintained for foot travel only and to wear lightly on the land. Associated structures are in harmony with the surrounding environment.		7/27: changes finalized 8/16/21: added "spur trails"

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AT	AT-DC-04	revision	Recreation opportunities are predominately in Semi-Primitive Non-Motorized ROS settings. However, where the ANST crosses roads or passes by developed sites, the setting may be Semi-Primitive Motorized, Roaded Natural or Rural. Where the ANST passes through recommended or designated wilderness management areas, the ROS setting is Primitive. Trailheads are sensitive to scale and character and set the tone for a non-motorized experience. Motorized recreation, bicycles, horses, and pack stock are not present on the ANST footpath, although rare exceptions occur. NFS roads within 1/2 mile of the ANST consider hiker security, safety, and ANST values	The ANST traverses Primitive, Semi-Primitive Non-Motorized, Semi-Primitive Motorized, Roaded Natural and Rural ROS classes. Management of ANST settings is consistent with the desired ROS class as mapped for each location within the corridor management area. Trailheads are sensitive to scale and character and set the tone for a non-motorized experience. Motorized recreation, bicycles, horses, and pack stock are not present on the ANST footpath except for authorized administrative use or at intersecting roads or trails. National Forest roads within 1/2 mile of the ANST are managed with consideration for hiker security, safety, and ANST values.		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review"
AT	AT-DC-05	revision	Roads, utility transmission corridors, and/or communication facilities exist or may be seen within the corridor, although the goal is to avoid these types of facilities and land uses to the greatest extent possible and blend facilities which cannot be avoided into the landscape so that they remain visually subordinate within the surrounding characteristic landscape.	Roads, utility transmission corridors, (delete and) or communication facilities exist and may be visible within the corridor, although the goal is to avoid these types of facilities and land uses to the greatest extent possible, and blend facilities which cannot be avoided into the landscape so that they remain visually subordinate. (deleted ending phrase)		19-Jul
AT	AT-DC-06	revision	The ANST corridor emphasizes retention of natural, forested, or pastoral characteristics shaped by both natural processes and humans. Management activities are designed to recognize the nationally-significant aesthetic and recreational values of the ANST. Stands of old growth continue to develop throughout the area.	The ANST corridor management area retains a natural, forested, or pastoral scenic character shaped by both natural processes and humans. While stands of old growth continue to develop in locations throughout the area, where appropriate, vegetation management activities are designed with recognition of the nationally significant aesthetic and recreational values of these lands. Low intensity vegetation management is appropriate to maintain the long-term goals and stewardship objectives of the ANST corridor management area. Management activities needed to preserve, maintain or create vistas, desirable open areas, and balds are a high priority. Activities are planned and carried out in cooperation with appropriate ANST management partners.		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review"
AT	AT-DC-07	revision	Existing wildlife fields and linear wildlife habitats are sustained. Some of these permanent openings may provide more shrub/sapling habitat as a result of longer maintenance cycles.	Existing wildlife fields, balds, and linear wildlife habitats are sustained. Some of these permanent openings may provide more shrub/sapling habitat as a result of longer maintenance cycles		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review"
AT	AT-DC-08	revision	Desired Landscape Character is Natural Evolving, Natural-Appearing, Rural Pastoral, or Cultural/Historic.	Desired Scenic Character is consistent with the following themes: natural evolving in Primitive ROS settings; predominately natural evolving, natural-appearing, or pastoral in Semi-Primitive settings; and natural appearing, rural forested, pastoral or cultural/historic in Roaded Natural or Rural settings		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review" 7/27: associated Table changed to reflect all scenic classes: All scenic class: "High or Moderate for any proposed action directly benefiting the ANST."
AT	AT-DC-09	revision to associated table: ANST Corridor Management Area	**draft text on the right of the table:** Low, Moderate, or High for any proposed action directly benefitting ANST values or user experience within the corridor; and High for all other proposed actions.	**final text on the right of table assc. w/ this DC**: High (Exceptions to the SIO may be allowed in coordination with the ATC for open area management, or shelter and overnight site developments)		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review" 8/16/21: parenthetical added
AT	AT-S-14	revision	Wind turbines shall be prohibited within the ANST corridor.	This corridor management area is unsuitable for special-use authorizations for new communication or energy generation sites.		7/19: entire S revised. Changes recorded
AT	AT-G-01/ (form	deleted, became Standard	New roads should not be authorized within the ANST management area unless the route is proven to be the only viable option determined via site specific analysis and coordination with the ATC.	see AT-S-05 above		7/19: need to confirm- is this former G now a S? yes, it is now a Standard

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AT	AT-G-03 (forme	revision	Spur or side trails to the Appalachian Trail (identified in ANST Local Management Plans for the Appalachian Trail) should be managed primarily as non-motorized trails designated for foot travel. Minor exceptions, such as sharing with motorized uses, may be allowed where there are no other reasonable alternatives.	Spur or side trails to the ANST (identified in Local Management Plans (deletion)) should be managed primarily as non-motorized trails designated for foot travel. Minor exceptions, such as sharing with motorized uses, may be allowed where there are no other reasonable alternatives		7/19: changes recorded. Due to deletion of former G-01, this has moved up
AT	AT-MA	revision	Trail shelters, developed campsites, and privies will be located, maintained and/or replaced where there is a demonstrated need for overnight use.	Trail shelters, designated overnight sites, and privies may be located, maintained (delete 'and')or replaced where there is a demonstrated need for overnight use. Each facility should be periodically evaluated for need, improvement, relocation, or removal		7/19: changes recorded. Formerly g-04 in draft
AT	AT-MA	revision	When locating or relocating shelter or designated overnight camping sites within the ANST corridor, consider the distance from open roads in order to provide for hiker safety	When locating or relocating shelter or designated overnight (deletion) sites within the ANST corridor management area, locate no closer than two miles from open roads and access points where possible		7/19: changes recorded
AT	AT-MA	deletion	**2 paragraphs deleted:** Where appropriate, methods and tools to manage vegetation may include but are not limited to timber harvest, prescribed fire, wildland fire use, mowing, hand tools, power tools, herbicides, biological controls, or grazing. As needed throughout the life of the Land Management Plan, review and update group volunteer agreements between ranger districts and ANST affiliated maintainer clubs. For consistency, favor developing Forests or multi-district group volunteer agreements where appropriate.	n/a. paragraphs deleted		7/19: changes recorded
AT	AT-O-01	new	n/a	Tier 1: Update group volunteer agreements between Ranger Districts and ATC-affiliated maintainer clubs on a 5-year cycle, or more frequently if needed. For consistency, favor developing multi-district group volunteer agreements where appropriate		7/19: new objective added
AT	AT-S-01	revision	The ANST corridor is unsuitable for timber production.	The ANST corridor management area is unsuitable for timber production.		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review"
AT	AT-S-02	revised/renumber	Vegetation management in the ANST corridor may be used to maintain or enhance the ANST environment or user experience for the following purposes: • Maintaining, expanding, or creating desirable open areas, old field habitats, or vistas that enhance scenic qualities or visitor experience of the ANST • Controlling diseases, insects, or non-native invasive vegetation • Maintaining or improving habitat for threatened, endangered, sensitive, or locally rare species • Maintaining, restoring, or expanding habitat for rare communities, species dependent on disturbance, or wildlife viewing opportunities • Meeting trail construction or maintenance needs, including shelters or other associated features • Managing fuels or mimicking historic fire regimes • Providing for public safety or resource protection	Vegetation management in the ANST corridor management area shall maintain or enhance the ANST environment or user experience. Allow timber harvest, prescribed burning, wildfire, hand tools, power tools, mowing, herbicides, biological controls, or grazing to manage vegetation as appropriate. Vegetation management may be used for the following purposes: • Maintaining, expanding, or creating desirable open areas, balds, old field habitats, or vistas that enhance scenic qualities or visitor experience of the ANST • Controlling diseases, insects, or non-native invasive vegetation • Ecological restoration or managing for resiliency in the face of change • Maintaining or improving habitat for threatened, endangered, sensitive, or locally rare species • Maintaining, restoring, or expanding habitat for rare communities, species dependent on disturbance, or wildlife viewing opportunities • Meeting trail construction or maintenance needs, including shelters or other associated features • Managing fuels or mimicking historic fire regimes • Providing for public safety or resource protection		7/19: changes recorded. Entire AT section was copied and pasted from Erik's final clean version in the Word document titled "AT MA edits-EC 7.13.21-ATC-NPS Review"
AT	AT-S-03	deletion	Vegetation management for reasons other than maintaining or enhancing the ANST environment or user experience are permitted within the Appalachian Trail Corridor provided they are not visible from the footpath or associated features.	n/a. standard deleted		7/19: changes recorded. Entire AT section was updated based on coversations with ATC

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
AT	AT-S-04	revision	Management activities within or outside the ANST Corridor which are potentially visible from the footpath or associated features shall be planned in cooperation with the Appalachian Trail Conservancy and affiliate hiking clubs.	Management activities within or outside the ANST Corridor which are potentially visible from the footpath or associated features shall be planned in cooperation with the ATC and affiliate maintainer clubs.		7/19: due to S-03 above, the # of this standard is now AT-S-03. all other subsequent S #s moved up by 1
AT	AT-S-05	revision	Project-level analysis of potential scenery impacts or verification of foreground visibility shall be done during leaf-off season.	Project-level analysis of potential scenery impacts (deletion) shall be done during leaf-off season.		7/19: revision recorded.S bumped down 1. now AT-S-04
AT	AT-S-05	new	New roads should not be authorized within the ANST management area unless the route is proven to be the only viable option determined via site specific analysis and coordination with the ATC.	Authorize new roads within the ANST corridor management area only if entering the management area is the only feasible and prudent location and the road is not visible from the ANST footpath or associated features.		7/19: formerly AT-G-01. 7/27: Heather to revisit and ensure language is the latest/accurate for final
AT	AT-S-07	revision	Prohibit hauling or skidding along or across the ANST footpath or using the footpath for a landing or temporary road. Hauling or skidding in other locations within the Corridor Management Area is allowed only if site-specific analysis indicates that it is the only feasible and prudent alternative and that the desired SIO can be met.	Prohibit hauling or skidding along or across the ANST footpath or using the footpath as a landing or temporary road. Hauling or skidding in other locations within the corridor management area is allowed only if site-specific analysis indicates that it is the only feasible and prudent alternative, and that activities are not visible from the ANST footpath or associated features		7/19: revision recorded
AT	AT-S-08	revision	Motorized, horse, pack stock, and bicycle use on the ANST are prohibited. Exceptions include where the ANST crosses or is located on open Forest Service system roads or trails designated for those uses or other Federal, state, county, and public roads; or as needed for management of the ANST; or for administrative or emergency purposes. Other uses within the ANST Corridor, including crossings of the ANST, may be authorized following coordination with appropriate ANST partners. Locate any authorized uses crossing the ANST to minimize impacts to the ANST environments, preferably where impacts already exist.	Motorized, horse, pack stock, and bicycle use on the ANST is prohibited. Exceptions include where the ANST crosses or is located on open Forest Service system roads or trails designated for those uses; federal, state or other public roads; or as needed for ANST management, administrative access, or emergency purposes. Other uses within the ANST corridor management area, including crossings of the ANST, may be considered following coordination with appropriate ANST partners. Locate (deletion) authorized uses crossing the ANST to minimize impacts to the ANST environment, preferably where impacts already exist.		7/19: changes recorded
AT	AT-S-09	revision	Overnight camping is allowed within the ANST Corridor, except as prohibited or restricted by forest supervisor's Closure Order.	Overnight camping is allowed within the ANST corridor management area, except as prohibited or restricted by Regional Forester's order.		7/19: changes recorded
AT	AT-S-11	revision	Commercial special use recreation events shall not be authorized on the ANST, except on intersecting trails or overlapping trails if approved in coordination with the ATC.	Commercial special use recreation events shall not be authorized on the ANST, except on intersecting (deletion) or overlapping trails if approved in coordination with the ATC.		7/19: changes recorded
AT	AT-S-14	revision	Outfitting and guiding permits will not be issued for overnight camping at Appalachian Trail shelters or within 300 feet of the footpath.	Outfitting and guiding permits will not be issued for overnight camping at ANST shelters, designated overnight sites, or within 300 feet of the footpath		7/19: changes recorded
AT	AT-S-16	new		Management of Inventoried Roadless Areas within the ANST management area shall conform to IRA management direction in Backcountry MA, in addition to ANST management area direction. Where ANST management area direction differs from IRA direction for roads or vegetation management, the more restrictive direction applies		
AT	background	revision	see plan	various changes made		6/28: there will be meetings with NPS and ATC this week. Changes anticipated. 7/19: all edits and updates to the AT section of the plan were made through discussions with ATC and NPS
AT		revision	See also: Forestwide: Scenery; Geographic Areas: Nantahala Mountains, Nantahala Gorge, Unicoi Mountains, and Fontana Lake	See also: Forestwide: Scenery; Dispersed Recreation; Geographic Areas: Nantahala Mountains, Nantahala Gorge, Unicoi Mountains, Fontana Lake, and Bald Mountains; MAs: Congressionally Designated Wilderness, Recommended Wilderness, Roan Mountain, Heritage Corridors, and Experimental Forests.		7/19: changes recorded

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Backcountry (BAC)	BAC-DC-04	revision	Wildlife habitat conditions support rare species and game species (such as veery, hermit thrush, Swainson's thrush, wood thrush, cerulean warbler, Kentucky warblers, salamanders, and black bear) that thrive in larger blocks of older forest.	Wildlife habitat conditions support rare species and game species (such as veery, hermit thrush, Swainson's thrush, wood thrush, cerulean warbler, Kentucky warblers, salamanders, and black bear) that respond to larger blocks of older forest.		
Backcountry (BAC)	BAC-S-02	revision	Within Inventoried Roadless Areas lands are not suitable for timber production. Timber may not be cut, sold, or removed except when the cutting, sale, or removal of generally small diameter timber is needed for one of the following purposes and will maintain or improve one or more of the Roadless Area characteristics. The latest Forest Service policy regarding delegation of approval of these activities must be considered:	Within Inventoried Roadless Areas lands are not suitable for timber production. Timber may not be cut, sold, or removed except when the cutting, sale, or removal of generally small diameter timber is needed for one of the following purposes and will maintain or improve one or more of the Roadless Area characteristics. Follow the latest Forest Service policy regarding delegation of approval for the following activities:		
Congressionally Designated Wilderness (CDW)	CDW-DC-01	revision		Preservation of the natural environment free from human influences predominates. The natural, undeveloped, and untrammeled character of Wilderness is preserved or enhanced as are other features of value. With a desired condition of a Primitive ROS setting, opportunities for solitude or primitive and unconfined recreation are maintained for visitors to experience. Scientific research or visitor education is conducted when consistent with Wilderness values. Commercial enterprise does not exist within these areas except through permitted outfitter and guide services which allow visitors to experience and be educated about the benefits of Wilderness preservation. Ecological and social characteristics of Wilderness are maintained or enhanced		
Congressionally Designated Wilderness (CDW)	CDW-DC-02	revision		The Desired Scenic Character of these areas is Natural Evolving and shaped primarily by natural processes, resulting in large patches of late successional and old growth forest conditions. Natural disturbance events, such as insects and diseases, ice storms, and lightning-caused fires, play a role in shaping forest structure, composition, and successional stages across these areas. Non-native vegetation occurs only as transient populations and is not self-perpetuating		
Congressionally Designated Wilderness (CDW)	CDW-DC-04	revision	Recreation management emphasizes solitude and remoteness in a primitive and natural setting, recognizing that different areas within a Wilderness, or proximity to trailheads, have varying degrees of human use. Access to the area is limited, and use is dispersed through visitor education and trail and trailhead design. Trailheads at surrounding roads are designed with sensitivity to scale and character to set the tone for a primitive recreation experience. Trails provide solitude, physical and mental challenge, spirit of adventure, and self-reliance. Once in the designated Wilderness, visitors on foot or horseback rely on their physical abilities and outdoor skills. Wilderness recreation includes inherent risks, such as adverse weather, isolation, natural physical hazards, or primitive travel. Visitors are isolated from the sights and sounds of others, and encounters with other visitors are rare. Travel within Wilderness is strictly non-motorized and non-mechanized.	Recreation management emphasizes solitude and remoteness in a primitive and natural setting, recognizing that different areas within a Wilderness, or proximity to trailheads, have varying degrees of human use. Access to the area is limited, and use is dispersed through visitor education and trail and trailhead design. Trailheads at surrounding roads are designed with sensitivity to scale and character to set the tone for a primitive recreation experience. Trails and off-trail foot travel provides solitude, physical and mental challenge, spirit of adventure, and self-reliance. Once in the designated Wilderness, visitors rely on their physical abilities and outdoor skills. Wilderness recreation includes inherent risks, such as adverse weather, isolation, natural physical hazards, or primitive travel. Visitors are isolated from the sights and sounds of others, and encounters with other visitors are rare. Travel within Wilderness is strictly non-motorized and non-mechanized.		
Congressionally Designated Wilderness (CDW)	CDW-DC-05	revision	Visitor information is primarily dispensed outside of the Wilderness at trailheads and through off-site public information and education efforts; an exception may be through personal interaction with wilderness rangers. Wilderness visitors are encouraged to "pack it-in and pack-it-out" and to implement "leave no trace" principles. Wilderness trails lie lightly on the land and are typically narrow footpaths or horse trails with minimum directional signing. Where signs exist, they blend with the natural surroundings. Visitors are physically challenged as they ford streams or climb over downed trees. They are also challenged by the area's undeveloped character, where outdoor skills or map and compass navigation may be required.	Visitor information is primarily dispensed outside of the Wilderness at trailheads and through off-site public information and education efforts; an exception may be through personal interaction with wilderness rangers. Wilderness visitors are encouraged to "pack it-in and pack-it-out" and to implement "leave no trace" principles. Wilderness trails lie lightly on the land and are typically narrow footpaths or horse trails with minimum directional signing. Where signs exist, they blend with the natural surroundings. Visitors are physically challenged by (deletion) the area's undeveloped character, where outdoor skills or map and compass navigation may be required.		

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Congressionally Designated Wilderness (CDW)	CDW-DC-06	revision	Within these areas, few if any facilities are provided. Permanent human-made shelters are rarely present, although some exist along the Appalachian National Scenic Trail. Creation of new shelters on new sites within Wilderness is not appropriate, unless there is an obvious and overriding need to protect natural resources from visitor impacts. Structures, including trail features, bridges, signs, or constructed water sources for the comfort or convenience of visitors, are minimal. The few structures appearing in Wilderness are generally for the protection of resources or were present prior to Wilderness designation.	Within these areas, few if any facilities are provided. Permanent human-made shelters are rarely present, and only exist along the Appalachian National Scenic Trail. Construction of new ANST shelters on new sites within Wilderness is not appropriate, unless there is an obvious and overriding need to protect natural resources from visitor impacts. Structures, including trail features, bridges, signs, or constructed water sources for the comfort or convenience of visitors, are minimal. The few structures appearing in Wilderness are generally for the protection of resources or were present prior to Wilderness designation.		
Congressionally Designated Wilderness (CDW)	CDW-G-07	deletion	Locate planned and approved long distance trails outside of Wilderness unless there is no other feasible route.	n/a. standard deleted	Heather-please advise. Are we replacing this language with anything, or simply deleting it? Heather: Just deleting it.	7/20: change finalized
Congressionally Designated Wilderness (CDW)	CDW-S-01	revision	Manage Wilderness as closed to all motorized vehicles and equipment and to mechanized means of transport, such as bicycles or wheeled carts. Administrative use of motorized equipment or mechanized transport shall only be allowed when determined to be the minimum tool necessary to preserve Wilderness character and with the apporpriate authorization for proposed activities or in emergency situations.	With the exception of wheelchairs , motorized equipment and mechanized transport are not allowed, unless determined to be the minimum tool necessary to preserve or enhance wilderness character or in an emergency. Motorized equipment or mechanized transport use authorizations require the appropriate line officer approval following the latest agency policy		8/16/21: Std was edited to be consistent with adjacent forest language (GW and Jeff).
Congressionally Designated Wilderness (CDW)	CDW-S-03	revision	Manage trails for hiking use only, except for existing desginated horse trails in Shining Rock Wilderness and Southern Nantahala Wilderness	Manage the trail system for non-motorized and non-mechanized recreation uses consistent with wilderness values.	plan componnent was updated in response to comments on no equestrian trails in wilderness	7/20: change finalized
Congressionally Designated Wilderness (CDW)	CDW-S-05	revision	Rock climbing or similar sports is allowed only where there is no resource damage resulting from the activity and where not prohibited by seasonal or permanent closure orders. Installation of new permanent anchors, or their replacement, shall only be done with the appropriate analysis and line officer approval. If replaced or installed, anchors shall be of a non-reflective or camouflaged finish. Use of motorized drills is prohibited.	Installation or replacement of fixed anchors for climbing or similar activities shall only be done following the latest agency policy on climbing and with the appropriate analysis and line officer approval to ensure no ecological or cultural resource damage occurs, and that wilderness values are not impacted. If user installation or replacement is approved, anchors shall be of a non-reflective or camouflaged finish. Use of motorized drills is prohibited.		7/20: change finalized
Congressionally Designated Wilderness (CDW)	CDW-S-09	revision	Allow no permanent camps other than existing Appalachian National Scenic Trail shelters or identified campsites.	Allow no permanent camps or shelters other than existing Appalachian National Scenic Trail shelters or designated overnight use sites		
Congressionally Designated Wilderness (CDW)	CDW-S-26 (now 25), bullet 2	revision	2. Existing Appalachian National Scenic Trail shelters and associated facilities located within Wilderness may be maintained, improved, or replaced in-kind. However, if replacement of structures is necessary, consider relocating them outside Wilderness boundaries.	Existing Appalachian National Scenic Trail shelters and associated facilities located within Wilderness may be maintained, improved, replaced in-kind, or removed. However, if replacement of structures is necessary, consider relocating them outside Wilderness boundaries.	Added per FEIS notebook: what plan components will be changing-"CDW-S-26, under bullet 2 add 'or removed' after 'replaced in-kind'	7/20: change finalized
Congressionally Designated Wilderness (CDW)	Mgmt Approach	revision	Naturalize campsites in trail-less areas and naturalize or rehabilitate trail-side campsites where resource damage or impacts to wWilderness character are occurring. Consider temporary or permanent site closures when other management techniques are not successful.	Naturalize and close campsites, unauthorized climbing access routes, and climbing staging areas where resource damage or impacts to wilderness character are occurring. Consider long-term closures when other management techniques are not successful .		8/16/21: changes finalized
Cradle of Forestry in America (CF)	CF-DC-01	revision	The Cradle of Forestry in America provides an opportunity for forest visitors to explore the past, present, and future of forest management through interpretation of historical resources and management activities.	The Cradle of Forestry in America provides an opportunity for forest visitors to explore the past, present, and future of forest management and resulting benefits through interpretation of historical resources and management activities.		7/27: changes finalized
Cradle of Forestry in America (CF)	CF-DC-02	revision	Visitors have an opportunity to experience interpretive trails, interactive exhibits, demonstrations, and special events that foster understanding of forestry, conservation, and cultural resources.	Visitors have an opportunity to experience interpretive trails, interactive exhibits, demonstrations, and special events that foster understanding of forestry, multiple use land management, conservation, and cultural resources		7/27: change finalized
Cradle of Forestry in America (CF)	CF-DC-05	deleted/renumber	Landscape character themes include Natural Appearing and Rural-Forested and/or – Pastoral and include a number of historic and cultural elements.	n/a-DC deleted		7/27: DC-5 was deleted, as it was duplicative of DC-10
Cradle of Forestry in America (CF)	CF-DC-05 (form	revised/renumber	Recreation settings range from Rural and Roaded Natural to Semi-Primitive Non-Motorized, based on level of development.	Recreation settings range from Roaded Natural and Rural. (rest of text deleted)		7/27: change finalized. CF DCs renumbered due to deletion of former DC-05

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Cradle of Forestry in America (CF)	CF-DC-06 (form	renumber		no change to text		7/27: change finalized. Fomerly CF-DC-07
Cradle of Forestry in America (CF)	CF-DC-07 (form	renumber		no changes to text.		7/27: change finalized. Fomerly CF-DC-08
Cradle of Forestry in America (CF)	CF-DC-08 (form	renumber		no changes to text		7/27: change finalized. Formerly CF-DC-09
Cradle of Forestry in America (CF)	CF-DC-09 (form	renumber & revision	Desired Landscape Character is Natural-Appearing, Rural Forested, Rural Pastoral, or Cultural/Historic.	Desired Scenic Character is Natural Appearing, Rural-Forested or Pastoral, with Historic/Cultural elements.		7/27: change finalized. Fomerly CF-DC-10. text also edited
Cradle of Forestry in America (CF)	CF-DC-10 (form	renumber & revision	Proposed actions are designed to meet or exceed the following desired Scenic Integrity Objectives on lands inventoried as the corresponding Scenic Classes: **assc. table text:** High, Moderate or Low for proposed actions related to forestry education or demonstration; but High or Moderate for any proposed actions visible from the Blue Ridge Parkway, Forest Heritage National Scenic Byway, or National Recreation Trails	**changes to assc. table text:** High, Moderate or Low SIO for proposed actions related to forestry education or demonstration which is visible primarily from area roads, trails or facilities. Moderate SIO for any proposed actions visible in the middleground from the Blue Ridge Parkway or National Recreation Trails. High SIO in the foreground of the Forest Heritage National Scenic Byway.		7/27: revisit, as the changes to the associated table are may be revised further
Cradle of Forestry in America (CF)	CF-DC-11 (form	renumber	no changes to text	no changes to text		7/27: DCs re-numbered
Cradle of Forestry in America (CF)	CF-DC-12 (form	renumber	Management of wildlife fields and other permanently open wildlife habitats is compatible with the congressional intent of the Cradle of Forestry in America.	no changes to text		7/27: changes finalized
Cradle of Forestry in America (CF)	CF-DC-13	new	n/a	Management activities demonstrate benefits to wildlife when appropriate.		7/27: new DC. Finalized
Ecological Interest Areas (EIA)	background	revision	see draft plan	EIAs are places where active management is desired to improve ecological species composition. Generally, these locations have fewer roads than the Matrix management area, and contain some concentrations of high-quality natural communities or high quality existing old growth, but these areas are not as biologically exceptional as Special Interest Areas. EIAs benefit from a management style that is focused on restoring and improving the unique values present, including perpetuating or enhancing plant or animal species and communities that are of national, regional, or state significance. Top priorities in this management area would be to restore community composition by treating stands with uncharacteristic vegetation. The need for balancing successional age classes at the landscape scale would not drive stand-level prescriptions. Ecological restoration would result in a mix of forest habitats of various ages, sizes, and configurations. Timber harvest, prescribed fire, nonnative invasive treatments and road construction are tools for achieving desired conditions.		7/22: changes accepted and finalized. EIAs seperated from SIAs into 2 different sections
Ecological Interest Areas (EIA)	EIA-DC-01	moved to SIA-DC-01	no changes to text.	no changes to text. DC moved, as EIA and SIA sections were seperated from draft		7/22: changes accepted
Ecological Interest Areas (EIA)	EIA-NA	new	n/a	Within this management area, the following types of timber treatments could be expected: removal of offsite species and regeneration to species that would be found in that ecozone; thinning to create woodland conditions and remove encroaching mesic species; thinning and understory treatments to increase the species diversity of regeneration layers; use of group selection and variable retention systems to foster development of diverse species compositions; harvest to accelerate development of late and old growth characteristics.		7/22: changes accepted

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Experimental Forests (EXF)	EXF-DC-07	revision	Experimental forests consist of Roaded Natural areas characterized by predominanatly natural appearing landscapes with moderate to substantial evidence of the sights and sounds of man. Interpretive information may be present within this setting for the enhancement of the visitor's recreational and educational experience.	Although research is the emphasis in these areas, recreation use does occur in some locations and the desired ROS setting is Roaded Natural. The scenic character is predominantly natural appearing, but deviations exist with moderate to substantial evidence of human modification. Interpretive information may be present within this setting for the enhancement of the visitor's recreational and educational experience.		
Experimental Forests (EXF)	EXF-S-15	new	(first draft of new std-In Coweeta Experimental Forest, conform to Appalachian National Scenic Trail management area direction within the visible foreground up to ½ mile from the footpath, vistas, and other associated features; provided it does not compromise experimental forest values)	Design experiments, access roads, wildlife habitat improvements, and/or vegetation management activities to minimize impacts to scenery where proposed actions may be visible from the Appalachian National Scenic Trail, Mountains-to-Sea National Recreation Trail, or the Blue Ridge Parkway; provided it does not compromise experimental forests values .		8/10- changes made in plan
Experimental Forests (EXF)	Mgmt Approac	new		Consult with Ranger District and/or Forest recreation program managers when planning proposed actions within ½ mile of nationally designated trails or the Blue Ridge Parkway .		8/10- changes made in plan
Heritage Corridors (HC)	HC-DC-06	revision	Desired recreation setting is predominantly roaded natural with some areas of Semi-Primitive Motorized and Semi-Primitive Non-Motorized	Desired recreation settings range from Semi-Primitive Non-Motorized and Semi-Primitive Motorized, to Roaded Natural and Rural		
Heritage Corridors (HC)	HC-DC-07	revision	Desired Landscpae Character is Natural-Appearing, Rural Forested, Rural Pastoral, or Cultural/Historic	Desired Scenic Character is Natural-Appearing for Semi-Primitive settings; and Rural Forested, Pastoral, or Cultural/Historic for Roaded Natural or Rural settings		
Heritage Corridors (HC)	HC-G-04	revised	Archeological investigations should be conducted in coordination with tribal interests to document locations and conditions of associated sites and components where appropriate and through formal consultation with all parties.	Archeological investigations should be conducted in coordination with tribal management recommendations. Where cultural resources are present, document locations and conditions through formal consultation with all parties.		8/17/21: changes finalized
Heritage Corridors (HC)	HC-S-11	new		Management of Inventoried Roadless Areas (IRA) within the Heritage Corridors management area shall conform to IRA management direction in Backcountry management area, in addition to Heritage Corridors management area direction. Where Heritage Corridors management area direction differs from IRA direction for roads or vegetation management, the more restrictive direction applies.		
Research Natural Areas (RNA)	RNA-DC-04	revision	These areas provide Primitive settings and are characterized by an essentially unmodified natural environment. Recreational use is limited and free from developed facilities.	These areas provide a Semi-Primitive Non-Motorized ROS setting and are characterized by an essentially unmodified natural environment. Recreational use is limited to foot travel and areas have no developed facilities		
Research Natural Areas (RNA)	RNA-DC-05	revision	Desired Landscape Character is Natural Evolving.	The Desired Scenic Character is Natural Evolving to Natural-Appearing		
Research Natural Areas (RNA)	RNA-S-12	revision	Consult with the station director concerning any research proposals.	Coordinate with the station director concerning any research proposals.		

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Research Natural Areas (RNA)	RNA-S-13	new		Management of Inventoried Roadless Areas within Research Natural Areas shall conform to IRA management direction in Backcountry MA, in addition to Research Natural Area management area direction. Where RNA management area direction differs from IRA direction for roads or vegetation management, the more restrictive direction applies		
RW	Mgmt Approac	new	n/a	If recommended wildernesses are designated by congress during the life of this Land Management Plan, consider area use levels, capacity to maintain opportunities for solitude, and existing group size limits in nearby designated areas. Establishment of area specific group size limits after designation may consider potential benefits of dispersing use from other heavily used wildernesses or introducing youth to a wilderness experience through O&G services.		
RW	RW-DC-03	revision	Non-motorized and non-mechanized recreation opportunities continue to be enjoyed, with an emphasis on providing a Primitive setting. Existing roads, trails, and wildlife improvements are maintained using current practices until the area is designated as Wilderness.	Non-motorized and non-mechanized recreation opportunities continue to be enjoyed, with an emphasis on providing a Primitive setting. Existing roads, trails, and wildlife improvements may be maintained using current practices until the area is designated as Wilderness.	Revised per note in FEIS notebook: "RW-DC-03 change 'improvements are maintained' to 'improvements may be maintained' regarding existing roads in recommended wilderness	
RW	RW-S-05	revision	Manage the trail system for hike-only opportunities, except where there are existing designated equestrian trails. Do not expand the existing network of equestrian trails. Designating bicycle trails is not allowed.	Manage the trail system for non-motorized and non-mechanized recreation uses consistent with wilderness values.		7/15: changes finalized
RW	RW-S-12	new	n/a	Installation or replacement of fixed anchors for climbing or similar activities shall only be done following the latest agency policy on climbing and with the appropriate analysis and line officer approval to ensure no ecological or cultural resource damage occurs, and that wilderness values are not impacted. If user installation or replacement is approved, anchors shall be of a non-reflective or camouflaged finish. Use of motorized drills is prohibited.		7/27: change finalized; this is std-13 now
RW	RW-S-13	new	n/a	Installation or replacement of fixed anchors for climbing or similar activities shall only be done following the latest agency policy on climbing and with the appropriate analysis and line officer approval to ensure no ecological or cultural resource damage occurs, and that wilderness values are not impacted. If user installation or replacement is approved, anchors shall be of a non-reflective or camouflaged finish .	Note- reference to drills being prohibited was dropped from this std that is in Rec Wilderness .	8/16/21: changes finalized
Special Interest Areas (SIA)	background	revision	see draft plan	minor revisions made. SIA section has been separated from EIA		7/22: changes accepted
Special Interest Areas (SIA)	placeholder	no changes to text				7/22: no changes to plan components. All SIA plan components have been seperated out from EIAs. There are now 2 sections.
Special Interest Areas (SIA)	Table 15	revision		changes made to acreages and added areas		
WSR	Table 18-Congressionally Designated River	revision		addition of "biological' ORV to row 1, Chattooga River		7/15: change finalized
WSR	Table 19-Eligible or Suitable Rivers	revision		deleted Overflow Creek from the table		7/15: change finalized
WSR	WSR-S-42	new		Management of Inventoried Roadless Areas within the Wilson Creek WSR corridor shall conform to IRA management direction in Backcountry MA, in addition to WSR management area direction. Where WSR management area direction differs from IRA direction for roads or vegetation management, the more restrictive direction applies		

Resource	Plan Component	New or Revision?	2020 Draft Plan Language	New, proposed Language (changes in RED)	Suggested revisions/additions/comments from Plan	Misc. Notes
Experimental Forests (EXF)	EXF-S-10	revision	All new special use permit issuances must meet current research and educational objectives and a primary purpose of education or research. Permit approvals require coordination with the station director or designated representative to ensure that no ongoing or projected experiments are interrupted. Special use permits for recreation events and non-commercial group user activities shall not be authorized.	All new special use permit issuances must have a primary purpose of education or research. Permit approvals require coordination with the station director or designated representative. Ensure that no ongoing or projected experiments are interrupted. Special use permits for recreation events and non-commercial group user activities shall not be authorized.		8/18/21: changes finalized

Attachment 18

Public Inspection document for proposed rule to reclassify the Northern Long-eared Bat as endangered (available through the Federal Register on 3/22/2022)

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DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

[Docket No. FWS-R3-ES-2021-0140; FF09E21000 FXES1111090FEDR 223]

RIN 1018–BG14

Endangered and Threatened Wildlife and Plants; Endangered Species Status for Northern Long-eared Bat

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Proposed rule.

SUMMARY: We, the U.S. Fish and Wildlife Service (Service), propose to reclassify the northern long-eared bat (*Myotis septentrionalis*), a bat species found in all or portions of 37 U.S. States, the District of Columbia, and much of Canada, as an endangered species under the Endangered Species Act of 1973, as amended (Act). The northern long-eared bat is currently listed as a threatened species with an accompanying rule issued under section 4(d) of the Act ("4(d) rule"). This document complies with a court order, which requires the Service to make a new listing decision for the northern long-eared bat. After a review of the best available scientific and commercial information, we find that the northern long-eared bat meets the Act's definition of an endangered species. Accordingly, we propose to list the northern long-eared bat as an endangered species under the Act. If we finalize this rule as proposed, it would reclassify this species as an endangered species on the List of Endangered and Threatened Wildlife and remove its species-specific 4(d) rule. Additionally, this proposed rule serves as our 5-year review of the species. We also are notifying the public that we have scheduled an informational

meeting followed by a public hearing on the proposed rule.

DATES: We will accept comments received or postmarked on or before [INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]. Comments submitted electronically using the Federal eRulemaking Portal (see **ADDRESSES**, below) must be received by 11:59 p.m. Eastern Time on the closing date.

Public informational meeting and public hearing: We will hold a public informational meeting from 6:00 p.m. to 7:30 p.m., Central Time, followed by a public hearing from 7:30 p.m. to 8:30 p.m., Central Time, on April 7, 2022.

ADDRESSES: You may submit comments by one of the following methods:

(1) *Electronically*: Go to the Federal eRulemaking Portal: *https://www.regulations.gov*. In the Search box, enter FWS-R3-ES-2021-0140. Then, click on the Search button. On the resulting page, in the panel on the left side of the screen, under the Document Type heading, check the Proposed Rule box to locate this document. You may submit a comment by clicking on “Comment.”

(2) *By hard copy*: Submit by U.S. mail to: Public Comments Processing, Attn: FWS-R3-ES-2021-0140, U.S. Fish and Wildlife Service, MS: PRB/3W, 5275 Leesburg Pike, Falls Church, VA 22041–3803.

We request that you send comments only by the methods described above. We will post all comments on *https://www.regulations.gov*. This generally means that we will post any personal information you provide us (see **Information Requested**, below, for more information).

Public informational meeting and public hearing: The public informational meeting and the public hearing will be held virtually using the Zoom platform. See *Public Hearing*, below, for more information.

FOR FURTHER INFORMATION CONTACT: Shauna Marquardt, Field Supervisor, U.S. Fish and Wildlife Service, Minnesota Wisconsin Ecological Services Field Office, 4101 American Boulevard East, Bloomington, MN 55425; telephone 952–252–0092. Individuals in the United States who are deaf, deafblind, hard of hearing, or have a speech disability may dial 711 (TTY, TDD, or TeleBraille) to access telecommunications relay services. Individuals outside the United States should use the relay services offered within their country to make international calls to the point-of-contact in the United States.

SUPPLEMENTARY INFORMATION:

Information Requested

We intend that any final action resulting from this proposed rule will be based on the best scientific and commercial data available and be as accurate and as effective as possible. Therefore, we request comments or information from other governmental agencies, Native American Tribes, the scientific community, industry, or any other interested parties concerning this proposed rule.

We particularly seek comments concerning:

(1) The species' biology, range, and population trends, including:

(a) Biological or ecological requirements of the species, including habitat requirements for feeding, breeding, and sheltering;

(b) Genetics and taxonomy;

(c) Historical and current range, including distribution patterns;

(d) Historical and current population levels, and current and projected trends; and

(e) Past and ongoing conservation measures for the species, its habitat, or both.

(2) Factors that may affect the continued existence of the species, which may include habitat modification or destruction, overutilization, disease, predation, the inadequacy of existing regulatory mechanisms, or other natural or manmade factors.

(3) Biological, commercial trade, or other relevant data concerning any threats (or lack thereof) to this species and existing regulations that may be addressing those threats.

(4) Additional information concerning the historical and current status, range, distribution, and population size of this species, including the locations of any additional populations of this species.

Please include sufficient information with your submission (such as scientific journal articles or other publications) to allow us to verify any scientific or commercial information you include.

Please note that submissions merely stating support for, or opposition to, the action under consideration without providing supporting information, although noted, will not be considered in making a determination, as section 4(b)(1)(A) of the Act directs that determinations as to whether any species is an endangered or a threatened species must be made "solely on the basis of the best scientific and commercial data available."

You may submit your comments and materials concerning this proposed rule by one of the methods listed in **ADDRESSES**. We request that you send comments only by the methods described in **ADDRESSES**.

If you submit information via *https://www.regulations.gov*, your entire submission—including any personal identifying information—will be posted on the website. If your submission is made via a hardcopy that includes personal identifying information, you may request at the top of your document that we withhold this information from public review. However, we cannot guarantee that we will be able to do so. We will post all hardcopy submissions on *https://www.regulations.gov*.

Comments and materials we receive, as well as supporting documentation we used in preparing this proposed rule, will be available for public inspection on *https://www.regulations.gov*.

Because we will consider all comments and information we receive during the comment period, our final determination may differ from this proposal. Based on the new information we receive (and any comments on that new information), we may conclude that the species should remain listed as a threatened species instead of reclassified as an endangered species, or we may conclude that the species does not warrant listing as either an endangered species or a threatened species.

Public Hearing

Section 4(b)(5) of the Act provides for a public hearing on this proposal, if requested. For the immediate future, we will provide these public hearings using webinars that will be announced on the Service's website, in addition to the *Federal Register*. The use of these virtual public hearings is consistent with our regulations at 50 CFR 424.16(c)(3). See **DATES** and **ADDRESSES** for information on a public hearing that we have scheduled for this rulemaking action.

Previous Federal Actions

On October 2, 2013, we proposed to list the northern long-eared bat as an endangered species under the Act (78 FR 61046); please refer to that proposed rule for a detailed description of previous Federal actions concerning this species.

On January 16, 2015, we proposed to create a 4(d) rule to provide measures that are necessary and advisable to provide for the conservation of the northern long-eared bat should we determine the species warrants listing as a threatened species under the Act (80 FR 2371). That document also reopened the public comment period on the October 2, 2013, proposed rule for another 60 days, ending on March 17, 2015.

On April 2, 2015, we finalized a rule listing the northern long-eared bat as a threatened species and established an interim 4(d) rule for the species (80 FR 17974). We solicited public comment on the interim 4(d) rule for 90 days, ending on July 1, 2015. On January 14, 2016, we finalized the 4(d) rule for the northern long-eared bat (81 FR 1900). On April 27, 2016, we published a not-prudent determination for critical habitat (81 FR 24707).

A January 28, 2020, court order requires the Service to make a new listing decision for the northern long-eared bat (*Center for Biological Diversity* v. *Everson*, 435 F. Supp. 3d. 69 (D.D.C. 2020)). The court order remanded our April 2, 2015, listing decision (80 FR 17974) but did not vacate that rule. This document complies with the court order.

Supporting Documents

A species status assessment (SSA) team prepared an SSA report for the northern long-eared bat (Service 2021, entire). The SSA report represents a compilation of the best scientific and commercial data available concerning the status of the species, including the impacts of past, present, and future factors (both negative and beneficial) affecting the species. In accordance with our joint policy on peer review published in the *Federal Register* on July 1, 1994 (59 FR 34270), and our August 22, 2016, memorandum updating and clarifying the role of peer review of listing actions under the Act, we sought the expert opinions of five species experts regarding the SSA report. We received responses from three of the five experts. We also sent the SSA report to approximately 150 State, Federal, Tribal, and other (for example, nongovernmental organizations) partners with expertise in bat biology or threats to the species for review. We received reviews from approximately 35 partners.

Proposed Listing Determination

Background

A thorough review of the taxonomy, life history, and ecology of the northern long-eared bat is presented in the SSA report (Service 2021, entire).

The northern long-eared bat is a wide-ranging bat species found in 37 States (Alabama, Arkansas, Connecticut, Delaware, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South

Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and Wyoming), the District of Columbia, and 8 Canadian provinces. The species typically overwinters in caves or mines and spends the remainder of the year in forested habitats. As its name suggests, the northern long-eared bat is distinguished by its long ears, particularly as compared to other bats in its genus, *Myotis*. The bat is medium to dark brown on its back, with dark brown ears and wings, and tawny to pale-brown fur on its ventral side. Its weight ranges from approximately 5 to 8 grams (0.2 to 0.3 ounces). Female northern long-eared bats produce a maximum of one pup per year; therefore, loss of one pup results in missing one year of recruitment for a female.

The individual, population-level, and species-level needs of the northern long-eared bat are summarized below in tables 1–3. For additional information, please see the SSA report (Service 2021, chapter 2).

TABLE 1—THE ECOLOGICAL REQUISITES FOR SURVIVAL AND REPRODUCTIVE SUCCESS OF NORTHERN-LONG-EARED BAT INDIVIDUALS

LIFE STAGE	SEASON			
	Spring	**Summer**	**Fall**	**Winter**
Pups (non-flying juveniles)		Roosting habitat with suitable conditions for lactating females and for pups to stay warm and protected from predators while adults are foraging.		
Juveniles		Other maternity colony members (colony dynamics, thermoregulation), and suitable roosting and foraging habitat near abundant food and water resources.	Suitable roosting and foraging habitat near abundant food and water resources.	Habitat with suitable conditions for prolonged bouts of torpor and shortened periods of arousal.
All adults	Suitable roosting and foraging habitat near abundant food and water resources, and habitat connectivity and open-air space for safe migration between winter and summer habitats.	Summer roosts and foraging habitat near abundant food and water resources.	Suitable roosting and foraging habitat near abundant food and water resources, cave and/or mine entrances or other similar locations (for example, culvert, tunnel) for conspecifics to swarm and mate, and habitat connectivity and open-air space for safe migration between winter and summer habitats.	Habitat with suitable conditions for prolonged bouts of torpor and shortened periods of arousal.
Reproductive females		Other maternity colony members (colony dynamics), a network of suitable roosts (i.e., multiple summer roosts in close proximity) near conspecifics, and foraging habitat near abundant food and water resources.		

TABLE 2—POPULATION-LEVEL REQUISITES FOR A HEALTHY NORTHERN LONG-EARED BAT POPULATION

Parameter	Requirements
Population growth rate, λ	At a minimum, λ must be ≥1 for a population to remain stable over time.
Population size, N	Sufficiently large N to allow for essential colony dynamics and to be adequately resilient to environmental fluctuations.
Winter roosting habitat	Safe and stable winter roosting sites with suitable microclimates.
Migration habitat	Safe space to migrate between spring/fall habitat and winter roost sites.
Spring and fall roosting, foraging, and commuting (i.e., traveling between habitat types) habitat	A matrix of habitat of sufficient quality and quantity to support bats as they exit hibernation (lowest body condition) or as they enter hibernation (need to put on body fat).
Summer roosting, foraging, and commuting habitat	A matrix of habitat of sufficient quality and quantity to support maternity colonies.

TABLE 3—SPECIES-LEVEL ECOLOGY: REQUISITES FOR LONG-TERM VIABILITY (ABILITY TO MAINTAIN SELF-SUSTAINING POPULATIONS OVER A BIOLOGICALLY MEANINGFUL TIMEFRAME)

3 Rs	Requisites for long-term viability	Description
Resiliency (populations able to withstand stochastic events)	Healthy populations across a diversity of environmental conditions	Self-sustaining populations are demographically, genetically, and physiologically robust, and have enough suitable habitat
Redundancy (number and distribution of populations to withstand catastrophic events)	Multiple and sufficient distribution of populations within areas of unique variation (representation units)	Sufficient number and distribution of populations to guard against population losses
Representation (genetic and ecological diversity to maintain adaptive potential)	Maintain adaptive diversity of the species	Populations maintained across a range of behavioral, physiological, ecological, and environmental diversity
	Maintain evolutionary processes	Maintain evolutionary drivers—gene flow, natural selection—to mimic historical patterns

Regulatory and Analytical Framework

Regulatory Framework

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species is an endangered species or a threatened species. The Act defines an "endangered species" as a species that is in danger of extinction throughout all or a significant portion of its range, and a "threatened species" as a species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. The Act requires that we determine whether any species is an endangered species or a threatened species because of any of the following factors:

(A) The present or threatened destruction, modification, or curtailment of its habitat or range;

(B) Overutilization for commercial, recreational, scientific, or educational purposes;

(C) Disease or predation;

(D) The inadequacy of existing regulatory mechanisms; or

(E) Other natural or manmade factors affecting its continued existence.

These factors represent broad categories of natural or human-caused actions or conditions that could have an effect on a species' continued existence. In evaluating these actions and conditions, we look for those that may have a negative effect on individuals of the species, as well as other actions or conditions that may ameliorate any negative effects or may have positive effects.

We use the term "threat" to refer in general to actions or conditions that are known to or are reasonably likely to negatively affect individuals of a species. The term "threat" includes actions or conditions that have a direct impact on individuals (direct impacts), as well as those that affect individuals through alteration of their habitat or required resources (stressors). The term “threat” may encompass—either together or separately—the source of the action or condition or the action or condition itself.

However, the mere identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an “endangered species” or a “threatened species.” In determining whether a species meets either definition, we must evaluate all identified threats by considering the expected response by the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species, such as any existing regulatory mechanisms or conservation efforts. The Secretary determines whether the species meets the definition of an “endangered species” or a “threatened species” only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

The Act does not define the term “foreseeable future,” which appears in the statutory definition of “threatened species.” Our implementing regulations at 50 CFR 424.11(d) set forth a framework for evaluating the foreseeable future on a case-by-case basis. The term “foreseeable future” extends only so far into the future as the Service can reasonably determine that both the future threats and the species’ responses to those threats are likely. In other words, the foreseeable future is the period of time in which we can make reliable predictions. “Reliable” does not mean “certain”; it means sufficient to provide a reasonable degree of confidence in the prediction. Thus, a prediction is reliable if it is reasonable to depend on it when making decisions.

It is not always possible or necessary to define foreseeable future as a particular number of years. Analysis of the foreseeable future uses the best scientific and commercial data available and should consider the timeframes applicable to the relevant threats and to the species' likely responses to those threats in view of its life-history characteristics. Data that are typically relevant to assessing the species' biological response include species-specific factors such as lifespan, reproductive rates or productivity, certain behaviors, and other demographic factors.

Analytical Framework

The SSA report documents the results of our comprehensive biological review of the best scientific and commercial data regarding the status of the northern long-eared bat, including an assessment of the potential threats to the species. The SSA report does not represent a decision by the Service on whether the species should be proposed for listing as an endangered or threatened species under the Act. However, it does provide the scientific basis that informs our regulatory decisions, which involve the further application of standards within the Act and its implementing regulations and policies. The following is a summary of the key results and conclusions from the SSA report; the full SSA report can be found at Docket No. FWS–R3–ES–2021–0140 on *https://www.regulations.gov*.

To assess the northern long-eared bat's viability, we used the three conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 306–310). Briefly, resiliency supports the ability of the species to withstand environmental and demographic stochasticity (for example, wet or dry or warm or cold years), redundancy supports the ability of the species to withstand catastrophic events (for example, droughts, large pollution events), and representation supports the ability of the species to adapt over time to long-term changes in the environment (for example, climate changes). In general, the more resilient and redundant a species is and the more representation it has, the more likely it is to sustain populations over time, even under changing environmental conditions. Using these principles, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the beneficial and risk factors influencing the species' viability.

The SSA process can be categorized into three sequential stages. During the first stage, we evaluated the individual species' life-history needs. The next stage involved an assessment of the historical and current condition of the species' demographics and habitat characteristics, including an explanation of how the species arrived at its current condition. The final stage of the SSA involved making predictions about the species' responses to positive and negative environmental and anthropogenic influences. Throughout all of these stages, we used the best available information to characterize viability as the ability of a species to sustain populations in the wild over time. We use this information to inform our regulatory decision.

Summary of Biological Status and Threats

In this discussion, we review the biological condition of the northern long-eared bat and its resources, and the threats that influence the species' current and future condition, in order to assess the species' overall viability and the risks to that viability. For a full description, see the SSA report (Service 2021, entire).

Although there are other stressors affecting the northern long-eared bat, the primary factor influencing its viability is white-nose syndrome (WNS), a disease of bats caused by a fungal pathogen. Some of the other factors that influence the northern long-eared bat's viability (though to a far lesser extent than the influence of WNS) include wind energy mortality, effects from climate change, and habitat loss. These stressors and their effects to the northern long-eared bat are summarized below:

- WNS has been the foremost stressor on the northern long-eared bat for more than a decade. The fungus that causes the disease, *Pseudogymnoascus destructans* (*Pd*), invades the skin of bats. Infection leads to increases in the frequency and duration of arousals during hibernation and eventual depletion of fat reserves needed to survive winter, and results in mortality. Since its discovery in New York in 2006, *Pd* has been confirmed (or presumed) in 37 States and 7 Canadian provinces. There is no known mitigation or treatment strategy to slow the spread of *Pd* or to treat WNS in bats. WNS has caused estimated northern long-eared bat population declines of 97–100 percent across 79 percent of the species' range.

- Wind energy-related mortality of the northern long-eared bat is a stressor at local and regional levels, where northern long-eared bat populations have been impacted by WNS. In 2020, northern long-eared bats were at risk from wind mortality in approximately 49 percent of their range, based on the areas where wind turbines were in place and operating (using known northern long-eared bat occurrences, average migration distance, and the spatial distribution of wind turbines) (Service 2021, p. iv). Most bat mortality at wind energy projects is caused by direct collisions with moving turbine blades.

- Climate change variables, such as changes in temperature and precipitation, may influence the northern long-eared bat's resource needs, such as suitable roosting habitat for all seasons, foraging habitat, and prey availability. Although a changing climate may provide some benefit to the northern long-eared bat, overall negative impacts are anticipated, especially at local levels.

- Habitat loss (including but not limited to forest conversion or hibernacula disturbance or destruction) may include loss of suitable roosting or foraging habitat, resulting in longer flights between suitable roosting and foraging habitats due to habitat fragmentation, fragmentation of maternity colony networks, and direct injury or mortality. Loss or modification of winter roosts (i.e., making hibernaculum no longer suitable) can result in impacts to individuals or at the population level. However, habitat loss alone is not considered to be a key stressor at the species level, and habitat does not appear to be limiting.

In evaluating current conditions of the northern long-eared bat, we used the best available data. Winter hibernacula counts provide the most consistent, long-term, reliable trend data and provide the most direct measure of WNS impacts. We also used summer data in evaluating population trends, although the availability and quality of summer data varies temporally and spatially.

Available evidence, including both winter and summer data, indicates northern long-eared bat abundance has and will continue to decline substantially under current demographic and stressor conditions, primarily driven by the effects of WNS. As part of our assessment of the current condition of northern long-eared bat's representation, we identified and delineated the variation across the northern long-eared bat's range into geographical representation units (RPUs) using the following proxies: variation in biological traits, genetic diversity, peripheral populations, habitat niche diversity, and steep environmental gradients.

Winter abundance (from known hibernacula) has declined rangewide (49 percent) and declined across all but one RPU (declines range from 0 to 90 percent). The number of extant winter colonies also declined rangewide (by 81 percent) and across all RPUs (40–88 percent). There has also been a noticeable shift towards smaller colony sizes, with a 96–100 percent decline in the number of large hibernacula (≥100 individuals) across the RPUs (figure 1.). We created projections (highest plausible and lowest plausible scenarios) for the species using its current condition and the current rates of mortality from WNS effects and wind energy. Rangewide abundance is projected to decline by 95 percent and the spatial extent to decline by 75 percent from historical conditions by 2030. Declines continue to be driven by the catastrophic effects of WNS.

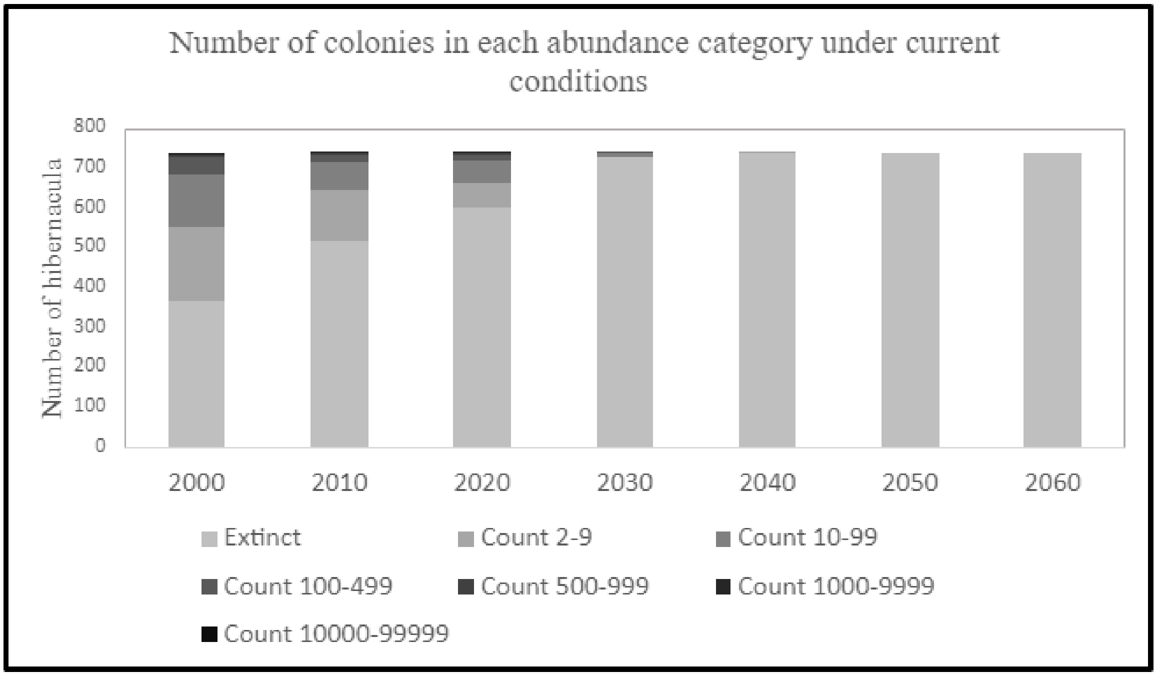

Figure 1. The number of hibernacula in each colony abundance category under current conditions.

Declining trends in abundance and extent of occurrence are also evident across much of the northern long-eared bat's summer range. Rangewide occupancy has declined by 80 percent from 2010–2019. Data collected from mobile acoustic transects found a 79 percent decline in rangewide relative abundance from 2009–2019, and summer mist-net captures declined by 43–77 percent (across RPUs) compared to pre-WNS capture rates.

As discussed above, multiple data types and analyses indicate downward trends in northern long-eared bat population abundance and distribution over the last 14 years, and the best available information indicates that this downward trend will continue. Northern long-eared bat abundance (winter and summer), number of occupied hibernacula, spatial extent, and summer habitat occupancy across the range and within all RPUs are decreasing. Since the occurrence of WNS, northern long-eared bat abundance has steeply declined, leaving populations with small numbers of individuals. At these low population sizes, colonies are vulnerable to extirpation from stochastic events and the deleterious effects of reduced population sizes such as limiting natural selection processes and decreased genetic diversity. Furthermore, small populations generally cannot rescue one another from such a depressed state because of the northern long-eared bat's low reproduction output (one pup per year) and its high philopatry (tending to return to a particular area). These inherent life-history traits limit the ability of populations to recover from low abundances. Consequently, effects of small population sizes exacerbate the effects of current and future declines due to continued exposure to WNS, mortality from wind turbines, and impacts associated with habitat loss and climate change.

Therefore, northern long-eared bat's resiliency is greatly compromised in its current condition. Because northern long-eared bat's abundance and spatial extent have so dramatically declined, it has also become more vulnerable to catastrophic events. In other words, its redundancy has also declined dramatically. The steep and continued declines in abundance have likely led to reductions in genetic diversity, and thereby reduced northern long-eared bat adaptive capacity, and a decline in the species' overall representation. Moreover, at its current low abundance, loss of genetic diversity will likely accelerate. Consequently, limited natural selection processes and decreased genetic diversity will further lessen the species' ability to adapt to novel changes and exacerbate declines due to continued exposure to WNS, mortality from wind turbines, and impacts associated with habitat loss and climate change. Thus, even without further WNS spread and additional wind energy development (northern long-eared bat's current condition), its viability is likely to continue to rapidly decline over the next 10 years.

Future Condition

As part of the SSA, we also developed two future condition scenarios to capture the range of uncertainties regarding future threats and the projected responses by the northern long-eared bat. Our scenarios included a plausible highest impact scenario and a plausible lowest impact scenario for each primary threat. Because we determined that the current condition of the northern long-eared bat is consistent with an endangered species (see Determination of Species Status, below), we are not presenting the results of the future scenarios in this proposed rule. Please refer to the SSA report (Service 2021) for the full analysis of future scenarios.

We note that, by using the SSA framework to guide our analysis of the scientific information documented in the SSA report, we have not only analyzed individual effects on the species, but we have also analyzed their potential cumulative effects. We incorporate the cumulative effects into our SSA analysis when we characterize the current and future condition of the species. To assess the current and future condition of the species, we undertake an iterative analysis that encompasses and incorporates the threats individually and then accumulates and evaluates the effects of all the factors that may be influencing the species, including threats and conservation efforts. Because the SSA framework considers not just the presence of the factors, but to what degree they collectively influence risk to the entire species, our assessment integrates the cumulative effects of the factors and replaces a standalone cumulative effects analysis.

Conservation Efforts and Regulatory Mechanisms

Below is a brief description of conservation measures and regulatory mechanisms currently in place. Please see the SSA report for a more detailed description (Service 2021, Appendix 4).

Multiple national and international efforts are underway in an attempt to reduce the impacts of WNS. Despite these efforts, there are no proven measures to reduce the severity of impacts of WNS. More than 100 State and Federal agencies, Tribes, organizations, and institutions are engaged in this collaborative work to combat WNS and conserve affected bats. Partners from all 37 States in the northern long-eared bat’s range, Canada, and Mexico are engaged in collaborations to conduct disease surveillance, population monitoring, and management actions in preparation for or response to WNS.

To reduce bat fatalities, some wind facilities “feather” turbine blades (i.e., pitch turbine blades parallel with the prevailing wind direction to slow rotation speeds) at low wind speeds at times when bats are more likely to be present. The wind speed at which the turbine blades begin to generate electricity is known as the “cut-in speed,” and this can be set at the manufacturer’s recommended speed or at a higher threshold, typically referred to as curtailment. The effectiveness of feathering below various cut-in speeds differs among sites and years (Arnett et al. 2013, entire; Berthinussen et al. 2021, pp. 94–106); nonetheless, most studies have shown all-bat (based on dead bats detected from all bat species) fatality reductions of greater than 50 percent associated with raising cut-in speeds by 1.0–3.0 meters per second (m/s) above the manufacturer’s cut-in speed (Arnett et al. 2013, entire; USFWS unpublished data). The effectiveness of curtailment at reducing fatality rates specifically for the northern long-eared bat has not been documented.

All States have active forestry programs with a variety of goals and objectives. Several States have established habitat protection buffers around known Indiana bat hibernacula that will also serve to benefit other bat species by maintaining sufficient quality and quantity of swarming habitat. Some States conduct some of their forest management activities in the winter within known listed bat home ranges as a measure that would protect maternity colonies and non-volant (non-flying) pups during summer months. Depending on the type and timing of activities, forest management can be beneficial to bat species (for example, maintaining or increasing suitable roosting and foraging habitat). Forest management that results in heterogeneous (including forest type, age, and structural characteristics) habitat may benefit tree-roosting bat species such as northern long-eared bat (Silvis et al. 2016, p. 37). Silvicultural practices can meet both male and female northern long-eared bats’ roosting requirements by maintaining large-diameter snags in early stages of decay, while allowing for regeneration of forests (Lacki and Schwierjohann 2001, p. 487).

Many State and Federal agencies, conservation organizations, and land trusts have installed bat-friendly gates to protect important hibernation sites. All known hibernacula within national grasslands and forestlands of the Rocky Mountain Region of the U.S. Forest Service (USFS) are closed during the winter hibernation period, primarily due to the threat of WNS, although this will reduce disturbance to bats in general inhabiting these hibernacula (USFS 2013, unpaginated). Because of concern over the importance of bat roosts, including hibernacula, the American Society of Mammalogists developed guidelines for protection of roosts, many of which have been adopted by government agencies and special interest groups (Sheffield *et al.* 1992, p. 707). Also, regulations, such as the Federal Cave Resources Protection Act (16 U.S.C. 4301 *et seq*.), protect caves on Federal lands by limiting access to some caves, thereby reducing disturbance. Finally, many Indiana bat hibernacula have been gated, and some have been permanently protected via acquisition or easement, which provides benefits to other bats that also use the sites, including the northern long-eared bat.

The northern long-eared bat is listed as endangered under Canada's Species at Risk Act (COSEWIC 2013, entire). In addition, the northern long-eared bat receives varying degrees of protection through State laws, which designate the species as endangered in 9 States (Arkansas, Connecticut, Delaware, Indiana, Maine, Massachusetts, Missouri, New Hampshire, and Vermont); as threatened in 10 States (Georgia, Illinois, Louisiana, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia, and Wisconsin); and as a species of special concern in 10 States (Alabama, Iowa, Michigan, Minnesota, Mississippi, Oklahoma, South Carolina, South Dakota, West Virginia, and Wyoming).

Determination of Northern Long-eared Bat Status

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of an endangered species or a threatened species. The Act defines an “endangered species” as a species in danger of extinction throughout all or a significant portion of its range, and a “threatened species” as a species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. The Act requires that we determine whether a species meets the definition of an endangered species or a threatened species because of any of the following factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence.

Status Throughout All of Its Range

WNS has been the foremost stressor on the northern long-eared bat for more than a decade and continues to be currently. The fungus that causes the disease, *Pd*, invades the skin of bats and leads to infection that increases the frequency and duration of arousals during hibernation that eventually deplete the fat reserves needed to survive winter and results in mortality. There is no known mitigation or treatment strategy to slow the spread of *Pd* or to treat WNS in bats. WNS has caused estimated northern long-eared bat population declines of 97–100 percent across 79 percent of the species’ range (Factor C). Winter abundance (from known hibernacula) has declined rangewide (49 percent) and declined across all but one RPU (declines range from 0 to 90 percent), and the number of extant winter colonies also declined rangewide (81 percent) and across all RPUs (40–88 percent). There has also been a noticeable shift towards smaller colony sizes, with a 96–100 percent decline in the number of large hibernacula (≥100 individuals). Rangewide summer occupancy has declined by 80 percent from 2010–2019. Summer data collected from mobile acoustic transects found a 79 percent decline in rangewide relative abundance from 2009–2019, and summer mist-net captures declined by 43–77 percent (across RPUs) compared to pre-WNS capture rates. We created projections for the species using its current condition and the current rates of mortality from WNS effects and wind energy. Rangewide abundance is projected to decline by 95 percent and the spatial extent is projected to decline by 75 percent from historical conditions by 2030.

As a result of these steep population declines, the northern long-eared bat's resiliency is greatly compromised in its current condition. Because the northern long-eared bat's abundance and spatial extent substantially declined, its redundancy has decreased such that northern long-eared bats are more vulnerable to catastrophic events. The northern long-eared bat's representation has also been reduced, as the steep and continued declines in abundance have likely led to reductions in genetic diversity, and thereby reduced the northern long-eared bat's adaptive capacity. Further, the projected widespread reduction in the distribution of occupied hibernacula under current conditions will lead to losses in the diversity of environments and climatic conditions occupied, which will impede natural selection and further limit the northern long-eared bat's ability to adapt to changing environmental conditions. Moreover, at its current low abundance, loss of genetic diversity via genetic drift will likely accelerate. Consequently, limiting natural selection process and decreasing genetic diversity will further lessen the northern long-eared bat's ability to adapt to novel changes (currently ongoing as well as future changes) and exacerbate declines due to continued exposure to WNS and other stressors. Thus, even without further *Pd* spread and additional pressure from other stressors, the northern long-eared bat's viability has declined substantially and is expected to continue to rapidly decline over the near term.

Current population trends and status indicate this species is currently in danger of extinction. The species continues to experience the catastrophic effects of WNS and the compounding effect of other stressors from which extinction is now a plausible outcome under the current conditions. Therefore, the species meets the Act's definition of an endangered species rather than of a threatened species. Thus, after assessing the best available information, we determine that the northern long-eared bat is in danger of extinction throughout all of its range.

Status Throughout a Significant Portion of Its Range

Under the Act and our implementing regulations, a species may warrant listing if it is in danger of extinction or likely to become so in the foreseeable future throughout all or a significant portion of its range. We have determined that the northern long-eared bat is in danger of extinction throughout all of its range and accordingly did not undertake an analysis of any significant portion of its range. Because the northern long-eared bat warrants listing as endangered throughout all of its range, our determination does not conflict with the decision in *Center for Biological Diversity* v. *Everson*, 2020 WL 437289 (D.D.C. Jan. 28, 2020), because that decision related to significant portion of the range analyses for species that warrant listing as threatened, not endangered, throughout all of their range.

Determination of Status

Our review of the best available scientific and commercial information indicates that the northern long-eared bat meets the Act's definition of an endangered species. Therefore, we propose to list the northern long-eared bat as an endangered species in accordance with sections 3(6) and 4(a)(1) of the Act.

Available Conservation Measures

Conservation measures provided to species listed as endangered or threatened species under the Act include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain practices. Recognition through listing results in public awareness, and conservation by Federal, State, Tribal, and local agencies, private organizations, and individuals. The Act encourages cooperation with the States and other countries and calls for recovery actions to be carried out for listed species. The protection required by Federal agencies and the prohibitions against certain activities are discussed, in part, below.

The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Section 4(f) of the Act calls for the Service to develop and implement recovery plans for the conservation of endangered and threatened species. The recovery planning process involves the identification of actions that are necessary to halt or reverse the species' decline by addressing the threats to its survival and recovery. The goal of this process is to restore listed species to a point where they are secure, self-sustaining, and functioning components of their ecosystems.

Recovery planning consists of preparing draft and final recovery plans, beginning with the development of a recovery outline, and making it available to the public within 30 days of a final listing determination. The recovery outline guides the immediate implementation of urgent recovery actions and describes the process to be used to develop a recovery plan. Revisions of the plan may be done to address continuing or new threats to the species, as new substantive information becomes available. The recovery plan also identifies recovery criteria for review of when a species may be ready for reclassification from endangered to threatened ("downlisting") or removal from protected status ("delisting"), and methods for monitoring recovery progress. Recovery plans also establish a framework for agencies to coordinate their recovery efforts and provide estimates of the cost of implementing recovery tasks. Recovery teams (composed of species experts, Federal and State agencies, nongovernmental organizations, and stakeholders) are often established to develop recovery plans. When completed, the recovery outline, draft recovery plan, and the final recovery plan will be available on our website (*https://www.fws.gov/species/northern-bat-myotis-septentrionalis*), or from our Minnesota Wisconsin Ecological Services Field Office (see **FOR FURTHER INFORMATION CONTACT**).

Implementation of recovery actions generally requires the participation of a broad range of partners, including other Federal agencies, States, Tribes, nongovernmental organizations, businesses, and private landowners. Examples of recovery actions include habitat restoration (for example, restoration of native vegetation), research, captive propagation and reintroduction, and outreach and education. The recovery of many listed species cannot be accomplished solely on Federal lands because their range may occur primarily or solely on non-Federal lands. To achieve recovery of these species requires cooperative conservation efforts on private, State, and Tribal lands.

For listed species, funding for recovery actions is available from a variety of sources, including Federal budgets, State programs, and cost-share grants for non-Federal landowners, the academic community, and nongovernmental organizations. In addition, pursuant to section 6 of the Act, the States of Alabama, Arkansas, Connecticut, Delaware, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and Wyoming will continue to be eligible for Federal funds to implement management actions that promote the protection or recovery of the northern long-eared bat. Information on our grant programs that are available to aid species recovery can be found at: *https://www.fws.gov/grants*.

Please let us know if you are interested in participating in recovery efforts for this species. Additionally, we invite you to submit any new information on this species whenever it becomes available and any information you may have for recovery planning purposes (see **FOR FURTHER INFORMATION CONTACT**).

Section 7(a) of the Act requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as an endangered or threatened species and with respect to its critical habitat, if any is designated. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR part 402. Section 7(a)(4) of the Act requires Federal agencies to confer with the Service on any action that is likely to jeopardize the continued existence of a species proposed for listing or result in destruction or adverse modification of proposed critical habitat. If a species is listed subsequently, section 7(a)(2) of the Act requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the species or destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into consultation with the Service.

Federal agency actions within the species' habitat that may require conference or consultation or both as described in the preceding paragraph include, but are not limited to, management and any other landscape-altering activities on Federal lands administered by the U.S. Fish and Wildlife Service, U.S. Forest Service, Bureau of Land Management, National Park Service, and other Federal agencies; issuance of section 404 Clean Water Act (33 U.S.C. 1251 *et seq*.) permits by the U.S. Army Corps of Engineers; and construction and maintenance of roads or highways by the Federal Highway Administration.

The Act and its implementing regulations set forth a series of general prohibitions and exceptions that apply to endangered wildlife. The prohibitions of section 9(a)(1) of the Act, codified at 50 CFR 17.21, make it illegal for any person subject to the jurisdiction of the United States to take (which includes harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect; or to attempt any of these) endangered wildlife within the United States or on the high seas. In addition, it is unlawful to import; export; deliver, receive, carry, transport, or ship in interstate or foreign commerce in the course of commercial activity; or sell or offer for sale in interstate or foreign commerce any species listed as an endangered species. It is also illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Certain exceptions apply to employees of the Service, the National Marine Fisheries Service, other Federal land management agencies, and State conservation agencies.

We may issue permits to carry out otherwise prohibited activities involving endangered wildlife under certain circumstances. Regulations governing permits are codified at 50 CFR 17.22. With regard to endangered wildlife, a permit may be issued for the following purposes: For scientific purposes, to enhance the propagation or survival of the species, and for incidental take in connection with otherwise lawful activities. The statute also contains certain exemptions from the prohibitions, which are found in sections 9 and 10 of the Act.

It is our policy, as published in the *Federal Register* on July 1, 1994 (59 FR 34272), to identify to the maximum extent practicable at the time a species is listed, those activities that would or would not constitute a violation of section 9 of the Act. The intent of this policy is to increase public awareness of the effect of a proposed listing on proposed and ongoing activities within the range of the species proposed for listing.

At this time, we are unable to identify specific activities that would not be considered to result in a violation of section 9 of the Act because the northern long-eared bat occurs in a variety of habitat conditions across its range and it is likely that site-specific conservation measures may be needed for activities that may directly or indirectly affect the species.

Based on the best available information, the following activities may potentially result in a violation of section 9 of the Act if they are not authorized in accordance with applicable law; this list is not comprehensive:

(1) Unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting of the species, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act.

(2) Incidental take of the species without authorization pursuant to section 7 or section 10(a)(1)(B) of the Act.

(3) Disturbance or destruction (or otherwise making a hibernaculum no longer suitable) of known hibernacula due to commercial or recreational activities during known periods of hibernation.

(4) Unauthorized destruction or modification of suitable forested habitat (including unauthorized grading, leveling, burning, herbicide spraying, or other destruction or modification of habitat) in ways that kills or injures individuals by significantly impairing the species' essential breeding, foraging, sheltering, commuting, or other essential life functions.

(5) Unauthorized removal or destruction of trees and other natural and manmade structures being used as roosts by the northern long-eared bat that results in take of the species.

(6) Unauthorized release of biological control agents that attack any life stage of this taxon.

(7) Unauthorized removal or exclusion from buildings or artificial structures being used as roost sites by the species, resulting in take of the species.

(8) Unauthorized building and operation of wind energy facilities within areas used by the species, which results in take of the species.

(9) Unauthorized discharge of chemicals, fill, or other materials into sinkholes, which may lead to contamination of known northern long-eared bat hibernacula.

Questions regarding whether specific activities would constitute a violation of section 9 of the Act should be directed to the Minnesota Wisconsin Ecological Services Field Office (see **FOR FURTHER INFORMATION CONTACT**).

Effects of This Rule

If this rule is adopted as proposed, it would reclassify the northern long-eared bat from a threatened species to an endangered species on the List of Endangered and Threatened Wildlife. It would also remove the species-specific section 4(d) rule for the northern long-eared bat, because 4(d) rules apply only to species listed as threatened species under the Act. The Act's full suite of prohibitions and exceptions to those prohibitions for endangered species (see sections 9 and 10 of the Act) would then apply to the northern long-eared bat.

Public Hearings

We have scheduled a public informational meeting with a public hearing on this proposed rule for the northern long-eared bat. We will hold the public informational meeting and public hearing on the date and time listed above under *Public informational meeting and public hearing* in **DATES**. We are holding the public informational meeting and public hearing via the Zoom online video platform and via teleconference so that participants can attend remotely. For security purposes, registration is required. To listen and view the meeting and hearing via Zoom, listen to the meeting and hearing by telephone, or provide oral public comments at the public hearing by Zoom or telephone, you must register. For information on how to register, or if you encounter problems joining Zoom the day of the meeting, visit *https://www.fws.gov/species/northern-bat-myotis-septentrionalis*. Registrants will receive the Zoom link and the telephone number for the public informational meeting and public hearing. If applicable, interested members of the public not familiar with the Zoom platform should view the Zoom video tutorials *(https://support.zoom.us/hc/en-us/articles/206618765-Zoom-video-tutorials*) prior to the public informational meeting and public hearing.

The public hearing will provide interested parties an opportunity to present verbal testimony (formal, oral comments) regarding this proposed rule. While the public informational meeting will be an opportunity for dialogue with the Service, the public hearing is not: It is a forum for accepting formal verbal testimony. In the event there is a large attendance, the time allotted for oral statements may be limited. Therefore, anyone wishing to make an oral statement at the public hearing for the record is encouraged to provide a prepared written copy of their statement to us through the Federal eRulemaking Portal, or U.S. mail (see **ADDRESSES**, above). There are no limits on the length of written comments submitted to us. Anyone wishing to make an oral statement at the public hearing must register before the hearing *https://www.fws.gov/species/northern-bat-myotis-septentrionalis.* The use of a virtual public hearing is consistent with our regulations at 50 CFR 424.16(c)(3).

Required Determinations

Clarity of the Rule

We are required by Executive Orders 12866 and 12988 and by the Presidential Memorandum of June 1, 1998, to write all rules in plain language. This means that each rule we publish must:

(1) Be logically organized;

(2) Use the active voice to address readers directly;

(3) Use clear language rather than jargon;

(4) Be divided into short sections and sentences; and

(5) Use lists and tables wherever possible.

If you feel that we have not met these requirements, send us comments by one of the methods listed in **ADDRESSES**. To better help us revise the rule, your comments should be as specific as possible. For example, you should tell us the numbers of the sections or paragraphs that are unclearly written, which sections or sentences are too long, the sections where you feel lists or tables would be useful, etc.

National Environmental Policy Act (42 U.S.C. 4321 et seq.)

We have determined that environmental assessments and environmental impact statements, as defined under the authority of the National Environmental Policy Act (NEPA; 42 U.S.C. 4321 et seq.), need not be prepared in connection with listing a species as an endangered or threatened species under the Endangered Species Act. We published a notice outlining our reasons for this determination in the *Federal Register* on October 25, 1983 (48 FR 49244). This position was upheld by the U.S. Court of Appeals for the Ninth Circuit (*Douglas County* v. *Babbitt*, 48 F.3d 1495 (9th Cir. 1995), cert. denied 516 U.S. 1042 (1996)).

Government-to-Government Relationship with Tribes

In accordance with the President's memorandum of April 29, 1994 (Government-to-Government Relations with Native American Tribal Governments; 59 FR 22951), Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments), and the Department of the Interior's manual at 512 DM 2, we readily acknowledge our responsibility to communicate meaningfully with recognized Federal Tribes on a government-to-government basis. In accordance with Secretarial Order 3206 of June 5, 1997 (American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act), we readily acknowledge our responsibilities to work directly with Tribes in developing programs for healthy ecosystems, to acknowledge that Tribal lands are not subject to the same controls as Federal public lands, to remain sensitive to Indian culture, and to make information available to Tribes. We solicited information, provided updates, and invited participation in the SSA process in emails sent to Tribes, nationally, in April 2020 and November 2020. We will continue to work with Tribal entities during the development of the northern long-eared bat final listing determination.

References Cited

A complete list of references cited in this rulemaking is available on the internet at *https://www.regulations.gov* and upon request from the Minnesota Wisconsin Ecological Services Field Office (see **FOR FURTHER INFORMATION CONTACT**).

Authors

The primary authors of this proposed rule are staff members of the Fish and Wildlife Service's Species Assessment Team and the Minnesota Wisconsin Ecological Services Field Office.

List of Subjects in 50 CFR Part 17

Endangered and threatened species, Exports, Imports, Reporting and recordkeeping requirements, Transportation.

Proposed Regulation Promulgation

Accordingly, we propose to amend part 17, subchapter B of chapter I, title 50 of the Code of Federal Regulations, as set forth below:

PART 17—ENDANGERED AND THREATENED WILDLIFE AND PLANTS

1. The authority citation for part 17 continues to read as follows:

AUTHORITY: 16 U.S.C. 1361-1407; 1531-1544; and 4201-4245, unless otherwise noted.

2. Amend § 17.11, in paragraph (h), by revising the entry for "Bat, northern long-eared" under MAMMALS in the List of Endangered and Threatened Wildlife to read as follows:

§ 17.11 Endangered and threatened wildlife.

* * * * *

(h) * * *

Common name	**Scientific name**	**Where listed**	**Status**	**Listing citations and applicable rules**
MAMMALS				
* * * * * * *				
Bat, northern long-eared	*Myotis septentrionalis*	Wherever found	E	80 FR 17973, 4/2/2015; [*Federal Register* citation when published as a final rule].
* * * * * * *				

§ 17.40 [Amended]

3. Amend §17.40 by removing and reserving paragraph (o).

Signing Authority

The Director, U.S. Fish and Wildlife Service, approved this document and authorized the undersigned to sign and submit the document to the Office of the Federal Register for publication electronically as an official document of the U.S. Fish and Wildlife Service. Martha Williams, Director, approved this document on March 18, 2022, for publication.

Madonna Baucum,
Regulations and Policy Chief,
Division of Policy, Risk Management, and Analytics of the Joint Administrative Operations,
U.S. Fish and Wildlife Service.

[FR Doc. 2022-06168 Filed: 3/22/2022 8:45 am; Publication Date: 3/23/2022]

Attachment 19

Small patch old-growth analysis

Table xx

Project	Ranger District	Reference	Acres Designated	Stands Omitted	Acres Omitted
Harmon Den	Appalachian	EA p. 5 & project maps	608	All	608
Shinwhite	Appalachian	EA p. 5 & project maps	124	Comp 68	54
Shope Creek	Appalachian	Stands 23-4, 23-5, 24-5, 24-9 FONSI p.1	123	All	123
Mulberry	Grandfather	EA p. 3	224		224
Baldwin Gap	Pisgah	1-13, 1-14 EA p. 7	88	1-13, 1-14	88
Brushy Ridge	Pisgah	EA p. 7	231		231
Upper Santeetlah	Cheoah	44-1, 44-4, 45-2, 45-5, 46-13, 47-9, 47-18, 48-7, 49-8, 49-11, 49-12, 50-4, 51-6, 52-3, 52-4, 53-7, 54-22, 54-23 FONSI p.3 and project maps	976	44-1 (13 acres), 45-2 & 45-5 (83 acres), 46-13 (53 acres), 47-9 & 47-18 (67 acres), 49-8 & 49-11& 49-12 (94 acres), 51-6 (70 acres), 52-3 & 52-4 (50 acres), 53-7 (68 acres)	498
Fatback	Nantahala	EA p. 74	425	102-13 (103 acres), 110-12 &23 (102 acres), 111-5 (57 acres), 121-2&3	391

Project	Ranger District	Reference	Acres Designated	Stands Omitted	Acres Omitted
				(101), 124-26&28 (28 acres),	
Haystack	Nantahala	EA p. 83	454 acres	106-18 & 26 (61 acres), 107-2 (67 acres), 108-11 (50 acres), 108-11 (50 acres), 109-3 (11 acres), 110-3,8,&11 (50 acres), 111-13&2 (53 acres),	343 acres
Thunderstruck	Tusquittee	Comp 105 portions of stands 3, 12, & 27 (99 acres), Comp 122 stand 1 (106 acres) EA p. 8	221	All	221
Total documented omitted acres					**2,390 acres**

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
Harmon Den	Appalachian	See Harmon Den 2 EA, Alt C	608	All	608
Shinwhite	Appalachian	Shinwhite EA Comp 65 & 68	124	Comp 68	54
Shope Creek	Appalachian	23-4, 23-5, 24-5, 24-9	123	All	123

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
Stateline	Appalachian	Need EA			All
Gentry Branch	Appalachian	Need EA			
Hurricane Ridge	Appalachian	Need EA			
Slim Ridge	Appalachian	Need EA			
Bluff Mountain	Appalachian	Need EA			
Skiffley Creek	Appalachian	Need EA			
Locust Creek	Appalachian	Need EA			
Mulberry	Grandfather	Stands not specific in EA	224		224
Baldwin Gap	Pisgah	1-13, 1-14	88	1-13, 1-14	88
Brushy Ridge	Pisgah	Stands not disclosed in EA or FONSI	231		231
Upper Santeetlah	Cheoah	44-1, 44-4, 45-2, 45-5, 46-13, 47-9, 47-18, 48-7, 49-8, 49-11, 49-12, 50-4, 51-6, 52-3, 52-4, 53-7, 54-22, 54-23	976	44-1 (13 acres), 45-2 & 45-5 (83 acres), 46-13 (53 acres), 47-9 & 47-18 (67 acres), 49-8 & 49-11& 49-12 (94 acres), 51-6 (70 acres), 52-3 & 52-4 (50	498

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
				acres), 53-7 (68 acres)	
Franks Creek	Cheoah	"Small patch old growth units total 1,105 acres for the compartments in the project area" EA p. 83	1,105	It is not clear what project designated the acreage alluded to in the Frank's Creek Project.	1,105
Fontana	Cheoah	"Small patch old growth units are in the process of being designated." EA p. 98	?	No record of designations in the project record	
Hazanat	Cheoah	Need EA			
East Buffalo	Cheoah	Need EA			
West Buffalo	Cheoah	Need EA			
Poison Cove	Cheoah	Need EA			
Buckwheat	Nantahala	"Small patch old growth patches total 1,105 acres for the compartments in the project area." EA p. 55	1,105	It is unclear what project would have designated this acreage. It is also suspicious that this is the same number referenced in the Fontana Project	1,105
Canepole	Nantahala	No OG designated but the compartments lack			

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
		designation			
Copeland	Nantahala	No OG designated in the project but many compartments lack OG			
Dylan	Nantahala	"For the compartments in the project, small old growth patches were selected in previous years, with the exceptions of one area each in Compartments 125 and 126. These have been selected this year, and all areas are displayed on the alternative maps in Appendix A" EA p. 69	?	Missing designations in Compartments 125 & 126	?
Fatback	Nantahala	The small patches include the following: 1) Compartment 102-stand 13, totaling 103 acres; 2) Compartment 110-stands 12 and 23, totaling 102 acres; 3) Compartment 111 – stand 5, totaling 57 acres; 4) Compartment 121– stands 2 and 3, totaling 101 acres; and 5) Compartment 124 – stands 26, 27, and	425	102-13 (103 acres), 110-12 &23 (102 acres), 111-5 (57 acres), 121-2&3 (101), 124-26&28 (28 acres),	391

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
		28, totaling 62 acres. The total small old growth patches for the area total 425 acres. EA p. 74			
Haystack	Nantahala	"For the compartments in the project, small old growth patches have been selected. The selected old growth totals 454 acres. The stands are as follows: 1) Cmpt. 106 – Stand 18 (31 acres) and Stand 26 (30 acres); 2) Cmpt. 107 – Stand 1 (44 acres) and Stand 2 (67 acres); 3) Cmpt. 108 – half of Stand 11 (50 acres); 4) Cmpt. 109 – Stand 3 (11 acres) and Stand 4 (48 acres); 5) Cmpt. 110 – Stand 3 (13 acres), Stand 8 (18 acres), and Stand 11 (19 acres); 6) Cmpt. 111 – Stand 13 (40 acres) and part of Stand 2 (13 acres); and 7) Cmpt. 112 - Stand 27 (70 acres). EA p. 83 (compartments 111 & 112 were not part of the Haystack Project. It appears this was copy and	454 acres	106-18 & 26 (61 acres), 107-2 (67 acres), 108-11 (50 acres), 108-11 (50 acres), 109-3 (11 acres), 110-3,8,&11 (50 acres), 111-13&2 (53 acres),	343 acres

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
		pasted from the Horse Bridge Project. Since the compartment numbers largely match, I think we should hold them to the text.)			
Horse Bridge Project	Nantahala	"For the compartments in the project, small old growth patches have been selected. The selected old growth totals 454 acres. The stands are as follows: 1) Cmpt. 106 – Stand 18 (31 acres) and Stand 26 (30 acres); 2) Cmpt. 107 – Stand 1 (44 acres) and Stand 2 (67 acres); 3) Cmpt. 108 – half of Stand 11 (50 acres); 4) Cmpt. 109 – Stand 3 (11 acres) and Stand 4 (48 acres); 5) Cmpt. 110 – Stand 3 (13 acres), Stand 8 (18 acres), and Stand 11 (19 acres); 6) Cmpt. 111 – Stand 13 (40 acres) and part of Stand 2 (13 acres); and 7) Cmpt. 112 - Stand 27 (70 acres). EA p. 65-66	454 acres	All are included	
Need					

Project	Ranger District	Stands Designated	Acres Designated	Stands Omitted	Acres Omitted
Whitebull EA					
Thunderstruck	Tusquittee	Comp 105 portions of stands 3, 12, & 27 (99 acres), Comp 122 stand 1 (106 acres)	221	All	221
Need Eagle Fork EA					
Need Buckhorn Gap EA					
Total documented omitted acres					2,390 acres with reference to 2,000+more acres in EA Documents

Attachment 21

Using Soil Quality Indicators for Monitoring Sustainable Forest Management

Using Soil Quality Indicators for Monitoring Sustainable Forest Management

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Abstract—Most private and public forest land owners and managers are compelled to manage their forests sustainably, which means management that is economically viable, environmentally sound, and socially acceptable. To meet this mandate, the USDA Forest Service protects the productivity of our nation's forest soils by monitoring and evaluating management activities to ensure they are both scientifically wise and socially responsive. The purpose of this paper is to review soil quality indicators and models for their possible use in soil management and evaluation programs. The Forest Service has taken a progressive stance on adapting their long-used soil quality monitoring program to take advantage of new science and technology. How forest soils function in terms of their stability, hydrology, and nutrient cycling is better understood, and indicators of these functions have been identified and tested for cause and effect relationships with tree growth and ecosystem health. Soil quality models are computer-based evaluation tools that quantify soil change and potential change in forest productivity due to management inputs or unintended detrimental disturbances. Soil quality models, when properly conceptualized, developed, and implemented, can provide a legally defensible monitoring and evaluation program based on firm scientific principles that produce unequivocal, credible results at minimum cost.

Introduction

Most private and public forest land owners are compelled to manage their forests sustainably. Sustainable forest management (SFM) is a 21st century management approach that has been branded by the forestry community in the United States and other parts of the world as a concept that provides the basis for site-specific management practices and guidelines. Sustainable forestry is economically viable, environmentally sound, and socially acceptable (Sample and others 2006).

Based on these SFM principles, groups of countries sharing similar forest resources developed criteria and indicators (C&Is) that measure and monitor sustainability (Montreal Process 1995). The C&Is serve as policy and management tools; they are neither management standards nor regulations. They provide a framework for determining the status of ecological, economic, and social conditions of forests, landowners and communities, and they provide the basis for SFM programs on private and public land (Roundtable on Sustainable Forests 2008). For example, Criterion 4, conservation and maintenance of soil and water resources, has two indicators pertaining to soil resources: (1) proportion of forest management activities that meet best management practices or other relevant legislation to protect soil resources; and (2) area and percent of forest land with significant soil degradation.

It remains the task of landowners or their representatives to develop and apply appropriate best management practices as called for by indicator #1, and to monitor the level of "significant soil degradation" referred to in indicator #2. Many private landowners have their forest operations certified by third-party entities against a set of standards (Rametsteiner and Simula 2002). Examples of certification programs include the Sustainable Forestry Initiative (SFI 2004), Forest Stewardship Council (FSC 1996), and the Canadian Standards Association (CSA 2003).

The U.S. National Forest System applies the Montreal Process C&Is through ecosystem management policies guided by federal law (the Multiple Use and Sustained Yield Act of 1960, The National Environmental Policy Act of 1969, the Forest and Rangeland Renewable Resources Planning Act of 1974, and the National Forest Management Act of 1976 [NFMA]). The NFMA requires that national forests be managed in a way that protects and maintains soil productivity (USDA Forest Service 1983). Section 2550.5 of the Forest Service Manual under soil management program (FSM 2009) defines soil productivity as "…the inherent capacity of the soil resource to support appropriate site-specific biological resource management objectives, which includes the growth of specified plants, plant communities, or a sequence of plant communities to support multiple land uses." The objective of the soil management program is to "maintain or improve soil quality on National Forest System lands to sustain ecological processes and function so that desired ecosystem services are provided in perpetuity." Soil quality management (FSM section 2551) is used to accomplish this objective by (1) using *adaptive management* (FSM 1905) to design and implement land management activities in a manner that achieves desired soil conditions to ensure that soil and water conservation practices are implemented and effective; (2) assessing the *current condition* of soil resources; and (3) *monitoring resource management activities and soil conditions* to ensure that soil and water conservation practices are implemented and effective (italics added for emphasis). Regional foresters, forest supervisors, district rangers, and soil scientists within each of the 10 Forest Service regions all play a role in achieving this objective. Soil quality monitoring programs are standardized in objectives and principles, but are region-specific to account for varying soils and ecosystems. The environmental and technical soundness of the soil quality monitoring program is important because it must withstand both scientific scrutiny and legal challenges. The Air, Water, and Soil Division and the research wing of the Forest Service periodically review the soil quality monitoring protocol to ensure that the standards and procedures are scientifically and technically up to date, and to ensure that the monitoring process is systematically achieved.

To help that review process, this paper provides an overview of soil quality principles and monitoring approaches that can be incorporated in an adaptive management process for achieving sustainable forest management.

Some Background

Adaptive Management

Various forest land management agencies and industries have developed processes for achieving SFM using logic models, reliable processes, and adaptive management. Several models are shown in figure 1. Each is conceptualized a little differently, but all contain the same basic elements: (1) an explicit or implied definition of SFM; (2) a knowledge database from which to develop management guidelines; (3) the guidelines or regulations from which best management practices are prescribed; (4) a process for monitoring compliance, effectiveness, and long-term efficacy; and (5) a research program that creates new knowledge for adaptive management.

As an example, we adapted and expanded the Heninger and others (1998) model with an SFM goal of maintaining forest and soil productivity after stand replacement harvesting (fig. 2), one of the key provisions of the "environmentally sound" component of SFM. The first step in the process after establishing or assuming a cause-and-effect relationship between harvesting disturbance and soil quality is to use existing data and knowledge (everything we know) from a "strategic database" to develop management "guidelines" that would prevent detrimental effects. All involved in applying the guidelines are trained. The guidelines, as applied in the forest, are the "best management practices" (BMPs), which are written policy guidelines that describe the manner in which specific forest operations or management activities will be conducted. They are

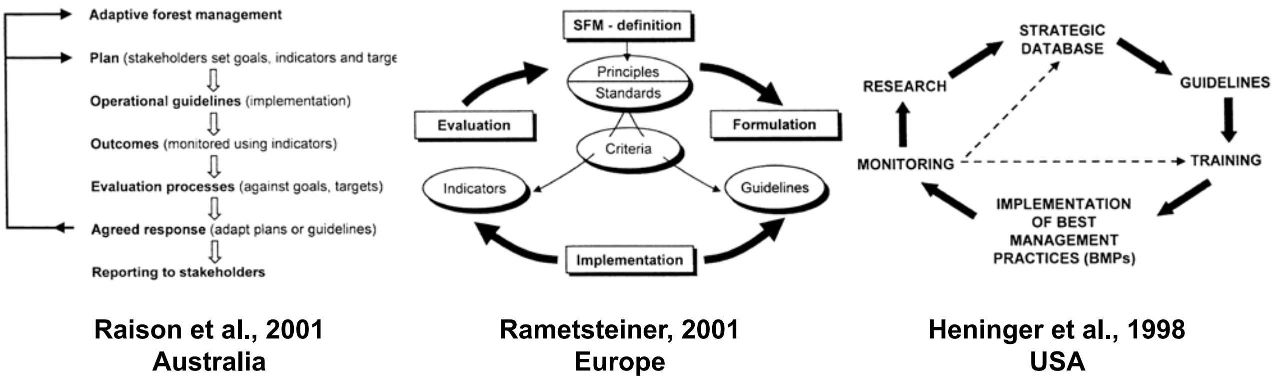

Figure 1. Examples of adaptive management models used for achieving sustainable forest management.

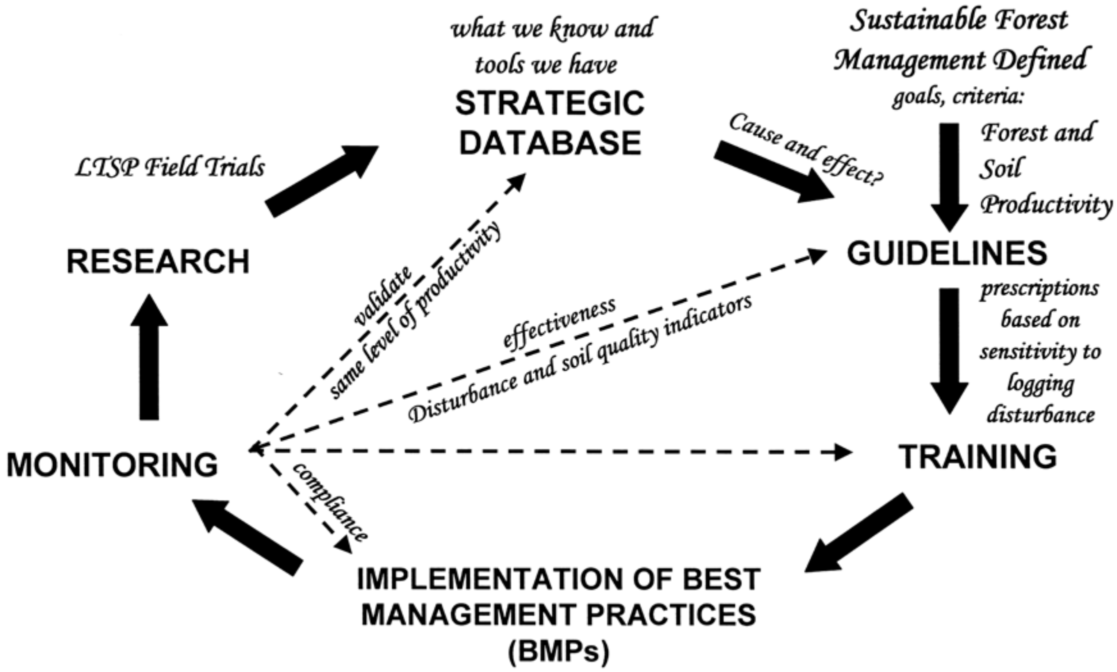

Figure 2. Components of an adaptive management model.

based on accomplishing the management objective in a cost-effective manner while maintaining or improving soil and forest productivity, and are subject to change as science and practice show ways for improvement.

Monitoring BMPs Used for Sustainable Forest Management

The next step is to determine if the BMPs are working as intended. Forest practices should be monitored for BMP compliance, a short-term indication of effectiveness of the BMPs, and long-term validation of SFM (Avers 1990) as defined by policy (*e.g.*, same growth potential and forest composition). Compliance monitoring simply ensures implementation of the BMPs. Effectiveness monitoring uses visual and measured soil disturbance indicators (DIs) and measured soil quality indicators (SQIs) to make a judgment of the efficacy of the BMPs, and whether they are likely to maintain soil and hydrologic function based on our cumulative research and knowledge. Because maintaining forest productivity and other services through time is the sustainability goal, long-term monitoring to determine if the forest is functioning the way it did before disturbance is validation that the BMPs are working as intended. When DIs and SQIs are properly chosen and calibrated, judgments on effectiveness of the BMPs can be made within weeks or months and guidelines can be modified as needed to improve forest practices. Because forests are long-lived, it may take years or decades to finally validate SFM. If monitoring shows that we need better guidelines, BMPs, or SQIs, targeted research should be conducted to expand our knowledge in the strategic database to further adapt our management to meet SFM goals. This adaptive management model, or some variant, can be applied to all managed forests, regardless of ownership, to achieve SFM required by law or compelled by forest certification processes.

For the purpose of this paper, we will assume that a primary SFM goal is maintaining soil and hydrologic function (Montreal Process Criterion #4) so that forest productivity (rate of biomass production per unit time and area) is not impaired. To accomplish this goal, BMPs are used by most public and private forest land owners, and BMP compliance (i.e., were the prescribed practices implemented?) is easily monitored. However, monitoring and demonstrating BMP effectiveness is challenging because forest managers must establish with certainty in a short period (*e.g.*, within 1 yr after completion of the operation) that forest operations in an activity area have not impaired soil and hydrologic function. The assumption is that pre- and post-disturbance soil and hydrologic function can be determined and compared. If they are the same, the BMPs were effective, and post-operation forest productivity and other forest services should be the same. This is the basis of the SFI and FSC standards and the USDA Forest Service soil management program (FSM 2009). However, the relationship between the measures of soil and hydrologic function and forest productivity must eventually be validated with long-term trials so that the standards and BMPs can be modified if needed (adaptive management process) (fig. 2).

The assumption that soil productivity, and by extension forest productivity, can be monitored, measured, and judged based on its combined attributes (properties and processes) is important because it provides a tool for land managers to meet forest sustainability standards established by law or policy (*e.g.*, U.S. National Environmental Policy Act of 1969). Because trees are long-lived, management impacts on productivity—positive or negative—may take decades to discern. Therefore, changes in soil and hydrologic properties and processes that can be measured immediately after a disturbance can serve as surrogates or proxies for change in soil and forest productivity as long as they are based on science and legally defensible. The change in soil properties and processes that results in an improved or degraded soil condition is a measure of soil quality.

Soil Quality Concepts and Principles

Soil Productivity Versus Soil Quality

Soil productivity is usually defined as a soil's ability to produce biomass or some harvestable crop. If not modified, soil has a natural or inherent productive potential based on its genesis and setting in the landscape. Some soils are naturally more productive than others, but not necessarily more valuable in terms of the role they play in their natural setting. For example, an Aridisol supporting a pinion-juniper forest in New Mexico is less productive than an Andisol supporting a mixed conifer forest in California, but each soil is providing ecosystem services commensurate with its development and setting. Within a given forest ecosystem, some soils are naturally more productive than others. This difference in soil productivity is reflected in a measure of forest site index or volume production after a given amount of time. Soil quality has been defined as its ability to provide services important to people. It is useful as a measure of the extent to which a managed soil is improved or degraded from its natural state or some other selected reference condition. Soil is complex; it has many physical, chemical, and biological properties that define its natural state and determine its productivity. Disturbances or management inputs usually change multiple properties at once. To evaluate soil change or soil quality, all or most of the important properties that were affected by the disturbance must be measured.

Agriculture scientists define soil quality as its ability to function (Larson and Pierce 1994) in a way that sustains biological productivity, environmental quality, and plant, animal, and human health and habitation (Doran and Parkin 1994; SSSA 1995). It is not a new concept. It was used by Storie (1933) 75 years ago to rate agricultural value of California soils. More recently, Warkentin and Fletcher (1977) recommended its use for monitoring the effects of intensive agriculture on soils. Karlen, and others (2003) reviewed its development and use in agriculture, and Burger and Kelting (1999) showed how one might use soil quality models to assess the impacts of intensive forest management.

Soil quality is analogous to the concepts of air and water quality where judgments are made concerning their fitness to breathe and drink based on selected, measurable standards. However, extending the air and water quality concepts to soil is less intuitive and more complex because we do not ingest soil directly. Its "fitness" is judged based on habitation and growth of plants and animals that are in turn ingested by humans; therefore, it is once removed from our personal experience. Soil also has multiple functions beyond food production: carbon sequestration, waste processing, and water regulation, among others. Furthermore, soil quality can change at different rates. Change can be slow and cumulative over time, and it can change in both negative and positive directions due to management. Finally, there is no "pure" (as in pure air or pure water) soil baseline against which to make judgments; there are many different soil types in nature each of which has its own natural condition. Nonetheless, the analogy with air and water holds in the sense that soil quality can be used to make judgments about the impacts of management, both negative and positive, against predetermined conditions or standards.

Soil Services, Functions, and Indicators

In order to use soil quality as a uniformly applied monitoring tool, there must be some agreement on its definition and use as a concept and monitoring tool. Similar to the concept of sustainable forestry, it is a work in progress. As a starting point, it is helpful to conceptualize soil in terms of "what it does for us" (services), "how it does it" (functions), "its character or attributes" (properties and processes), and "how we monitor and measure its performance or change in the level of services provided" (indicators).

Forest productivity, carbon sequestration, and a regulated hydrologic cycle are examples of soil services, sometimes called management goals (Andrews and others 2004) (table 1). Some soil services are more important than others in a given forest ecosystem. Therefore, forest managers should judge soil quality in terms of how management affects the most important services that soils provide. Soil services may not be completely complementary with respect to soil quality; one soil service may, in fact, reduce soil quality for another service. For example, longleaf pine ecosystems are managed primarily for biodiversity, not productivity. Longleaf pine as a species can be used effectively in production-based silvicultural systems, but generally speaking the interest in longleaf pine as opposed to other southern pines is the biodiversity value the entire ecosystem provides. However, the longleaf pine ecosystem thrives on disturbance, and in fact, the ecosystem loses much of its biodiversity value without disturbance. These disturbances clearly have the potential to alter soil quality, but the alterations may be positive or negative depending on the soil service. If the service managed for is biodiversity, repeated burning or other disturbances required for the main soil service increase the potential risk for surface erosion (reduction of soil quality for water quality protection), and nutrient loss (reduction of soil quality for soil productivity), but increase soil quality for a multitude of herbaceous plants that require not only the open conditions that burning provides, but also the specific soil conditions that allow them to compete with more nutrient-demanding plants. In other words, the best soils for the highest biodiversity in the longleaf pine ecosystem may not be the best soils for tree growth, and they may not be as capable of protecting water quality or sequestering carbon.

Using forest productivity as an example of a desired service, the soil functions to provide this service in several ways: (1) it remains stable and intact as a medium for root growth and habitat for soil animals; (2) it accepts, holds, and supplies water; (3) it

Table 1—Examples of soil services, functions, properties, processes, and indicators useful for monitoring sustainable forest management.

Soil services	Soil function	Soil properties and processes	Soil indicators	
			Disturbance	Soil quality
	Soil stability: Intact medium to promote root growth and provide habitat for soil animals	Horizonation Depth Strength Water content	Mass movement Erosion Ground cover	Soil horizon depth Strength Soil loss (t/ac) Aggregate uniformity SOM
Forest productivity	**Soil hydrology:** (accept, hold, and supply water, and drain properly for optimum gas exchange)	Texture Structure Porosity Infiltration Conductivity Water storage Gas exchange	Soil compaction Rutting Puddling Impeded drainage Surface runoff	θ vol. between 1/3 bar and 15 bar Soil structure Soil consistence Macroporosity Redox potential O_2 level
Regulated hydrologic cycle Regulated carbon balance Waste bioremediation	**Nutrient cycling:** (sequester, hold, and cycle organic matter and nutrients and promote biological activity)	SOM content Nutrient content pH CEC Decomposition Mineralization N fixation Acidification Leaching	CWD amount and distribution Litter displacement Severe burn Organic matter loss Acid deposition Accelerated nutrient leaching	C content Active organic matter Effective CEC Extractable nutrients N mineralization Microbial biomass Biopores Fecal deposits Soil respiration

promotes optimum gas exchange; (4) it sequesters, holds, and cycles organic matter and nutrients; and (5) it promotes biological activity (Doran and Parkin 1994; Burger and Kelting 1999; Andrews and others 2004). In the context of forest soils and forestry operations, these functions might be consolidated to soil stability, soil hydrology, and nutrient cycling (table 1). If a soil is protected from erosion, mass wasting, and displacement, it is stable and can provide a medium for plant growth. If it is protected from compaction, rutting, and puddling, it can function hydrologically, that is, water can infiltrate the soil, be stored, and be released for uptake by plants, and the soil will have the right proportion of macro- and micropore space so that it can drain properly. In forest soils, nutrient supply and biological activity are intimately tied to organic matter and nutrient cycling processes, including rates of input, decomposition and mineralization, storage, and release or uptake. Protection of these processes from soil surface disturbances, displacement of soil organic matter layers, and severe burns should maintain function in a given soil of a certain ecosystem. Of course, soil function is ecosystem-specific and must be assessed in the context of desired ecological condition. For example, soils in tupelo-cypress, longleaf pine, pinion-juniper, and black spruce ecosystems have the same functional elements, but each ecosystem will have different levels of soil properties and processes considered "normal."

Examples of the soil properties and processes, sometimes called soil attributes (Nortcliff 2002), associated with the first function (soil stability) are horizonation, strength, depth, and water content (table 1). Some soil properties and processes cannot be measured directly or efficiently; therefore, DIs, SQIs, measurable surrogates, or proxies of soil function must be used. Indicators may be a soil condition, property, or process such as soil compaction, soil strength, or water infiltration, or a combination of several soil properties such as soil tilth (soil tilth combines a measure of bulk density, strength, aggregate uniformity, soil organic matter, and plasticity index [Singh and others 1990]). Soil DIs or SQIs may be determined visually, or via measurement by laboratory or field testing (table 1).

Regardless of their simplicity or complexity, ideal indicators should (1) have a baseline against which to compare change; (2) provide a sensitive and timely measure of a soil's ability to function within a given ecosystem; (3) be applicable over large areas; (4) be capable of providing a continuous assessment; (5) be inexpensive and easy to use, collect, and calculate; (6) discriminate between natural changes and those induced by management; (7) have a cause-and-effect connection with forest productivity; and (8) be responsive to corrective measures (Burger and Kelting 1999).

These indicator characteristics are mostly obvious and intuitive, but two common monitoring pitfalls are using indicators too broadly, and not having a cause-and-effect relationship with the soil service or management goal. The ideal indicator would be applicable over large areas, but in reality indicators and their relative importance are quite soil- and site-specific.

Perhaps the most serious monitoring pitfall is using indicators with no cause-and-effect relationship with the soil service (*e.g.*, soil productivity) (Powers and others 1998; Miller and others, in preparation). Many forest disturbances, both natural and human-induced, are totally benign. In fact, the health and productivity of some forest ecosystems require disturbance (*e.g.*, ground fire, litter layer disturbance by animals). A detrimental disturbance in one forest ecosystem may be a beneficial process in another. Furthermore, disturbances are often soil- and species-specific (Page-Dumroese and others 2000; Powers and others 2005; Kranabetter and others 2006). Indicators of detrimental disturbance must be applied carefully, and they should have known correlations with forest productivity or some other service or management goal. All indicators will not have all eight features listed above, which is why several may be needed to adequately measure BMP effectiveness.

Different Indicators Needed for Different Soils

Soil services (what soils do for us) and soil functions (how they do it) are fairly universal. However, soil types and their properties and processes (attributes) vary greatly, which requires site-specific selection of indicators for monitoring the most important soil functions for a given soil type and disturbance activity. Furthermore, some soils are more resistant to impact than others; a given impact may be detrimental to one soil and have no effect on another. This is illustrated in the example in figure 3: Soil quality is shown as a function of a soil's ability to hold, supply, and cycle organic matter and nutrients (nutrient cycling) on the y axis, and the ability to accept, hold, and supply water, air and heat (air/water balance) on the x axis (Burger 1997); both are important forest soil functions identified by several researchers (Powers and others 1998; Burger and Kelting 1998). Soil quality generally increases as organic matter and nutrients are conserved, and soil quality increases as the air/water ratio is balanced. Soil specificity is shown in several general ways:

- Alfisols (*e.g.*, Soil A) are more likely to be detrimentally impacted by changes in air/water balance than changes in fertility, while the opposite is true for Entisols (*e.g.*, Soil B). Alfisols are usually better buffered than Entisols against nutrient removals, while Entisols usually have a coarser texture and resist compaction and loss of macropore space. Ultisols and Inceptisols are likely to be more equally impacted by changes in both soil functions, but are better buffered against extreme changes in air/water balance and nutrient cycling, respectively, for the Alfisols and Entisols.
- The risk of a detrimental impact varies within a soil order. For example, a low-quality Entisol (well-drained marine sand, Soil C) is more likely to be detrimentally impacted by organic matter and nutrient removal (Brendemuehl 1967) than a high-quality Entisol (alluvial flood plain soil, Soil B) (Aust and others 1997), which is illustrated in figure 3 by convergence of a possible response surface toward higher soil quality.
- Soil compaction and organic matter removal may be good indicators for air/water balance and nutrient cycling, respectively, for most soils, but their relative importance (weight) would be different for different soils. Soil compaction would be more detrimental to most Alfisols than organic matter removal, and organic matter removal would be more detrimental to most Entisols than compaction. Therefore, a uniform, one-size-fits-all soil quality monitoring program would not be applicable across all soils and forest sites. This was illustrated in a study by Page-Dumroese and others (2000) who evaluated the effectiveness of applying uniform soil quality standards

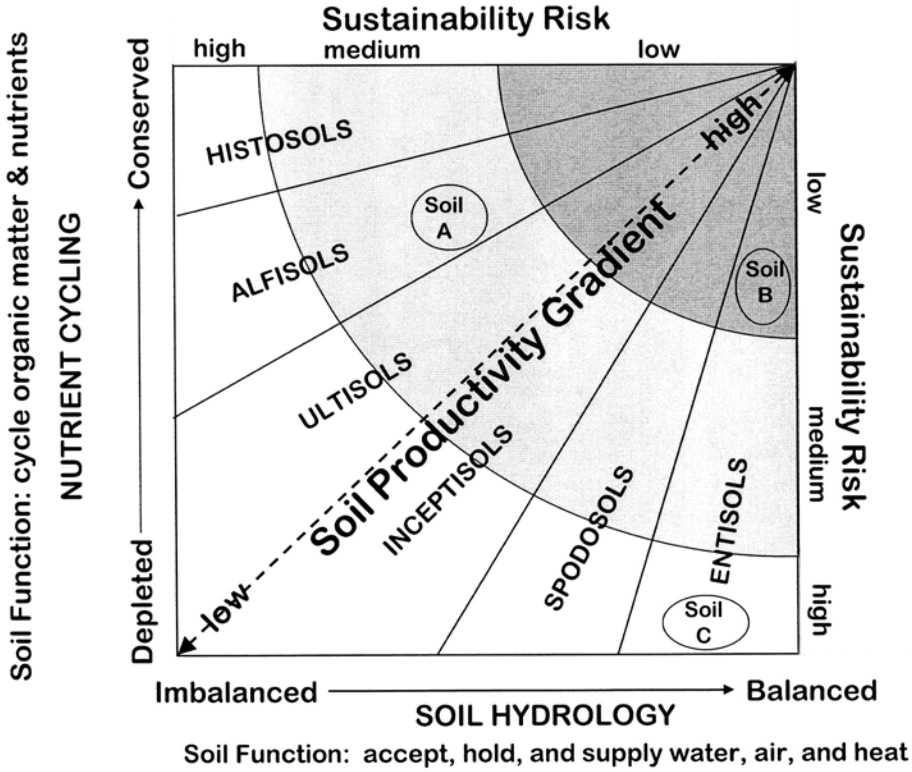

Figure 3. Soil quality response surface defined by soil nutrient cycling and hydrology (after Burger 1997).

to disturbances caused by forest operations over diverse forest landscapes in the Pacific Northwest. They concluded that application of selected USDA Forest Service standards (USDA Forest Service 1991) did not provide a comparative accounting of detrimental change in soil quality for the sites measured, and that some level of soil and site specificity needs to be incorporated in monitoring protocols.

USDA Forest Service Soil Monitoring and Research Programs

Soil Quality Monitoring

The USDA Forest Service has a well-established soil quality monitoring program that has been in place for several decades (USDA Forest Service 1991; Powers and others 1998). The program is a process by which data are collected to determine if soil management objectives have been achieved. It is meant to assist land managers in making better decisions on how to maintain or improve long-term soil productivity. The program and its evolution were described by Powers and others (1998) and by Page-Dumroese and others (2000). A fundamental assumption is that forest operations cause soil disturbances at some critical level that interfere with soil function (soil stability, soil hydrology, and nutrient cycling), which in turn have a detrimental effect on soil and forest productivity. A second assumption is that measures of one or more soil disturbances can be used to judge whether an operation had a detrimental impact on productivity, provided the disturbance, or a combination of disturbances, exceeded a predetermined threshold (usually 15 percent of the pre-disturbance condition) on more than 15 percent of the activity area. Disturbance and SQIs used by Forest Service Regions as reported in supplements to FSH 2509.18 are shown in table 2. Regions 1, 2, 4, 6, 8, and 9 use DIs for monitoring sustainable management, while Regions 3 and 5 use SQIs representing soil functions (table 2). The use of different sets of indicators and different approaches suggest a degree of region-specific application of the soil quality monitoring process; however, standardization of approach to the extent feasible would be advantageous for withstanding public and legal scrutiny.

Table 2—Detrimental soil disturbances or soil functions monitored by Forest Service Region (R1 through R10) and those listed in the Soil Management Handbook (USDA Forest Service 1991).

	Region and effective date									
	R1 1999	R2 1992	R3 1999	R4 2003	R5 1995	R6 1998	R8 2003	R9 2005	R10 1992	HB 1991
Disturbance:										
Compaction	X	X		X		X	X	X	X	X
Rutting	X					X	X	X	X	
Displacement									X	X
Severely burned	X	X		X		X		X	X	X
Surface erosion	X					X	X	X	X	X
Organic matter loss	X			X		X	X	X		
Mass movement	X					X		X	X	
Puddling		X		X				X	X	X
Ground cover				X				X	X	
Altered wetness									X	
Functions:										
Stability			X							
Hydrology			X		X					
Nutrient cycling			X							
Soil productivity					X					
Buffering capacity					X					

According to Powers and others (1998), the soil quality standards are meant as early warning thresholds of impaired soil conditions. When threshold standards for detrimental disturbance are exceeded, a 15 percent decline in productivity is assumed. Threshold standards are based on scientific findings or best professional judgment, but there is little or no documented evidence of any connection between disturbance thresholds and productivity. When critical data are lacking, it is prudent to err on the conservative side to ensure that productivity is not impaired; on the other hand, unreasonably strict standards having no basis in fact can limit forest use opportunities and tie up human resources in unnecessary litigation.

Following an assessment of soil disturbance in forests of the Interior Columbia Basin, Miller and others (in preparation) suggest that current soil quality methodology is inadequate, and they make a case for a more rigorous approach underpinned by research findings and sound scientific interpretations. Their finding was based on 15 soil monitoring projects after logging in which they visually classified disturbance and took bulk density samples along transects. They concluded that (1) different applications of a visual assessment protocol by different people led to different conclusions as to whether a logging operation is judged detrimental; (2) visual versus measured estimates of bulk density showed that visual estimates are unreliable; (3) the effect of equipment tracks and surface soil displacement is often over estimated, which overstates detrimental impacts of logging operations; (4) because current interpretations of detrimental disturbance are seldom justified by scientific investigations (*e.g.*, the assumption that a 15 percent increase in bulk density reduces tree growth on all soils is not supported by research), classification of soil disturbance should be for descriptive purposes only; (5) given broad variation in soils and climate among national forests, using the same standards for defining detrimental disturbance as it affects tree growth is not reasonable; and (6) current soil disturbance interpretations are based on experience and opinions of local specialists that are seldom documented or peer-reviewed. To overcome these limitations, they recommend a formal process for selecting activity areas for monitoring, and a revised set of descriptive disturbance and SQIs that account for both severity and extent of disturbance. For making judgments on impaired productivity, they recommend using risk-rating models based on research findings and collective expert opinion that account for specific site factors, potential vegetation, and forestry activity. Risk rating can then be used for site-specific prescriptions allocated to high-risk sites.

Synthesis of LTSP Research Findings

If the critique of the Forest Service's soil quality monitoring program by Miller and his co-workers has merit, the adaptive management model (fig. 2) suggests that the way to improve effectiveness monitoring is to adjust DIs and SQIs using current research findings. The North American long-term soil productivity study (LTSP) (Powers and others 1990) was installed, in part, to validate or improve SQIs used for short-term judgments of sustainable forest management. The study addressed organic matter removal and compaction DIs each at three levels: stem-only harvest, whole-tree harvest, and whole-tree harvest plus litter layer removal; and none, moderate, and high levels of compaction, respectively. Although still a relatively young project after only 15 years, preliminary results have been reported that suggest several ways in which the selection and interpretation of USFS DIs and SQIs might be reconsidered or adjusted.

Powers and others (2005) reported findings from the first 10 years of study for a range of LTSP study sites in CA, ID, LA, MI, MS, and NC. Several other key papers reported site-specific responses to the LTSP treatments at different locations. Key findings include the following:

- Soil organic matter across all sites was generally unaffected by complete removal of surface organic matter (stem-only versus whole-tree plus litter removal). Based on composite results, it appears that carbon inputs to mineral soil horizons are due primarily to root decomposition, while carbon mineralized in the surface Oi and Oe layers efflux as CO_2.
- For four contrasting CA sites, whole-tree plus litter removal caused substantial declines in soil C and N concentrations and mineralizable N. In a later report for the NC and LA loblolly pine LTSP plots (age 10 data), Sanchez and others (2006) reported no organic matter removal effects on tree growth. Heavy compaction resulted in a slight increase in stand volume on LA plots and a slight decrease in growth on NC plots. Organic matter removal had little effect on soil N but significantly reduced extractable P. This effect on P was also reported by Scott and others (2004) for LA plots at age 5.
- Composite data for all sites indicated no general decline in productivity with organic matter removal, which is consistent with the observation by Blake and Ruark (1992) that effects of organic matter removal is confounded by an array of influences both positive and negative. One exception was that aspen biomass on the MI plots was significantly less on plots where trees and litter were removed due to vigorous sprouting and dieback of root suckers. Another was on some inherently P-deficient soils in LA and MS, which showed substantial declines due to whole-tree harvesting at age 10 (Scott and Dean 2006).
- Severe soil compaction increased D_b an average of 18 percent in the 10- to 20-cm soil layer, but little compaction occurred if initial D_b was >1.4 Mg m^{-3}. Composite data for all sites showed that severe compaction had little or no effect on standing biomass; however, biomass on sandy sites increased by 40 percent while that on clayey sites decreased by half. This textural influence was clearly demonstrated across three CA LTSP sites (Gomez and others 2002). The authors reported growth responses to compaction by mixed conifers that decreased, remained the same, and increased for a clay, loam, and sandy loam, respectively. The soil series, in the same order, were Challenge (Typic Palexerults), Cohasset (Ultic Haploxeralfs), and Chaix (Typic Dystroxerepts). The different impacts of compaction among soils (negative, benign, positive) were attributed to changes in strength, pore space distribution (which changed available water holding capacity), and an interaction between these factors.

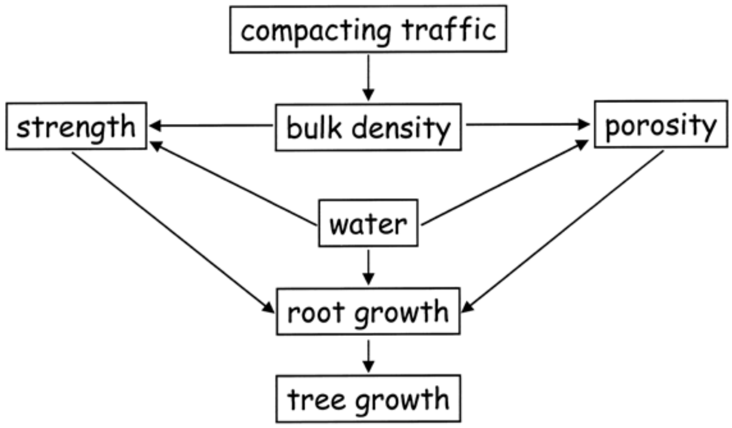

Figure 4. Root and tree growth as a function of soil compaction effects on bulk density, soil strength, porosity, and water content (after Greacen and Sands 1980).

This finding corroborates the Greacen and Sands (1980) model showing that strength and porosity are the static physical properties most directly affecting the tree (fig. 4). The clay soil suffered the greatest increase in soil strength and the greatest loss in porosity with no increase in available water holding capacity (AWHC) resulting in decreased tree growth on compacted plots. Although the loam soil had a strength exceeding 3 MPa below 10 cm, its AWHC increased significantly, which resulted in a negative/positive tradeoff and a net result of no change in tree response. Compaction increased strength of the sandy loam soil, but AWHC increased at all depths of the measured profile, resulting in a net positive change in growth.

Implications of LTSP Research Findings for Soil Quality Monitoring

Collectively, the LTSP research results have the following implications for the Forest Service's soil quality monitoring protocol:

- The age-10 LTSP data clearly demonstrate site- and soil-specific responses to disturbance, which further explains the inconsistent conclusions provided by soil disturbance monitoring when applied across different sites (Page-Dumroese and others 2000) or when applied by different people (Miller and others, in preparation). Currently used detrimental DIs are all good in principle, but they need to be selectively applied and weighted by importance in different regions and within regions.
- The effect of organic matter removal (*e.g.*, whole-tree plus litter) from the surface of a forest site is clearly site-specific (sucker sprouting in aspen; P depletion in Gulf Coast loblolly pine; N depletion in CA mixed conifers). The LTSP data show that much higher levels of removal are needed to affect a detrimental response than are currently set as regional standards on most sites, yet some highly sensitive sites may be impaired by removals currently allowed. Organic matter is a master variable in the sense that it plays multiple roles in forest ecosystems. In addition to N and P cycling and natural regeneration demonstrated in the LTSP trials, it is habitat for myriad animals, protects mineral soil from erosion, buffers temperature and water extremes in the surface mineral soil, and is an energy source for plants and animals. Some of these functions are more important than others on a given site, but, in any case, those that play a clear role in productivity should be monitored. In addition to the DI (area and degree of organic matter displacement), one or more soil/site quality indicators (N mineralization, sucker sprouting, etc.) should be used to make judgments about SFM.
- Soil compaction is an important and useful DI, but it is clear from the LTSP data that it is not always detrimental; in fact, it clearly enhances soil productivity in some cases. In other cases, forest productivity may be improved while soil productivity is unchanged. Stagg and Scott (2006) found that planted loblolly pine growth was increased by compaction through reducing understory competition. Planted tree growth on plots with herbicide applications to control competition showed little response to

compaction. This finding reinforces the principle that many types of disturbance in ecosystems are beneficial and sometimes necessary for normal ecosystem function (for example, fire, windthrow, and deposition of sediment by natural processes); human influences often enforce these positive processes. Therefore, simple visual indicators of compaction are inadequate for judging detrimental disturbance (Aust and others 1998; Steber and others 2007). A measure of bulk density, the one commonly measured SQI in Forest Service monitoring protocols, will often lead to erroneous conclusions because detrimental effects of compaction can occur in clayey soils with less than a 15 percent change, and beneficial effects can occur in sandy soils with an even greater change. Better indicators of compaction are soil strength and the ratio between macro- and micro-porosity as shown by the conceptual model by Greacen and Sands (1980) (fig. 4). Compaction increases D_b, but the impact of the D_b change on strength and pore space distribution are the real drivers of root growth and productivity (fig. 4), and D_b change is not always a reliable surrogate for these soil properties. Attempts have been made to determine root-growth limiting D_b for forests (Daddow and Warrington 1983), but rules of thumb from these attempts have not been successfully applied to forests.

More Known About Soil Response to Disturbance Than Reflected in Current Monitoring Protocols

The old cliché "more research is needed" certainly applies to our quest for a better understanding of site-specific forest response to disturbances for achieving SFM. However, we maintain that more is known about soil disturbance processes and effects than is currently reflected in Forest Service SQM protocols. For example, a 15 percent increase in D_b is used by most Forest Service regions as an indication of detrimental disturbance. The empirical findings by Gomez and others (2002) clearly show that this indicator will lead to erroneous conclusions on many sites and strongly suggests that we need to move beyond a blanket approach of using visually estimated or measured D_b. Gomez and others (2002) showed that soil strength and pore space distribution were better SQIs than D_b, as conceptualized by Greacan and Sands (1980) decades ago. Furthermore, we understand the basis for this model given decades of research on the interactions among factors in the model. Recent work by Siegel-Issem and others (2005) contrasting data from California and Missouri LTSP sites demonstrates our understanding of compaction effects that can be extrapolated to many soils across regions. A brief summary of selected bits of their results are presented to make the point that a synthesis of knowledge can be used to improve SQM.

The California soil was a Cohasset coarse sandy loam (Haploxeralf) (fig. 5A) from the Tahoe National Forest similar to the one Gomez and others (2002) studied, but with a sandy loam texture. Its parent material is an andesitic mudflow and the dominant vegetation is mixed conifers. The Missouri soil was a Clarksville silt loam (Paleudult) (fig. 5B) from the Carr Creek State Forest. Its parent material is a sandstone residuum and the dominant vegetation is oak-hickory with a component of shortleaf pine. Given the contrasting particle size distributions and different levels of organic matter, the soils reacted very differently to compaction. The MO soil reached proctor level D_b (maximum possible under controlled conditions) at 1.53 Mg kg^{-3} compared to 1.25 Mg kg^{-3} for the CA soil. As D_b increased and volumetric water content (θ) decreased, soil strength increased. For the CA coarse sandy loam, above D_b 1.00 Mg kg^{-1} and below 35 percent θ, soil strength approached or exceeded 2MPa, the strength that becomes root-limiting. Below 1.00 Mg kg^{-1}, D_b had virtually no effect on soil strength at any θ (fig. 5C). By contrast, soil strength of the MO silt loam did not reach the 2MPa threshold until D_b exceeded 1.5 Mg kg^{-1}, which was nearly the proctor limit (fig. 5D).

The total and available water holding capacity (AWHC) of the CA soil increased significantly with increasing D_b (fig. 6A), but there was little change in the AWHC of the MO soil (fig. 6B). Increasing D_b dramatically reduces the non-capillary or macropore space in most soils. When macropore space drops below 10 percent, roots of upland species become hypoxic due to inadequate gas exchange rates (Grable and Siemer 1968).

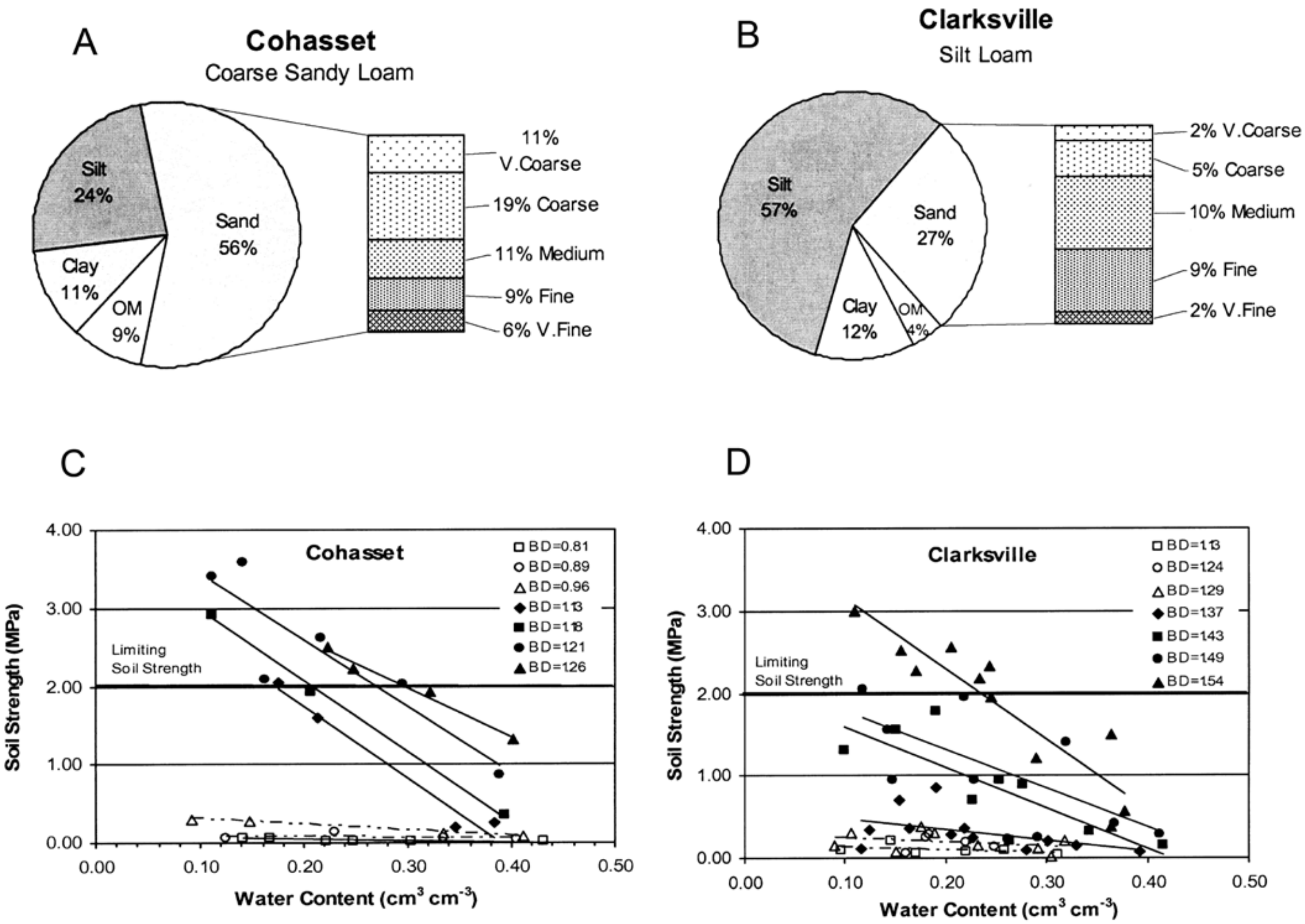

Figure 5. Particle size distribution of a Clarksville and Cohasset soil series from MO and CA LTSP study sites, respectively (from Siegel-Issem and others 2005).

This is illustrated in figure 6D for shortleaf pine in the MO soil. Root length density followed a classic bell-shaped response for upland species in loam soils, decreasing from optimum water content as the soil became both drier and wetter due to inadequate available water on the dry end and inadequate aeration on the wet end of the soil water gradient (da Silva and others 1994). As D_b increases, the range in soil water content within which roots can grow narrows, which in turn causes a decrease in root length density. The trees growing in the CA soil suffered from increased strength on the dry end of the θ gradient, but not at all on the wet end of the θ gradient, despite reduced aeration porosity (fig. 6C).

These soil and tree responses to compaction under controlled lab conditions corroborate the field results reported by Gomez and others (2002). Soil texture and organic matter content influence the extent to which a soil can be compacted and the relative influence of strength versus pore size distribution. The degree and influence of compaction are predictable based on texture and organic matter content and thus could be used to adjust the importance of D_b change relative to other DIs. Furthermore, soil strength and pore space distribution could be used as soil texture-specific SQIs in lieu of estimated or measured D_b. Clearly, we know enough about soil physical processes to create a combined basic/empirical mathematical model to estimate and make definitive judgments of detrimental compaction, rutting, and puddling impacts on productivity. The same could probably be said for organic matter displacement and loss, and good models already exist for soil erosion prediction and risk assessment (Laflen and others 1997). A similar argument was made by Miller and others (in preparation) based on their firsthand experience with the limitations of current SQM protocols. Modeled soil disturbance processes that address the stability, hydrology, and nutrient cycling functions

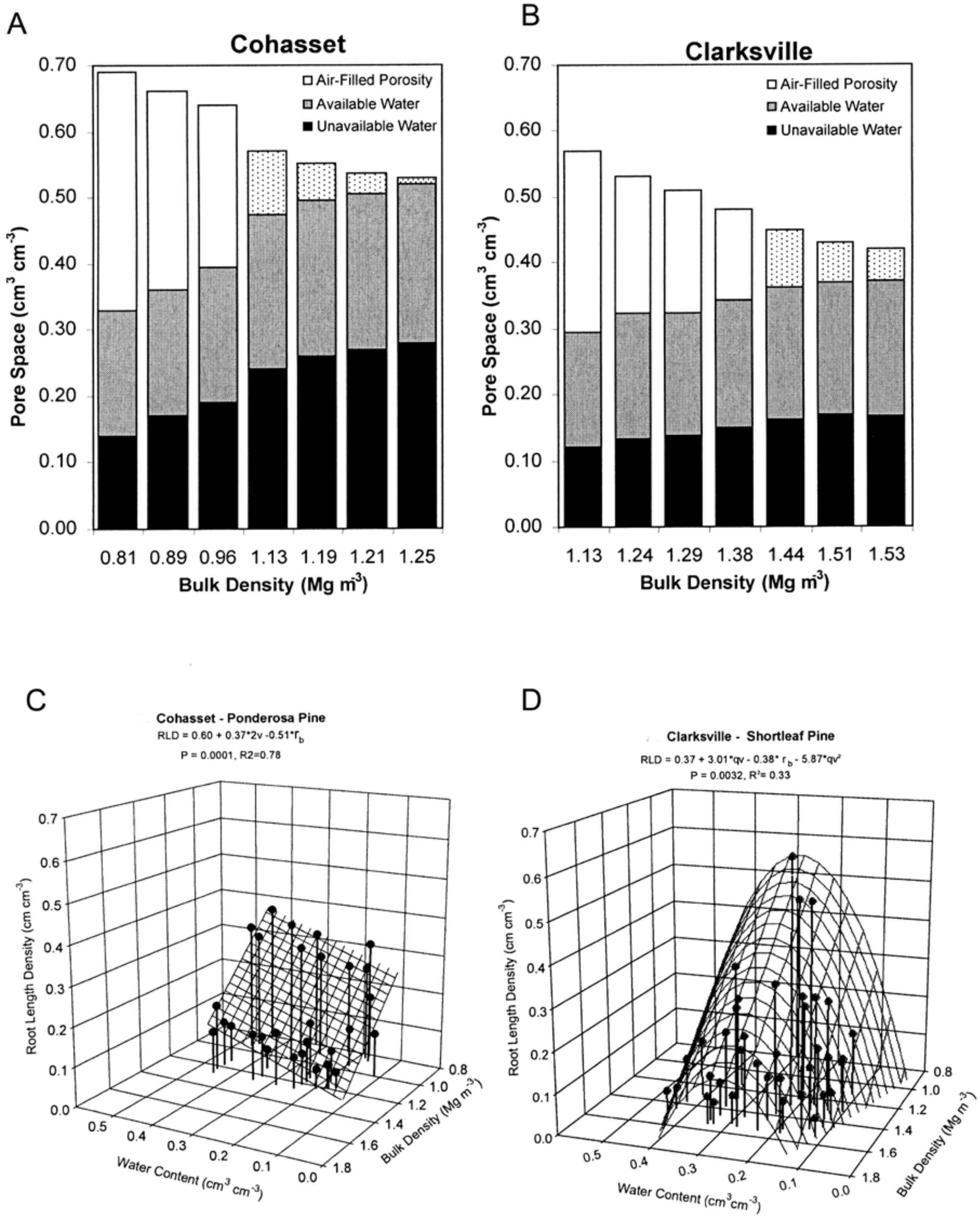

Figure 6. Pore space distribution and root length density of shortleaf pine seedlings and ponderosa pine seedlings grown on Clarksville and Cohasset soils, respectively, as a function of soil bulk density and volumetric water content (Siegel-Issem and others 2005).

of soils need to be combined in a single, workable, cost-effective protocol that can be continuously updated as new findings warrant.

Modeling Soil Quality

An Approach for Modeling Soil Quality

A number of efforts have been made to model soil quality (Doran and Parkin 1994; Carter and others 1997), quantitatively score soil quality for use as a performance standard (Larson and Pierce 1994; Andrews and others 2004), and extrapolate soil quality classes or risk assessments to an activity area (Halvorson and others 1996; Wendroth and others 1997; Kelting and others 1999). Most of these efforts have been made on agricultural landscapes, and extensive reviews of these topics are covered in several publications (Doran and Parkin 1994; Doran and Jones 1996; Gregorich and Carter 1997; Lal 1999). Several compilations have also been made for forest landscapes (Ramakrishna and Davidson 1998; Raison and others 2001).

This approach is conceptualized in figure 7. Forest practices can degrade or improve soil quality compared to a pre-disturbance or reference condition (solid circle in diagram). Often, positive and negative effects occur simultaneously. Degrading processes include soil displacement or erosion, water logging, compaction, organic matter loss, nutrient depletion, and acidification, among others. Soil improvement can include enhanced fertility, better tilth, increased available water holding capacity, better drainage of excess water, organic matter addition, and liming. Intensive industrial forest operations may impose a combination of these effects with a net result of better, same, or worse soil quality. Extensive forest operations that only include harvesting during wet weather could have a net negative effect on soil quality due to soil compaction and water logging. Soil quality is the ability of the soil to function by storing and releasing water to plants, cycling nutrient elements, buffering organisms from temperature extremes, decomposing organic debris, etc. As mentioned above, they can be categorized as soil stability, hydrology, and nutrient cycling functions (table 1). These soil functions can be monitored and measured using soil properties or processes (depicted by letters A through G in fig. 7), or by using DIs or SQIs that serve as surrogates for properties and processes (table 1). Forest operations may improve some properties (arc of wedges exceeding the pre-disturbance or reference condition), and they may degrade others (arc of wedges less than the reference condition) (fig. 7). The net effect of the disturbance on soil quality may be the same (sum of the area of the wedges equal to the area of the reference condition), or the net effect may be better or worse than the reference condition. Some soil properties may be more important to forest productivity than others (greater angle, thus area, of some wedges compared to others), but seldom is one "all" important or even dominantly important. However, if Liebig's principle of "most limiting" factor applied, one could select and monitor the function most affected (*e.g.*, function A) as it is degraded most from the reference condition and is below the standard or allowable limit (dashed circle). In most cases, all properties (A through G) contribute to soil quality in interactive ways, and those interactions are often complex and unknown. A better judgment of soil quality change would entail a composite, weighted score of all soil functions (sum of the area of the wedges compared to the area of the allowable condition).

Forest Service Regions 3 and 5 use this general approach as reported in supplements to 2509.18 (USDA Forest Service 1991). Region 3 (R3) defines soil function in terms of stability, hydrology, and nutrient cycling and uses a combination of DIs and SQIs as indicators of those functions to classify soil condition as satisfactory, impaired, or unsatisfactory. Given our previous discussion of the limitations of arbitrarily (meaning no evidence of cause and effect) applying visual DIs, we suggest that the R3 approach is the most comprehensive and sophisticated. Lacking are justifications for indicator selection, site-specific weighting, and relationships with vegetative productivity, and a scoring mechanism to show that combined indicators will result in a specified amount of productivity decline over a specified areal extent. Nonetheless, the approach is conceptually based with logical linkages among soil function, properties, and indicators, and it includes a risk assessment within three categories.

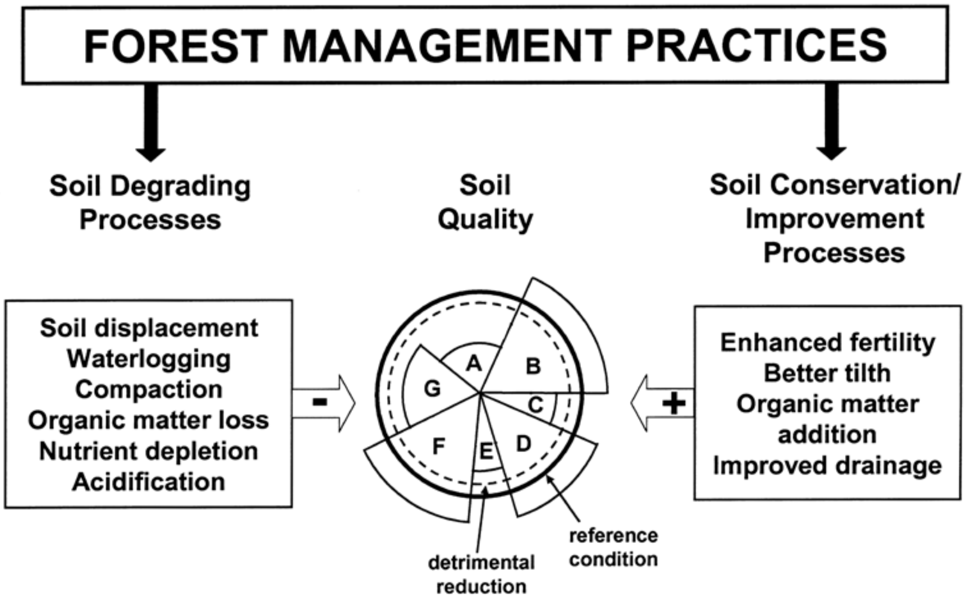

Figure 7. Conceptualization of the effects of forest management practices on soil quality.

Steps for Building a Soil Quality Model

A common approach to soil quality monitoring is to (1) select key disturbance or soil quality indicators representing soil function, (2) develop sufficiency relationships between soil services and the indicators, and (3) weight and combine sufficiency levels for all indicators in additive or multiplicative models based on their importance and vertical and spatial extent in an activity area.

Step 1: Select Key Soil Quality Indicators—Two good review papers on indicator selection for forest soils are by Schoenholtz and others (2000) and Moffat (2003). Both reviews provide lists of physical, chemical, and biological indicators with a rationale for their potential use. Ultimately, selection of indicators for a given forest type and land region must be done by scientists and practitioners with expert knowledge of specific forest ecosystems, forestry operations, and forest response to disturbances. However, in addition to local expertise, there is a large body of research literature on soil/site effects on growth and yield for forest ecosystems for every region of the country. This research has been ongoing for nearly a century as foresters have striven to understand fundamental relationships underpinning productivity.

Carmean (1975) did an early review of this literature, and Pritchett and Fisher (1987) did a follow-up review listing the number of reports in which a given soil property was found to be a determinant of growth and yield. For example, for western conifers the key soil properties and the number of times reported were effective soil depth (20), available water (8), surface soil texture (8), soil fertility (4), subsoil texture (3), and stone content (4). For southern pines the key soil properties and number of times reported were subsoil depth and consistency (23), surface soil depth (21), surface and internal drainage (19), depth to least permeable horizon (14), depth to mottling (13), subsoil imbibitional water value (8), N, P, or K content, and surface organic content (3). Moffat (2003) also has a short literature synthesis on soil/site growth and yield relationships in his review. These reviews demonstrate that there is a huge knowledge base on which to draw for first approximation soil quality models.

Step 2: Developing Soil Quality Sufficiency Curves—Central to soil quality models are sufficiency curves, which are cause-and-effect relationships between a soil service such as forest productivity and a soil indicator. For forest productivity, sufficiency of a given soil indicator is often based on its ability to support root growth. The assumption is that if a soil indicator is sufficient for root growth, it will be sufficient for tree growth. Sufficiency for each soil indicator is scaled from 0 to 1, where a value of 0 is totally root-growth limiting and a value of 1 has no limitations for root growth. Sufficiency relationships can be developed based on the literature, designed

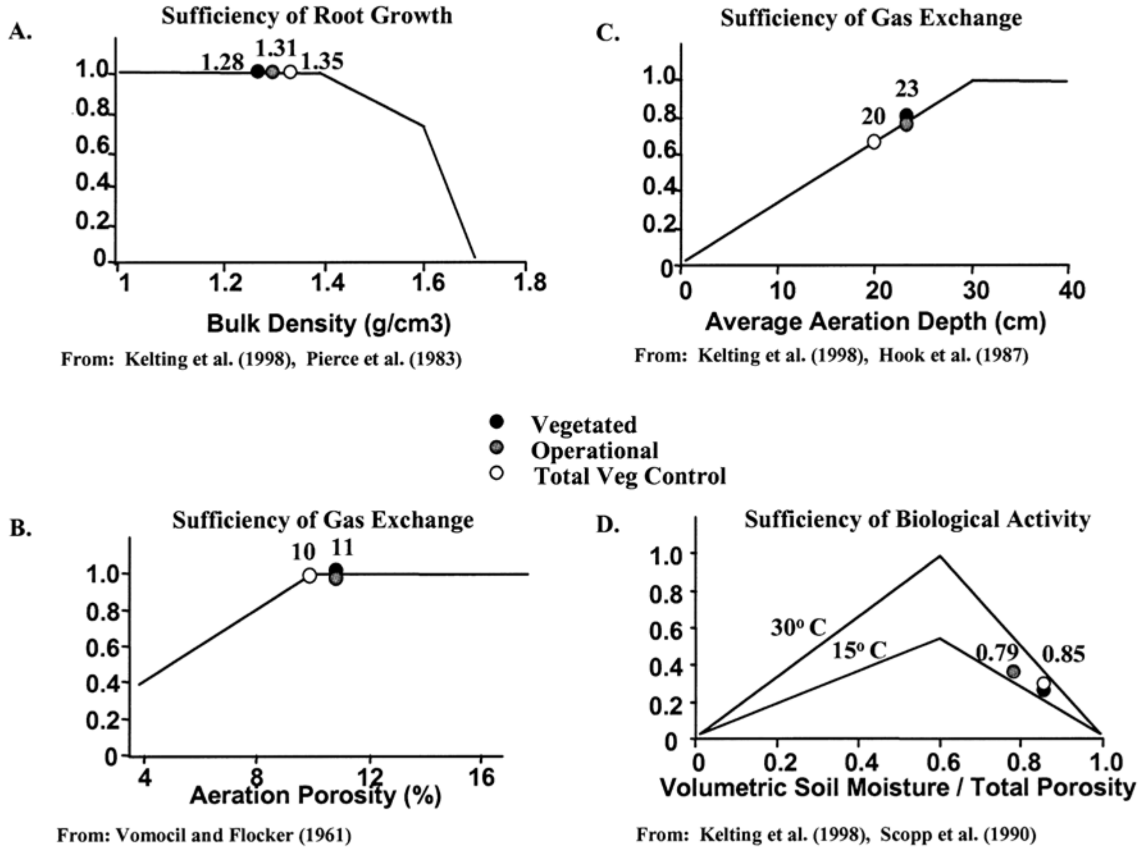

Figure 8. Sufficiency curves for vegetation treatment effect on (A) the soil rooting environment, (B and C) aeration, and (D) soil biological activity.

experiments, or professional experience and judgment. For example, Kelting and others (1999) developed sufficiency relationships for loblolly pine response to soil conditions on poorly drained soils. The curves were based on a combination of compiled literature and research. Lister and others (2004) used these relationships to judge the effect of different levels of ground cover vegetation on soil quality recovery after wet-weather logging (fig. 8).

Furthermore, most of this work was regression-based, so sufficiency curves are often reported or can be constructed from reported data. Lacking past research of this type, soil scientists can develop their own soil/site growth and yield relationships for specific forests or land types. The results accumulating from LTSP studies that have been targeted for this purpose are even better.

Step 3: Combining and Weighting Indicators in a Soil Quality Model—After indicators are selected and their sufficiency curves established, they can be incorporated in a model for an overall index of soil quality (Gale and others 1991). Eq. (1) is a soil-quality model developed by Kelting and others (1999) and Lister and others (2004) for loblolly pine on an affiliate LTSP site on Mead-Westvaco property in the lower coastal plain of SC. The soils were predominantly poorly drained Argent loam (Ochraqualf) and Santee loam (Argiaquoll) subject to compaction, rutting, and puddling when tree stands are harvested under wet conditions. The model provides an index of the net effect of harvesting disturbance using key soil quality indicators that are disturbed by wet-weather logging and influence tree growth predictably:

$$SQ = \sum_{i=1}^{area} \left[(D_b \times wt) + (P_a \times wt) + (AD \times wt) + (\Theta / P_t \times wt)\right] \times WF_{area} \quad (1)$$

where SQ is the overall soil quality index (0 to 1), D_b the sufficiency for bulk density, P_a the sufficiency for aeration porosity, AD the sufficiency for aeration depth, Θ/P_t the

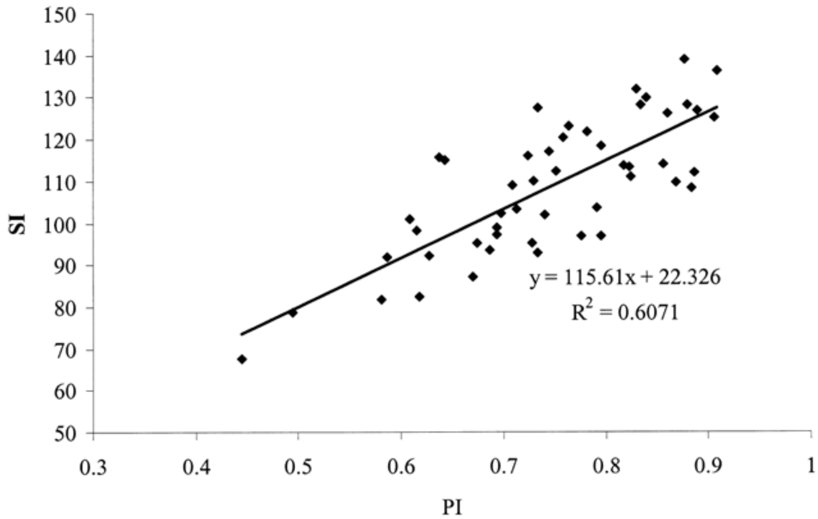

Figure 9. Relationship between site index (tree height at age 50) of white pine and a productivity index (soil quality) calculated from literature-based sufficiency curves for pH, soluble salts, soil density, slope, coarse fragment content, and aspect. Site index and soil measurements were for 52 reclaimed mined sites in the Appalachian region of Virginia and West Virginia.

sufficiency for biological activity, wt the relative weight or standardized coefficient for each indicator, WF_{area} the weighting factor for the extent of the overall activity area impacted, and area is each subsection of the overall activity area surveyed.

Jones and others (2005) developed a soil quality model to judge suitability of land reclaimed to forest after mining disturbance. Their work demonstrates all steps in the development of a soil quality modeling approach and might be used as a template for similar efforts. Previous soil/site regression studies suggested that the major mine soil growth limiting factors were soil density, P deficiency, toxic levels of soluble salts, extremes in pH, soil texture, coarse fragment content (Torbert and others 1988a, b; Torbert and others 1990; Andrews and others 1998; Rodrigue and Burger 2004). Using these reported relationships between tree growth and mine soil properties, Jones and co-workers developed sufficiency curves for mine soil properties that were consistently related to growth in these regression studies, and then used the following general soil quality model as a first approximation:

$$SQI = (pH \times texture \times density \times CF)^{1/4} \times depth \qquad (2)$$

where SQI = site quality index; pH = sufficiency of pH; texture = sufficiency of texture; density = sufficiency of soil density; CF = sufficiency of coarse fragments; and depth = sufficiency of rooting depth (equivalent to WF in Eq. 1). To test the performance of the model, a SQI was calculated for each of 52 reclaimed sites planted with white pine. Tree height and age were used to determine site index (SI), and soils were sampled for pH, texture, density, CF, and depth. SQI values were calculated using Equation 2 and regressed with white pine SI. SI was significantly linearly related to SQI (calculated from Eq. 2) with an R^2 value of 0.63 (fig. 9), showing that this general SQI model could be used with acceptable accuracy to predict forest productivity based on mine soil properties; that is, it could be used as a performance standard to determine if post-mining productivity equaled pre-mining productivity as required by law.

The SQI model (Eq. 2) assumes that all soil variables are equally important, which is unlikely. Jones and co-workers refined the model to make it locally specific. They regressed measured SI with measured soil properties from the 52 study sites. Standardized coefficients were calculated and used to develop relative importance factors for weighting the soil variables in the final site-specific model:

$$SQI_{ss} = (pH \times IF) + (texture \times IF) + (density \times IF) + (depth \times IF) \qquad (3)$$

where SQIss = site-specific SQI; pH = sufficiency of pH; texture = sufficiency of texture; density = sufficiency of soil density; depth = sufficiency of rooting depth; and IF = importance factor for each soil property (table 3). This weighted, additive, site-specific model improved the fit with measured SI somewhat with an R^2 of 0.68 (fig. 10). This model can and should be further validated with additional field testing. It, along

Table 3—Standardized coefficients, importance factors, and significance values for the independent variables used in the final model (Equation 4).

Variable	Standardized coefficient	Importance factor	*p*-value
Density	–0.54789	0.44	<0.0001
Rooting depth	0.34989	0.28	0.0004
Texture	–0.25135	0.20	0.0039
pH	–0.10393	0.08	0.2167

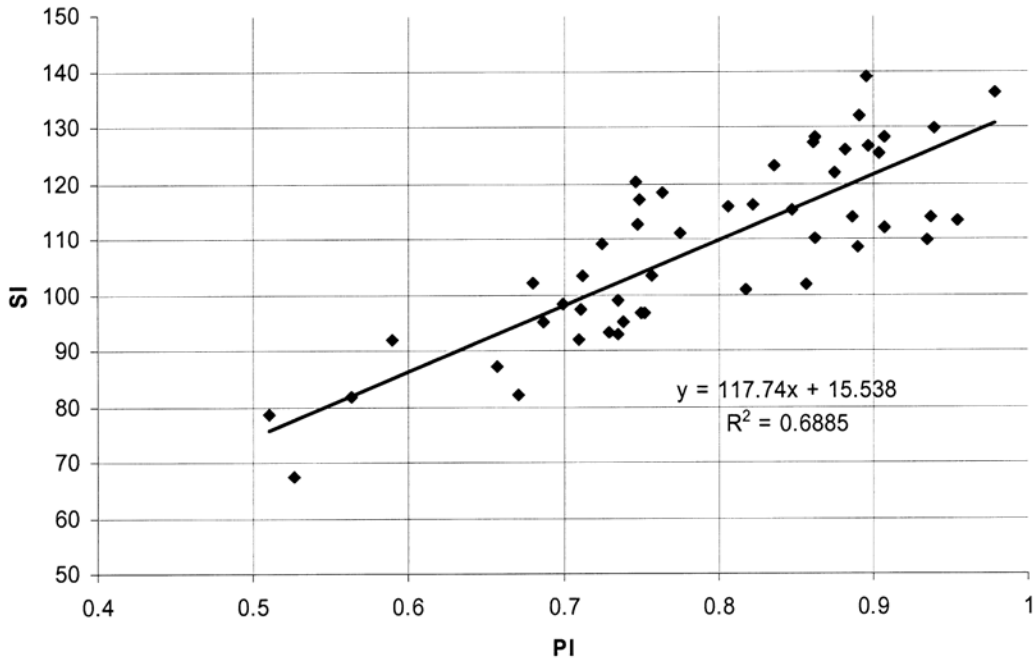

Figure 10. Relationship between site index (tree height at age 50) of white pine and a productivity index (soil quality) calculated from literature-based sufficiency curves for pH, soil density, soil depth, and soil texture. Sufficiency values for the four soil properties were weighted based on their relative contribution to white pine site index. Soil measurements were for 52 reclaimed mined sites in the Appalachian region of Virginia and West Virginia.

with similar earlier work (Torbert and others 1994; Burger and others 1994, 2002), is currently being advocated for use as a mechanism to judge post-mining forest productivity in the Appalachian region.

Site quality models as outlined above can easily be applied to different sections of an activity area by calculating SQIs by section (*e.g.*, percent of area compacted) and weighting indices by areal extent. The model, sufficiency calculations, weighting by importance, and weighting by areal extent can all be part of a SQI algorithm programmed in field computers. Immediately after field and laboratory sampling data are entered, an area based SQI can be generated.

This work by Jones and others (2005) shows that a first approximation general SQ model can be developed based on a compilation and synthesis of research results for a given area, and that further refinement can improve its specificity. Using this model within current operational and regulatory frameworks is entirely feasible. General models that incorporate the known productivity determinants could be made for general forest types across Forest Service regions and made more region- and site-specific with local data on sufficiency curves for specific forest types and plant species.

Classifying and Mapping Risk of Soil Impairment Across Landscapes

Once armed with a good soil quality monitoring protocol, another consideration is applying monitoring effort proportional to risk of soil impairment due to natural or human-caused disturbances. Some soils and sites are relatively more resistant than others to the same disturbance impacts, and some soils and sites rebound to pre-disturbance conditions faster than others. GIS-based risk assessments at a landscape, watershed, or national forest scale would be helpful for allocated monitoring resources and prescribing appropriate management practices.

Elias and Burger (in preparation) recently developed acid deposition (AD) resistance maps for the Monongahela National Forest in West Virginia to help target monitoring efforts cost effectively. Increasing soil acidification, base leaching, and soil Al toxicity may adversely impact forest productivity. Stand volume in about one-third of 91 Forest Inventory and Analysis (FIA) plots recently (10-yr period between 1989-2000) declined periodic annual increment (PAI) of by up to 9.5 $m^3ha^{-1}yr^{-1}$, while another one-third was less than 3 $m^3ha^{-1}yr^{-1}$ growth (Elias and others 2009), which is less than expected growth. Incremental growth was not correlated with site index, but was strongly correlated with Ca/Al molar ratio, effective base saturation, and other indicators of acidification. Given the broad range in periodic annual increment (PAI) and the diverse terrain and soil parent materials that range from acid sandstones to limestone, a GIS-based acid deposition resistance index was modeled to help direct monitoring efforts.

Elias and Burger (in preparation) created AD resistance relationships for parent material, slope, aspect, elevation, soil mineralogy, depth, texture, and rock fragments based on published relationships and expert knowledge to encompass the range of each factor found on the Monongahela National Forest (MNF) (table 4). All soil and site factors were tied to existing MNF GIS layers. At each FIA plot location, values for each site factor were determined using 30 by 30 m U.S. Geologic Survey Digital Elevation Models (USGS DEM), SSURGO, and MNF maps (table 4). A resistance index ($RI_{general}$) was then calculated for each FIA plot using the following model:

$$RI_{general} = [.2\,(\text{parent material score}) + .2(\text{aspect score}) + .2(\text{elevation score}) + .2(\text{soil depth score}) + .2(\text{texture score})]^2 \quad (4)$$

PAI was significantly correlated with $RI_{general}$ indicating that the combined soil/site factors were associated with forest productivity and that the modeling approach had merit. A site-specific AD resistance model (RI_{MNF}) was then developed by weighting

Table 4—Range of site factors used to create a Resistance Index for the Monongahela National Forest in West Virginia.

Factor	Range of characteristics and resistance: 0				1
Parent material[‡]	Acidic				Calcareous
Slope	Resistance = $-0.00005x^2 + 0.0055x*2.7$				
Aspect	235 – 286	197 – 234/ 285 – 325	145 – 196/ 326 – 15	107 – 144/ 16 – 55	56 – 106
Elevation	Resistance = $-0.0005* e^{0.005x} + 1$				
Mineralogy	Siliceous				Mixed
Depth	Resistance = $1.3* e^{-55/(x + 0.0001)}$				
Rock fragments	Resistance = $-0.0175* e^{0.045x} + 1.015$				
Texture	Resistance = $-0.001x^2 + 0.06x$				

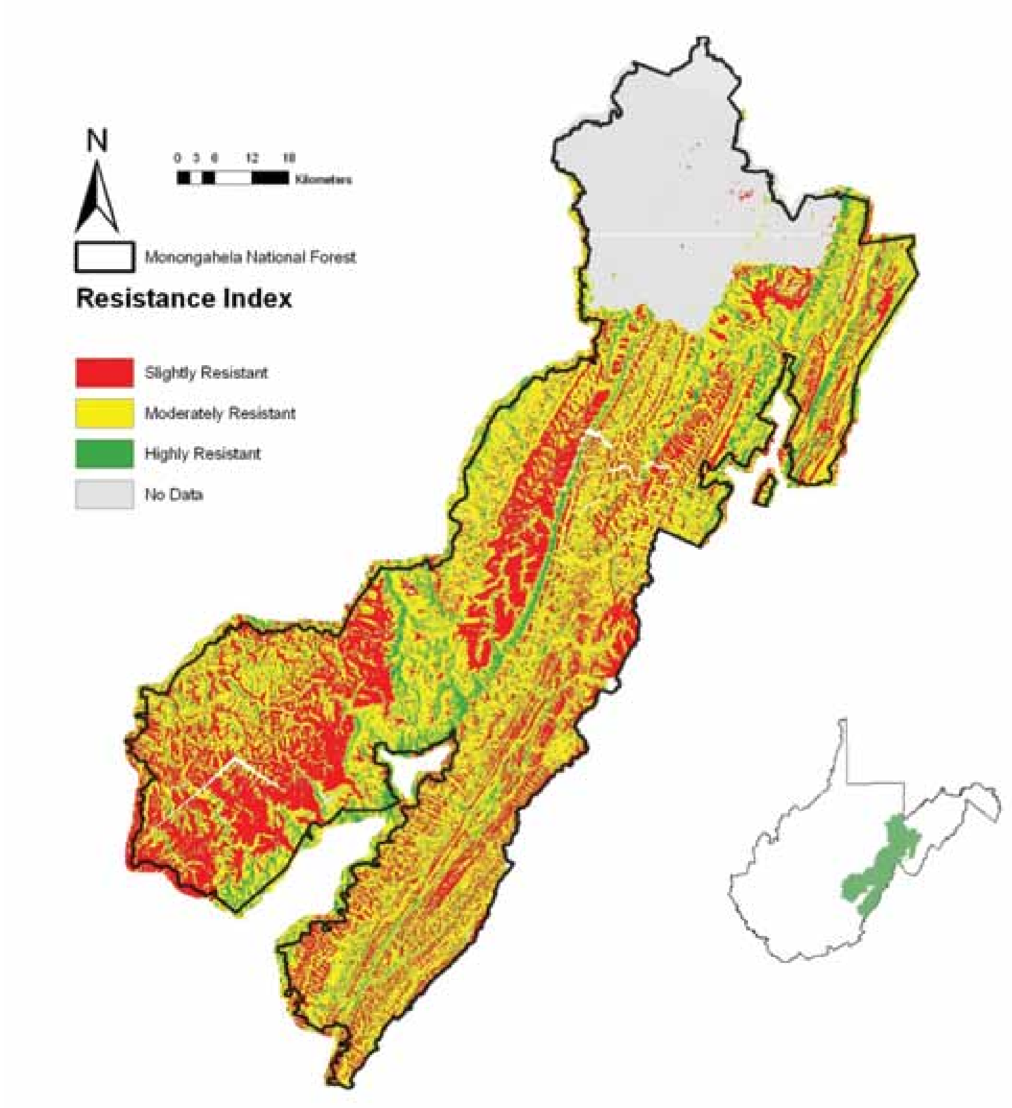

Figure 11. Map of resistance to acidification on the Monongahela National Forest.

the influence of each site factor to reflect current forest conditions as measured on MNF FIA plots.

The relationship between RI_{MNF} and significant indicators (pH, EBS, Ca/Al ratio, Al content) were used to create RI classes (slightly, moderately, and highly resistant). Class breaks were made at indicator levels associated with forest response in similar ecosystems (Cronan and Grigal 1995; Fenn and others 1998). A resistance index based on the classes of weighted site and soil factors (RI_{MNF}) was mapped across the Monongahela National Forest (fig. 11). Across the MNF, 14 percent of the land area was mapped as highly resistance to acidification ($RI_{MNF} \geq 0.7$), 57 percent was mapped as moderately resistant ($0.7 > RI_{MNF} > 0.45$), and 29 percent was mapped as slightly resistant ($RI_{MNF} \leq 0.45$).

This work by Elias (2008) demonstrates the use of soil quality monitoring principles for assessing risk of soil quality change across a forest. Correlation between forest growth and disturbance (PAI and AD) was established; criteria and indicators were selected based on a synthesis of previous research; the indicators were tested and those correlated with growth were selected; and a gradient of sensitivity (RI) to AD was developed and mapped based on available GIS layers. A systematic monitoring protocol using these soil quality indicators can now be directed to the least resistant sites, but soil-specific soil quality standards still need to be established for triggering mitigative and preventive management practices.

Incorporating Adaptive Management and Soil Quality Models Into the Forest Service Soil Management Program

Stewards of the public's forests are compelled to manage in a way that is economically viable, environmentally sound, and socially acceptable; this is called sustainable forest management (SFM). The Montreal Process is a multi-national initiative providing policy and management tools for achieving SFM. The United States is a Montreal Process signatory and the U.S. Forest Service represents the United States on its various committees. The organization establishes criteria and indicators for monitoring the status and health of temperate forests (Montreal Process 1995). Criterion #4 calls for monitoring the level of significant soil degradation. Various monitoring methods have been proposed and tried throughout the world with varying degrees of success, but the general approach of using indicators to measure change in soil function due to forest management disturbances is central to all.

The USDA Forest Service has a long-established soil quality monitoring program (USDA Forest Service 1991) with a goal of "developing a legally defensible monitoring and evaluation program based on firm scientific principles that produces unequivocal, credible results at minimum cost." Attaining this goal is a work in progress, as it is for all land management agencies, private landowners, and third-party certification entities. Due to recent legal challenges associated with management activities within the National Forest System, the Forest Service is especially compelled to review and update its soil management program.

The current objectives of the Forest Service Soil Management program as recently amended in the Forest Service Manual (FSM 2500-2009-1) are good and should meet the spirit and letter of the authorities that govern Forest Service management, but the policies and program approach for achieving the objectives fall short of getting the job done. The current approach is essentially one of inventorying the soil resource, classifying and describing its current condition, and monitoring its condition after management activities using disturbance indicators with threshold levels that, if exceeded, indicate that the soil has been impaired. This approach has limitations: (1) it is a passive and reactive approach; (2) it requires the use of disturbance indicators that have little or no science-based cause-and-effect relationship with ecological processes and function; (3) it uses the same disturbance indicators (one size fits all) across a gradient of highly variable soils and forest ecosystem, which is not workable; and (4) experience shows that different people applying current methods on the same site produce different results and assessments. Increasingly, elements of the public are challenging this approach as being inadequate for protecting soil quality and forest productivity.

We believe a broader, proactive, adaptive management approach that would (1) explicitly define best management practices for use on NFS lands, (2) monitor their implementation and effectiveness using science-based soil quality models, and (3) continually incorporate research results into the adaptive management process via established mechanisms would better serve the soil management program and achieve the overall goal of SFM. The use of adaptive management is now policy according to the recently revised Forest Service Manual (Section 2551.02). The overall approach, objective, policy, and even the general ecological processes and functions being sustained could be common across the NFS. However, the soil and ecosystem services, the indicators of change, and soil quality models, and the interpretations of the models regarding risk and judgments of impairment and mitigation need to be region-, forest-, and soil-specific as needed, although much overlap is possible and desirable.

Using similar adaptive management approaches across Forest Service Regions, to the extent possible, would provide better credibility with the public, and it would be more efficient to share techniques, models, and protocols. Choices for the hierarchical components of adaptive management would best follow biological, not jurisdictional boundaries. In order to develop guidelines for BMPs and evaluate soil quality, the soil services in question must first be selected. These would most likely be selected at large biological and jurisdictional scales. For example, the NFS would likely choose soil productivity, protection of water quality, biodiversity, and ability to sequester or buffer C and pollutants as major soil services that differ in relative importance at smaller scales. Within each soil service, soil functions can generally be set at broad biological spatial scales, because the fundamental functions that allow soils to provide services are not specific to biological systems. To protect soil and ecosystem function, management guidelines applied as BMPs could be developed inter-regionally in many cases. Some management practices are site- and forest-specific, while others can be broadly applied across Forest Service regions.

The attributes and indicators that provide the details of soil quality modeling, however, cannot cross biological boundaries as well as they can cross jurisdictional boundaries. Sufficiency curves for a given indicator are generally forest-type specific. For example, sufficiency curves for soil productivity of upland oak-dominated forests are likely to be similar in Tennessee or Wisconsin, even though these forests are located in two separate Forest Service regions. Similarly, ponderosa pine likely has more in common with loblolly pine than with redwood. In some cases, different forest types might have more in common with respect to soil indicator sufficiency responses than site types within a forest type. Coastal Douglas-fir may respond to soil indicators more similarly to redwood than to Douglas-fir in the Rocky Mountains. The best first approximation would likely be to adapt Bailey's (1995) ecoregions for development of SQMs.

In many cases, SQMs might be developed at the province or section level, while in other cases land type association might be more appropriate. While this would require increased regional cooperation, and in some cases more local involvement, it would reduce duplicative efforts where provinces or land type associations crossed regional boundaries, and it could increase the reliability and appropriateness of an SQM. The relative importance of specific land type associations or the relative management intensity within land types would help to prioritize the scale at which SQMs would need to be developed. SQMs might be able to be developed at the province level for provinces that have few management activities or for which certain services are of less importance, while heavily managed or critical areas might require SQMs at land type association levels to ensure their effectiveness.

Compared to current use of disturbance indicators with ill-defined "impairment" thresholds, soil quality models have the potential to improve monitoring and evaluation protocols when based on the following: (1) a clear management goal is defined (*e.g.*, maintain soil and function for long-term forest productivity); (2) soil function (stability, hydrology, nutrient cycling) is monitored and evaluated using site-specific indicators based on a synthesis of research and expert opinion; (3) indicators, both disturbance and soil quality, are correlated with productivity; (4) disturbance and soil quality indicators can be uniformly used and applied by trained technicians; (5) measures of disturbance and soil quality can be weighted based on importance and areal extent and combined into a single index that is correlated with tree growth or some other measure of productivity; (6) performance standards (some score or level of the combined indicators) can be established based on pre-disturbance conditions.

Powers and others (1998) stress that SQM protocols must be operationally feasible and cost effective, and they and others (Fox 2000) have criticized soil quality models as too complicated and too costly for routine monitoring. We believe this criticism is based on a misunderstanding of effort and cost of developing the models and protocol versus applying them. The models and protocols are developed by soil scientists as relatively simple and straightforward decision-support computer programs. Soil technicians apply the field protocols and enter data for computation. We believe the extent and quality of our current research database and our ability to select good, cost-effective indicators has been underestimated. The general literature, combined with up-to-date results from LTSP trials, could serve as a source for a refined soil quality monitoring protocol. For example, several soil properties recently shown to be correlated with both disturbance and tree growth are pore size distribution, strength, extractable P, and mineralizable N. Sampling for all these properties, except strength, is no more complicated than taking a soil core sample for bulk density, and strength is measured directly in the field using a penetrometer. Testing for density, pore size distribution, N, and P are routine tests that can be done locally or via contract.

In any case, implementation protocols for Soil Quality Management policy (FSM Section 2551.03) need to be reviewed and revised to be legally defensible. For years, soil quality managers have used disturbance and soil productivity indicators in the same way that air and water quality indicators are used, yet soil quality indicators do not perform properly alone or apart from a more comprehensive soil quality assessment. Similarly, reporting monitoring results without putting them in proper context within an adaptive management program (FSM 2009: 2551.03) will likely be inefficient or counterproductive.

Soil quality cannot be defined by individual indicator threshold values the way indicators for air and water quality can be. Water quality, for example, can be defined based on whether values for temperature, oxygenation, sediment load, and various chemicals are within some defined tolerance level. Tolerance levels are easily set because the effects have been directly observed in either humans or other animals. In soils, indicators work indirectly in concert with other indicators. Soil quality indicators show the sufficiency of a combination of soil properties and processes to function toward providing a service. Sufficiency is based on a reference level (*e.g.*, pre-harvest soil condition) specific for a given soil in a given forest ecosystem.

Critics of the soil quality modeling approach for assessing soils worry about a lack of threshold values for soil quality indicators beyond which a soil is "impaired"; however, currently used threshold values for individual indicators are usually not appropriate for judging impairment because they do not have actual cause-effect relationships with soil functions. There is little or no science for establishing threshold levels for soils. By contrast, the basic science needed to create and develop first-approximation sufficiency curves for most soil functions is widely available. Sufficiency curves can be improved with additional research and monitoring over time, but the basic structure of each curve can be developed today with our current understanding of soil functions.

Soil quality models created with a set of well-selected indicators and associated sufficiency curves do not provide threshold levels. SQMs provide a scaled "score" that indicates the direction and magnitude of change in the ability of a soil to function to provide a particular service. For example, Kelting and others (1999) developed a soil quality model that used bulk density, aeration porosity, and nitrogen mineralization (indicators) to evaluate sufficiency for root growth and biological activity (soil functions). They used the SQM to evaluate the impact of wet-weather harvesting (management action) on intensively managed loblolly pine growth (soil service) in the lower coastal plain of South Carolina. The SQM was scaled to actual loblolly pine growth on these sites. The SQM could be generally adapted to most southern pine forests with imperfect drainage, but the score would need to be scaled to be site- and species-specific (*e.g.*, naturally managed longleaf pine on the flatwoods of central Louisiana).

Soil quality models also have the ability to provide much more information about soil services other than soil productivity. Because of forest management's agronomic-based background and focus on producing timber, soil scientists and forest managers have focused on soil productivity (measured as wood production: $m^3\ ha^{-1}\ yr^{-1}$). However, across the National Forest System, other soil services such as water quality protection, wildlife habitat, and carbon, nutrient and pollutant sequestration and processing are vitally important. These services are even more difficult to measure directly, and threshold values for individual indicators are probably even less useful. However, sufficiency curves and SQMs can be created for the soil functions that provide these services (Scott and others 2006), and they can be continually improved through targeted research and monitoring.

The final key to developing soil quality models is to recognize their proper place within an adaptive management program. As mentioned above, soil quality models do not provide threshold standards for individual indicators that can be applied across sites, forests and regions; they provide relative values for overall sufficiency or ability to provide a soil service that changes in response to management. Threshold values can be set for the overall change in soil quality, but not individual indicators. Because of this, soil quality models (and their indicators) do not function well as broad spatial scale monitoring tools. Rather, they work best as tools to help evaluate management impacts at the site level. They provide the ability to evaluate BMP effectiveness within adaptive management frameworks.

In summary, we believe there is ample opportunity given our current knowledge and technical skills to improve soil management in the context of adaptive management programs. Action and change are needed in order to meet the goal of legally defensible, science-based soil management that produces “unequivocal and credible results.” Required is a commitment by regional foresters and soil specialists to accept the challenge of developing sophisticated, computer-based soil quality models as part of the monitoring process. Also required is a commitment by Forest Service soil scientists to be part of the adaptive management process by providing input for the selection of soil quality indicators, development of sufficiency curves, and construction of the actual SQMs. The process of discovering “how the forest works” (creating knowledge) may be more enticing to soil scientists than applying knowledge for protecting it; but we would argue that the outcome of applying existing knowledge for a good adaptive management for the NFS is equally important and rewarding.

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The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.

Attachment 22

Excerpt from the George Washington Jefferson NF Land and Resource Management Plan

United States
Department of
Agriculture

1910
George Washington
National Forest

2010
George Washington
National Forest

Revised Land and Resource Management Plan

Forest Service | Region 8 | George Washington National Forest | R8-MB 143 A | November 2014

STANDARDS FOR 11 - RIPARIAN CORRIDORS

Standards refer to the entire riparian corridor (core and extended area) unless specified otherwise. Refer to Appendix A for slope restriction tables.

General

11-001 Any human-caused disturbances or modifications that may concentrate runoff, erode the soil, or transport sediment to the channel or waterbody are rehabilitated or mitigated to reduce or eliminate impacts. Channel stability of streams is protected during management activities.

11-002 Motorized vehicles are restricted to designated crossings. Access for motorized vehicles may be allowed on a case-by-case basis, after site-specific analysis, outside of designated crossings where it can be shown to benefit riparian resources.

11-003 Management activities expose no more than 10 percent mineral soil within the project area riparian corridor.

Aquatic Habitats within Streams and Rivers

11-004 The removal of large woody debris (pieces greater than 4 feet long and 4 inches in diameter on the small end) is allowed if it otherwise poses a risk to water quality, degrades habitat for aquatic or riparian wildlife species, impedes water recreation (e.g. rafting) or poses a threat to private property or Forest Service infrastructure (e.g. bridges). The need for removal must be determined on a case-by-case basis.

11-005 The addition of large woody debris for stream habitat diversity will generally favor stream reaches with an average bank full width of less than 30 feet in Rosgen B channel types. Log length will generally be 50% greater than bank full width. In stream reaches where there may be potential debris impacts to downstream private or public infrastructure (e.g. bridges) or to water-based recreation (e.g. rafting), the active recruitment (placement) of large woody debris will be limited in quantity and scope.

11-006 Stocking of new non-native species and stocking of previously unstocked areas is not allowed where it will negatively impact native aquatic species or communities. Prior to any stocking, national forests coordinate with the appropriate State and Federal agencies to ensure that populations and habitats of native species are maintained.

11-007 Restoration of chemical integrity of aquatic ecosystems (from impacts such as acid deposition and acid mine drainage) is allowed on a site-specific basis for protection or for restoration of aquatic species.

11-008 Instances where the flow regime is modified for other purposes (such as reservoir releases for recreational sports or hydroelectric demand), evaluate instream flow needs in accordance with the national strategy for water rights and instream flows.

11-009 In-stream habitat improvements, and stream-connected disturbances will be designed and implemented after consideration of the life-cycle requirements of at risk species or species of management concern.

11-010 In cold water stream habitats, activities that unfavorably affect trout spawning should be avoided from October 1 to April 1 in brook trout and brown trout streams and/or March 15 to May 15 in rainbow trout streams. Any necessary in-stream disturbance activities within these time limits must have consultation with state and Forest biologists.

11-011 When working in any waterbody, especially those known to have aquatic nuisance species, remove any visible mud, plants, fish or animals before transporting equipment, eliminate water from equipment before transporting, clean and dry anything that came in contact with water (boats, trailers, equipment, clothing, dogs, etc.), and never release plants, fish or animals into a body of water unless they came out of that body of water.

11-012 When working in a stream with *Didymosphenia geminta*, soak and scrub all gear for at least one minute in a 2% solution of household bleach, or if cleaning is not practical, dry equipment in the sun for at least 48 hours before using it in another stream. Fish, plants, rocks, and vegetation should not be moved between waterways.

Terrestrial Species

11-013 Existing permanent wildlife openings may be maintained within the riparian corridor. However, permanent wildlife openings identified as causing environmental degradation through concentrated runoff, soil erosion, sediment transport to the channel or water body are mitigated or closed and restored. New permanent wildlife openings within the riparian corridor are permitted where needed to provide habitat for riparian species, or threatened, endangered, sensitive, and locally rare species.

11-014 Use no-till mechanical cultivation methods for maintenance of wildlife openings.

11-015 Small patches of early successional forest may be created within the riparian corridor to provide shrubby areas with low gradient and moist soils to provide habitat for woodcock and meet a habitat need for ruffed grouse and other high priority species. This can be done through cut and leave, girdling trees to create snags, or thinning through timber harvest leaving at least 30 square feet basal area per acre; as determined by site-specific analysis. Trees within 30 feet of the waterbody must be left to maintain bank and floodplain stability.

Rare Communities

11-016 Management actions that may negatively alter the hydrologic conditions of wetland rare communities are prohibited. Such actions may include livestock grazing and construction of roads, plowed or bladed firelines, and impoundments in or near these communities. Exceptions may be made for actions designed to control undesirable impacts caused by beavers, or where needed to control fires to provide for public and employee safety and to protect adjacent private land resources. Beaver impoundments may be removed if they are negatively affecting federally listed species.

11-017 Introducing fish into wetland rare communities is prohibited.

Vegetation and Forest Health

11-018 Insect and disease control measures will be determined on the basis of risk to adjacent resources, long-term sustainability, and appropriate needs for the function and condition of the riparian area. When cutting is an appropriate control tactic, cut and leave is the preferred method for control and suppression of insects and disease in the core of the riparian corridor. Cut and remove is permitted in the extended area beyond the core. Other control measures may be used when a condition poses a risk to stream stability, degrades water quality, adversely affects habitat for aquatic or riparian species, poses a threat to public safety or facilities, or when cut and leave is not effective.

11-019 Tree removals from the core of the riparian corridor may only take place if needed to:

- Enhance the recovery of the diversity and complexity of vegetation native to the site;
- Rehabilitate both natural and human-caused disturbances;
- Provide habitat improvements for aquatic or riparian species, or threatened, endangered, sensitive, and locally rare species;
- Reduce fuel buildup;

- Provide for public safety;
- For approved facility construction/renovation; or
- As allowed in standards 11-015 and 11-024.

11-020 Tree removals from the extended area beyond the core of the riparian corridor may take place to meet the objectives of the adjacent management prescription.

Timber Management

11-021 Lands in the core of the riparian corridor are classified as not suitable for timber production. Vegetation management may be accomplished with commercial timber sales when that is the most practical or economically efficient method.

11-022 Lands in the extended area beyond the core of the riparian corridor may be suitable for timber production when the adjacent management prescription is also suitable.

11-023 When timber harvest occurs in the extended area beyond the core of the riparian corridor for purposes of meeting the objectives of the adjacent management prescription, then vehicles will be excluded from the extended area.

11-024 Corridors for cable logging in areas adjacent to the riparian corridor may cross the riparian corridor. Crossing will be at as near a right angle as possible, with full suspension preferred.

11-025 In cable logging, when full suspension is not possible, partial suspension is allowed with armoring when yarding logs across perennial and intermittent streams.

Non-timber Forest Products

11-026 Do not permit commercial collection of botanical products in the riparian corridor if it would adversely affect the functions and values of the riparian area.

11-027 Permitted firewood cutting within the riparian corridor must take into consideration large woody debris needs. Ranger Districts will identify areas where firewood cutting is not permitted due to large woody debris concerns.

Wildland Fire Management

11-028 Avoid aerial application of retardant or foam within 300 feet of waterways. Fire retardants should not be applied directly over open water.

11-029 Use existing fire barriers; such as streams, roads, trails, etc. for control lines where possible.

11-030 When necessary to construct firelines with heavy equipment (e.g. bulldozers) that cross riparian areas and streams, construct turnouts that will allow runoff to be dispersed and infiltrated into the soil before reaching the stream, and then cross stream at right angle. These firelines should be stabilized and/or revegetated as soon as possible after the fire is controlled.

11-031 Plan prescribed fires to use existing barriers, e.g. streams, lakes, wetlands, roads, and trails, to reduce the need for fireline construction.

11-032 Construction of firelines with heavy mechanized equipment (e.g. bulldozers) in riparian corridors is prohibited. Hand lines, wet lines, or black lines are used to create firelines within the riparian corridor to minimize soil disturbance. Water diversions are used to keep sediment out of streams. Firelines are not constructed in stream channels, but streams may be used as firelines.

APPENDIX A: DEFINITION OF RIPARIAN CORRIDOR

RIPARIAN CORRIDORS VERSUS RIPARIAN AREAS

Riparian Areas are functionally defined as areas with three-dimensional ecotones of interaction that include both terrestrial and aquatic ecosystems. They extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain into the water, laterally into the terrestrial ecosystem, and along the watercourse at a variable width (Ilhardt et al. 2000). A Riparian Corridor, on the other hand, is a management prescription area designed to include much of the Riparian Area. Within the riparian corridor management prescription area, management practices are specified to maintain riparian functions and values. As a management prescription area, this includes corridors along all defined perennial and intermittent stream channels that show signs of scour, and around natural ponds, lakeshores, wetlands, springs, and seeps.

DETERMINATION OF RIPARIAN CORRIDORS

Due to their spatial extent, riparian corridors are not identified on the Forest Plan map of prescription allocations. Estimated acreages of the Riparian Prescription allocations are based on the widths described in Tables in A-1 and A-2. For project planning and implementation, the following process will be used to determine the extent of site-specific riparian corridors.

Riparian corridor widths are designed to encompass the riparian area defined on the basis of soils, vegetation and hydrology and the ecological functions and values associated with the riparian area. The widths in Tables A-1 and A-2 shall be used to define the riparian corridor if the corridor is not site-specifically determined as described below.

If a site-specific field investigation determines the need to vary the widths in Table A-1 and A-2, that width shall become the project level riparian corridor. This corridor shall be determined by an interdisciplinary analysis using site-specific information to ensure that riparian values and functions are maintained.

The slope-dependent riparian corridor widths are measured in on-the-ground surface feet perpendicular from the edge of the channel or bank (stream, waterbody, etc.) and extend out from each side of a stream. For ponds, lakes, sloughs, and wetlands (including seeps or springs associated with wetlands) the measurement would start at the ordinary high water mark and go around the perimeter. For braided streams, the outermost braid will be used as the water's edge. An interrupted stream (a watercourse that goes underground and then reappears) will be treated as if the stream were above ground. (An acceptable level of error for on-the-ground measurements of these widths is ± 10%.) The riparian corridor includes human-created reservoirs, wildlife ponds, wetlands, and waterholes connected to or associated with natural water features. In addition, those areas not associated with natural water features, but support riparian flora or fauna, will have a riparian corridor designation. The riparian corridor management direction does not apply to constructed ponds developed for recreation uses; or to human-made ditches, gullies, or other features that are maintained or in the process of restoration. For these areas, site-specific analysis will determine appropriate protective measures. (See also the Forestwide Standards in Chapter 4.)

Tables A-1 and A-2 do not apply to constructed ponds developed for recreation uses; or to human-made ditches, gullies, or other features that are maintained or in the process of restoration. For these areas, site-specific analysis will determine the appropriate protective measures.

Table A-1. Riparian Corridor Minimum Widths for Perennial Streams, Lakes, Ponds, Wetlands, Springs or Seeps

Slope Class	0-10% Core Area	11-45% Core + Extended Area	45%+ Core + Extended Area
Minimum width in feet (as described above)	100	125	150*

Table A-2. Riparian Corridor Minimum Widths for Intermittent Streams

Slope Class	0-10% Core Area	11-45% Core + Extended Area	45%+ Core + Extended Area
Minimum width in feet (as described above)	50	75*	100*

* The Extended Area is the outer 25 feet (on 11-45 % slopes) and 50 feet (on 45% and greater slopes).

OVERVIEW OF RIPARIAN CORRIDORS

The figure below is a simplified representation of the Riparian Corridor that demonstrates its extension on both sides of a watercourse, down into the water table, and laterally around wetlands and other surface water sources. The Riparian Corridor may fall within or beyond the true Riparian Area.

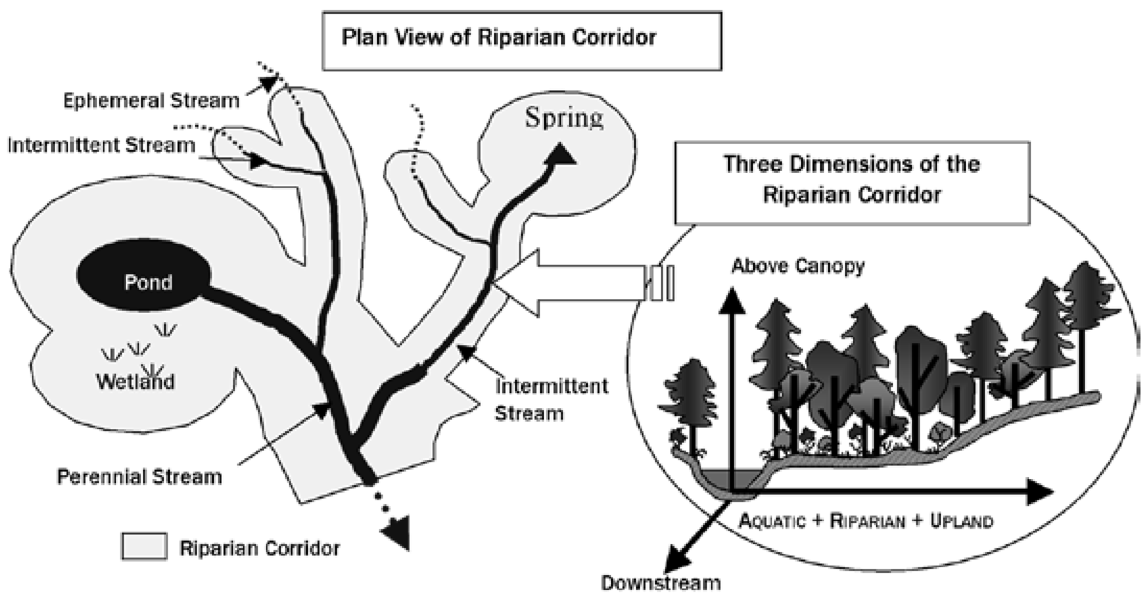


Figure A-1. Simplified Representation of a Riparian Corridor

OPERATIONAL DEFINITION FOR A RIPARIAN AREA

Riparian Areas are areas associated with the aquatic ecosystem and that portion of the terrestrial ecosystem that is substantially affected by the presence of surface and groundwater. Riparian areas consist of perennial streams, natural ponds, lakes, wetlands, and adjacent lands with soils, vegetation and landform indicative of high soil moisture or frequent flooding. Riparian areas have variable widths that are determined by ecologically significant boundaries rather than arbitrary distances. The extent of riparian areas is determined on-the-ground using features of soil, landform, and vegetation. No feature is used alone to delineate these ecosystems. Characteristics indicative of these areas are:

- Soils – dark colored Entisols, Inceptisols, and Mollisols;
- Landform – the 100-year floodplain;
- Vegetation – the presence of wetland plants classified as obligates or facultative wetland species as defined by the U.S. Fish and Wildlife Service in the National List of Plants that Occur in Wetlands: Northeast (Region 1). (Reed, P.B., Jr., 1988).

RELATIONSHIP WITH OTHER MANAGEMENT PRESCRIPTIONS

The Riparian Corridors overlap with other management prescription allocations. In order to establish precedence, the following rules apply:

Where the Riparian Corridor management prescription area overlaps with lands that have been allocated to the following Management Prescriptions, then whichever management direction is the most restrictive will apply:

- 1A or 1B – Wilderness and Recommended Wilderness Study,
- 2C2 or 2C3 – Eligible Scenic and Recreational Rivers,
- 8E7 – Shenandoah Mountain Crest
- 8E4a – Indiana Bat Primary Cave Protection Area,
- 12D - Backcountry Recreation Areas

For lands allocated to any of the other management prescriptions, where the riparian corridor overlaps with these allocations, the direction in the Riparian Corridor Management Prescription will take precedence.

RELATIONSHIP WITH BEST MANAGEMENT PRACTICES

This Forest Plan meets or exceeds State Best Management Practices. Current State BMP handbooks or manuals are incorporated as direction in the Forest Plan and are implemented for those resource management activities that are covered by the handbooks/manuals. Standards for activities not included in BMP handbooks/manuals are included in Chapter 4 of this Forest Plan.

The Streamside Management Zones (SMZ) recommended in State BMPs are designated areas directly adjacent to streams and water bodies where land management activities are controlled or regulated to primarily protect water quality and aquatic organisms from upslope land uses. Provisions within the SMZ typically contain sediment filter strips, a base shade level, restriction on ground disturbance and protection of stream banks and streambeds. As described, Riparian Corridors are management prescription areas that maintain ecological processes and functions. SMZs may be the same width or smaller than the riparian corridor, however, in some cases they may extend beyond the corridor.

RELATIONSHIP WITH CHANNELED EPHEMERAL STREAMS

Ephemeral streams do not have true riparian areas but are hydrologically connected to perennial and intermittent streams. Channeled Ephemeral Stream Zones include and are directly adjacent to all scoured ephemeral channels. Standards for the Channeled Ephemeral Zone are found in Chapter 4 of this Forest Plan. The primary purpose of this zone is to maintain the ability of the land to filter sediment from upslope disturbances while achieving the goals of the adjacent management prescription area. In addition, the emphasis along ephemeral streams is to maintain channel stability and sediment control by keeping vehicles away from stream banks and maintaining, restoring, or enhancing large woody debris. The management direction in this zone reflects the adjacent management prescription and may be modified as a result of watershed analysis.

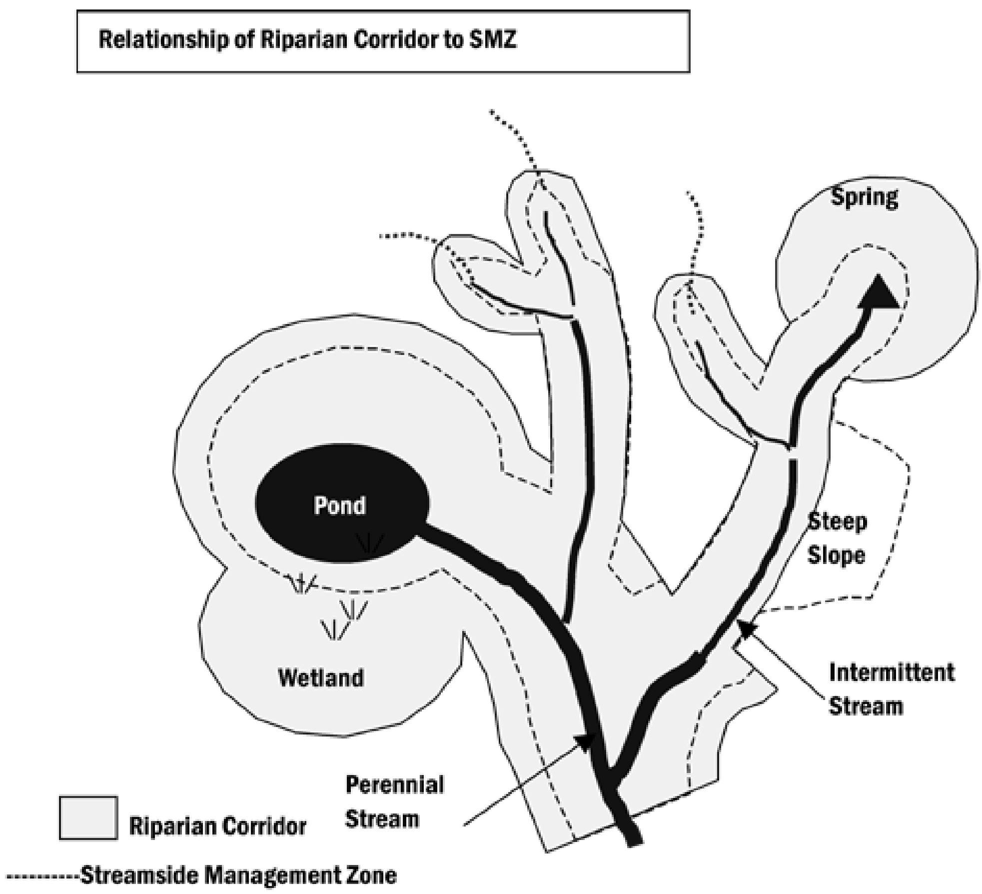


Figure A-2. Relationship of Riparian Corridor to Streamside Management Zone

Attachment 23

Excerpt from the Cherokee NF Land and Resource Management Plan

United States
Department of
Agriculture

Forest Service
Southern Region

Revised Land and Resource Management Plan

Cherokee National Forest

Management Bulletin R8-MB 114A

January, 2004

PRESCRIPTION 11 - RIPARIAN CORRIDORS: STREAMS, LAKES, WETLANDS, AND FLOODPLAINS

Estimated 126,000 Acres

Riparian areas are functionally defined as areas with three-dimensional ecotones of interaction that include both terrestrial and aquatic ecosystems. They extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain into the water, laterally into the terrestrial ecosystem, and along the watercourse at a variable width (Ilhardt, 2000). (For an operational definition of a riparian area based on soils, vegetation, and hydrologic characteristics see Appendix C.) A riparian corridor is a management prescription area designed to include all or much of the riparian area, as determined by Table 3-3 or a site-specific, interdisciplinary analysis. Within the riparian corridor management prescription area, management practices are specified to maintain riparian functions and values. As a management prescription area, this includes corridors along all defined perennial and intermittent stream channels that show signs of scour, and around natural ponds, lakeshores, wetlands, springs, and seeps. (See *APPENDIX C – RIPARIAN CORRIDORS* for a graphical representation of a riparian corridor.)

Relationship of Riparian Corridors with Streamside Filter Zones

This Plan utilizes riparian corridors and streamside filter zones (defined in Standard FW-3, p. 25) to protect/enhance riparian and aquatic resources and values. Together, these two areas comprise the streamside management zone (Figure 3-1). The riparian corridor provides water quality protection (shade and filter zone), large woody debris input and recruitment, and other physical and biological components such as the maintenance of habitat and micro-climate conditions needed for riparian and associated plant and animal species. The primary purpose of the streamside filter zone is to protect water quality and is, as a minimum, the width of the riparian corridor, but can extend to a wider zone depending upon the adjacent land slope (see **FIGURE 3-1**).

Tennessee's current best management practices (BMP's) are incorporated as direction in this LMP. A component of the BMP's are designated areas (also referred to as streamside management zones) directly adjacent to streams and water bodies where land management activities are controlled or regulated primarily to protect water quality and aquatic organisms from upslope land uses. The management standards in the LMP for the combined riparian corridor and streamside filter zone (streamside management zone) are more restrictive than Tennessee BMP's. The LMP also applies additional standards that are applicable to the riparian corridor and streamside filter zone that are not found in Tennessee's BMP's. These standards apply to non-forestry practices or uses such as recreation.

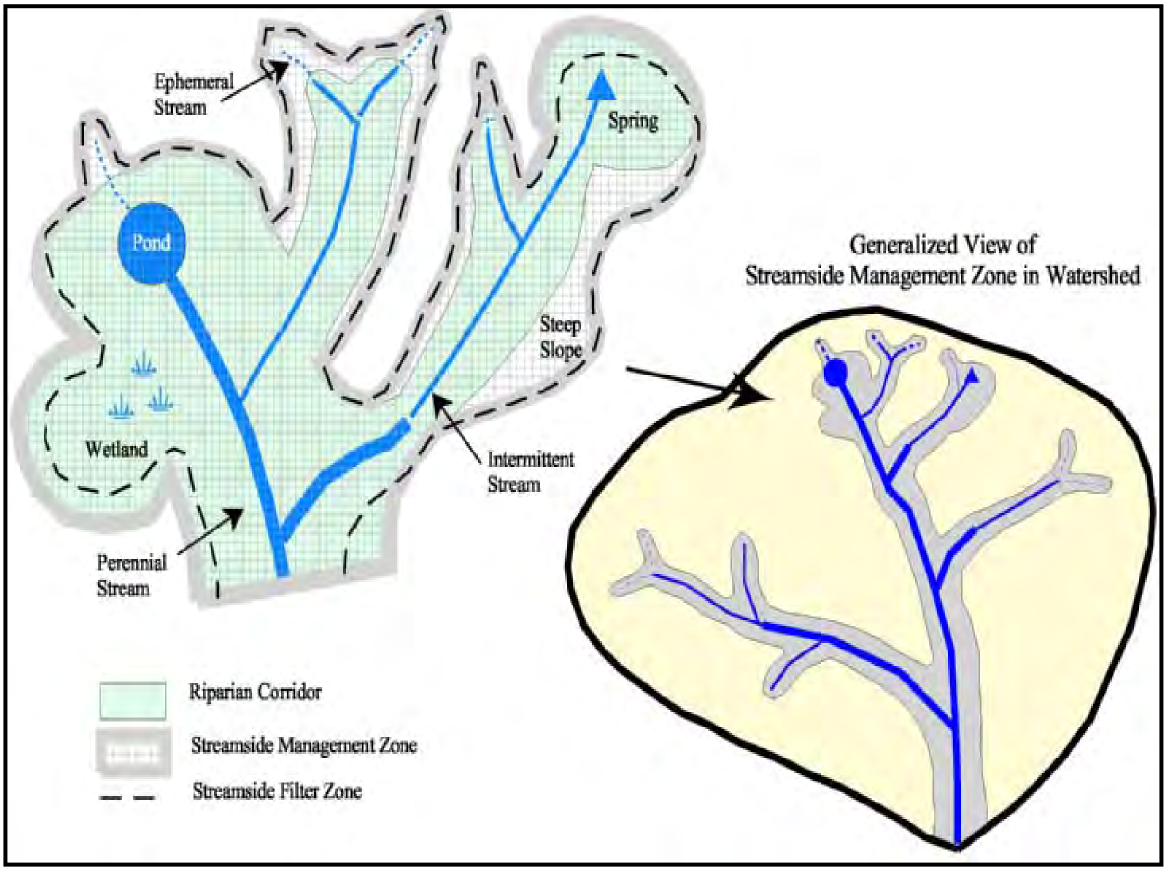


FIGURE 3-1. THE RELATIONSHIP OF THE RIPARIAN CORRIDOR/STREAMSIDE FILTER ZONE TO THE STREAMSIDE MANAGEMENT ZONE

EMPHASIS

Riparian corridors will be managed to retain, restore and/or enhance the inherent ecological processes and functions of the associated aquatic, riparian, and upland components within the corridor. Primarily, natural processes (floods, erosion, seasonal fluctuations, etc.) will modify most of the areas within the riparian corridor. However, management activities may be used to provide terrestrial or aquatic habitat improvement, favor recovery of native vegetation, control insect infestation and disease, comply with legal requirements (e.g. ESA, CWA), provide for public safety, and to meet other riparian functions and values. Silvicultural treatments including timber and vegetation removal may occur to restore and/or enhance riparian resources such as water, wildlife and natural communities.

DESIRED CONDITION

Riparian corridors reflect the physical structure, biological components, and ecological processes that sustain aquatic, riparian, and associated upland functions and values. The preferred management for riparian corridors is one that maintains, or moves toward, the restoration of

Attachment 24

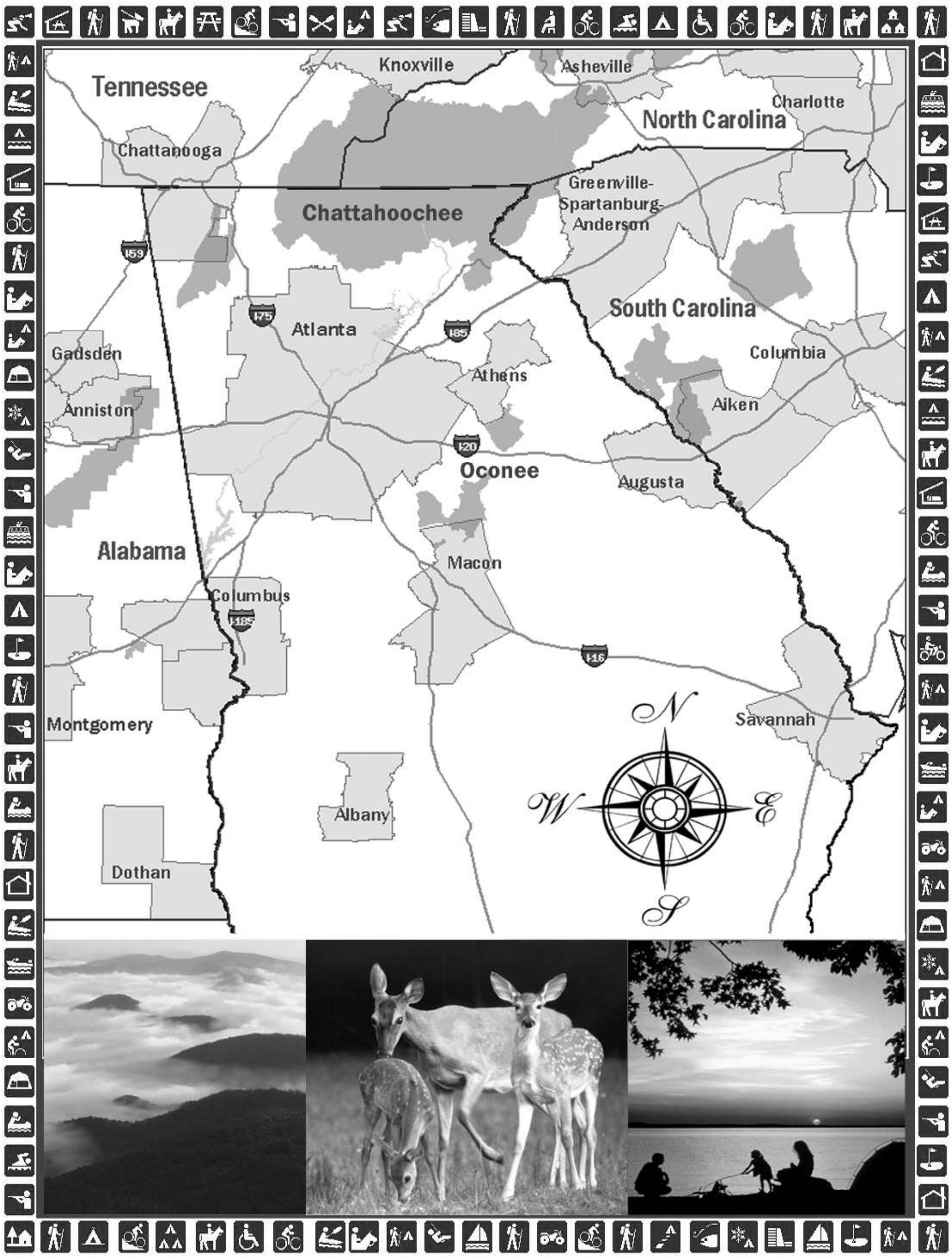
Excerpt from the Chattahoochee Oconee NF Land and Resource Management Plan

United States
Department of
Agriculture

Forest Service
Southern Region

Land and Resource Management Plan

Chattahoochee-Oconee National Forests



Management Bulletin R8-MB 113 A

January 2004

Determination of Riparian Corridors

The Riparian Corridor Prescription Area encompasses riparian areas, as well as adjacent associated upland components. A riparian area is functionally defined as a three-dimensional ecotone of interaction that includes both terrestrial and aquatic ecosystems. They extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain into the water, laterally into the terrestrial ecosystem, and along the watercourse at a variable width (Ilhardt et al. 2000). A riparian corridor, on the other hand, is a management prescription designed to include much of the riparian area. Within the riparian corridor management prescription area, management practices are specified to maintain riparian functions and values. As a management prescription area, this includes corridors along all defined perennial and intermittent stream channels that show signs of scour, and around natural ponds, lakeshores, wetlands, springs, and seeps.

An operational definition of a riparian area based on soils, vegetation and hydrologic characteristics can be found in Forest Plan Appendix C, along with a graphical representation of a Riparian Corridor.

Due to their spatial extent, riparian corridors are not identified on the Forest Plan map of prescription allocations. Estimated acreages of the Riparian Corridor allocations are based on the widths described in Tables 3-11 through 3-14. For project planning and implementation, the following process will be used to determine the extent of site-specific riparian corridors.

Riparian corridor widths are designed to encompass the riparian area defined on the basis of soils, vegetation and hydrology as described in Appendix C, and the ecological functions and values associated with the riparian area. The widths in Tables 3-11 through 3-14 shall be used to define the riparian corridor if site-specific delineation is not determined as described below.

If a site-specific field investigation determines the need to vary the widths in Tables 3-11 through 3-14, that width shall become the project level riparian corridor. This corridor shall be determined by an interdisciplinary analysis using site-specific information to ensure that riparian values and functions are maintained.

The slope-dependent Riparian Corridor widths are measured in on-the-ground surface feet perpendicular from the edge of the channel or bank (stream, water body, etc.) and extend out from each side of a stream. For ponds, lakes, sloughs, and wetlands (including seeps or springs associated with wetlands) the measurement would start at the ordinary high water mark and go around the perimeter. For braided streams, the outermost braid will be used as the water's edge. An interrupted stream (a watercourse that goes underground and then reappears) will be treated as if the stream were above ground. (An acceptable level of error for on-the-ground measurements of these widths is ± 10%.)

Portions of the corridor may extend into upland areas, outside the area with riparian vegetation. This would most likely occur in steep-sided stream valleys and headwater reaches. The riparian corridor is also delineated around human-created reservoirs, wildlife ponds, wetlands, and waterholes connected to or associated with natural water features. In addition, those areas not associated with natural water features, but supporting riparian-associated flora or fauna, will have a riparian corridor designation. The Riparian Corridor management prescription direction does not apply to constructed ponds developed for recreation uses; or to human-made ditches, gullies, or other features that are maintained or in the process of restoration. For these areas, site-specific analysis will determine the appropriate protective measures. (See also the forestwide standards in Chapter 2.)

Riparian Corridors for the Chattahoochee National Forest

The following widths are used to identify and map riparian corridors for all activities and projects on the Chattahoochee National Forest. Most of the streams on the Chattahoochee are designated as cool or cold water, and are further identified as trout watersheds by the Georgia Department of Natural Resources. These streams require protection of streams and associated riparian areas to provide optimum cool and cold water habitat.

Widths are slope distances, measured from the stream bank edge on each side of the stream. It is recognized that the actual riparian ecosystem extent may vary with the site-specific conditions and the riparian boundary may be expanded through field investigation. Individual tables are displayed for perennial streams and intermittent streams to emphasize the need for protection on these different stream types on the Chattahoochee National Forest.

Table 3- 11. Riparian Corridor Widths For Perennial Streams, Lakes, Ponds, Or Wetlands *(In Feet, Measured As Described Above)*

Physiographic Area	Slope Class		
	0-10%	11-45%	45% +
Blue Ridge Mtns, Ridge & Valley, Upper Piedmont	**100**	**125**	**150**

Table 3- 12. Riparian Corridor Widths For Intermittent Streams (In Feet,Measured as Described Above)

Physiographic Area	Slope Class		
	0-10%	11-45%	45% +
Blue Ridge Mtns, Ridge & Valley, Upper Piedmont	**100**	**125**	**150**

Riparian Corridors for the Oconee National Forest

The following widths are used for delineating riparian corridors for all activities on the Oconee National Forest. Streams on the Oconee are classified as warm water. Widths are slope distances, measured from the stream bank edge on each side of the stream. It is recognized that the actual riparian ecosystem extent may vary with the site-specific conditions and the riparian boundary may be expanded through field investigation.

Table 3- 13. Riparian Corridor Widths For Perennial Streams, Lakes, Ponds, Or Wetlands *(In Feet, Measured As Described Above)*

Physiographic Area	Slope Class		
	0-30%	31-45%	45% +
Lower Piedmont	100	125	150

Table 3- 14. Riparian Corridor Widths For Intermittent Streams (In Feet, Measured as Described Above)

Physiographic Area	Slope Class		
	0-30%	31-45%	45% +
Lower Piedmont	50	75	100

Relationship with Ephemeral Streams

Ephemeral streams do not have riparian areas, but are hydrologically connected to perennial and intermittent streams downstream. They flow only in direct response to precipitation, lack defined channels and are above the water table at all times. Some ephemeral streams exhibit evidence of scouring from storm events.

Standards for the Ephemeral Stream Zone are found in chapter 2, Forestwide Direction, of this Forest Plan. The primary purpose of this zone is to maintain the ability of the land areas to filter sediment from upslope disturbances while achieving the goals of the adjacent management prescription area. In addition, the emphasis along ephemeral streams is to maintain stream stability and sediment controls by minimizing vehicle entry into the stream bottom and maintaining, restoring, or enhancing large woody debris. The management direction in this zone reflects the adjacent management prescription and may be modified as a result of watershed analysis.

The ephemeral stream zone is identified as 25 feet on each side of an ephemeral with evidence of scouring. Scouring is described as movement of the duff or litter material on the surface due to water movement, exposing the soil below.

Relationship with Other Management Prescriptions

The Riparian Corridor management prescription is 'embedded' within each of the other management prescriptions; it does not stand alone. The Riparian Corridor prescription must be identified and considered whenever any of the other management prescriptions are to be implemented at the project/site specific level.

The Riparian Corridor overlaps with other management prescription allocations. In order to establish precedence, the following rules apply:

1. Where the Riparian Corridor management prescription area overlaps with lands that have been allocated to the following management prescriptions, the most restrictive management prescription direction will apply:

    a. 1A or 1B - Wilderness and Recommended Wilderness areas
    b. 2A or 2B - Rivers Designated in or Recommended for the Wild and Scenic System
    c. 3A - National Scenic Areas
    d. 4D and 4F - Special Areas
    e. 4H - Forest-Designated Outstandingly Remarkable Streams
    f. 9F - Rare Communities

2. For lands allocated to any of the other management prescriptions, where the riparian corridor overlaps with these allocations, the direction in the Riparian Corridor Management Prescription will take precedence.

<u>Attachment 25</u>

Analysis of Forest Road Conditions and the Impact on Water Quality and Aquatic Organisms in the Pisgah-Nantahala National Forests

Analysis of Forest Road Conditions and the Impact on Water Quality and Aquatic Organisms in the Pisgah-Nantahala National Forests

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Supervised by Sam Evans, Staff Attorney with Southern Environmental Law Center, and Hugh Irwin, Landscape Conservation Planner with The Wilderness Society

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Study Conducted May - August 2015

I. Introduction

National Forests encompass some of America's most scenic, visited, and ecologically important public lands. Unlike many public lands, however, such as National Parks, the National Forests are managed for "multiple uses," which include not only scenery, ecological values, and recreation, but also extractive uses like timber harvest. Timber production is one of the accepted uses of national forest land and is also a useful tool in ecological restoration. Timber harvest requires access for logging equipment, and it therefore usually involves road construction and maintenance. However, the ground disturbance from roads and skid trails, especially when appropriate best management practices (BMPs) are not used, installed, and maintained, can damage critical habitats, isolate populations of aquatic organisms, cause landslides and mass wasting, and pollute water systems on which humans and wildlife rely.

To combat potential detrimental environmental impacts of logging, including logging on National Forest lands, the state of North Carolina has implemented the Forest Practices Guidelines Related to Water Quality (FPGs), a set of mandatory performance standards for forest harvesting practices intended to protect aquatic resources. In order to facilitate FPG execution, North Carolina also developed a set of more specific BMPs. While BMPs are voluntary, loggers who employ the techniques outlined in BMP documents are expected to meet the performance standards in the FPGs. National Forests are operated under a "Forest Plan," which usually requires mandatory adherence to state forestry BMPs, as well as other BMPs developed by the Forest Service.

North Carolina's FPGs and BMPs apply to both private lands and the National Forests, but the impacts of logging on national forests go beyond the aquatic impacts addressed by those standards. Logging and logging roads are often in tension with recreational and ecological goals of the national forests. To the extent that national forest land managers view their job as harvesting and growing new crops of trees, they must build and maintain an extensive network of roads which sometimes reach into remote backcountry areas of the forest. These backcountry areas are generally much more healthy and undisturbed, and logging in them often introduces invasive species, causes degradation of soil resources, leads to shifts in species composition, and ultimately degrades the area as a wildlife habitat. It also interferes with backcountry recreation, a use that continues to grow in importance. This study addresses these types of impacts only indirectly, revealing that roads into sensitive backcountry areas are often inadequately constructed and maintained.

The primary focus of this study is the direct impact of national forest roads to aquatic resources. Forest roads are the most significant contributors of pollution to the mountain streams in the national forests of western North Carolina (Fulton and West 2002). As discussed herein, forest roads are not adequately maintained. In fact, the Pisgah National Forest has the funds to maintain less than 13% of its road network, resulting in a $41 million backlog in road maintenance (Pisgah National Forest Transportation Analysis Process 2012). This implies that BMPs and erosion control devices are not being routinely maintained and replaced. The implications are that failing BMPs may be allowing sediment to flow into streams, harming water quality and damaging habitat for sediment-sensitive aquatic species like trout.

Many forest road stream crossings utilize culverts that, either through neglect due to maintenance backlog or poor initial design and construction, create barriers to aquatic organism passage and/or contribute to accelerated erosion and stream sedimentation. Many of the streams originating on the national forests, and especially in backcountry areas, are designated as outstanding resource waters, water supply waters, or high quality waters. There are several characteristics of culverts that cause negative impacts, including "perching," blockages, steep grades, lack of natural substrate, inadequate size, and excessive lengths. Aquatic organisms including fish, salamanders, and macroinvertebrates are often unable to pass freely through culverts as a result of these characteristics, fragmenting habitats and populations. Furthermore, these characteristics can lead to erosion problems. For example, a steep grade increases the velocity of water flow through a culvert and, especially if the culvert is perched, can erode the bed area around the culvert outfall. Blocked or undersized culverts often lead to redirection of streamflow over the road surface and road fill, causing an increased accumulation of sediment and, occasionally, entire road washouts at the site.

The Nantahala and Pisgah National Forests have estimated that 88.5% of stream crossings on national forest system roads meet or exceed BMP requirements (NC Forest Service 2014). Research in other national forest units in the Southern Region, however, has shown a much lower compliance rate. In 2005, researchers surveyed 297 stream crossings in national forest units in four states (not including the Nantahala or Pisgah NF). Of those, 239 were considered to be barriers to aquatic passage for fish (Coffman et al. 2005). Only 36 were passable for fish, and the remaining 22 were indeterminate. In other words, almost 80% of stream crossings were not in compliance with BMPs. Furthermore, this research addressed only barriers to aquatic passage, and it did not document other types of BMP violations. A major goal of this study, therefore, was to either confirm or refute the assumption that Nantahala and Pisgah NF roads are generally in good compliance with BMPs. It would be remarkable if, with such a dramatic maintenance backlog, BMP compliance was as high as reported by the Nantahala and Pisgah NFs. Instead, we consider it more plausible that the lack of road maintenance funding has also left Forest Service staff without the resources to accurately assess the degree to which its roads are out of compliance with BMPs.

Our observations suggest that the backlog of maintenance has caused many forest roads to become impassable and riddled with BMP violations, yet they remain on the national forest's official road system. This study is intended to document the extent to which forest roads in backcountry areas are in violation of the Forest Service's BMP requirements. We focused on backcountry areas because the roads in these areas are generally closed to public use and therefore BMP failures are less likely to be addressed for public safety purposes. Our observations confirmed that BMP failures often go unremedied for years after they occur: "out of sight; out of mind." We are also mindful of the Forest Service's agency-wide emphasis on ecological restoration, which can be summarized as an initiative to use logging and other management to improve the ecological integrity of aquatic and terrestrial ecosystems. Our working assumption is that backcountry ecosystems with less history of abusive management are less likely to benefit from restoration logging and, to the extent that the Forest Service cannot afford to maintain its entire road system, it should consider divesting roads in areas where the need for logging is lowest.

The project was a joint project of The Wilderness Society and Southern Environmental Law Center. The authors of this report are two graduate students at Duke University Nicholas School of the Environment and one undergraduate student at Duke University. The authors worked with staff from The Wilderness Society and Southern Environmental Law Center on field study design, field work, and analysis. The study also brought in two water quality experts, Barry W. Sulkin and Dr. Richard Urban to help design the study and to train the interns and staff in the field methodology to be used for the study. Mr. Sulkin's long experience in water quality issues include his position as Water Quality Specialist and later as Special Projects Assistant to the Director with the Tennessee Department of Environment and Conservation. His duties in these positions dealt with issues of water quality impacts of forestry practices and implementation of BMPs including the inspection of logging sites. He also has served as state-wide manager of the Enforcement and Compliance Section for the Division of Water Pollution Control. In this capacity he was responsible for investigating and preparing enforcement cases, supervising the inspection programs and permit compliance monitoring. Dr. Urban worked also had a long career with the Tennessee Department of Environment & Conservation, Division of Water Resources, Chattanooga Field Office. Both Dr. Urban and Mr. Sulkin also have extensive experience consulting on water quality issues and BMPs. Following a one week professional training period in the field with the consultants, we conducted our road prioritization analysis. Once at risk roads were identified, the research team proceeded to survey the roads by foot in order to identify road quality issues.

II. Methods

A. Prioritization Analysis

In order to choose which roads to survey, we conducted a prioritization analysis in ArcGIS by acquiring data from different sources, including the NC Roads Analysis Project for The Wilderness Society by Ben Riegel, Ann Ingerson and Brent Martin (2011). This analysis used the system roads layer from the United States Forest Service, elevation data from the United States Geological Survey, soil data from the Natural Resources Conservation Service, precipitation data from Oregon State University, streams and water supply data from the NC State Department of Water Quality, and Natural Heritage data from the NC State Department of Environment and Natural Resources to create six erosion-potential criteria in ArcGIS.

The road risk analysis used the following criteria: 1) slope of the terrain, 2) erodibility of the soil, 3) precipitation amount, 4) road gradient, 5) proximity of the road to streams, and 6) number of stream crossings per mile. For each road and each criterion, a binary evaluation was made: high risk for each criterion received a value of one (1), and low risk received a value of zero (0). For the slopes statistic, for example, the top half of the events with the steepest slopes were noted as having high erosion risk. The same method of evaluation was used for the soil erodibility criterion, precipitation, stream proximity, and stream crossings. The road grade criterion was identified as high risk by comparing the grade to a threshold for each surface type. The total number of positive values were then calculated for each road, thus giving each system road a score of 0-6, 6 being the highest total erosion potential. In our prioritization analysis, we included roads that had erosion scores from 4 to 6. We imported the road risk layer to ArcGIS and extracted all roads with values of 4 and above and created a new layer file to use for the analysis.

The second item we considered was maintenance level. Each road in the forest system has an objective and an operational maintenance level between 1 and 5. Operational maintenance level, which is the category utilized in this study, is defined as "*the maintenance level currently assigned to a road considering today's needs, road condition, budget constraints, and environmental concerns; in other words, it defines the level to which the road is currently being* maintained." (USDA, 2005).These maintenance levels are defined as:

- ML 5 roads are the highest maintenance roads that include roads that provide a high degree of user comfort and convenience. These roads are normally but not always double-lane, paved facilities.
- ML 4 roads provide a moderate degree of user comfort and convenience at moderate travel speeds. Most ML 4 roads are double lane and aggregate surfaced.; However, some ML 4 roads may be single lane.
- ML 3 roads are open roads maintained for travel by prudent drivers in a standard passenger cars. User comfort and convenience are low priorities.
- ML 2 roads are roads suitable for high-clearance vehicles. Passenger car traffic is not a consideration. ML 2 roads in some portions of the national forest system are open roads.

However on Nantahala-Pisgah NF most ML 2 roads are closed year round. A few ML 2 roads are seasonally open.

- ML 1 roads are intermittent service roads which have been closed for longer than one year to vehicular traffic. These roads are also referred to as roads in storage. ML 1 roads can be any level of road when not closed. However, ML 1 roads on Nantahala-Pisgah are almost always very low maintenance roads that have not been used for any purpose in a long time.
(USDA, 2005)

For this analysis, we considered roads with an operational maintenance levels of 1, 2, and 3. To do this, we joined a maintenance level data table from the Forest Service with the system roads layer based on the CN number of the road. We then deleted all system roads that had a maintenance level of a 4 or 5. Because level 4 and 5 roads receive higher public use, we assumed they are more frequently maintained to protect public safety.

The third component we considered in our analysis were Mountain Treasures Areas (MTAs). The layer data for MTAs was obtained from The Wilderness Society. MTAs are areas within the Nantahala and Pisgah National Forests that are primarily wild and without passable roads. The Mountain Treasures provide the most inclusive dataset available for backcountry areas of the Nantahala and Pisgah NFs. Other potential datasets for backcountry areas include the Inventoried Roadless Areas (IRAs) delineated by the Forest Service and the Potential Wilderness Areas (PWAs or WIAs - wilderness inventory areas) which are currently being delineated to update the Forest Service's inventory of undeveloped areas. Neither of these datasets were deemed adequate. First, IRAs omit important wildland areas . Many of the Mountain Treasures areas have IRAs at their cores, but their boundaries are more inclusive than IRA boundaries and include areas not protected by the Roadless Rule. In other words, many of them have not been designated as protected and therefore remain available for timber harvest. ("North Carolina's Mountain Treasures" 2011). Yet areas outside the IRAs are certainly of similar backcountry character to the IRAs, as demonstrated by the current expansion of the PWA inventory. The WIA data is more inclusive, but it was not final when priority areas were being selected for this study. It was anticipated that most of the MTAs will be included as WIAs, and all the WIAs will be considered for possible wilderness recommendation and for other protective designation during the ongoing Forest Plan revision process (Irwin 2015). As a result, information about these areas gathered during our study is relevant and timely.

The final component we utilized in our prioritization were GIS layers on high quality waters, outstanding resource waters, and water supply waters, which we obtained as NCDENR datasets from NC One.

Using the “Intersection” tool in ArcGIS, we looked at which roads with maintenance levels 1, 2, and 3 fell within MTAs and have high erosion potential (between 4 and 6). The tool generated a list of 120 roads. These did not include roads bordering MTAs. After using the intersect tool a second time with the NC One high quality water (HQW), outstanding resource waters (ORW), and water supply waters (WSW) data it was found that 30 of the priority roads were in ORW watersheds, 31 were in HQW watersheds, 6 were in WSW watersheds, 2 were in both ORW and WSW watersheds,

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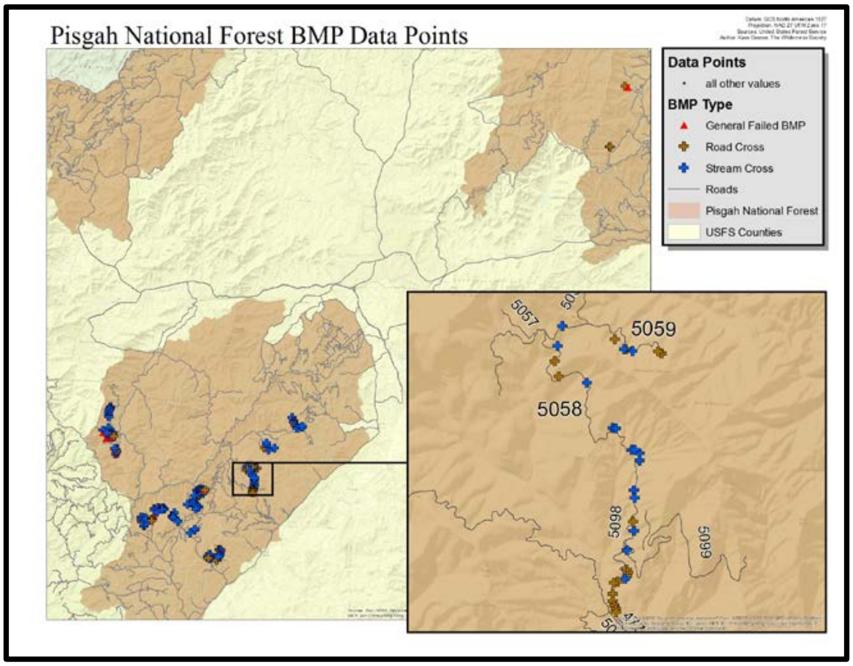


B. Data Collection

From June 1, 2015 to July 24, 2015 we collected data by foot on the priority roads. On the designated roads, each road and stream-cross culvert was examined for problems. For stream crossings, we identified perched culverts, accelerated erosion at stream crossings, and other BMP failures, such as blocked inside ditches causing road surface erosion and sediment entering streams. We focused on issues that would violate BMP requirements, and we therefore collected detailed information only for the problems that were affecting jurisdictional streams. In delineating jurisdictional streams, we followed the new definition of “waters of the United States” rule available at (“Clean Water Rule: Definition of ‘Waters of the United States’” 2015). In other words, we took detailed data for problems affecting streams with a clear bed and banks above the culvert. We took note of some other problems associated with inadequate maintenance, but the analysis provided in this study did not consider problems to be violations unless they affected jurisdictional streams. We documented four basic categories of violations: (1) barriers to aquatic organism passage, (2) undersized or obstructed culverts that are inadequate for expected flood flows, (3) accelerated erosion and/or visible sediment in stream crossings, and (4) visible sediment entering streams at locations other than stream crossings.

We included data on each road’s operational and, if available, optimal maintenance level from the Pisgah NF TAP in order to inform the GIS analysis. Additionally, the road maintenance objectives (RMO) were included. Operational maintenance level indicates the current road maintenance level with 1 being the lowest (road in storage) and 5 being the highest. RMOs essentially describe how the road is used within the forest system. Optimal Maintenance Level data were taken from the Pisgah TAP. A Nantahala TAP was not complete at the time of the study so this data was not available for Nantahala. Road condition found in the field often provided a clearer look into the true maintenance level. For example, many ML 2 roads, which by definition are “roads open to high clearance vehicles,” when surveyed were often not passable by a high clearance vehicle and, occasionally, barely passable by foot, indicating discrepancies between the operational ML and the objective and the actual conditions to which roads are being maintained. Often, these ML 2 roads appear to be treated as if they were in “storage,” with no maintenance being performed until they are used for logging access again in the future. However, these roads have not been put into storage per agency rules (by removing culverts and rehabilitating stream crossings), and our observations show that neglected stream crossings are the most likely locations of BMP violations.

We conducted further data collection for culverts that we deemed during field examination to have clear problems. For each site, we recorded the location using GPS. We also recorded a narrative describing each problem for future reference, and we collected pictures with annotations to further document the problems. The metadata for the pictures includes their GPS locations. Additional information was collected based on the type of problem we encountered.

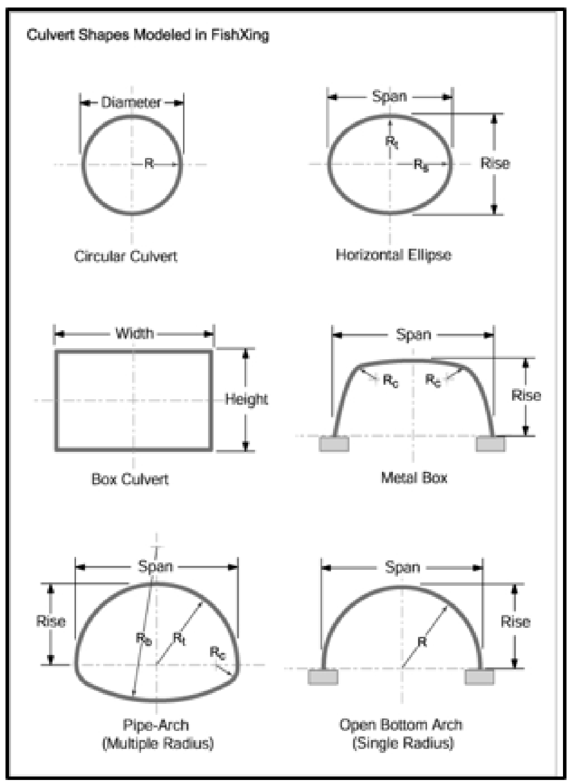
An explanation of measurements and terms used for culvert examination are as follows:

Purpose of culvert: Stream crossing or road culvert.

Stream crossings allow for the passage of a stream beneath a road. Road culverts divert water collected in an inside ditch under the road and the outfall should ideally disperse this water into foliage, rather than into or near a stream.

Type of culvert: Open bottom arch, vented ford, box, pipe arch, corrugated metal pipe (CMP)/circular (Fig. 1).

There are five common types of culverts, as listed above. CMP/circular was by far the most prevalent for both road and stream crossings. Many of the larger CMP/circular culverts were built inside of concrete stabilizers, but still lacked many ideal characteristics for aquatic organism passage.



Continuous Substrate: Substrate continuous through culvert and sediment flowing through the culvert.

The bottom of culverts should possess a substrate that mimics the natural bed of stream to enable easier organismal passage. Few culverts we examined possessed this attribute.

Length: The horizontal distance of the pipe from intake to outfall.

This measurement was taken using either a rangefinder or tape measure to ensure the horizontal distance was taken, not the “length” (hypotenuse). Taking the measurement straight down the hill would have produced a hypotenuse. Culvert length is a factor in calculating fish exhaustion factor calculated in the analysis.

Slope: The grade of the culvert in degrees.

This measurement was taken using a digital level application or “app.” Slope also contributes to fish exhaustion factor.

Fig 1. Types of culverts. http://www.fsl.orst.edu/geowater/FX3/help/Graphics/CV_type.jpg

Diameter: Diameter was recorded for all stream crossing culverts of jurisdictional streams.

Problem description: Undersized, blocked/buried, perched.

An undersized culvert could not be definitely determined in the field as it required further GIS analysis, but suspected undersized culverts were marked. A culvert was marked as potentially undersized if it appeared that pooling above the intake had occurred or there was washout over the road, both of which imply that the flow capacity of the culvert was less than required by the amount of flow it received. GIS analysis of potential undersized culverts will be discussed later on. A blocked/buried culvert could occur at the intake or outfall, and was fairly obvious to assess as the intake or outfall could not be seen or could be seen but was full of debris. Perched culverts were also easy to assess. If the bottom lip of the culvert did not touch the stream bed below, it was considered to be perched. Many culverts were perched on to fill; that is, rocks that had been placed around the culvert for stabilization. Even if these culverts touch the top of a rock fill, they were still considered perched as they did not touch the natural stream bed. Not all perched culverts are barriers to aquatic organism passage, which will be discussed in our analysis section.

Perch: For perched culverts, the height of the perch was recorded

Flow condition: Dry, isolated pools, flowing.

Flow was assessed based on its condition at the time of inspection. Even if it was clear a stream was ephemeral and would be flowing in winter, it was assessed based on its condition at the time of observation (the summer dry season).

Flow depth: For flowing streams, the average flow depth was recorded.

Streambed width: The streambed both above and below the culvert were measured. If an upstream bed was largely braided, each separate channel was measured. If the width was variable, a representative or average width was used.

Aquatic organisms observed: Aquatic organisms included fish, crayfish, salamanders, and macroinvertebrates, the most common of which were caddisflies, stoneflies, and mayflies.

For visible sediment problems, we conducted the data collection as follows:

Flow condition of receiving water: Dry, isolated pools, flowing.

This measurement referred to the water that was receiving accumulating sediment. If, for example, a road culvert was contributing visible sediment into a larger stream, it would be the flow condition of that stream that would be marked, rather than the flow condition of the water exiting the culvert.

Streambed width: The streambed width of the receiving water.

Aquatic organisms observed: Followed the same criteria as mentioned above, but examined in receiving water.

Accelerated erosion occurring where: We recorded the location where the eroded material was originating: road surface, cut slope, inside ditch, stream bank, fill, or in-channel.

Absence of ground cover and size of bare area: Bare area refers to a largely unvegetated area caused by accelerated erosion (eg. water cutting a channel, road washout, etc.) This area was measured in square feet. The roads observed were not in construction or use, and they should therefore have been stabilized with vegetation or other appropriate cover to prevent erosion.

How was visible sediment movement detected: We took note of deltas in streams, buried vegetation trails, channels to stream, observed plumes of turbid water, accelerated erosion in stream crossings (where eroded material is directly entering waters), mass soil movement into stream, and embeddedness.

Deltas in stream refer to areas in which large amounts of unnatural sediment have collected and created deltas. Buried vegetation trails are areas in which sediment movement have buried the vegetation and can be visibly followed to receiving waters. Channels to stream occur from water eroding new, unnatural paths to a stream. Plumes of turbid water are areas in which the water was clearly contained more sediment than other areas as a result of accelerated erosion. Embeddedness was not determined through pebble counts or detailed examination of substrate, but instead we roughly assessed the degree of sediment input based on whether there seemed to be much more silt/sediment below the site of accelerated erosion or culvert outfall than there was above, usually by gauging the depth of silt in pools. We often found many of these issues all occurring at a single site.

C. AOP Barrier Analysis

Aquatic organism passage is a requirement under section 404 of the Clean Water Act. Logging roads are exempt from 404 permitting requirements, but only if they provide for adequate passage (along with other BMPs) (Federal Water Pollution Control Act of 1977). If a permit is required, moreover, aquatic organism passage is generally a condition of receiving that permit (Corp of Engineers Nationwide Permit 14 2012). Blocking aquatic organism passage is therefore considered to be a violation of BMP requirements.

All types of stream crossings have the potential to negatively affect AOP (aquatic organism passage), but by far the most common type of crossing we observed was the corrugated metal pipe culvert. To determine whether a culvert was functioning as a barrier to AOP, two questions were assessed: (1) what are the relevant organisms for the stream, and (2) what thresholds (height, length, slope) would cause a culvert to block passage of those species?

We first determined which fish were relevant organisms for which streams. We focused on categories of species based on their stratified abilities to pass obstacles: trout, small fish including darters, sculpin, minnows, and juvenile trout, and salamanders. We chose these groupings of small fish based on the 2005 work of a group of graduate students at U.S. Forest Service (USFS) Aquatic Ecology Unit -- East at James Madison University, who published a set of filters to determine AOP barriers for three categories of fish: species with strong leaping capabilities, species with moderate leaping capabilities, and species with weak leaping capabilities. These simple models allow researchers and land managers to quickly assess whether a stream crossing is passable, impassable, or indeterminate (requiring further biological analysis) for representative groupings of species (Coffman et al. 2005). We added salamanders because they are also important members of aquatic communities and because salamander diversity (and, consequently, the importance of habitat protection for salamanders) is higher in this region than anywhere else in the country (Jenkins et al. 2015).

The "filters" for these species groupings are thresholds beyond which the relevant species are not expected to be able to pass. These filters are described in Appendix I.

While ditch lines and road crossings may support aquatic organisms, the purpose of this research was to assess how BMPs in jurisdictional stream crossings affected AOP. Thus, while data was collected involving road culverts, road culverts were not included in the assessment of of AOP barriers.

Filter A: Trout

Trout are not only an important indicator species for healthy water conditions within mountain streams, but the southern strain of brook trout is genetically unique to the waters of western North Carolina, providing an appropriate proxy for strong jumping fish in streams near surveyed roads (NC Wildlife Resources Commission 2015).

We had sufficient data to associate particular streams with trout habitat. We identified streams expected to support trout by first removing all dry or dripping stream crossings from consideration. We then ran Filter A for species with strong leaping capabilities to determine barrier candidates (Coffman et al 2005). Filter A uses the following decision tree:

1. A culvert with continuous substrate is considered passable by adult trout. If it lacks continuous substrate:
2. An outlet drop less than 24 inches is passable. If higher;
3. A slope of less than 7% is passable. If steeper;
4. A slope x length of less than or equal to 50 is passable. More than or equal to 600 is impassable, and 50-600 is deemed indeterminate.

In other words, Filter A was used to determine which stream crossings would be barriers to trout (if trout were present). We then took the potential trout barriers and compared them to the NC Wildlife Resource Commission Public Mountain Trout Waters GIS data. The barrier candidates that fell in trout waters were marked; the rest were discarded.

Finally, we visually confirmed that any culverts marked passable or indeterminate were passable by fish (i.e.- not blocked, buried, or flowing onto rocks) by reviewing pictures of those sites.

Filters B and C: Designation of Darters, Sculpin, Minnows, and Juvenile Trout as Fish Proxies

These fish were largely chosen because of their use in the Coffman et al. 2005 study, providing a basis for data comparison. Minnows and darter species were chosen as a proxy for small fish within the streams of western North Carolina because of their specific habitat range and frequency within the types of streams examined in this study, representing more than 70% of southeastern freshwater fish diversity (Warren et al. 2000). Additionally, these species account for "65% of the imperiled fish taxa in the Southeast" (Warren et al. 2000). Minnows, furthermore, are an important part of the food web of freshwater ecosystems (Lee et al. 1994). While there is insufficient data to specifically associate these species to the stream segments we surveyed, we were able to identify which streams are likely to support these fish or other fish with similar habitat requirements by using a minimum flow depth as a proxy (4 inches).

These small fish are broken into two groupings with associated thresholds or "filters" to determine whether passage is possible: Filter B (minnows and Juvenile trout) applies the thresholds for species with "moderate" ability to pass obstacles, while Filter C (darters and sculpins) applies the thresholds for "weak" swimmers and leapers (Coffman et al. 2005).

Filter B: Minnows and Juvenile Trout

We first removed all dry or dripping stream crossings from consideration. We then further removed all streams that were not observed with at least 4 inches of flow, because these were the streams deemed suitable for small fish. We considered the observed flow depth to be a minimum flow depth for the surveyed streams, because we took data during the summer dry season. The "Region 1 Fish Passage Evaluation Criteria" (Pacificorp 2008) outlines a literature review of suggested minimum flow depths for fish passage, and recommends a minimum flow depth of 4 inches for juvenile trout passage as a conservative average of previous studies. So, we only considered streams with at least 4 inches of average flow as candidates for barriers for minnows and juvenile trout.

We then ran Filter B for species with moderate leaping capabilities to determine whether the stream crossings would act as a barrier (Coffman et al. 2005):

1. A culvert with continuous substrate is considered passable by minnows and juvenile trout. If it lacks continuous substrate:
2. An outlet drop less than 10 inches is passable. If higher;
3. A slope of less than 3.5% is passable. If steeper;
4. A slope x length of less than or equal to 25 is passable. More than or equal to 200 is impassable, and 25-200 is deemed indeterminate.

Finally, we visually confirmed that any culverts marked passable or indeterminate were passable by fish (i.e.- not blocked, buried, or flowing onto rocks) by reviewing pictures of those sites.

Filter C: Darters and Sculpins

We first removed all dry or dripping stream crossings from consideration. We then further removed all streams that were not observed with at least 4 inches of flow, because these were the streams deemed suitable for small fish. We considered the observed flow depth to be a minimum flow depth for the surveyed streams, because we took data during the summer dry season. Dewey (2008) recommends 0.1 meter (3.9 inches) as a minimum flow depth for Sculpin passage, so we considered only streams with at least 4 inches of average flow as suitable habitat for Darters and Sculpins.

We then ran Filter C to determine whether the stream crossings were barriers for species with weak leaping capabilities (Coffman et al. 2005):

1. A culvert with continuous substrate is considered passable by darters and sculpins. If it lacks continuous substrate:
2. An outlet drop less than 4 inches is passable. If higher;
3. A slope of less than 3.5% is passable. If steeper;
4. A slope x length of less than or equal to 15 is passable. More than or equal to 150 is impassable, and 15-150 is deemed indeterminate.

Finally, we visually confirmed that any culverts marked passable or indeterminate were passable by fish (i.e.- not blocked, buried, or flowing onto rocks) by reviewing pictures of those sites.

Salamanders

The Blue Ridge Mountains are a hotspot of amphibian diversity, with many endemic species, and the region containing the Nantahala and Pisgah NFs "is a major priority for [conserving habitat for] amphibians, mainly because of salamanders" (Jenkins, et al. 2015). Even well-functioning culverts that allow passage for most species are often passage barriers to salamanders, causing habitat fragmentation and posing serious risks to salamander populations. First, we narrowed salamander passage barrier candidates to culverted stream crossings that were flowing at the time of the survey. This is considered to conservatively limit the number of passage barriers, because salamanders occur in ephemeral stream habitats, too. As a qualitative observation, however, nearly all ephemeral stream crossings we observed would have been barriers to salamander passage because of high vertical drop (perch). Indeed, the ephemeral stream culverts were often the highest perched because they occur on steeper terrain.

In flowing streams, we used the criteria outlined in the Anderson et al. 2014 study to test for salamander passage.

1.Does the culvert have continuous substrate?

2.If so, is the culvert perched no more than 0.1m?

If the culvert fails either question, it is a barrier to salamander passage upstream.

D. NC FGP Violations in Stream Crossings

The North Carolina FPGs provide the following requirements for stream crossings (15A NCAC 01I .0203):

> Stream crossings shall be avoided when possible. Access roads and skid trails which must cross intermittent or perennial streams or perennial waterbodies shall be constructed so as to minimize the amount of sediment that enters the streams because of the construction. These crossings shall be installed so that:
>
> (1) stream flow will not be obstructed or impeded;
>
> (2) no stream channel or perennial waterbody shall be used as an access road or skid trail;
>
> (3) crossings are provided with effective structures or ground cover to protect the banks and channel from accelerated erosion;

(4) they shall have sufficient water control devices to collect and divert surface flow from the access road or skid trail into undisturbed areas or other control structures to restrain accelerated erosion and prevent visible sediment from entering intermittent and perennial streams; and
(5) ground cover, or other means, sufficient to prevent visible sediment from entering intermittent and perennial streams and perennial waterbodies shall be provided within ten working days of initial disturbance and will be maintained until the site is permanently stabilized.

North Carolina law also prohibits other impacts, such as obstruction by logging debris. NCGS 77-13; 77-14.

A stream crossing was determined to violate the NC FPGs if:
1.The receiving stream was at least intermittent (ie- flowing at the time of study); and
2. There was accelerated erosion in the stream crossing itself or there was accelerated erosion elsewhere (outside the stream crossing) but with visible sediment entering the stream.

E. Obstruction of flow

Similar to allowing for adequate aquatic organism passage, a stream crossing is eligible for the logging exemption under the clean water act only if it provides for adequate flow for expected storm events (NCGS 77-13; 77-14). This is an issue both of culvert installation (i.e. installing a big enough culvert) and maintenance. If roads are not maintained, culvert intakes can easily become blocked and therefore are unable to function and accommodate storm flows. We considered a culvert to be a flow obstruction violation if it was undersized (discussed later on) or if it was blocked to the degree that it would not accommodate heavy flows. Often, blocked culverts were already showing the effects of the blockage during storms because the road surface was being eroded when the culvert overflowed.

See Appendix II for examples of FGP Violations in Stream Crossings.

E. FPG Failures in Other Places

While FPG failures most often occur in stream crossings, they can also occur when a non-stream BMP causes harm to a nearby stream.

See Appendix III for examples of FGP Violations in locations other than stream crossings.

F. Other BMP Failures

Some culverts do not violate the FPGs but still cause serious problems for their surroundings. In addition, while FPG violations are largely restricted to streams that are intermittent or perennial, we marked BMP failures regardless of flow. We marked the following issues as BMP failures (North Carolina Forestry Best Practices Manual 2006).

- The inside ditch line flows into a stream crossing.
- The outlet of a runoff culvert flows into a stream.
- Use of open top drains or trenches to control runoff.
- Failure of an erosion control BMP.
- The BMP causes accelerated erosion.
- Lack of a BMP (e.g.- a stream crosses and erodes the road because there is no BMP).
- Use of check dams in a jurisdictional stream.
- Overflow as a result of an undersized or blocked culvert.
- Blocked and buried culverts.

See Appendix IV for examples of other BMP failures.

III. Results

In total, 45 roads were surveyed. While we were not able to survey all 120 prioritized roads, we did visit all road maintenance levels and roads in all districts of the Nantahala and Pisgah National Forests. Additionally, there were several instances where we added roads to our priority list ad hoc. This occurred for several reasons: a need to walk a gated road to reach a prioritized road, roads on the border or between Mountain Treasures areas, or personal knowledge or interest of TWS and SELC staff. Of these 45 roads, 8 were in Outstanding Resource Waters/Water Supply Water zones, 16 were in high quality water zones, 5 were in water supply water zones, 8 were in outstanding resource water areas, and 10 were in general water quality standard zones. Water quality standard zones "define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provision such as anti-degradation policies to protect waterbodies from pollutants" (Water Quality Standards for Surface Water 2014).

On the 45 roads surveyed, we took data at 438 culverts and 67 BMP sites--a total of 505 sites.

	Total # of Candidates	Total Violations	%
FPGs	322	127	40.4%
Other BMPs	505	314	62.2%
Total	505	441	87.3%

Of those 505 sites, 322 affected streams that were at least intermittent, making them candidates for FPG violations. We considered streams to be at least intermittent if they were flowing at the time of observation, because we observed them during the summer dry season. (At the time of this writing, many counties in the region are considered to be in “moderate drought” because of low rainfall during the survey period.) Of the 322 candidates, 127, or approximately 40% constituted a violation of the North Carolina Performance Standards, with accelerated erosion in a stream crossing of an intermittent or perennial stream or visible sediment directly entering an intermittent or perennial stream. These violations are compromising the quality of the water and causing potential harm to aquatic biota. The majority of these violations occurred at stream crossings, with erosion commonly resulting from a perched culvert outfall. Furthermore, many culverts blocked or buried at the intake created an overflow of the upstream area, causing water to flow over the road and carry road and fill sediment downstream. Many areas that needed a culvert either did not have one, the culvert was malfunctioning (broken, crushed), or had been taken out without re-establishing natural stream channels.

BMP failures do not necessarily cause FPG violations, at least not immediately. BMP violations left unaddressed, however, are more likely to cause FPG violations in the future. Violations can include cutslope failures, inside ditch blockages, lack of inside ditch-line, erosion control failures, and issues regarding the placement of roads and the locations of BMPs. 314, or 62%, of the total sites surveyed contained BMP failures that did not currently constitute FPG violations. Many of these BMP failures involved visible sediment or eroded channels leaving the road surface and traveling downslope, but visible sediment was not detected entering streams because the streams were far enough away from the problem.

General Data Info						
Data Type	Total # points	Functioning Properly	# Problems	No Culvert	Culvert Problems	Vis. Sediment Problems
Road Crosses	98	6	92	24	16	8
Stream Crosses	340	50	290	56	192	55
Failed BMP's	57	N/A	42	N/A	N/A	2
Totals	**495**	**56**	**368**	**80**	**208**	**65**

Culvert Problems						
Data Type	Total #	Blocked/Buried	Perched	Flowing & Perched	Undersized (diameter)	Crushed
Road Crosses	71	29	38	13	0	1
Stream Crosses	216	23	189	172	8	1
Totals	**287**	**52**	**227**	**185**	**8**	**2**

Visible Sediment & Accelerated Erosion								
Data Type	**Total #**	**Flowing**	**Accelerated Erosion from Road**	**Embeddedness**	**ORW**	**HQW**	**WSW**	**ORW/WSW**
Road Crosses	8	7	2	4	6	3	0	2
Stream Crosses	90	52	27	34	9	40	10	4
Failed BMP's	15	2	2	1	1	1	0	5
Totals	**113**	**61**	**31**	**39**	**16**	**44**	**10**	**11**

Another factor that often contributed to visible sediment entering a stream was if the inside road ditch was draining directly into the stream crossing, which expressly does not meet with the North Carolina BMPs. Finally, a common issue occurred when the inside ditch was either blocked or there was no inside ditch or other design features to control runoff, forcing cut slope runoff to flow over the road and create a downhill erosion gully that many times led directly to a stream. Two common causes were observed for roads without an inside ditch: some roads appeared to be old temporary roads that did not have inside ditches installed in the first place, and some roads appeared to have had functioning inside ditches at one time, but slumping of the upslope fill had blocked the ditch.

Although it is difficult to quantify because our biotic surveys were not comprehensive, we did find that sediment accumulation in streams has an observable impact on the presence of benthic macroinvertebrates. Macroinvertebrates are essential to freshwater stream ecosystems and exist as a fundamental aspect of the food web. Macroinvertebrates are ubiquitous in mountain streams but highly sensitive to both point and nonpoint source pollution. Therefore, the presence of macroinvertebrates in mountain streams is an excellent indicator of stream health. We failed to find any aquatic organisms at 55 out of 194 culverted, flowing stream crossings, a failure rate of 28%. These were often streams with a high level of embeddedness.

AOP Barriers

	# of barrier candidates	# of barriers	# of passable culverts	% passage
Salamanders	192	164	28	14.5%
Darter and Sculpin	22	22	0	0%
Minnow and Juvenile Trout	22	22	0	0%
Trout	37	24	13	35.1%

Western North Carolina's streams may be famous for trout fishing, but they also provide critical habitats for many other kinds of aquatic organisms. To assess small fish passage, we only considered streams with at least 4 inches of flow to be candidates for small fish passage barriers because that was our designated minimum flow depth. Of 22 stream crossings with at least 4 inches of flow, one of the culverts had continuous substrate throughout, which usually signals that the culvert is passable, but the outflow fell onto rocks. Fish need a pool of water in order to initiate a leap. Of the 21 remaining candidates, none had a perch of 4 inches or less, making all potential candidates impassible by darters and sculpin. Of the 9 culverts that had a perch of 10 inches or less (the passable height for minnows and juvenile trout), all failed the 3.5% maximum slope. That constitutes a 100% failure rate for small fish.

The relatively high passage rate of crossing in Brook Trout waters (35%) may be an indication of prioritization of trout waters in ecosystem management. Smaller fish, however, are highly affected by the placement of culverts, with no culverts allowing for passage of darters, sculpins, minnow, and juvenile trout. Salamanders fell in the middle, with a passage allowance of 14%.

Undersized Culverts

We took data on culvert size and location for all stream crossings, even where the culvert was functioning without causing accelerated erosion and where it was not perched. Several culverts were identified as likely being undersized, but this was not confirmed by analysis. These data should be analyzed in the future to determine, based on upstream acreage, whether the culvert is adequately sized to provide for expected storm flows. Storm flows can cause tremendous damage quickly at stream crossings. We observed several crossings where it was evident that a storm had overwhelmed the culvert's capacity causing major washouts. In addition, although we noted that many culverts were fully or partially obstructed, we did not analyze the impact of these obstructions on flow capacity. Obstructed culverts, however, are more likely to cause problems during storm flows even if they were adequately sized when they were installed, and they should receive maintenance so that they do not result in resource damage.

IV. Discussion

> "High-quality water is one of the most important natural resources coming from the national forests and grasslands. National Forest System (NFS) lands, which represent about 8 percent of the land area of the contiguous United States, contribute 18 percent of the Nation's water supply (Brown et al. 2008; Sedell et al. 2000). About 124 million people rely on NFS lands as the primary source of their drinking water (USDA Forest Service 2008a). In addition to drinking water and other municipal needs, water on NFS lands is important to sustaining populations of fish and wildlife, providing various recreation opportunities, and providing supplies to meet agricultural and industrial needs across the country" (USDA 2012).

The Forest Practices Guidelines Related to Water Quality are a set of laws designed to preserve the quality of our natural resources and protect wildlife within our national forest land, specifically fresh-water resources and aquatic organisms. Failure to comply with these FPG standards results in the degradation of our natural resources and wildlife habitat. Of the 322 flowing, jurisdictional streams surveyed, 127 (40%) were found to be FPG violations. We found seven more violations in non-stream crossings. Aquatic organism passage is also very important throughout aquatic systems, because small streams provide the food organisms for species downstream, upstream movement is needed for spawning, and interconnectivity is important to recolonize areas after disturbances (Coffman et al. 2005). Nearly all the stream crossings we surveyed would have been barriers to passage for at least some aquatic organisms.

Our research and analysis refutes the Forest Service's estimate that 88.5% of stream crossings meet or exceed BMP standards. For (1) low maintenance level roads (2) with high risk factors for BMP failure (3) in or near backcountry areas, our study shows that very few stream crossings are in compliance with BMPs. The stream crossings most likely to be compliant are on perennial trout streams where bridging is used rather than culverting. Stream crossings on smaller streams and stream crossings with pipe culverts are the most likely to be out of compliance.

Conclusions

The roads in our survey were all closed to the public, they are mainly dead-ends not providing network connections, and they often go deep into remote areas where there is no motorized traffic. These roads are often not in passable condition. The Forest Service lacks the budget to maintain all of its roads, and neglect of these roads in particular is causing demonstrable, systematic degradation of aquatic resources. Neglected stream crossings, in particular, are the sites most likely to function as AOP barriers or sources of sediment. Under agency rules, placing roads into storage or decommissioning them while stabilizing and addressing problem areas. would address these issues at stream crossings. Proper maintenance and replacement of problematic culverts would also address these issues, but the Forest Service's budget is inadequate. It is therefore the conclusion of this study's authors that these roads should be considered for placing in storage or decommissioning.

Recommendations for Further Study

As noted in this report, we did not perform a comprehensive biotic survey at each stream crossing because of time constraints. We cannot therefore confirm which streams are in fact providing habitat for which species. Without detailed species data, our use of flow depth as a proxy to determine which fish were relevant species for a particular crossing was a necessary first approximation for the fish crossing assessment. We reviewed many sources, compared FishXing data, and chose a 4 inch minimum flow depth for small fish as a reasonable standard based on credible studies. Furthermore, the streams with 4 inches of flow during the summer dry season are likely to have considerably more flow during wetter seasons. Streams with 4 inches or greater of flow are expected to provide suitable habitat for at least some small fish, and Filters B and C, for smaller fish with weak and moderate passage abilities, should provide a useful gauge of which streams are in fact obstructing aquatic passage for small fish. The criteria used actually provide a conservative screen for fish passage barriers, and most failures significantly exceeded these criteria.

A more detailed field survey than that conducted could certainly be envisioned. A survey incorporating a detailed biotic survey component would add more specificity to the organisms identified that are being blocked by aquatic organism barriers. We were surprised that there was very little data available documenting the aquatic species that use specific stream segments, except for trout stream stretches. This aquatic organism use of Forest Service streams is essential information for maintaining and restoring aquatic organism habitat and passage and should be the focus of future research and monitoring efforts.

A more comprehensive survey could also be envisioned that documents the conditions of more roads and more road stream crossings. These surveys could be useful in better quantifying the extent of the BMP failures across all Forest Service system roads and prioritizing the maintenance and remediation of the issues identified. However, the road problems identified in this field survey point to pervasive and urgent issues on many Forest Service roads that should be addressed as soon as possible. More detailed surveys of road conditions involving all roads would seem to be most appropriate as a part of regular road monitoring and maintenance efforts on an ongoing basis.

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Attachment 26

Climate Change 2021: The Physical Science Basis Summary for Lawmakers

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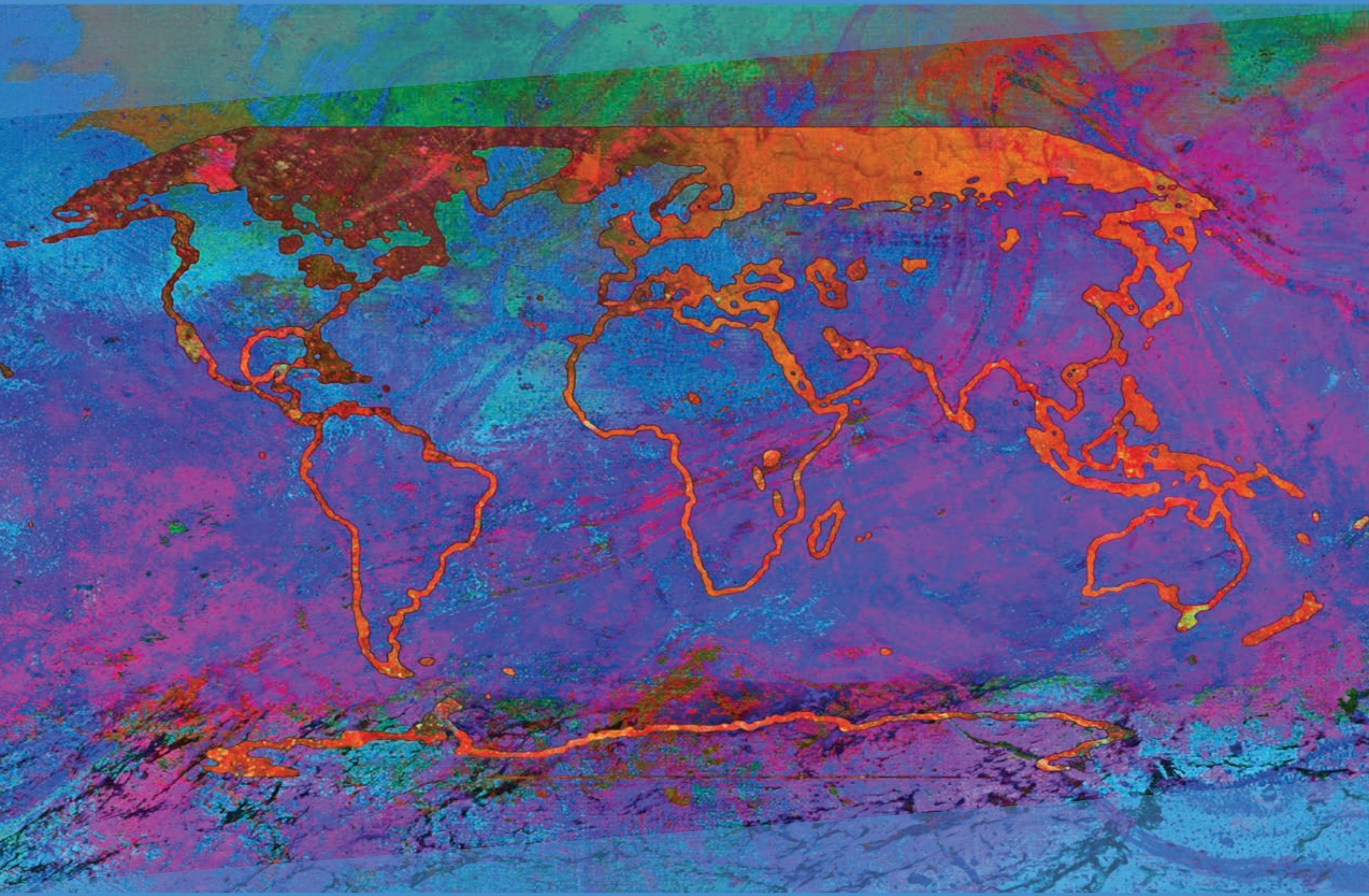
Climate Change 2021
The Physical Science Basis
Summary for Policymakers



WGI

Working Group I Contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

WMO UNEP

Climate Change 2021
The Physical Science Basis

Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

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Summary for Policymakers

SPM

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Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group I (WGI) contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)[1] on the physical science basis of climate change. The report builds upon the 2013 Working Group I contribution to the IPCC's Fifth Assessment Report (AR5) and the 2018–2019 IPCC Special Reports[2] of the AR6 cycle and incorporates subsequent new evidence from climate science.[3]

This SPM provides a high-level summary of the understanding of the current state of the climate, including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change.

Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence indicated using the IPCC calibrated language.[4]

The scientific basis for each key finding is found in chapter sections of the main Report and in the integrated synthesis presented in the Technical Summary (hereafter TS), and is indicated in curly brackets. The AR6 WGI Interactive Atlas facilitates exploration of these key synthesis findings, and supporting climate change information, across the WGI reference regions.[5]

A. The Current State of the Climate

Since AR5, improvements in observationally based estimates and information from paleoclimate archives provide a comprehensive view of each component of the climate system and its changes to date. New climate model simulations, new analyses, and methods combining multiple lines of evidence lead to improved understanding of human influence on a wider range of climate variables, including weather and climate extremes. The time periods considered throughout this section depend upon the availability of observational products, paleoclimate archives and peer-reviewed studies.

A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.
{2.2, 2.3, Cross-Chapter Box 2.3, 3.3, 3.4, 3.5, 3.6, 3.8, 5.2, 5.3, 6.4, 7.3, 8.3, 9.2, 9.3, 9.5, 9.6, Cross-Chapter Box 9.1} (Figure SPM.1, Figure SPM.2)

A.1.1 Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2), 1866 parts per billion (ppb) for methane (CH_4), and 332 ppb for nitrous oxide (N_2O) in 2019.[6] Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO_2 emissions from human activities over the past six decades, with regional differences (*high confidence*).[7]
{2.2, 5.2, 7.3, TS.2.2, Box TS.5}

1 Decision IPCC/XLVI-2.

2 The three Special Reports are: Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5); Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL); IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC).

3 The assessment covers scientific literature accepted for publication by 31 January 2021.

4 Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or result: virtually certain 99–100% probability; very likely 90–100%; likely 66–100%; about as likely as not 33–66%; unlikely 0–33%; very unlikely 0–10%; and exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%; more likely than not >50–100%; and extremely unlikely 0–5%) are also used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5. In this Report, unless stated otherwise, square brackets [x to y] are used to provide the assessed *very likely* range, or 90% interval.

5 The Interactive Atlas is available at https://interactive-atlas.ipcc.ch

6 Other GHG concentrations in 2019 were: perfluorocarbons (PFCs) – 109 parts per trillion (ppt) CF_4 equivalent; sulphur hexafluoride (SF_6) – 10 ppt; nitrogen trifluoride (NF_3) – 2 ppt; hydrofluorocarbons (HFCs) – 237 ppt HFC-134a equivalent; other Montreal Protocol gases (mainly chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)) – 1032 ppt CFC-12 equivalent). Increases from 2011 are 19 ppm for CO_2, 63 ppb for CH_4 and 8 ppb for N_2O.

7 Land and ocean are not substantial sinks for other GHGs.

A.1.2 Each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature[8] in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C higher than 1850–1900.[9] Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C). The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C). Additionally, methodological advances and new datasets contributed approximately 0.1°C to the updated estimate of warming in AR6.[10]
{2.3, Cross-Chapter Box 2.3} (Figure SPM.1)

A.1.3 The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019[11] is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver[12] of tropospheric warming since 1979 and *extremely likely* that human-caused stratospheric ozone depletion was the main driver of cooling of the lower stratosphere between 1979 and the mid-1990s.
{3.3, 6.4, 7.3, TS.2.3, Cross-Section Box TS.1} (Figure SPM.2)

A.1.4 Globally averaged precipitation over land has *likely* increased since 1950, with a faster rate of increase since the 1980s (*medium confidence*). It is *likely* that human influence contributed to the pattern of observed precipitation changes since the mid-20th century and *extremely likely* that human influence contributed to the pattern of observed changes in near-surface ocean salinity. Mid-latitude storm tracks have *likely* shifted poleward in both hemispheres since the 1980s, with marked seasonality in trends (*medium confidence*). For the Southern Hemisphere, human influence *very likely* contributed to the poleward shift of the closely related extratropical jet in austral summer.
{2.3, 3.3, 8.3, 9.2, TS.2.3, TS.2.4, Box TS.6}

A.1.5 Human influence is *very likely* the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (decreases of about 40% in September and about 10% in March). There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability. Human influence *very likely* contributed to the decrease in Northern Hemisphere spring snow cover since 1950. It is *very likely* that human influence has contributed to the observed surface melting of the Greenland Ice Sheet over the past two decades, but there is only *limited evidence*, with *medium agreement*, of human influence on the Antarctic Ice Sheet mass loss.
{2.3, 3.4, 8.3, 9.3, 9.5, TS.2.5}

A.1.6 It is *virtually certain* that the global upper ocean (0–700 m) has warmed since the 1970s and *extremely likely* that human influence is the main driver. It is *virtually certain* that human-caused CO_2 emissions are the main driver of current global acidification of the surface open ocean. There is *high confidence* that oxygen levels have dropped in many upper ocean regions since the mid-20th century and *medium confidence* that human influence contributed to this drop.
{2.3, 3.5, 3.6, 5.3, 9.2, TS.2.4}

A.1.7 Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea level rise was 1.3 [0.6 to 2.1] mm yr^{-1} between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018 (*high confidence*). Human influence was *very likely* the main driver of these increases since at least 1971.
{2.3, 3.5, 9.6, Cross-Chapter Box 9.1, Box TS.4}

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8 The term 'global surface temperature' is used in reference to both global mean surface temperature and global surface air temperature throughout this SPM. Changes in these quantities are assessed with *high confidence* to differ by at most 10% from one another, but conflicting lines of evidence lead to *low confidence* in the sign (direction) of any difference in long-term trend. {Cross-Section Box TS.1}

9 The period 1850–1900 represents the earliest period of sufficiently globally complete observations to estimate global surface temperature and, consistent with AR5 and SR1.5, is used as an approximation for pre-industrial conditions.

10 Since AR5, methodological advances and new datasets have provided a more complete spatial representation of changes in surface temperature, including in the Arctic. These and other improvements have also increased the estimate of global surface temperature change by approximately 0.1°C, but this increase does not represent additional physical warming since AR5.

11 The period distinction with A.1.2 arises because the attribution studies consider this slightly earlier period. The observed warming to 2010–2019 is 1.06 [0.88 to 1.21] °C.

12 Throughout this SPM, 'main driver' means responsible for more than 50% of the change.

A.1.8 Changes in the land biosphere since 1970 are consistent with global warming: climate zones have shifted poleward in both hemispheres, and the growing season has on average lengthened by up to two days per decade since the 1950s in the Northern Hemisphere extratropics (*high confidence*).
{2.3, TS.2.6}

Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850–1900

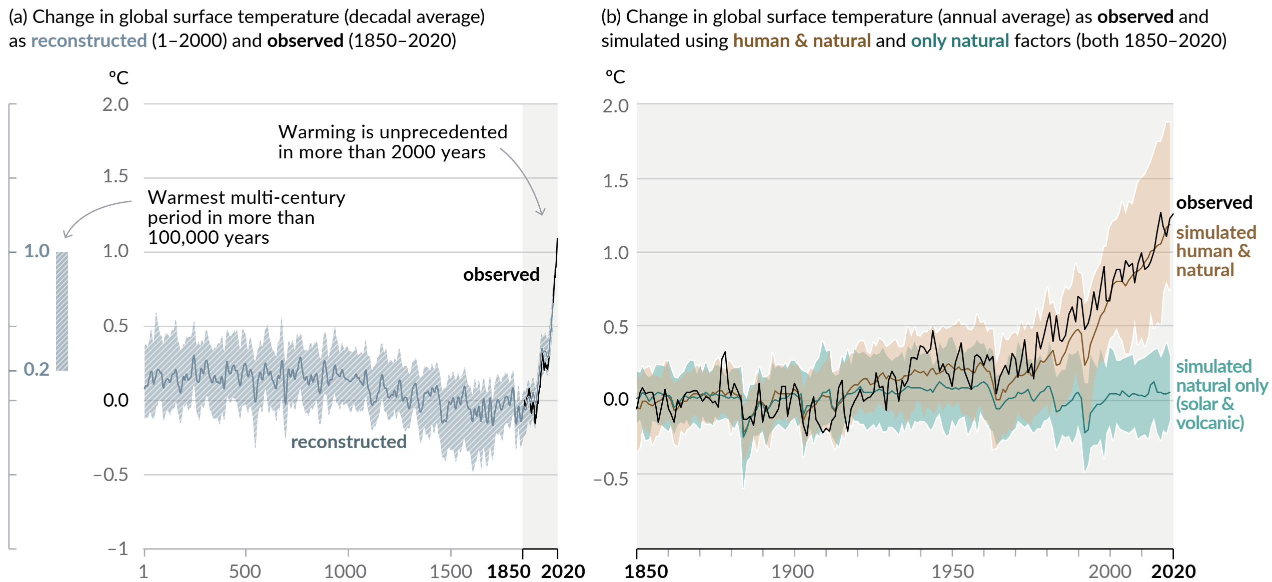

Figure SPM.1 | History of global temperature change and causes of recent warming

Panel (a) Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line, years 1–2000) **and from direct observations** (solid black line, 1850–2020), both relative to 1850–1900 and decadally averaged. The vertical bar on the left shows the estimated temperature (*very likely* range) during the warmest multi-century period in at least the last 100,000 years, which occurred around 6500 years ago during the current interglacial period (Holocene). The Last Interglacial, around 125,000 years ago, is the next most recent candidate for a period of higher temperature. These past warm periods were caused by slow (multi-millennial) orbital variations. The grey shading with white diagonal lines shows the *very likely* ranges for the temperature reconstructions.

Panel (b) Changes in global surface temperature over the past 170 years (black line) relative to 1850–1900 and annually averaged, compared to Coupled Model Intercomparison Project Phase 6 (CMIP6) climate model simulations (see Box SPM.1) of the temperature response to both human and natural drivers (brown) and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the *very likely* range of simulations. (See Figure SPM.2 for the assessed contributions to warming).

{2.3.1; Cross-Chapter Box 2.3; 3.3; TS.2.2; Cross-Section Box TS.1, Figure 1a}

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

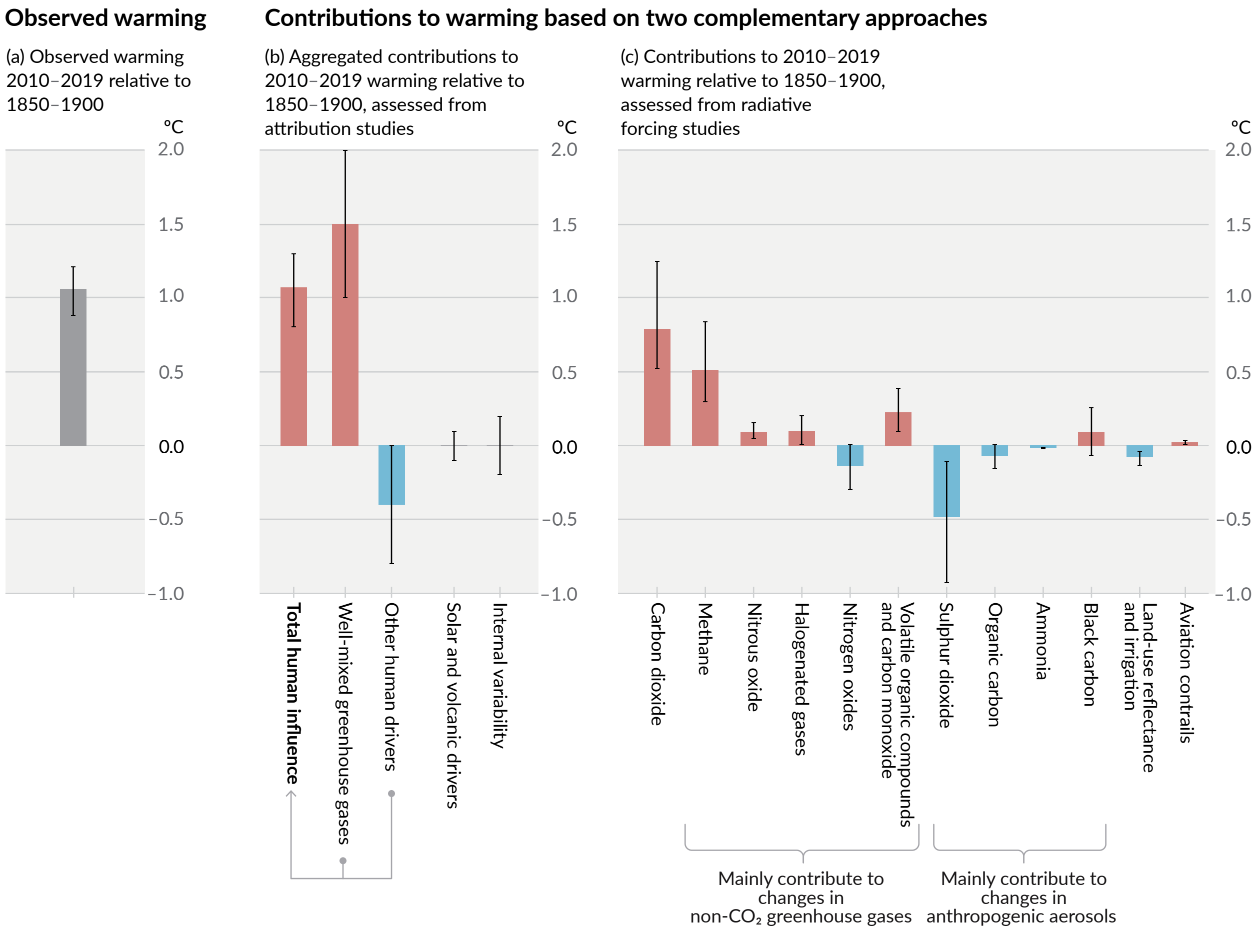

Figure SPM.2 | Assessed contributions to observed warming in 2010–2019 relative to 1850–1900

Panel (a) Observed global warming (increase in global surface temperature). Whiskers show the *very likely* range.

Panel (b) Evidence from attribution studies, which synthesize information from climate models and observations. The panel shows temperature change attributed to: total human influence; changes in well-mixed greenhouse gas concentrations; other human drivers due to aerosols, ozone and land-use change (land-use reflectance); solar and volcanic drivers; and internal climate variability. Whiskers show *likely* ranges.

Panel (c) Evidence from the assessment of radiative forcing and climate sensitivity. The panel shows temperature changes from individual components of human influence: emissions of greenhouse gases, aerosols and their precursors; land-use changes (land-use reflectance and irrigation); and aviation contrails. Whiskers show *very likely* ranges. Estimates account for both direct emissions into the atmosphere and their effect, if any, on other climate drivers. For aerosols, both direct effects (through radiation) and indirect effects (through interactions with clouds) are considered.

{Cross-Chapter Box 2.3, 3.3.1, 6.4.2, 7.3}

A.2 The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years. {2.2, 2.3, Cross-Chapter Box 2.1, 5.1} (Figure SPM.1)

A.2.1 In 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years (*high confidence*), and concentrations of CH_4 and N_2O were higher than at any time in at least 800,000 years (*very high confidence*). Since 1750, increases in CO_2 (47%) and CH_4 (156%) concentrations far exceed – and increases in N_2O (23%) are similar to – the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years (*very high confidence*). {2.2, 5.1, TS.2.2}

A.2.2 Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (*high confidence*). Temperatures during the most recent decade (2011–2020) exceed those of the most recent multi-century warm period, around 6500 years ago[13] [0.2°C to 1°C relative to 1850–1900] (*medium confidence*). Prior to that, the next most recent warm period was about 125,000 years ago, when the multi-century temperature [0.5°C to 1.5°C relative to 1850–1900] overlaps the observations of the most recent decade (*medium confidence*). {2.3, Cross-Chapter Box 2.1, Cross-Section Box TS.1} (Figure SPM.1)

A.2.3 In 2011–2020, annual average Arctic sea ice area reached its lowest level since at least 1850 (*high confidence*). Late summer Arctic sea ice area was smaller than at any time in at least the past 1000 years (*medium confidence*). The global nature of glacier retreat since the 1950s, with almost all of the world's glaciers retreating synchronously, is unprecedented in at least the last 2000 years (*medium confidence*). {2.3, TS.2.5}

A.2.4 Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years (*high confidence*). The global ocean has warmed faster over the past century than since the end of the last deglacial transition (around 11,000 years ago) (*medium confidence*). A long-term increase in surface open ocean pH occurred over the past 50 million years (*high confidence*). However, surface open ocean pH as low as recent decades is unusual in the last 2 million years (*medium confidence*). {2.3, TS.2.4, Box TS.4}

A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. {2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, Box 9.2, 10.6, 11.2, 11.3, 11.4, 11.6, 11.7, 11.8, 11.9, 12.3} (Figure SPM.3)

A.3.1 It is *virtually certain* that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe, with *high confidence* that human-induced climate change is the main driver[14] of these changes. Some recent hot extremes observed over the past decade would have been *extremely unlikely* to occur without human influence on the climate system. Marine heatwaves have approximately doubled in frequency since the 1980s (*high confidence*), and human influence has *very likely* contributed to most of them since at least 2006. {Box 9.2, 11.2, 11.3, 11.9, TS.2.4, TS.2.6, Box TS.10} (Figure SPM.3)

A.3.2 The frequency and intensity of heavy precipitation events have increased since the 1950s over most land area for which observational data are sufficient for trend analysis (*high confidence*), and human-induced climate change is *likely* the main driver. Human-induced climate change has contributed to increases in agricultural and ecological droughts[15] in some regions due to increased land evapotranspiration[16] (*medium confidence*). {8.2, 8.3, 11.4, 11.6, 11.9, TS.2.6, Box TS.10} (Figure SPM.3)

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13 As stated in section B.1, even under the very low emissions scenario SSP1-1.9, temperatures are assessed to remain elevated above those of the most recent decade until at least 2100 and therefore warmer than the century-scale period 6500 years ago.

14 As indicated in footnote 12, throughout this SPM, 'main driver' means responsible for more than 50% of the change.

15 Agricultural and ecological drought (depending on the affected biome): a period with abnormal soil moisture deficit, which results from combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general (see Annex VII: Glossary). Observed changes in meteorological droughts (precipitation deficits) and hydrological droughts (streamflow deficits) are distinct from those in agricultural and ecological droughts and are addressed in the underlying AR6 material (Chapter 11).

16 The combined processes through which water is transferred to the atmosphere from open water and ice surfaces, bare soils and vegetation that make up the Earth's surface (Glossary).

A.3.3 Decreases in global land monsoon precipitation[17] from the 1950s to the 1980s are partly attributed to human-caused Northern Hemisphere aerosol emissions, but increases since then have resulted from rising GHG concentrations and decadal to multi-decadal internal variability (*medium confidence*). Over South Asia, East Asia and West Africa, increases in monsoon precipitation due to warming from GHG emissions were counteracted by decreases in monsoon precipitation due to cooling from human-caused aerosol emissions over the 20th century (*high confidence*). Increases in West African monsoon precipitation since the 1980s are partly due to the growing influence of GHGs and reductions in the cooling effect of human-caused aerosol emissions over Europe and North America (*medium confidence*).
{2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, 10.6, Box TS.13}

A.3.4 It is *likely* that the global proportion of major (Category 3–5) tropical cyclone occurrence has increased over the last four decades, and it is *very likely* that the latitude where tropical cyclones in the western North Pacific reach their peak intensity has shifted northward; these changes cannot be explained by internal variability alone (*medium confidence*). There is *low confidence* in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones. Event attribution studies and physical understanding indicate that human-induced climate change increases heavy precipitation associated with tropical cyclones (*high confidence*), but data limitations inhibit clear detection of past trends on the global scale.
{8.2, 11.7, Box TS.10}

A.3.5 Human influence has *likely* increased the chance of compound extreme events[18] since the 1950s. This includes increases in the frequency of concurrent heatwaves and droughts on the global scale (*high confidence*), fire weather in some regions of all inhabited continents (*medium confidence*), and compound flooding in some locations (*medium confidence*).
{11.6, 11.7, 11.8, 12.3, 12.4, TS.2.6, Table TS.5, Box TS.10}

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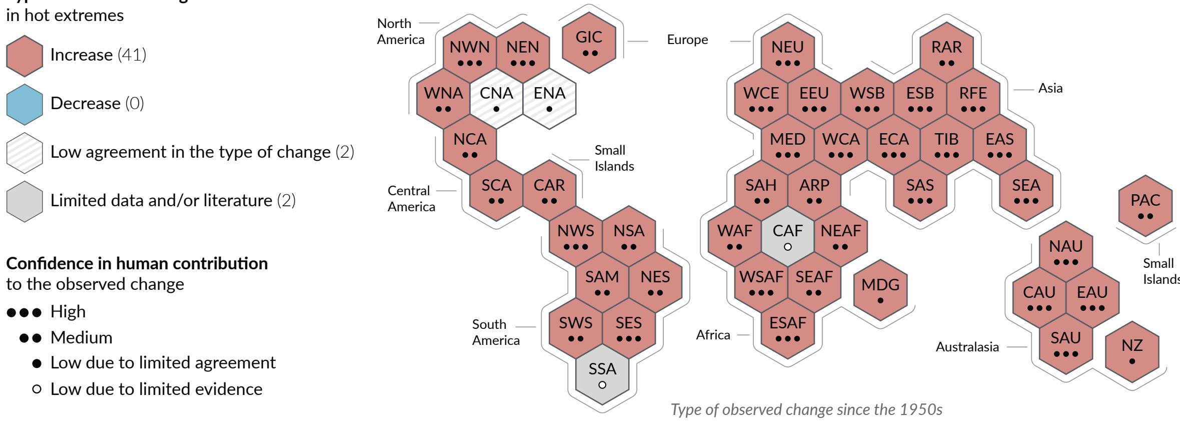
17 The global monsoon is defined as the area in which the annual range (local summer minus local winter) of precipitation is greater than 2.5 mm day^{-1} (Glossary). Global land monsoon precipitation refers to the mean precipitation over land areas within the global monsoon.

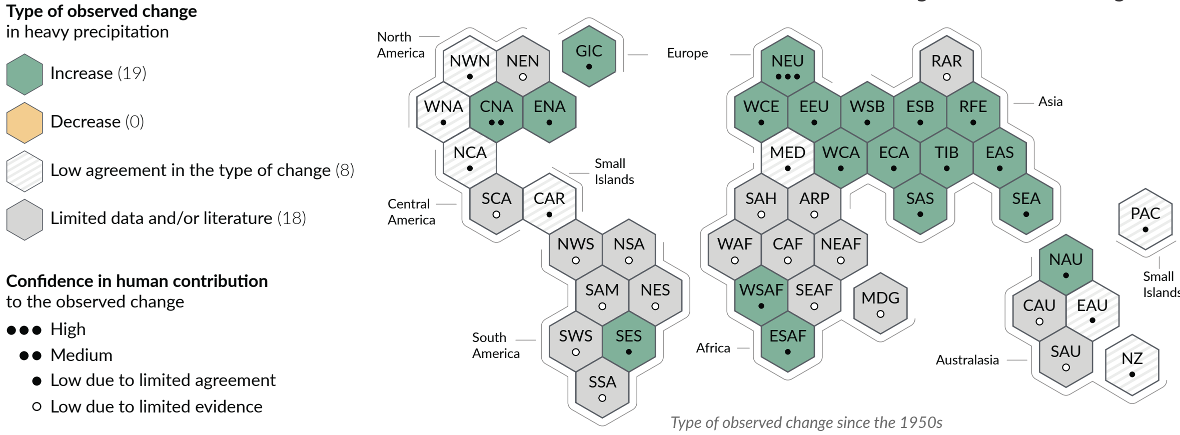
18 Compound extreme events are the combination of multiple drivers and/or hazards that contribute to societal or environmental risk (Glossary). Examples are concurrent heatwaves and droughts, compound flooding (e.g., a storm surge in combination with extreme rainfall and/or river flow), compound fire weather conditions (i.e., a combination of hot, dry and windy conditions), or concurrent extremes at different locations.

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes

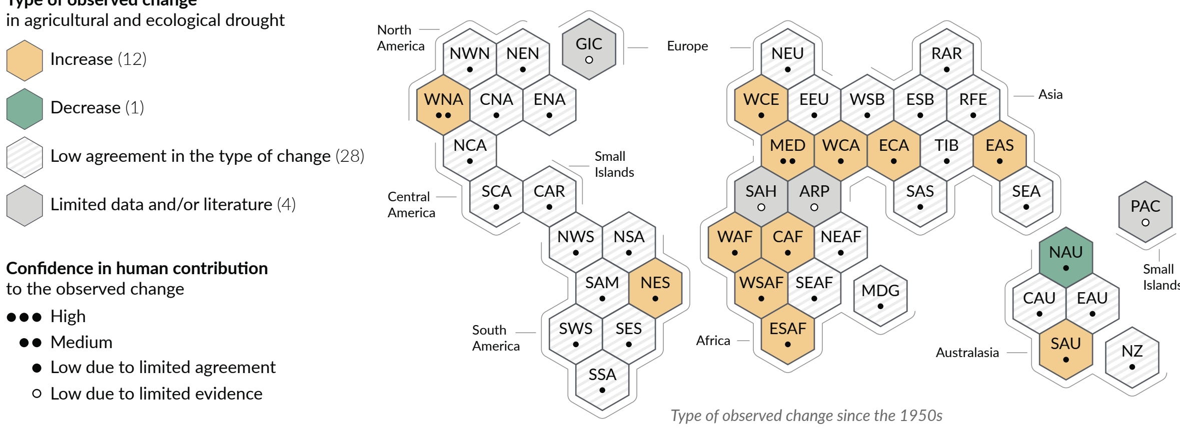
(a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



(b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



(c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions



Each hexagon corresponds to one of the IPCC AR6 WGI reference regions

NWN *North-Western North America*

IPCC AR6 WGI reference regions: **North America:** ***NWN*** *(North-Western North America,* ***NEN*** *(North-Eastern North America),* ***WNA*** *(Western North America),* ***CNA*** *(Central North America),* ***ENA*** *(Eastern North America),* **Central America:** ***NCA*** *(Northern Central America),* ***SCA*** *(Southern Central America),* ***CAR*** *(Caribbean),* **South America:** ***NWS*** *(North-Western South America),* ***NSA*** *(Northern South America),* ***NES*** *(North-Eastern South America),* ***SAM*** *(South American Monsoon),* ***SWS*** *(South-Western South America),* ***SES*** *(South-Eastern South America),* ***SSA*** *(Southern South America),* **Europe:** ***GIC*** *(Greenland/Iceland),* ***NEU*** *(Northern Europe),* ***WCE*** *(Western and Central Europe),* ***EEU*** *(Eastern Europe),* ***MED*** *(Mediterranean),* **Africa:** ***MED*** *(Mediterranean),* ***SAH*** *(Sahara),* ***WAF*** *(Western Africa),* ***CAF*** *(Central Africa),* ***NEAF*** *(North Eastern Africa),* ***SEAF*** *(South Eastern Africa),* ***WSAF*** *(West Southern Africa),* ***ESAF*** *(East Southern Africa),* ***MDG*** *(Madagascar),* **Asia:** ***RAR*** *(Russian Arctic),* ***WSB*** *(West Siberia),* ***ESB*** *(East Siberia),* ***RFE*** *(Russian Far East),* ***WCA*** *(West Central Asia),* ***ECA*** *(East Central Asia),* ***TIB*** *(Tibetan Plateau),* ***EAS*** *(East Asia),* ***ARP*** *(Arabian Peninsula),* ***SAS*** *(South Asia),* ***SEA*** *(South East Asia),* **Australasia:** ***NAU*** *(Northern Australia),* ***CAU*** *(Central Australia),* ***EAU*** *(Eastern Australia),* ***SAU*** *(Southern Australia),* ***NZ*** *(New Zealand),* **Small Islands:** ***CAR*** *(Caribbean),* ***PAC*** *(Pacific Small Islands)*

Figure SPM.3 | Synthesis of assessed observed and attributable regional changes

The IPCC AR6 WGI inhabited regions are displayed as **hexagons** with identical size in their approximate geographical location (see legend for regional acronyms). All assessments are made for each region as a whole and for the 1950s to the present. Assessments made on different time scales or more local spatial scales might differ from what is shown in the figure. The **colours** in each panel represent the four outcomes of the assessment on observed changes. Striped hexagons (white and light-grey) are used where there is *low agreement* in the type of change for the region as a whole, and grey hexagons are used when there is limited data and/or literature that prevents an assessment of the region as a whole. Other colours indicate at least *medium confidence* in the observed change. The **confidence level** for the human influence on these observed changes is based on assessing trend detection and attribution and event attribution literature, and it is indicated by the number of dots: three dots for *high confidence*, two dots for *medium confidence* and one dot for *low confidence* (single, filled dot: limited agreement; single, empty dot: limited evidence).

Panel (a) For hot extremes, the evidence is mostly drawn from changes in metrics based on daily maximum temperatures; regional studies using other indices (heatwave duration, frequency and intensity) are used in addition. Red hexagons indicate regions where there is at least *medium confidence* in an observed increase in hot extremes.

Panel (b) For heavy precipitation, the evidence is mostly drawn from changes in indices based on one-day or five-day precipitation amounts using global and regional studies. Green hexagons indicate regions where there is at least *medium confidence* in an observed increase in heavy precipitation.

Panel (c) Agricultural and ecological droughts are assessed based on observed and simulated changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water balance (precipitation minus evapotranspiration) and indices driven by precipitation and atmospheric evaporative demand. Yellow hexagons indicate regions where there is at least *medium confidence* in an observed increase in this type of drought, and green hexagons indicate regions where there is at least *medium confidence* in an observed decrease in agricultural and ecological drought.

For all regions, Table TS.5 shows a broader range of observed changes besides the ones shown in this figure. Note that Southern South America (SSA) is the only region that does not display observed changes in the metrics shown in this figure, but is affected by observed increases in mean temperature, decreases in frost and increases in marine heatwaves.

{11.9, Atlas 1.3.3, Figure Atlas.2, Table TS.5; Box TS.10, Figure 1}

A.4 Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3°C, with a narrower range compared to AR5.
{2.2, 7.3, 7.4, 7.5, Box 7.2, 9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

A.4.1 Human-caused radiative forcing of 2.72 [1.96 to 3.48] W m^{-2} in 2019 relative to 1750 has warmed the climate system. This warming is mainly due to increased GHG concentrations, partly reduced by cooling due to increased aerosol concentrations. The radiative forcing has increased by 0.43 W m^{-2} (19%) relative to AR5, of which 0.34 W m^{-2} is due to the increase in GHG concentrations since 2011. The remainder is due to improved scientific understanding and changes in the assessment of aerosol forcing, which include decreases in concentration and improvement in its calculation (*high confidence*).
{2.2, 7.3, TS.2.2, TS.3.1}

A.4.2 Human-caused net positive radiative forcing causes an accumulation of additional energy (heating) in the climate system, partly reduced by increased energy loss to space in response to surface warming. The observed average rate of heating of the climate system increased from 0.50 [0.32 to 0.69] W m^{-2} for the period 1971–2006[19] to 0.79 [0.52 to 1.06] W m^{-2} for the period 2006–2018[20] (*high confidence*). Ocean warming accounted for 91% of the heating in the climate system, with land warming, ice loss and atmospheric warming accounting for about 5%, 3% and 1%, respectively (*high confidence*).
{7.2, Box 7.2, TS.3.1}

A.4.3 Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming. Thermal expansion explained 50% of sea level rise during 1971–2018, while ice loss from glaciers contributed 22%, ice sheets 20% and changes in land-water storage 8%. The rate of ice-sheet loss increased by a factor of four between 1992–1999 and 2010–2019. Together, ice-sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006–2018 (*high confidence*).
{9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

A.4.4 The equilibrium climate sensitivity is an important quantity used to estimate how the climate responds to radiative forcing. Based on multiple lines of evidence,[21] the *very likely* range of equilibrium climate sensitivity is between 2°C (*high confidence*) and 5°C (*medium confidence*). The AR6 assessed best estimate is 3°C with a *likely* range of 2.5°C to 4°C (*high confidence*), compared to 1.5°C to 4.5°C in AR5, which did not provide a best estimate.
{7.4, 7.5, TS.3.2}

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19 Cumulative energy increase of 282 [177 to 387] ZJ over 1971–2006 (1 ZJ = 10^{21} joules).

20 Cumulative energy increase of 152 [100 to 205] ZJ over 2006–2018.

21 Understanding of climate processes, the instrumental record, paleoclimates and model-based emergent constraints (Glossary).

B. Possible Climate Futures

A set of five new illustrative emissions scenarios is considered consistently across this Report to explore the climate response to a broader range of greenhouse gas (GHG), land-use and air pollutant futures than assessed in AR5. This set of scenarios drives climate model projections of changes in the climate system. These projections account for solar activity and background forcing from volcanoes. Results over the 21st century are provided for the near term (2021–2040), mid-term (2041–2060) and long term (2081–2100) relative to 1850–1900, unless otherwise stated.

Box SPM.1 | Scenarios, Climate Models and Projections

Box SPM.1.1: This Report assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate change found in the literature. They start in 2015, and include scenarios[22] with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO_2 emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO_2 emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions[23] (SSP1-1.9 and SSP1-2.6), as illustrated in Figure SPM.4. Emissions vary between scenarios depending on socio-economic assumptions, levels of climate change mitigation and, for aerosols and non-methane ozone precursors, air pollution controls. Alternative assumptions may result in similar emissions and climate responses, but the socio-economic assumptions and the feasibility or likelihood of individual scenarios are not part of the assessment.
{1.6, Cross-Chapter Box 1.4, TS.1.3} (Figure SPM.4)

Box SPM.1.2: This Report assesses results from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme. These models include new and better representations of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns. The CMIP6 historical simulations assessed in this Report have an ensemble mean global surface temperature change within 0.2°C of the observations over most of the historical period, and observed warming is within the *very likely* range of the CMIP6 ensemble. However, some CMIP6 models simulate a warming that is either above or below the assessed *very likely* range of observed warming.
{1.5, Cross-Chapter Box 2.2, 3.3, 3.8, TS.1.2, Cross-Section Box TS.1} (Figure SPM.1b, Figure SPM.2)

Box SPM.1.3: The CMIP6 models considered in this Report have a wider range of climate sensitivity than in CMIP5 models and the AR6 assessed *very likely* range, which is based on multiple lines of evidence. These CMIP6 models also show a higher average climate sensitivity than CMIP5 and the AR6 assessed best estimate. The higher CMIP6 climate sensitivity values compared to CMIP5 can be traced to an amplifying cloud feedback that is larger in CMIP6 by about 20%.
{Box 7.1, 7.3, 7.4, 7.5, TS.3.2}

Box SPM.1.4: For the first time in an IPCC report, assessed future changes in global surface temperature, ocean warming and sea level are constructed by combining multi-model projections with observational constraints based on past simulated warming, as well as the AR6 assessment of climate sensitivity. For other quantities, such robust methods do not yet exist to constrain the projections. Nevertheless, robust projected geographical patterns of many variables can be identified at a given level of global warming, common to all scenarios considered and independent of timing when the global warming level is reached.
{1.6, 4.3, 4.6, Box 4.1, 7.5, 9.2, 9.6, Cross-Chapter Box 11.1, Cross-Section Box TS.1}

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22 Throughout this Report, the five illustrative scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway or 'SSP' describing the socio-economic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in watts per square metre, or W m^{-2}) resulting from the scenario in the year 2100. A detailed comparison to scenarios used in earlier IPCC reports is provided in Section TS.1.3, and Sections 1.6 and 4.6. The SSPs that underlie the specific forcing scenarios used to drive climate models are not assessed by WGI. Rather, the SSPx-y labelling ensures traceability to the underlying literature in which specific forcing pathways are used as input to the climate models. IPCC is neutral with regard to the assumptions underlying the SSPs, which do not cover all possible scenarios. Alternative scenarios may be considered or developed.

23 Net negative CO_2 emissions are reached when anthropogenic removals of CO_2 exceed anthropogenic emissions (Glossary).

Box SPM.1 (continued)

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

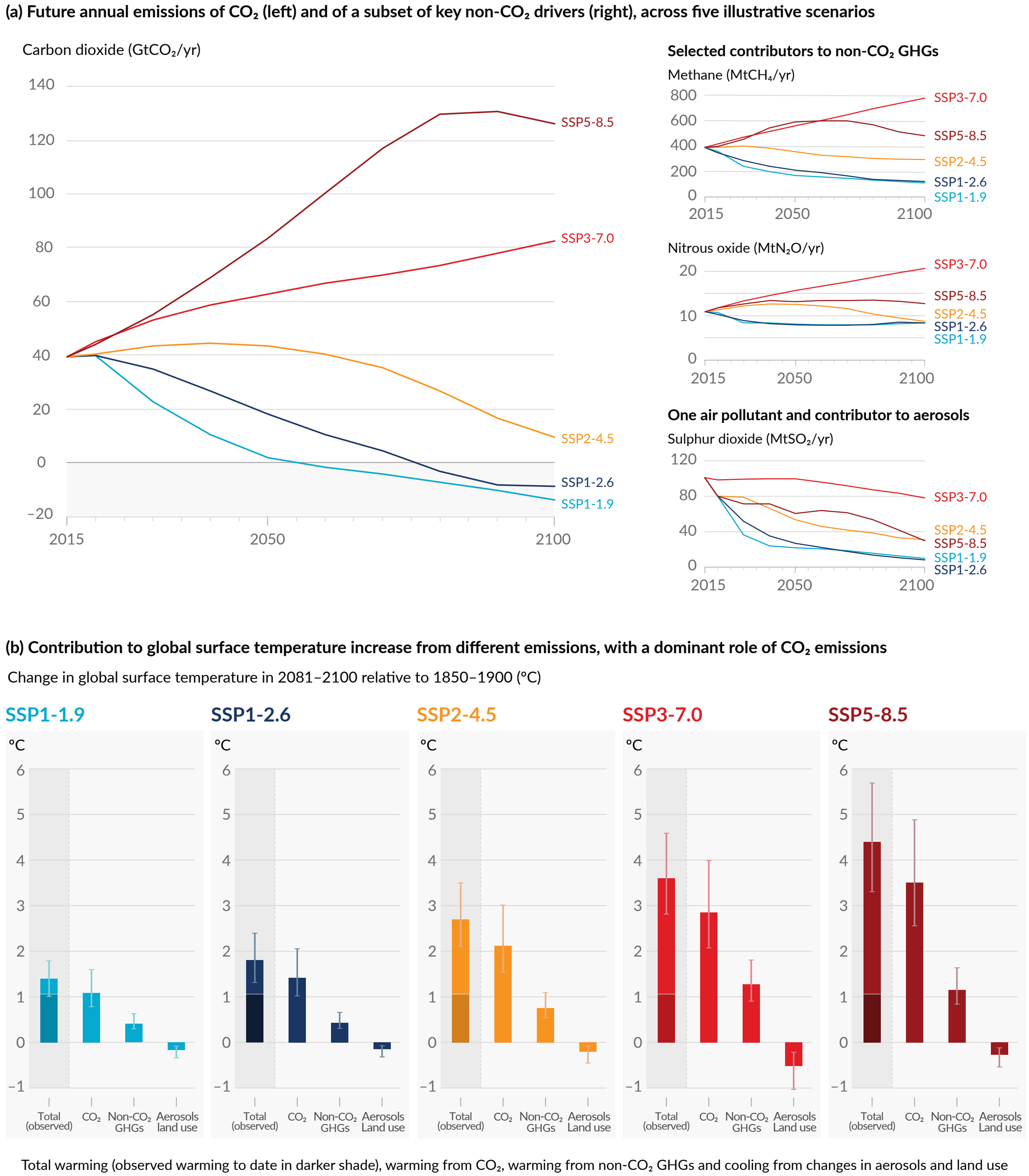

Figure SPM.4 | Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report

The five scenarios are SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5.

Panel (a) Annual anthropogenic (human-caused) emissions over the 2015–2100 period. Shown are emissions trajectories for carbon dioxide (CO_2) from all sectors ($GtCO_2$/yr) (left graph) and for a subset of three key non-CO_2 drivers considered in the scenarios: methane (CH_4, $MtCH_4$/yr, top-right graph); nitrous oxide (N_2O, MtN_2O/yr, middle-right graph); and sulphur dioxide (SO_2, $MtSO_2$/yr, bottom-right graph, contributing to anthropogenic aerosols in panel (b).

Panel (b) Warming contributions by groups of anthropogenic drivers and by scenario are shown as the change in global surface temperature (°C) in 2081–2100 relative to 1850–1900, with indication of the observed warming to date. Bars and whiskers represent median values and the *very likely* range, respectively. Within each scenario bar plot, the bars represent: total global warming (°C; 'total' bar) (see Table SPM.1); warming contributions (°C) from changes in CO_2 ('CO_2' bar) and from non-CO_2 greenhouse gases (GHGs; 'non-CO_2 GHGs' bar: comprising well-mixed greenhouse gases and ozone); and net cooling from other anthropogenic drivers ('aerosols and land use' bar: anthropogenic aerosols, changes in reflectance due to land-use and irrigation changes, and contrails from aviation) (see Figure SPM.2, panel c, for the warming contributions to date for individual drivers). The best estimate for observed warming in 2010–2019 relative to 1850–1900 (see Figure SPM.2, panel a) is indicated in the darker column in the 'total' bar. Warming contributions in panel (b) are calculated as explained in Table SPM.1 for the total bar. For the other bars, the contribution by groups of drivers is calculated with a physical climate emulator of global surface temperature that relies on climate sensitivity and radiative forcing assessments.

{Cross-Chapter Box 1.4; 4.6; Figure 4.35; 6.7; Figures 6.18, 6.22 and 6.24; 7.3; Cross-Chapter Box 7.1; Figure 7.7; Box TS.7; Figures TS.4 and TS.15}

B.1 Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.
{2.3, Cross-Chapter Box 2.3, Cross-Chapter Box 2.4, 4.3, 4.4, 4.5} (Figure SPM.1, Figure SPM.4, Figure SPM.8, Table SPM.1, Box SPM.1)

B.1.1 Compared to 1850–1900, global surface temperature averaged over 2081–2100 is *very likely* to be higher by 1.0°C to 1.8°C under the very low GHG emissions scenario considered (SSP1-1.9), by 2.1°C to 3.5°C in the intermediate GHG emissions scenario (SSP2-4.5) and by 3.3°C to 5.7°C under the very high GHG emissions scenario (SSP5-8.5).[24] The last time global surface temperature was sustained at or above 2.5°C higher than 1850–1900 was over 3 million years ago (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, Box TS.2, Box TS.4, Cross-Section Box TS.1} (Table SPM.1)

Table SPM.1 | Changes in global surface temperature, which are assessed based on multiple lines of evidence, for selected 20-year time periods and the five illustrative emissions scenarios considered. Temperature differences relative to the average global surface temperature of the period 1850–1900 are reported in °C. This includes the revised assessment of observed historical warming for the AR5 reference period 1986–2005, which in AR6 is higher by 0.08 [–0.01 to +0.12] °C than in AR5 (see footnote 10). Changes relative to the recent reference period 1995–2014 may be calculated approximately by subtracting 0.85°C, the best estimate of the observed warming from 1850–1900 to 1995–2014.
{Cross-Chapter Box 2.3, 4.3, 4.4, Cross-Section Box TS.1}

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

B.1.2 Based on the assessment of multiple lines of evidence, global warming of 2°C, relative to 1850–1900, would be exceeded during the 21st century under the high and very high GHG emissions scenarios considered in this report (SSP3-7.0 and SSP5-8.5, respectively). Global warming of 2°C would *extremely likely* be exceeded in the intermediate GHG emissions scenario (SSP2-4.5). Under the very low and low GHG emissions scenarios, global warming of 2°C is *extremely unlikely* to be exceeded (SSP1-1.9) or *unlikely* to be exceeded (SSP1-2.6).[25] Crossing the 2°C global warming level in the mid-term period (2041–2060) is *very likely* to occur under the very high GHG emissions scenario (SSP5-8.5), *likely* to occur under the high GHG emissions scenario (SSP3-7.0), and *more likely than not* to occur in the intermediate GHG emissions scenario (SSP2-4.5).[26]
{4.3, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.4, Box SPM.1)

24 Changes in global surface temperature are reported as running 20-year averages, unless stated otherwise.

25 SSP1-1.9 and SSP1-2.6 are scenarios that start in 2015 and have very low and low GHG emissions, respectively, and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions.

26 Crossing is defined here as having the assessed global surface temperature change, averaged over a 20-year period, exceed a particular global warming level.

B.1.3 Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century under the intermediate, high and very high GHG emissions scenarios considered in this report (SSP2-4.5, SSP3-7.0 and SSP5-8.5, respectively). Under the five illustrative scenarios, in the near term (2021–2040), the 1.5°C global warming level is *very likely* to be exceeded under the very high GHG emissions scenario (SSP5-8.5), *likely* to be exceeded under the intermediate and high GHG emissions scenarios (SSP2-4.5 and SSP3-7.0), *more likely than not* to be exceeded under the low GHG emissions scenario (SSP1-2.6) and *more likely than not* to be reached under the very low GHG emissions scenario (SSP1-1.9).[27] Furthermore, for the very low GHG emissions scenario (SSP1-1.9), it is *more likely than not* that global surface temperature would decline back to below 1.5°C toward the end of the 21st century, with a temporary overshoot of no more than 0.1°C above 1.5°C global warming.
{4.3, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.4)

B.1.4 Global surface temperature in any single year can vary above or below the long-term human-induced trend, due to substantial natural variability.[28] The occurrence of individual years with global surface temperature change above a certain level, for example 1.5°C or 2°C, relative to 1850–1900 does not imply that this global warming level has been reached.[29]
{Cross-Chapter Box 2.3, 4.3, 4.4, Box 4.1, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.1, Figure SPM.8)

B.2 Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, and, in some regions, agricultural and ecological droughts; an increase in the proportion of intense tropical cyclones; and reductions in Arctic sea ice, snow cover and permafrost.
{4.3, 4.5, 4.6, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, Box 9.2, 11.1, 11.2, 11.3, 11.4, 11.6, 11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} (Figure SPM.5, Figure SPM.6, Figure SPM.8)

B.2.1 It is *virtually certain* that the land surface will continue to warm more than the ocean surface (*likely* 1.4 to 1.7 times more). It is *virtually certain* that the Arctic will continue to warm more than global surface temperature, with *high confidence* above two times the rate of global warming.
{2.3, 4.3, 4.5, 4.6, 7.4, 11.1, 11.3, 11.9, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Section Box TS.1, TS.2.6} (Figure SPM.5)

B.2.2 With every additional increment of global warming, changes in extremes continue to become larger. For example, every additional 0.5°C of global warming causes clearly discernible increases in the intensity and frequency of hot extremes, including heatwaves (*very likely*), and heavy precipitation (*high confidence*), as well as agricultural and ecological droughts[30] in some regions (*high confidence*). Discernible changes in intensity and frequency of meteorological droughts, with more regions showing increases than decreases, are seen in some regions for every additional 0.5°C of global warming (*medium confidence*). Increases in frequency and intensity of hydrological droughts become larger with increasing global warming in some regions (*medium confidence*). There will be an increasing occurrence of some extreme events unprecedented in the observational record with additional global warming, even at 1.5°C of global warming. Projected percentage changes in frequency are larger for rarer events (*high confidence*).
{8.2, 11.2, 11.3, 11.4, 11.6, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, TS.2.6} (Figure SPM.5, Figure SPM.6)

B.2.3 Some mid-latitude and semi-arid regions, and the South American Monsoon region, are projected to see the highest increase in the temperature of the hottest days, at about 1.5 to 2 times the rate of global warming (*high confidence*). The Arctic is projected to experience the highest increase in the temperature of the coldest days, at about three times the rate of global warming (*high confidence*). With additional global warming, the frequency of marine heatwaves will continue to increase (*high confidence*), particularly in the tropical ocean and the Arctic (*medium confidence*).
{Box 9.2, 11.1, 11.3, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, 12.4, TS.2.4, TS.2.6} (Figure SPM.6)

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27 The AR6 assessment of when a given global warming level is first exceeded benefits from the consideration of the illustrative scenarios, the multiple lines of evidence entering the assessment of future global surface temperature response to radiative forcing, and the improved estimate of historical warming. The AR6 assessment is thus not directly comparable to the SR1.5 SPM, which reported *likely* reaching 1.5°C global warming between 2030 and 2052, from a simple linear extrapolation of warming rates of the recent past. When considering scenarios similar to SSP1-1.9 instead of linear extrapolation, the SR1.5 estimate of when 1.5°C global warming is first exceeded is close to the best estimate reported here.

28 Natural variability refers to climatic fluctuations that occur without any human influence, that is, internal variability combined with the response to external natural factors such as volcanic eruptions, changes in solar activity and, on longer time scales, orbital effects and plate tectonics (Glossary).

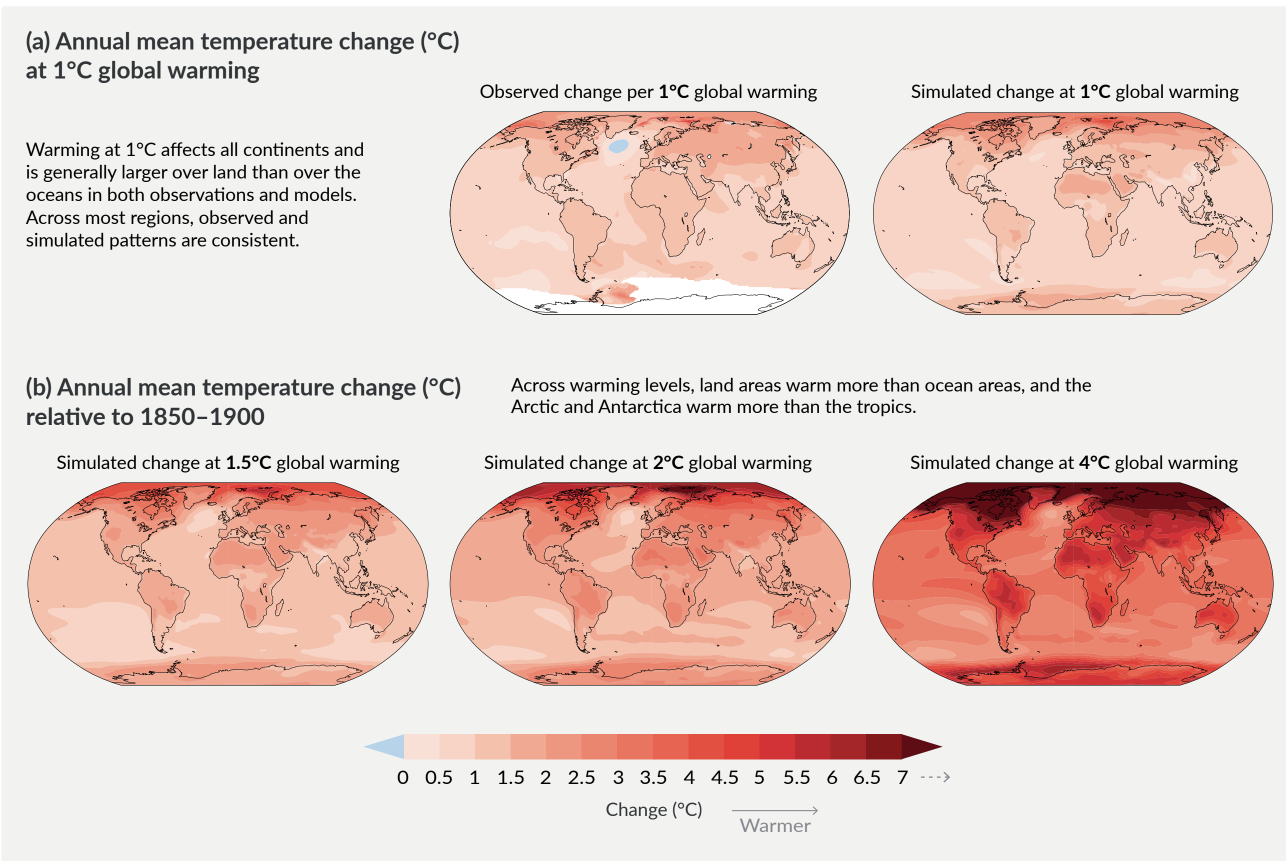
29 The internal variability in any single year is estimated to be about ±0.25°C (5–95% range, *high confidence*).

30 Projected changes in agricultural and ecological droughts are primarily assessed based on total column soil moisture. See footnote 15 for definition and relation to precipitation and evapotranspiration.

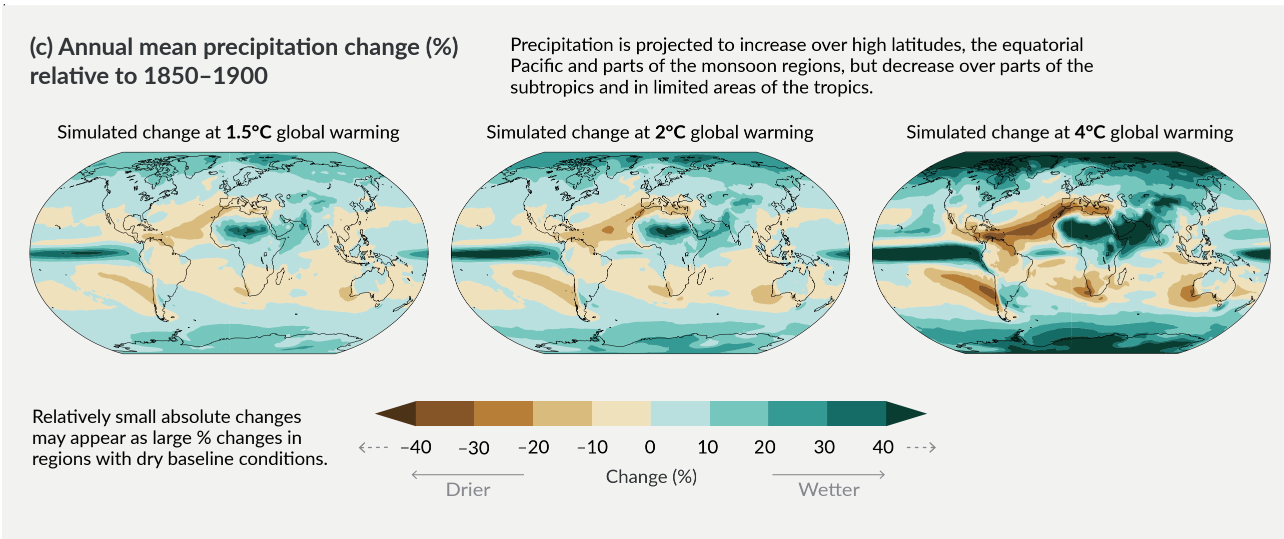
B.2.4 It is *very likely* that heavy precipitation events will intensify and become more frequent in most regions with additional global warming. At the global scale, extreme daily precipitation events are projected to intensify by about 7% for each 1°C of global warming (*high confidence*). The proportion of intense tropical cyclones (Category 4–5) and peak wind speeds of the most intense tropical cyclones are projected to increase at the global scale with increasing global warming (*high confidence*). {8.2, 11.4, 11.7, 11.9, Cross-Chapter Box 11.1, Box TS.6, TS.4.3.1} (Figure SPM.5, Figure SPM.6)

B.2.5 Additional warming is projected to further amplify permafrost thawing and loss of seasonal snow cover, of land ice and of Arctic sea ice (*high confidence*). The Arctic is *likely* to be practically sea ice-free in September[31] at least once before 2050 under the five illustrative scenarios considered in this report, with more frequent occurrences for higher warming levels. There is *low confidence* in the projected decrease of Antarctic sea ice. {4.3, 4.5, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, 12.4, Cross-Chapter Box 12.1, Atlas.5, Atlas.6, Atlas.8, Atlas.9, Atlas.11, TS.2.5} (Figure SPM.8)

With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture



31 Monthly average sea ice area of less than 1 million km², which is about 15% of the average September sea ice area observed in 1979–1988.



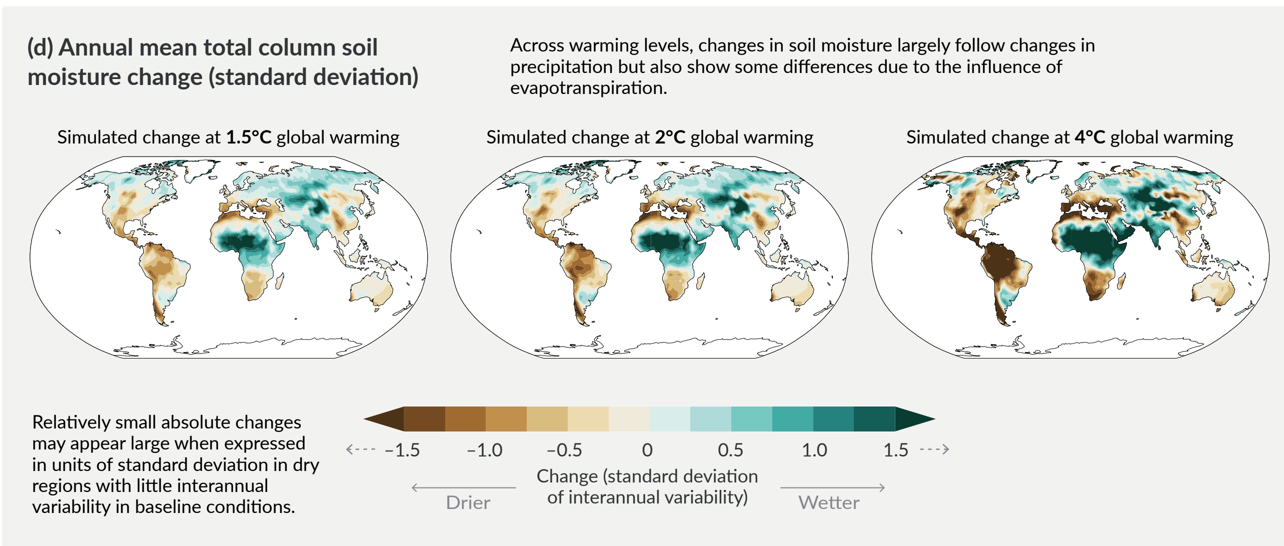


Figure SPM.5 | Changes in annual mean surface temperature, precipitation, and soil moisture

Panel (a) Comparison of observed and simulated annual mean surface temperature change. The **left map** shows the observed changes in annual mean surface temperature in the period 1850–2020 per °C of global warming (°C). The local (i.e., grid point) observed annual mean surface temperature changes are linearly regressed against the global surface temperature in the period 1850–2020. Observed temperature data are from Berkeley Earth, the dataset with the largest coverage and highest horizontal resolution. Linear regression is applied to all years for which data at the corresponding grid point is available. The regression method was used to take into account the complete observational time series and thereby reduce the role of internal variability at the grid point level. White indicates areas where time coverage was 100 years or less and thereby too short to calculate a reliable linear regression. The **right map** is based on model simulations and shows change in annual multi-model mean simulated temperatures at a global warming level of 1°C (20-year mean global surface temperature change relative to 1850–1900). The triangles at each end of the colour bar indicate out-of-bound values, that is, values above or below the given limits.

Panel (b) Simulated annual mean temperature change (°C), panel (c) precipitation change (%), and panel (d) total column soil moisture change (standard deviation of interannual variability) at global warming levels of 1.5°C, 2°C and 4°C (20-year mean global surface temperature change relative to 1850–1900). Simulated changes correspond to Coupled Model Intercomparison Project Phase 6 (CMIP6) multi-model mean change (median change for soil moisture) at the corresponding global warming level, that is, the same method as for the right map in panel (a).

In **panel (c)**, high positive percentage changes in dry regions may correspond to small absolute changes. In **panel (d)**, the unit is the standard deviation of interannual variability in soil moisture during 1850–1900. Standard deviation is a widely used metric in characterizing drought severity. A projected reduction in mean soil moisture by one standard deviation corresponds to soil moisture conditions typical of droughts that occurred about once every six years during 1850–1900. In panel (d), large changes in dry regions with little interannual variability in the baseline conditions can correspond to small absolute change. The triangles at each end of the colour bars indicate out-of-bound values, that is, values above or below the given limits. Results from all models reaching the corresponding warming level in any of the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are averaged. Maps of annual mean temperature and precipitation changes at a global warming level of 3°C are available in Figure 4.31 and Figure 4.32 in Section 4.6. Corresponding maps of panels (b), (c) and (d), including hatching to indicate the level of model agreement at grid-cell level, are found in Figures 4.31, 4.32 and 11.19, respectively; as highlighted in Cross-Chapter Box Atlas.1, grid-cell level hatching is not informative for larger spatial scales (e.g., over AR6 reference regions) where the aggregated signals are less affected by small-scale variability, leading to an increase in robustness.

{Figure 1.14, 4.6.1, Cross-Chapter Box 11.1, Cross-Chapter Box Atlas.1, TS.1.3.2, Figures TS.3 and TS.5}

SPM

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

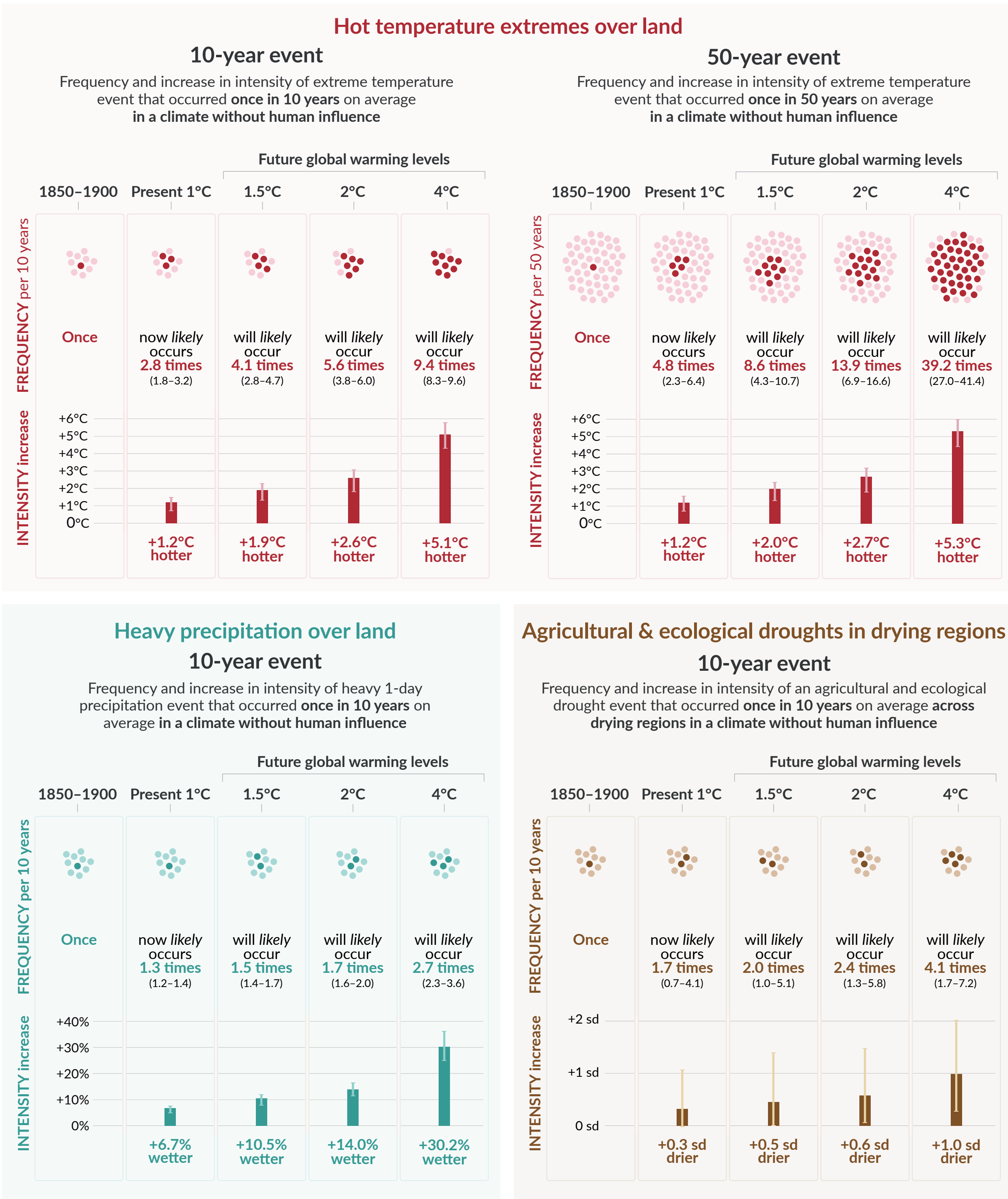


Figure SPM.6 | Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions

Projected changes are shown at global warming levels of 1°C, 1.5°C, 2°C, and 4°C and are relative to 1850–1900,[9] representing a climate without human influence. The figure depicts frequencies and increases in intensity of 10- or 50-year extreme events from the base period (1850–1900) under different global warming levels.

Hot temperature extremes are defined as the daily maximum temperatures over land that were exceeded on average once in a decade (10-year event) or once in 50 years (50-year event) during the 1850–1900 reference period. **Extreme precipitation events** are defined as the daily precipitation amount over land that was exceeded on average once in a decade during the 1850–1900 reference period. **Agricultural and ecological drought events** are defined as the annual average of total column soil moisture below the 10th percentile of the 1850–1900 base period. These extremes are defined on model grid box scale. For hot temperature extremes and extreme precipitation, results are shown for the global land. For agricultural and ecological drought, results are shown for drying regions only, which correspond to the AR6 regions in which there is at least *medium confidence* in a projected increase in agricultural and ecological droughts at the 2°C warming level compared to the 1850–1900 base period in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These regions include Western North America, Central North America, Northern Central America, Southern Central America, Caribbean, Northern South America, North-Eastern South America, South American Monsoon, South-Western South America, Southern South America, Western and Central Europe, Mediterranean, West Southern Africa, East Southern Africa, Madagascar, Eastern Australia, and Southern Australia (Caribbean is not included in the calculation of the figure because of the too-small number of full land grid cells). The non-drying regions do not show an overall increase or decrease in drought severity. Projections of changes in agricultural and ecological droughts in the CMIP Phase 5 (CMIP5) multi-model ensemble differ from those in CMIP6 in some regions, including in parts of Africa and Asia. Assessments of projected changes in meteorological and hydrological droughts are provided in Chapter 11.

In the **'frequency' section**, each year is represented by a dot. The dark dots indicate years in which the extreme threshold is exceeded, while light dots are years when the threshold is not exceeded. Values correspond to the medians (in bold) and their respective *likely* ranges based on the 5–95% range of the multi-model ensemble from simulations of CMIP6 under different Shared Socio-economic Pathway scenarios. For consistency, the number of dark dots is based on the rounded-up median. In the **'intensity' section**, medians and their *likely* ranges, also based on the 5–95% range of the multi-model ensemble from simulations of CMIP6, are displayed as dark and light bars, respectively. Changes in the intensity of hot temperature extremes and extreme precipitation are expressed as degree Celsius and percentage. As for agricultural and ecological drought, intensity changes are expressed as fractions of standard deviation of annual soil moisture.

{11.1; 11.3; 11.4; 11.6; 11.9; Figures 11.12, 11.15, 11.6, 11.7, and 11.18}

B.3 Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events.
{4.3, 4.4, 4.5, 4.6, 8.2, 8.3, 8.4, 8.5, Box 8.2, 11.4, 11.6, 11.9, 12.4, Atlas.3} (Figure SPM.5, Figure SPM.6)

B.3.1 There is strengthened evidence since AR5 that the global water cycle will continue to intensify as global temperatures rise (*high confidence*), with precipitation and surface water flows projected to become more variable over most land regions within seasons (*high confidence*) and from year to year (*medium confidence*). The average annual global land precipitation is projected to increase by 0–5% under the very low GHG emissions scenario (SSP1-1.9), 1.5–8% for the intermediate GHG emissions scenario (SSP2-4.5) and 1–13% under the very high GHG emissions scenario (SSP5-8.5) by 2081–2100 relative to 1995–2014 (*likely* ranges). Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and limited areas in the tropics in SSP2-4.5, SSP3-7.0 and SSP5-8.5 (*very likely*). The portion of the global land experiencing detectable increases or decreases in seasonal mean precipitation is projected to increase (*medium confidence*). There is *high confidence* in an earlier onset of spring snowmelt, with higher peak flows at the expense of summer flows in snow-dominated regions globally.
{4.3, 4.5, 4.6, 8.2, 8.4, Atlas.3, TS.2.6, TS.4.3, Box TS.6} (Figure SPM.5)

B.3.2 A warmer climate will intensify very wet and very dry weather and climate events and seasons, with implications for flooding or drought (*high confidence*), but the location and frequency of these events depend on projected changes in regional atmospheric circulation, including monsoons and mid-latitude storm tracks. It is *very likely* that rainfall variability related to the El Niño–Southern Oscillation is projected to be amplified by the second half of the 21st century in the SSP2-4.5, SSP3-7.0 and SSP5-8.5 scenarios.
{4.3, 4.5, 4.6, 8.2, 8.4, 8.5, 11.4, 11.6, 11.9, 12.4, TS.2.6, TS.4.2, Box TS.6} (Figure SPM.5, Figure SPM.6)

B.3.3 Monsoon precipitation is projected to increase in the mid- to long term at the global scale, particularly over South and South East Asia, East Asia and West Africa apart from the far west Sahel (*high confidence*). The monsoon season is projected to have a delayed onset over North and South America and West Africa (*high confidence*) and a delayed retreat over West Africa (*medium confidence*).
{4.4, 4.5, 8.2, 8.3, 8.4, Box 8.2, Box TS.13}

B.3.4 A projected southward shift and intensification of Southern Hemisphere summer mid-latitude storm tracks and associated precipitation is *likely* in the long term under high GHG emissions scenarios (SSP3-7.0, SSP5-8.5), but in the near term the effect of stratospheric ozone recovery counteracts these changes (*high confidence*). There is *medium confidence* in a continued poleward shift of storms and their precipitation in the North Pacific, while there is *low confidence* in projected changes in the North Atlantic storm tracks.
{4.4, 4.5, 8.4, TS.2.3, TS.4.2}

B.4 Under scenarios with increasing CO_2 emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of CO_2 in the atmosphere.
{4.3, 5.2, 5.4, 5.5, 5.6} (Figure SPM.7)

B.4.1 While natural land and ocean carbon sinks are projected to take up, in absolute terms, a progressively larger amount of CO_2 under higher compared to lower CO_2 emissions scenarios, they become less effective, that is, the proportion of emissions taken up by land and ocean decrease with increasing cumulative CO_2 emissions. This is projected to result in a higher proportion of emitted CO_2 remaining in the atmosphere (*high confidence*).
{5.2, 5.4, Box TS.5} (Figure SPM.7)

B.4.2 Based on model projections, under the intermediate GHG emissions scenario that stabilizes atmospheric CO_2 concentrations this century (SSP2-4.5), the rates of CO_2 taken up by the land and ocean are projected to decrease in the second half of the 21st century (*high confidence*). Under the very low and low GHG emissions scenarios (SSP1-1.9, SSP1-2.6), where CO_2 concentrations peak and decline during the 21st century, the land and ocean begin to take up less carbon in response to declining atmospheric CO_2 concentrations (*high confidence*) and turn into a weak net source by 2100 under SSP1-1.9 (*medium confidence*). It is *very unlikely* that the combined global land and ocean sink will turn into a source by 2100 under scenarios without net negative emissions (SSP2-4.5, SSP3-7.0, SSP5-8.5).[32]
{4.3, 5.4, 5.5, 5.6, Box TS.5, TS.3.3}

B.4.3 The magnitude of feedbacks between climate change and the carbon cycle becomes larger but also more uncertain in high CO_2 emissions scenarios (*very high confidence*). However, climate model projections show that the uncertainties in atmospheric CO_2 concentrations by 2100 are dominated by the differences between emissions scenarios (*high confidence*). Additional ecosystem responses to warming not yet fully included in climate models, such as CO_2 and CH_4 fluxes from wetlands, permafrost thaw and wildfires, would further increase concentrations of these gases in the atmosphere (*high confidence*).
{5.4, Box TS.5, TS.3.2}

The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO_2 emissions

Total cumulative CO_2 emissions **taken up by land and ocean** (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100

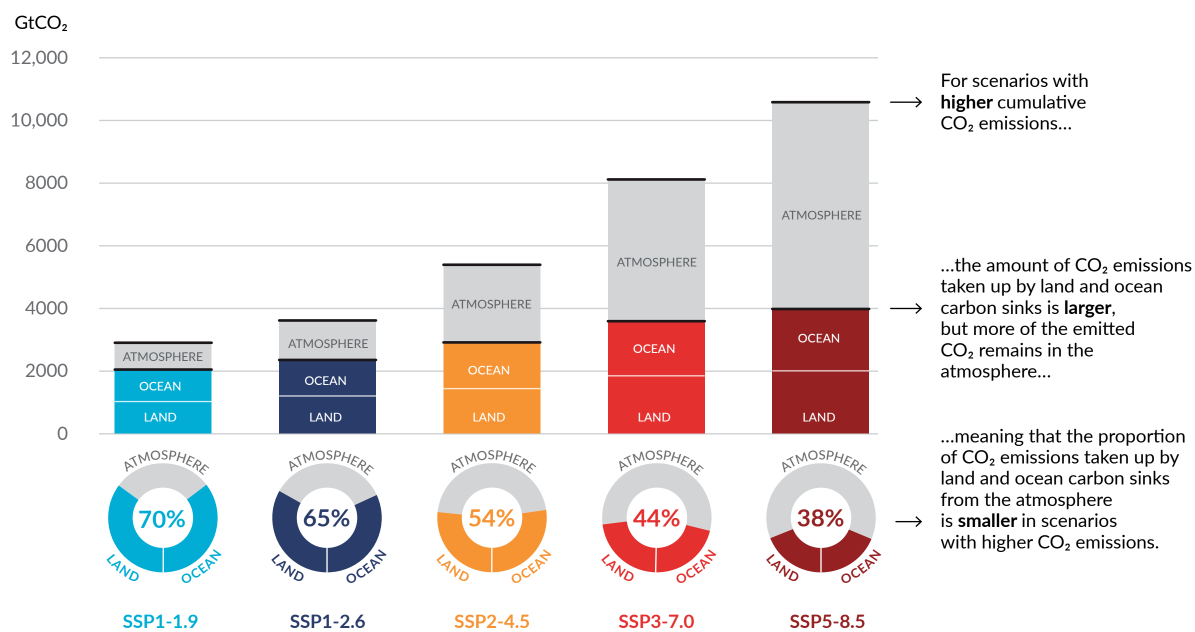


Figure SPM.7 | Cumulative anthropogenic CO_2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios

The cumulative anthropogenic (human-caused) carbon dioxide (CO_2) emissions taken up by the land and ocean sinks under the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are simulated from 1850 to 2100 by Coupled Model Intercomparison Project Phase 6 (CMIP6) climate models in the concentration-driven simulations. Land and ocean carbon sinks respond to past, current and future emissions; therefore, cumulative sinks from 1850 to 2100 are presented here. During the historical period (1850–2019) the observed land and ocean sink took up 1430 $GtCO_2$ (59% of the emissions).

32 These projected adjustments of carbon sinks to stabilization or decline of atmospheric CO_2 are accounted for in calculations of remaining carbon budgets.

The bar chart illustrates the projected amount of cumulative anthropogenic CO_2 emissions ($GtCO_2$) between 1850 and 2100 remaining in the atmosphere (grey part) and taken up by the land and ocean (coloured part) in the year 2100. **The doughnut chart** illustrates the proportion of the cumulative anthropogenic CO_2 emissions taken up by the land and ocean sinks and remaining in the atmosphere in the year 2100. Values in % indicate the proportion of the cumulative anthropogenic CO_2 emissions taken up by the combined land and ocean sinks in the year 2100. The overall anthropogenic carbon emissions are calculated by adding the net global land-use emissions from the CMIP6 scenario database to the other sectoral emissions calculated from climate model runs with prescribed CO_2 concentrations.[33] Land and ocean CO_2 uptake since 1850 is calculated from the net biome productivity on land, corrected for CO_2 losses due to land-use change by adding the land-use change emissions, and net ocean CO_2 flux.

{5.2.1; Table 5.1; 5.4.5; Figure 5.25; Box TS.5; Box TS.5, Figure 1}

B.5 Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.
{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, 4.7, 5.3, 9.2, 9.4, 9.5, 9.6, Box 9.4} (Figure SPM.8)

B.5.1 Past GHG emissions since 1750 have committed the global ocean to future warming (*high confidence*). Over the rest of the 21st century, *likely* ocean warming ranges from 2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5) the 1971–2018 change. Based on multiple lines of evidence, upper ocean stratification (*virtually certain*), ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the 21st century, at rates dependent on future emissions. Changes are irreversible on centennial to millennial time scales in global ocean temperature (*very high confidence*), deep-ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*).
{4.3, 4.5, 4.7, 5.3, 9.2, TS.2.4} (Figure SPM.8)

B.5.2 Mountain and polar glaciers are committed to continue melting for decades or centuries (*very high confidence*). Loss of permafrost carbon following permafrost thaw is irreversible at centennial time scales (*high confidence*). Continued ice loss over the 21st century is *virtually certain* for the Greenland Ice Sheet and *likely* for the Antarctic Ice Sheet. There is *high confidence* that total ice loss from the Greenland Ice Sheet will increase with cumulative emissions. There is *limited evidence* for low-likelihood, high-impact outcomes (resulting from ice-sheet instability processes characterized by deep uncertainty and in some cases involving tipping points) that would strongly increase ice loss from the Antarctic Ice Sheet for centuries under high GHG emissions scenarios.[34]
{4.3, 4.7, 5.4, 9.4, 9.5, Box 9.4, Box TS.1, TS.2.5}

B.5.3 It is *virtually certain* that global mean sea level will continue to rise over the 21st century. Relative to 1995–2014, the *likely* global mean sea level rise by 2100 is 0.28–0.55 m under the very low GHG emissions scenario (SSP1-1.9); 0.32–0.62 m under the low GHG emissions scenario (SSP1-2.6); 0.44–0.76 m under the intermediate GHG emissions scenario (SSP2-4.5); and 0.63–1.01 m under the very high GHG emissions scenario (SSP5-8.5); and by 2150 is 0.37–0.86 m under the very low scenario (SSP1-1.9); 0.46–0.99 m under the low scenario (SSP1-2.6); 0.66–1.33 m under the intermediate scenario (SSP2-4.5); and 0.98–1.88 m under the very high scenario (SSP5-8.5) (*medium confidence*).[35] Global mean sea level rise above the *likely* range – approaching 2 m by 2100 and 5 m by 2150 under a very high GHG emissions scenario (SSP5-8.5) (*low confidence*) – cannot be ruled out due to deep uncertainty in ice-sheet processes.
{4.3, 9.6, Box 9.4, Box TS.4} (Figure SPM.8)

B.5.4 In the longer term, sea level is committed to rise for centuries to millennia due to continuing deep-ocean warming and ice-sheet melt and will remain elevated for thousands of years (*high confidence*). Over the next 2000 years, global mean sea level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming, and it will continue to rise over subsequent millennia (*low confidence*). Projections of multi-millennial global mean sea level rise are consistent with reconstructed levels during past warm climate periods: *likely* 5–10 m higher than today around 125,000 years ago, when global temperatures were *very likely* 0.5°C–1.5°C higher than 1850–1900; and *very likely* 5–25 m higher roughly 3 million years ago, when global temperatures were 2.5°C–4°C higher (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 9.6, Box TS.2, Box TS.4, Box TS.9}

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33 The other sectoral emissions are calculated as the residual of the net land and ocean CO_2 uptake and the prescribed atmospheric CO_2 concentration changes in the CMIP6 simulations. These calculated emissions are net emissions and do not separate gross anthropogenic emissions from removals, which are included implicitly.

34 Low-likelihood, high-impact outcomes are those whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high. A tipping point is a critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly. (Glossary) {1.4, Cross-Chapter Box 1.3, 4.7}

35 To compare to the 1986–2005 baseline period used in AR5 and SROCC, add 0.03 m to the global mean sea level rise estimates. To compare to the 1900 baseline period used in Figure SPM.8, add 0.16 m.

SPM

Human activities affect all the major climate system components, with some responding over decades and others over centuries

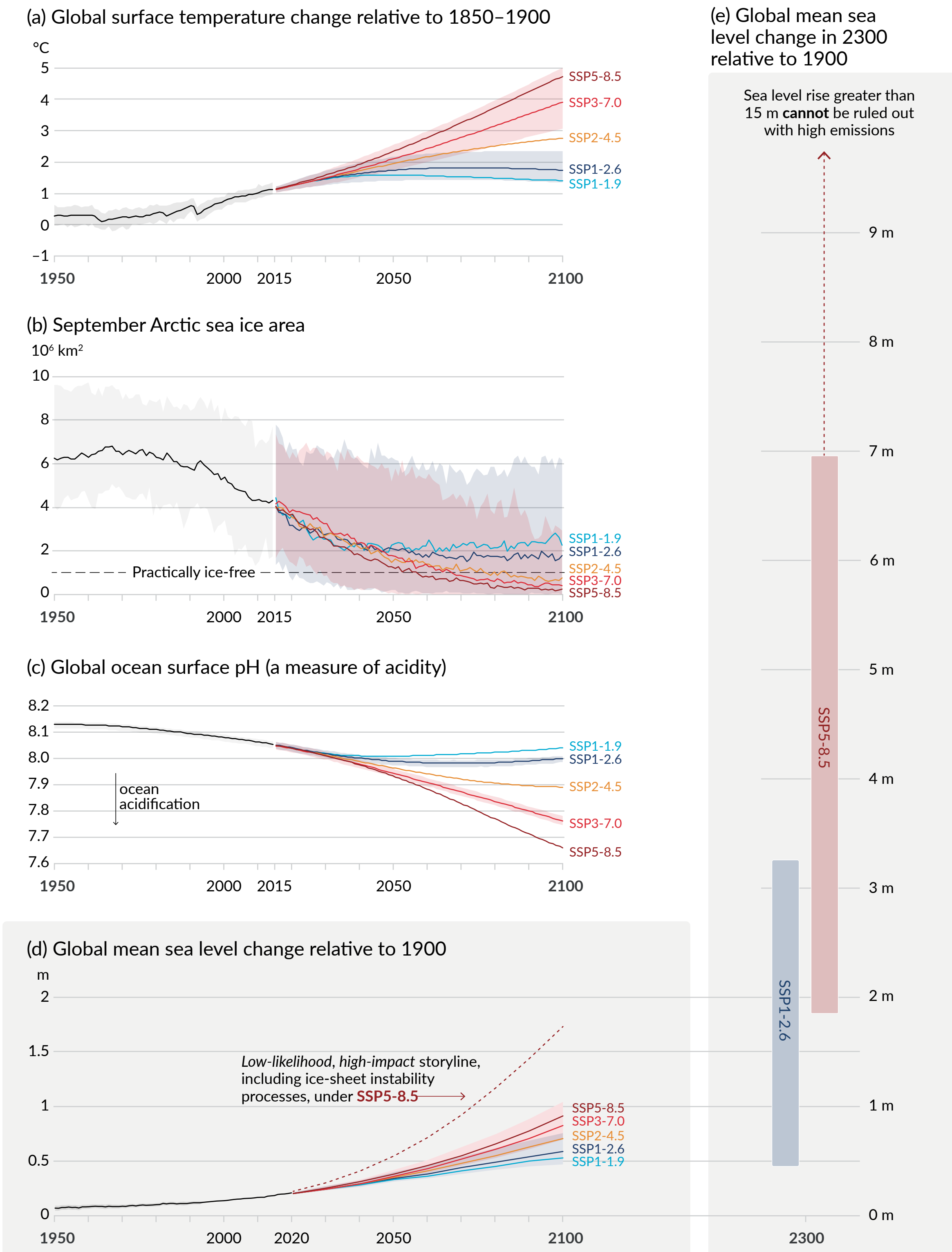

Figure SPM.8 | Selected indicators of global climate change under the five illustrative scenarios used in this Report

The projections for each of the five scenarios are shown in colour. Shades represent uncertainty ranges – more detail is provided for each panel below. The black curves represent the historical simulations (panels a, b, c) or the observations (panel d). Historical values are included in all graphs to provide context for the projected future changes.

Panel (a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining Coupled Model Intercomparison Project Phase 6 (CMIP6) model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (see Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (b) September Arctic sea ice area in 10^6 km^2 based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0. The Arctic is projected to be practically ice-free near mid-century under intermediate and high GHG emissions scenarios.

Panel (c) Global ocean surface pH (a measure of acidity) based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (d) Global mean sea level change in metres, relative to 1900. The historical changes are observed (from tide gauges before 1992 and altimeters afterwards), and the future changes are assessed consistently with observational constraints based on emulation of CMIP, ice-sheet, and glacier models. *Likely* ranges are shown for SSP1-2.6 and SSP3-7.0. Only *likely* ranges are assessed for sea level changes due to difficulties in estimating the distribution of deeply uncertain processes. The dashed curve indicates the potential impact of these deeply uncertain processes. It shows the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out; because of *low confidence* in projections of these processes, this curve does not constitute part of a *likely* range. Changes relative to 1900 are calculated by adding 0.158 m (observed global mean sea level rise from 1900 to 1995–2014) to simulated and observed changes relative to 1995–2014.

Panel (e) Global mean sea level change at 2300 in metres relative to 1900. Only SSP1-2.6 and SSP5-8.5 are projected at 2300, as simulations that extend beyond 2100 for the other scenarios are too few for robust results. The 17th–83rd percentile ranges are shaded. The dashed arrow illustrates the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out.

Panels (b) and (c) are based on single simulations from each model, and so include a component of internal variability. Panels (a), (d) and (e) are based on long-term averages, and hence the contributions from internal variability are small.

{4.3; Figures 4.2, 4.8, and 4.11; 9.6; Figure 9.27; Figures TS.8 and TS.11; Box TS.4, Figure 1}

C. Climate Information for Risk Assessment and Regional Adaptation

Physical climate information addresses how the climate system responds to the interplay between human influence, natural drivers and internal variability. Knowledge of the climate response and the range of possible outcomes, including low-likelihood, high impact outcomes, informs climate services, the assessment of climate-related risks, and adaptation planning. Physical climate information at global, regional and local scales is developed from multiple lines of evidence, including observational products, climate model outputs and tailored diagnostics.

C.1 Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes.
{1.4, 2.2, 3.3, Cross-Chapter Box 3.1, 4.4, 4.6, Cross-Chapter Box 4.1, Box 7.2, 8.3, 8.5, 9.2, 10.3, 10.4, 10.6, 11.3, 12.5, Atlas.4, Atlas.5, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box Atlas.2}

C.1.1 The historical global surface temperature record highlights that decadal variability has both enhanced and masked underlying human-caused long-term changes, and this variability will continue into the future (*very high confidence*). For example, internal decadal variability and variations in solar and volcanic drivers partially masked human-caused surface global warming during 1998–2012, with pronounced regional and seasonal signatures (*high confidence*). Nonetheless, the heating of the climate system continued during this period, as reflected in both the continued warming of the global ocean (*very high confidence*) and in the continued rise of hot extremes over land (*medium confidence*).
{1.4, 3.3, Cross-Chapter Box 3.1, 4.4, Box 7.2, 9.2, 11.3, Cross-Section Box TS.1} (Figure SPM.1)

C.1.2 Projected human-caused changes in mean climate and climatic impact-drivers (CIDs),[36] including extremes, will be either amplified or attenuated by internal variability (*high confidence*).[37] Near-term cooling at any particular location with respect to present climate could occur and would be consistent with the global surface temperature increase due to human influence (*high confidence*).
{1.4, 4.4, 4.6, 10.4, 11.3, 12.5, Atlas.5, Atlas.10, Atlas.11, TS.4.2}

36 Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions (Glossary). CID types include heat and cold, wet and dry, wind, snow and ice, coastal and open ocean.

37 The main internal variability phenomena include El Niño–Southern Oscillation, Pacific Decadal Variability and Atlantic Multi-decadal Variability through their regional influence.

C.1.3 Internal variability has largely been responsible for the amplification and attenuation of the observed human-caused decadal-to-multi-decadal mean precipitation changes in many land regions (*high confidence*). At global and regional scales, near-term changes in monsoons will be dominated by the effects of internal variability (*medium confidence*). In addition to the influence of internal variability, near-term projected changes in precipitation at global and regional scales are uncertain because of model uncertainty and uncertainty in forcings from natural and anthropogenic aerosols (*medium confidence*).
{1.4, 4.4, 8.3, 8.5, 10.3, 10.4, 10.5, 10.6, Atlas.4, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box Atlas.2, TS.4.2, Box TS.6, Box TS.13}

C.1.4 Based on paleoclimate and historical evidence, it is *likely* that at least one large explosive volcanic eruption would occur during the 21st century.[38] Such an eruption would reduce global surface temperature and precipitation, especially over land, for one to three years, alter the global monsoon circulation, modify extreme precipitation and change many CIDs (*medium confidence*). If such an eruption occurs, this would therefore temporarily and partially mask human-caused climate change.
{2.2, 4.4, Cross-Chapter Box 4.1, 8.5, TS.2.1}

C.2 With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.
{8.2, 9.3, 9.5, 9.6, Box 10.3, 11.3, 11.4, 11.5, 11.6, 11.7, 11.9, Box 11.3, Box 11.4, Cross-Chapter Box 11.1, 12.2, 12.3, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} (Table SPM.1, Figure SPM.9)

C.2.1 All regions[39] are projected to experience further increases in hot climatic impact-drivers (CIDs) and decreases in cold CIDs (*high confidence*). Further decreases are projected in permafrost; snow, glaciers and ice sheets; and lake and Arctic sea ice (*medium* to *high confidence*).[40] These changes would be larger at 2°C global warming or above than at 1.5°C (*high confidence*). For example, extreme heat thresholds relevant to agriculture and health are projected to be exceeded more frequently at higher global warming levels (*high confidence*).
{9.3, 9.5, 11.3, 11.9, Cross-Chapter Box 11.1, 12.3, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} (Table SPM.1, Figure SPM.9)

C.2.2 At 1.5°C global warming, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia (*high confidence*), North America (*medium* to *high confidence*)[40] and Europe (*medium confidence*). Also, more frequent and/or severe agricultural and ecological droughts are projected in a few regions in all inhabited continents except Asia compared to 1850–1900 (*medium confidence*); increases in meteorological droughts are also projected in a few regions (*medium confidence*). A small number of regions are projected to experience increases or decreases in mean precipitation (*medium confidence*).
{11.4, 11.5, 11.6, 11.9, Atlas.4, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} (Table SPM.1)

C.2.3 At 2°C global warming and above, the level of confidence in and the magnitude of the change in droughts and heavy and mean precipitation increase compared to those at 1.5°C. Heavy precipitation and associated flooding events are projected to become more intense and frequent in the Pacific Islands and across many regions of North America and Europe (*medium* to *high confidence*).[40] These changes are also seen in some regions in Australasia and Central and South America (*medium confidence*). Several regions in Africa, South America and Europe are projected to experience an increase in frequency and/or severity of agricultural and ecological droughts with *medium* to *high confidence*;[40] increases are also projected in Australasia, Central and North America, and the Caribbean with *medium confidence*. A small number of regions in Africa, Australasia, Europe and North America are also projected to be affected by increases in hydrological droughts, and several regions are projected to be affected by increases or decreases in meteorological droughts, with more regions displaying an increase (*medium confidence*). Mean precipitation is projected to increase in all polar, northern European and northern North American regions, most Asian regions and two regions of South America (*high confidence*).
{11.4, 11.6, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.11, TS.4.3} (Table SPM.1, Figure SPM.5, Figure SPM.6, Figure SPM.9)

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38 Based on 2500 year reconstructions, eruptions more negative than $-1\ W\ m^{-2}$ occur on average twice per century.

39 Regions here refer to the AR6 WGI reference regions used in this Report to summarize information in sub-continental and oceanic regions. Changes are compared to averages over the last 20–40 years unless otherwise specified. {1.4, 12.4, Atlas.1}.

40 The specific level of confidence or likelihood depends on the region considered. Details can be found in the Technical Summary and the underlying Report.

C.2.4 More CIDs across more regions are projected to change at 2°C and above compared to 1.5°C global warming (*high confidence*). Region-specific changes include intensification of tropical cyclones and/or extratropical storms (*medium confidence*), increases in river floods (*medium* to *high confidence*),[40] reductions in mean precipitation and increases in aridity (*medium* to *high confidence*),[40] and increases in fire weather (*medium* to *high confidence*).[40] There is *low confidence* in most regions in potential future changes in other CIDs, such as hail, ice storms, severe storms, dust storms, heavy snowfall and landslides.
{11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.6, Atlas.7, Atlas.8, Atlas.10, TS.4.3.1, TS.4.3.2, TS.5} (Table SPM.1, Figure SPM.9)

C.2.5 It is *very likely* to *virtually certain*[40] that regional mean relative sea level rise will continue throughout the 21st century, except in a few regions with substantial geologic land uplift rates. Approximately two-thirds of the global coastline has a projected regional relative sea level rise within ±20% of the global mean increase (*medium confidence*). Due to relative sea level rise, extreme sea level events that occurred once per century in the recent past are projected to occur at least annually at more than half of all tide gauge locations by 2100 (*high confidence*). Relative sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts (*high confidence*).
{9.6, 12.4, 12.5, Cross-Chapter Box 12.1, Box TS.4, TS.4.3} (Figure SPM.9)

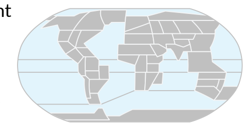
C.2.6 Cities intensify human-induced warming locally, and further urbanization together with more frequent hot extremes will increase the severity of heatwaves (*very high confidence*). Urbanization also increases mean and heavy precipitation over and/or downwind of cities (*medium confidence*) and resulting runoff intensity (*high confidence*). In coastal cities, the combination of more frequent extreme sea level events (due to sea level rise and storm surge) and extreme rainfall/riverflow events will make flooding more probable (*high confidence*).
{8.2, Box 10.3, 11.3, 12.4, Box TS.14}

C.2.7 Many regions are projected to experience an increase in the probability of compound events with higher global warming (*high confidence*). In particular, concurrent heatwaves and droughts are *likely* to become more frequent. Concurrent extremes at multiple locations, including in crop-producing areas, become more frequent at 2°C and above compared to 1.5°C global warming (*high confidence*).
{11.8, Box 11.3, Box 11.4, 12.3, 12.4, Cross-Chapter Box 12.1, TS.4.3} (Table SPM.1)

SPM

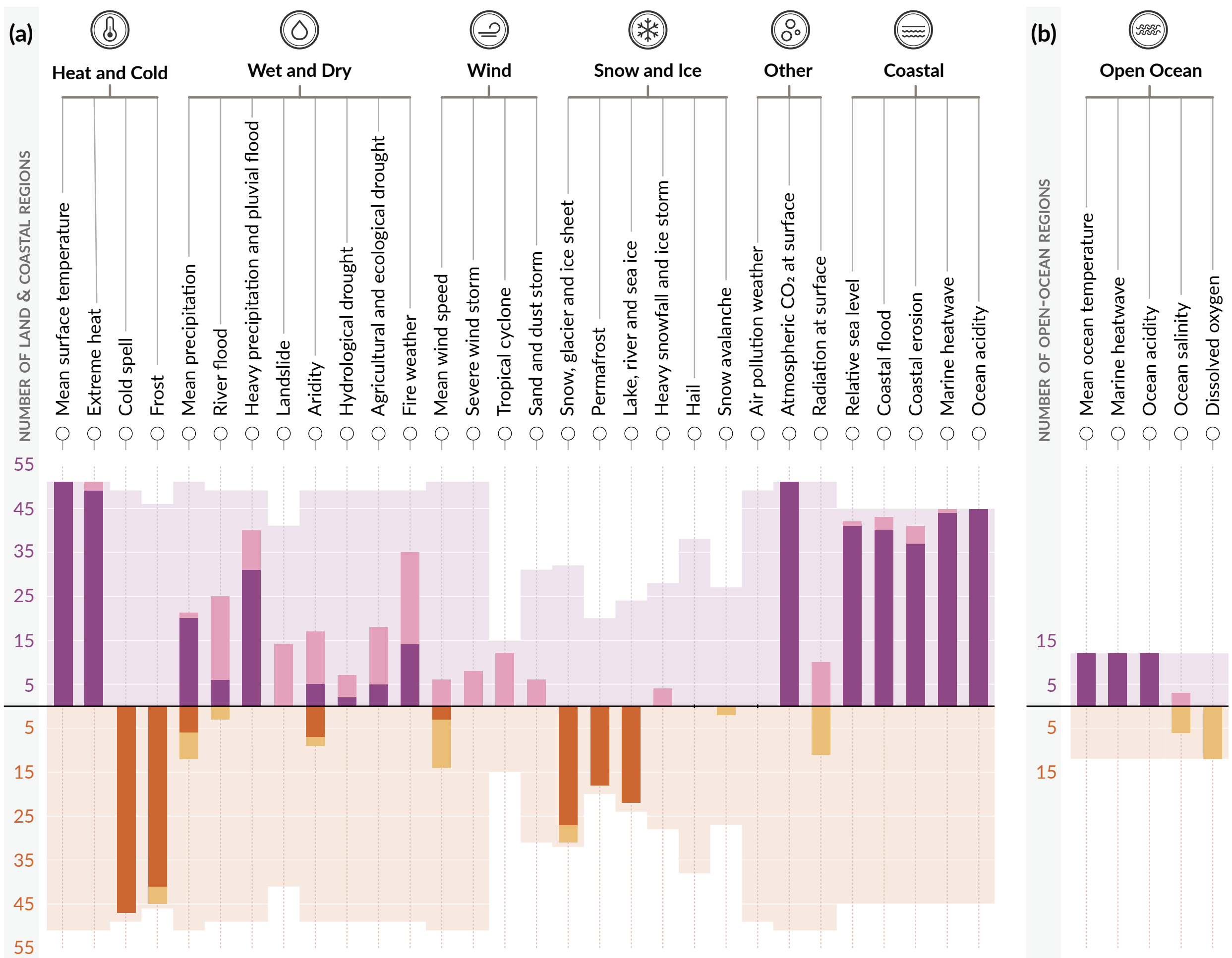
Multiple climatic impact-drivers are projected to change in all regions of the world

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions. The CIDs are grouped into seven types, which are summarized under the icons in the figure. All regions are projected to experience changes in at least 5 CIDs. Almost all (96%) are projected to experience changes in at least 10 CIDs and half in at least 15 CIDs. For many CID changes, there is wide geographical variation, and so each region is projected to experience a specific set of CID changes. Each bar in the chart represents a specific geographical set of changes that can be explored in the WGI Interactive Atlas.



interactive-atlas.ipcc.ch

Number of land & coastal regions (a) and **open-ocean regions** (b) where each **climatic impact-driver** (CID) is projected to **increase** or **decrease** with ***high** confidence* (dark shade) or ***medium** confidence* (light shade)



BAR CHART LEGEND

- Regions with ***high** confidence* **increase**
- Regions with ***medium** confidence* **increase**
- Regions with ***high** confidence* **decrease**
- Regions with ***medium** confidence* **decrease**

LIGHTER-SHADED 'ENVELOPE' LEGEND

The height of the lighter shaded 'envelope' behind each bar represents the maximum number of regions for which each CID is relevant. The envelope is symmetrical about the x-axis showing the maximum possible number of relevant regions for CID increase (upper part) or decrease (lower part).

ASSESSED FUTURE CHANGES

Changes refer to a 20–30 year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960–2014 or 1850–1900.

Figure SPM.9 | Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change

A total of 35 climatic impact-drivers (CIDs) grouped into seven types are shown: heat and cold; wet and dry; wind; snow and ice; coastal; open ocean; and other. For each CID, the bar in the graph below displays the number of AR6 WGI reference regions where it is projected to change. The **colours** represent the direction of change and the level of confidence in the change: purple indicates an increase while brown indicates a decrease; darker and lighter shades refer to *high* and *medium confidence*, respectively. Lighter background colours represent the maximum number of regions for which each CID is broadly relevant.

Panel (a) shows the 30 CIDs relevant to the **land and coastal regions**, while **panel (b)** shows the five CIDs relevant to the **open-ocean regions**. Marine heatwaves and ocean acidity are assessed for coastal ocean regions in panel (a) and for open-ocean regions in panel (b). Changes refer to a 20–30-year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960–2014, except for hydrological drought and agricultural and ecological drought, which is compared to 1850–1900. Definitions of the regions are provided in Sections 12.4 and Atlas.1 and the Interactive Atlas (see https://interactive-atlas.ipcc.ch/).

{11.9, 12.2, 12.4, Atlas.1, Table TS.5, Figures TS.22 and TS.25} (Table SPM.1)

C.3 Low-likelihood outcomes, such as ice-sheet collapse, abrupt ocean circulation changes, some compound extreme events, and warming substantially larger than the assessed *very likely* range of future warming, cannot be ruled out and are part of risk assessment.
{1.4, Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Cross-Chapter Box 4.1, 8.6, 9.2, Box 9.4, 11.8, Box 11.2, Cross-Chapter Box 12.1} (Table SPM.1)

C.3.1 If global warming exceeds the assessed *very likely* range for a given GHG emissions scenario, including low GHG emissions scenarios, global and regional changes in many aspects of the climate system, such as regional precipitation and other CIDs, would also exceed their assessed *very likely* ranges (*high confidence*). Such low-likelihood, high-warming outcomes are associated with potentially very large impacts, such as through more intense and more frequent heatwaves and heavy precipitation, and high risks for human and ecological systems, particularly for high GHG emissions scenarios.
{Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Box 9.4, Box 11.2, Cross-Chapter Box 12.1, TS.1.4, Box TS.3, Box TS.4} (Table SPM.1)

C.3.2 Low-likelihood, high-impact outcomes[34] could occur at global and regional scales even for global warming within the *very likely* range for a given GHG emissions scenario. The probability of low-likelihood, high-impact outcomes increases with higher global warming levels (*high confidence*). Abrupt responses and tipping points of the climate system, such as strongly increased Antarctic ice-sheet melt and forest dieback, cannot be ruled out (*high confidence*).
{1.4, 4.3, 4.4, 4.8, 5.4, 8.6, Box 9.4, Cross-Chapter Box 12.1, TS.1.4, TS.2.5, Box TS.3, Box TS.4, Box TS.9} (Table SPM.1)

C.3.3 If global warming increases, some compound extreme events[18] with low likelihood in past and current climate will become more frequent, and there will be a higher likelihood that events with increased intensities, durations and/or spatial extents unprecedented in the observational record will occur (*high confidence*).
{11.8, Box 11.2, Cross-Chapter Box 12.1, Box TS.3, Box TS.9}

C.3.4 The Atlantic Meridional Overturning Circulation is *very likely* to weaken over the 21st century for all emissions scenarios. While there is *high confidence* in the 21st century decline, there is only *low confidence* in the magnitude of the trend. There is *medium confidence* that there will not be an abrupt collapse before 2100. If such a collapse were to occur, it would *very likely* cause abrupt shifts in regional weather patterns and water cycle, such as a southward shift in the tropical rain belt, weakening of the African and Asian monsoons and strengthening of Southern Hemisphere monsoons, and drying in Europe.
{4.3, 8.6, 9.2, TS2.4, Box TS.3}

C.3.5 Unpredictable and rare natural events not related to human influence on climate may lead to low-likelihood, high-impact outcomes. For example, a sequence of large explosive volcanic eruptions within decades has occurred in the past, causing substantial global and regional climate perturbations over several decades. Such events cannot be ruled out in the future, but due to their inherent unpredictability they are not included in the illustrative set of scenarios referred to in this Report
{2.2, Cross-Chapter Box 4.1, Box TS.3} (Box SPM.1)

D. Limiting Future Climate Change

Since AR5, estimates of remaining carbon budgets have been improved by a new methodology first presented in SR1.5, updated evidence, and the integration of results from multiple lines of evidence. A comprehensive range of possible future air pollution controls in scenarios is used to consistently assess the effects of various assumptions on projections of climate and air pollution. A novel development is the ability to ascertain when climate responses to emissions reductions would become discernible above natural climate variability, including internal variability and responses to natural drivers.

D.1 From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH_4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.
{3.3, 4.6, 5.1, 5.2, 5.4, 5.5, 5.6, Box 5.2, Cross-Chapter Box 5.1, 6.7, 7.6, 9.6} (Figure SPM.10, Table SPM.2)

D.1.1 This Report reaffirms with *high confidence* the AR5 finding that there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to *likely* cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C.[41] This is a narrower range compared to AR5 and SR1.5. This quantity is referred to as the transient climate response to cumulative CO_2 emissions (TCRE). This relationship implies that reaching net zero anthropogenic CO_2 emissions[42] is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO_2 emissions to within a carbon budget.[43] {5.4, 5.5, TS.1.3, TS.3.3, Box TS.5} (Figure SPM.10)

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)

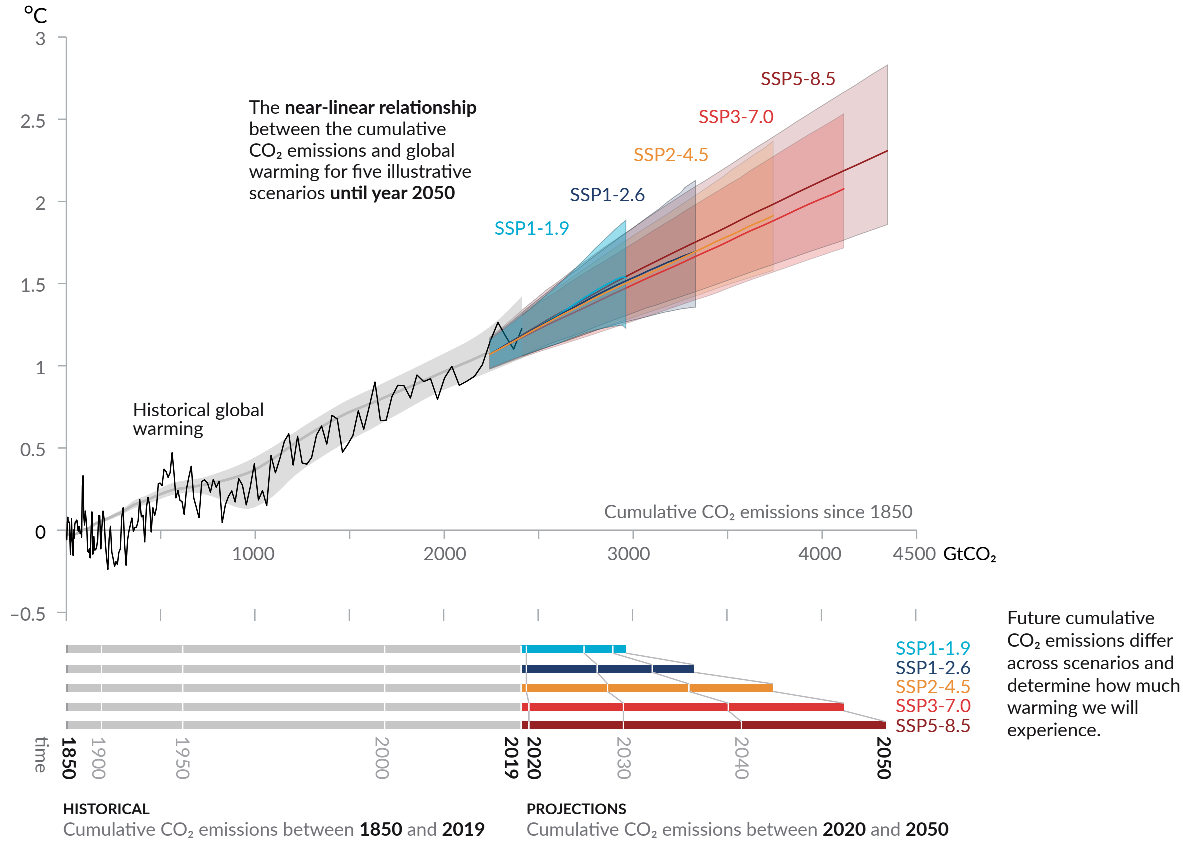


Figure SPM.10 | Near-linear relationship between cumulative CO_2 emissions and the increase in global surface temperature

Top panel: Historical data (thin black line) shows observed global surface temperature increase in °C since 1850–1900 as a function of historical cumulative carbon dioxide (CO_2) emissions in $GtCO_2$ from 1850 to 2019. The grey range with its central line shows a corresponding estimate of the historical human-caused surface warming (see Figure SPM.2). Coloured areas show the assessed *very likely* range of global surface temperature projections, and thick coloured central lines show the median estimate as a function of cumulative CO_2 emissions from 2020 until year 2050 for the set of illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5; see Figure SPM.4). Projections use the cumulative CO_2 emissions of each respective scenario, and the projected global warming includes the contribution from all anthropogenic forcers. The relationship is illustrated over the domain of cumulative CO_2 emissions for which there is *high confidence* that the transient climate response to cumulative CO_2 emissions (TCRE) remains constant, and for the time period from 1850 to 2050 over which global CO_2 emissions remain net positive under all illustrative scenarios, as there is *limited evidence* supporting the quantitative application of TCRE to estimate temperature evolution under net negative CO_2 emissions.

Bottom panel: Historical and projected cumulative CO_2 emissions in $GtCO_2$ for the respective scenarios.

{Section 5.5, Figure 5.31, Figure TS.18}

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41 In the literature, units of °C per 1000 PgC (petagrams of carbon) are used, and the AR6 reports the TCRE ***likely*** range as 1.0°C to 2.3°C per 1000 PgC in the underlying report, with a best estimate of 1.65°C.

42 The condition in which anthropogenic carbon dioxide (CO_2) emissions are balanced by anthropogenic CO_2 removals over a specified period (Glossary).

43 The term 'carbon budget' refers to the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date (Glossary). Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level.

D.1.2 Over the period 1850–2019, a total of 2390 ± 240 (*likely* range) $GtCO_2$ of anthropogenic CO_2 was emitted. Remaining carbon budgets have been estimated for several global temperature limits and various levels of probability, based on the estimated value of TCRE and its uncertainty, estimates of historical warming, variations in projected warming from non-CO_2 emissions, climate system feedbacks such as emissions from thawing permafrost, and the global surface temperature change after global anthropogenic CO_2 emissions reach net zero.
{5.1, 5.5, Box 5.2, TS.3.3} (Table SPM.2)

Table SPM.2 | Estimates of historical carbon dioxide (CO_2) emissions and remaining carbon budgets. Estimated remaining carbon budgets are calculated from the beginning of 2020 and extend until global net zero CO_2 emissions are reached. They refer to CO_2 emissions, while accounting for the global warming effect of non-CO_2 emissions. Global warming in this table refers to human-induced global surface temperature increase, which excludes the impact of natural variability on global temperatures in individual years.
{Table 3.1, 5.5.1, 5.5.2, Box 5.2, Table 5.1, Table 5.7, Table 5.8, Table TS.3}

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

[a] Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.

[b] This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.

[c] Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

D.1.3 Several factors that determine estimates of the remaining carbon budget have been re-assessed, and updates to these factors since SR1.5 are small. When adjusted for emissions since previous reports, estimates of remaining carbon budgets are therefore of similar magnitude compared to SR1.5 but larger compared to AR5 due to methodological improvements.[44]
{5.5, Box 5.2, TS.3.3} (Table SPM.2)

D.1.4 Anthropogenic CO_2 removal (CDR) has the potential to remove CO_2 from the atmosphere and durably store it in reservoirs (*high confidence*). CDR aims to compensate for residual emissions to reach net zero CO_2 or net zero GHG emissions or, if implemented at a scale where anthropogenic removals exceed anthropogenic emissions, to lower surface temperature. CDR methods can have potentially wide-ranging effects on biogeochemical cycles and climate, which can either weaken or strengthen the potential of these methods to remove CO_2 and reduce warming, and can also influence water availability and quality, food production and biodiversity[45] (*high confidence*).
{5.6, Cross-Chapter Box 5.1, TS.3.3}

D.1.5 Anthropogenic CO_2 removal (CDR) leading to global net negative emissions would lower the atmospheric CO_2 concentration and reverse surface ocean acidification (*high confidence*). Anthropogenic CO_2 removals and emissions are partially

44 Compared to AR5, and when taking into account emissions since AR5, estimates in AR6 are about 300–350 $GtCO_2$ larger for the remaining carbon budget consistent with limiting warming to 1.5°C; for 2°C, the difference is about 400–500 $GtCO_2$.

45 Potential negative and positive effects of CDR for biodiversity, water and food production are methods-specific and are often highly dependent on local context, management, prior land use, and scale. IPCC Working Groups II and III assess the CDR potential and ecological and socio-economic effects of CDR methods in their AR6 contributions.

compensated by CO_2 release and uptake respectively, from or to land and ocean carbon pools (*very high confidence*). CDR would lower atmospheric CO_2 by an amount approximately equal to the increase from an anthropogenic emission of the same magnitude (*high confidence*). The atmospheric CO_2 decrease from anthropogenic CO_2 removals could be up to 10% less than the atmospheric CO_2 increase from an equal amount of CO_2 emissions, depending on the total amount of CDR (*medium confidence*).
{5.3, 5.6, TS.3.3}

D.1.6 If global net negative CO_2 emissions were to be achieved and be sustained, the global CO_2-induced surface temperature increase would be gradually reversed but other climate changes would continue in their current direction for decades to millennia (*high confidence*). For instance, it would take several centuries to millennia for global mean sea level to reverse course even under large net negative CO_2 emissions (*high confidence*).
{4.6, 9.6, TS.3.3}

D.1.7 In the five illustrative scenarios, simultaneous changes in CH_4, aerosol and ozone precursor emissions, which also contribute to air pollution, lead to a net global surface warming in the near and long term (*high confidence*). In the long term, this net warming is lower in scenarios assuming air pollution controls combined with strong and sustained CH_4 emissions reductions (*high confidence*). In the low and very low GHG emissions scenarios, assumed reductions in anthropogenic aerosol emissions lead to a net warming, while reductions in CH_4 and other ozone precursor emissions lead to a net cooling. Because of the short lifetime of both CH_4 and aerosols, these climate effects partially counterbalance each other, and reductions in CH_4 emissions also contribute to improved air quality by reducing global surface ozone (*high confidence*).
{6.7, Box TS.7} (Figure SPM.2, Box SPM.1)

D.1.8 Achieving global net zero CO_2 emissions, with anthropogenic CO_2 emissions balanced by anthropogenic removals of CO_2, is a requirement for stabilizing CO_2-induced global surface temperature increase. This is different from achieving net zero GHG emissions, where metric-weighted anthropogenic GHG emissions equal metric-weighted anthropogenic GHG removals. For a given GHG emissions pathway, the pathways of individual GHGs determine the resulting climate response,[46] whereas the choice of emissions metric[47] used to calculate aggregated emissions and removals of different GHGs affects what point in time the aggregated GHGs are calculated to be net zero. Emissions pathways that reach and sustain net zero GHG emissions defined by the 100-year global warming potential are projected to result in a decline in surface temperature after an earlier peak (*high confidence*).
{4.6, 7.6, Box 7.3, TS.3.3}

D.2 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) lead within years to discernible effects on greenhouse gas and aerosol concentrations and air quality, relative to high and very high GHG emissions scenarios (SSP3-7.0 or SSP5-8.5). Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers (*high confidence*).
{4.6, 6.6, 6.7, Cross-Chapter Box 6.1, 9.6, 11.2, 11.4, 11.5, 11.6, Cross-Chapter Box 11.1, 12.4, 12.5} (Figure SPM.8, Figure SPM.10)

D.2.1 Emissions reductions in 2020 associated with measures to reduce the spread of COVID-19 led to temporary but detectable effects on air pollution (*high confidence*) and an associated small, temporary increase in total radiative forcing, primarily due to reductions in cooling caused by aerosols arising from human activities (*medium confidence*). Global and regional climate responses to this temporary forcing are, however, undetectable above natural variability (*high confidence*). Atmospheric CO_2 concentrations continued to rise in 2020, with no detectable decrease in the observed CO_2 growth rate (*medium confidence*).[48]
{Cross-Chapter Box 6.1, TS.3.3}

D.2.2 Reductions in GHG emissions also lead to air quality improvements. However, in the near term,[49] even in scenarios with strong reduction of GHGs, as in the low and very low GHG emissions scenarios (SSP1-2.6 and SSP1-1.9), these improvements

46 A general term for how the climate system responds to a radiative forcing (Glossary).

47 The choice of emissions metric depends on the purposes for which gases or forcing agents are being compared. This Report contains updated emissions metric values and assesses new approaches to aggregating gases.

48 For other GHGs, there was insufficient literature available at the time of the assessment to assess detectable changes in their atmospheric growth rate during 2020.

49 Near term: 2021–2040.

are not sufficient in many polluted regions to achieve air quality guidelines specified by the World Health Organization (*high confidence*). Scenarios with targeted reductions of air pollutant emissions lead to more rapid improvements in air quality within years compared to reductions in GHG emissions only, but from 2040, further improvements are projected in scenarios that combine efforts to reduce air pollutants as well as GHG emissions, with the magnitude of the benefit varying between regions (*high confidence*).
{6.6, 6.7, Box TS.7}.

D.2.3 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) would have rapid and sustained effects to limit human-caused climate change, compared with scenarios with high or very high GHG emissions (SSP3-7.0 or SSP5-8.5), but early responses of the climate system can be masked by natural variability. For global surface temperature, differences in 20-year trends would *likely* emerge during the near term under a very low GHG emissions scenario (SSP1-1.9), relative to a high or very high GHG emissions scenario (SSP3-7.0 or SSP5-8.5). The response of many other climate variables would emerge from natural variability at different times later in the 21st century (*high confidence*).
{4.6, Cross-Section Box TS.1} (Figure SPM.8, Figure SPM.10)

D.2.4 Scenarios with very low and low GHG emissions (SSP1-1.9 and SSP1-2.6) would lead to substantially smaller changes in a range of CIDs[36] beyond 2040 than under high and very high GHG emissions scenarios (SSP3-7.0 and SSP5-8.5). By the end of the century, scenarios with very low and low GHG emissions would strongly limit the change of several CIDs, such as the increases in the frequency of extreme sea level events, heavy precipitation and pluvial flooding, and exceedance of dangerous heat thresholds, while limiting the number of regions where such exceedances occur, relative to higher GHG emissions scenarios (*high confidence*). Changes would also be smaller in very low compared to low GHG emissions scenarios, as well as for intermediate (SSP2-4.5) compared to high or very high GHG emissions scenarios (*high confidence*).
{9.6, 11.2, 11.3, 11.4, 11.5, 11.6, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, TS.4.3}

Attachment 27

Climate Change 2022: Impacts, Adaptation, and Vulnerability
Summary for Lawmakers

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INTERGOVERNMENTAL PANEL ON climate change

Climate Change 2022

Impacts, Adaptation and Vulnerability

Summary for Policymakers

WGII

Working Group II contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

WMO UNEP

Summary for Policymakers

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Table of Contents

SPM.A: Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group II (WGII) contribution to the Sixth Assessment Report (AR6) of the IPCC[1]. The report builds on the WGII contribution to the Fifth Assessment Report (AR5) of the IPCC, three Special Reports[2], and the Working Group I (WGI) contribution to the AR6 cycle.

This report recognizes the interdependence of climate, ecosystems and biodiversity[3], and human societies (Figure SPM.1) and integrates knowledge more strongly across the natural, ecological, social and economic sciences than earlier IPCC assessments. The assessment of climate change impacts and risks as well as adaptation is set against concurrently unfolding non-climatic global trends e.g., biodiversity loss, overall unsustainable consumption of natural resources, land and ecosystem degradation, rapid urbanisation, human demographic shifts, social and economic inequalities and a pandemic.

The scientific evidence for each key finding is found in the 18 chapters of the underlying report and in the 7 cross-chapter papers as well as the integrated synthesis presented in the Technical Summary (hereafter TS) and referred to in curly brackets {}. Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence using the IPCC calibrated language[4]. The WGII Global to Regional Atlas (Annex I) facilitates exploration of key synthesis findings across the WGII regions.

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[1] Decision IPCC/XLVI-3, The assessment covers scientific literature accepted for publication by 1 September 2021.

[2] The three Special Reports are: 'Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5)'; 'Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL)'; 'IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)'

[3] Biodiversity: Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

[4] Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, e.g., *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99-100% probability, very likely 90-100%, likely 66-100%, as likely as not 33-66%, unlikely 0-33%, very unlikely 0-10%, exceptionally unlikely 0-1%. Assessed likelihood is typeset in italics, e.g., *very likely*. This is consistent with AR5 and the other AR6 Reports.

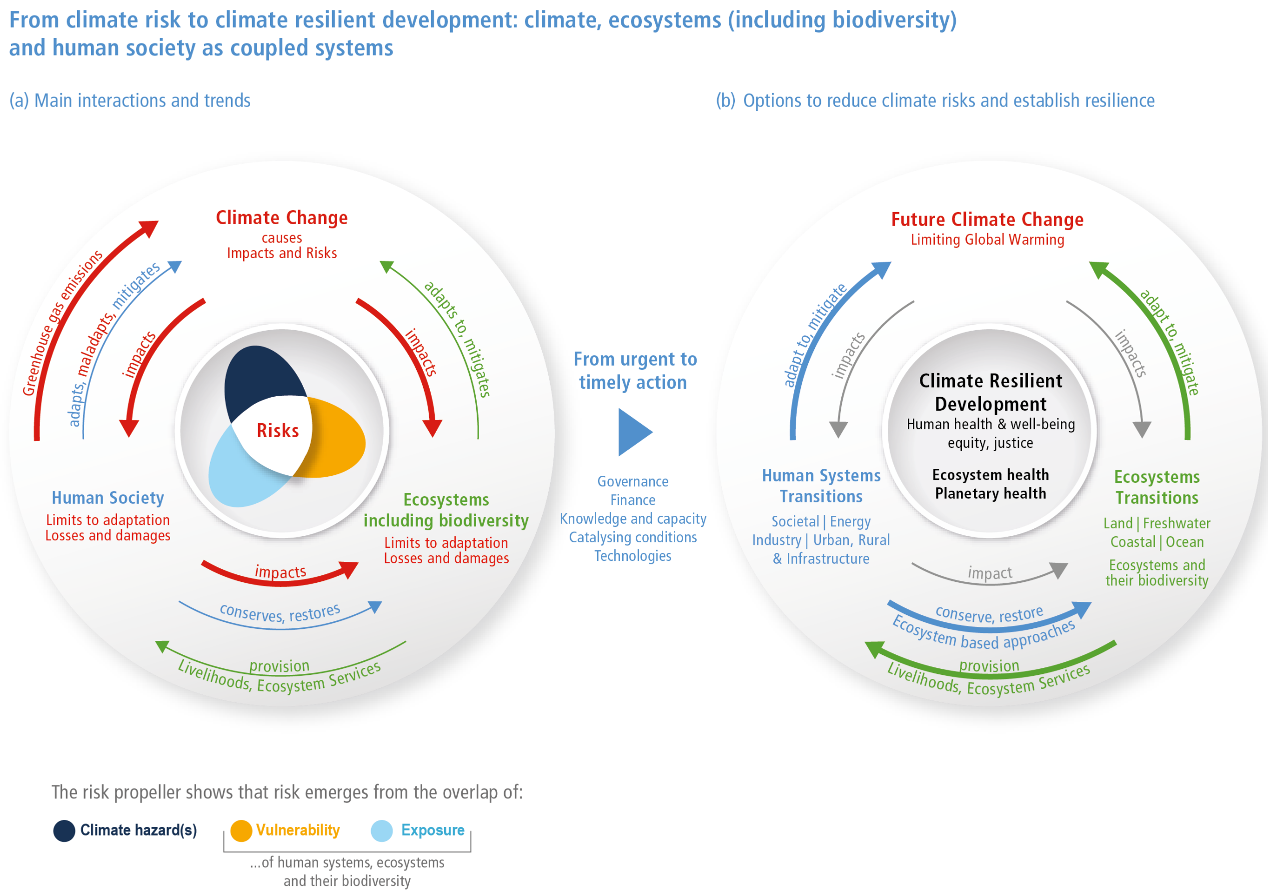

Figure SPM.1: This report has a strong focus on the interactions among the coupled systems climate, ecosystems (including their biodiversity) and human society. These interactions are the basis of emerging risks from climate change, ecosystem degradation and biodiversity loss and, at the same time, offer opportunities for the future. (a) Human society causes climate change. Climate change, through hazards, exposure and vulnerability generates impacts and risks that can surpass limits to adaptation and result in losses and damages. Human society can adapt to, maladapt and mitigate climate change, ecosystems can adapt and mitigate within limits. Ecosystems and their biodiversity provision livelihoods and ecosystem services. Human society impacts ecosystems and can restore and conserve them. (b) Meeting the objectives of climate resilient development thereby supporting human, ecosystem and planetary health, as well as human well-being, requires society and ecosystems to move over (transition) to a more resilient state. The recognition of climate risks can strengthen adaptation and mitigation actions and transitions that reduce risks. Taking action is enabled by governance, finance, knowledge and capacity building, technology and catalysing conditions. Transformation entails system transitions strengthening the resilience of ecosystems and society (Section D). In a) arrow colours represent principle human society interactions (blue), ecosystem (including biodiversity) interactions (green) and the impacts of climate change and human activities, including losses and damages, under continued climate change (red). In b) arrow colours represent human system interactions (blue), ecosystem (including biodiversity) interactions (green) and reduced impacts from climate change and human activities (grey). {1.2, Figure 1.2, Figure TS.1}

The concept of risk is central to all three AR6 Working Groups. A risk framing and the concepts of adaptation, vulnerability, exposure, resilience, equity and justice, and transformation provide alternative, overlapping, complementary, and widely used entry points to the literature assessed in this WGII report.

Across all three AR6 working groups, **risk**[5] provides a framework for understanding the increasingly severe, interconnected and often irreversible impacts of climate change on ecosystems, biodiversity, and human systems; differing impacts across regions, sectors and communities; and how to best reduce adverse

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[5] Risk is defined as the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems

consequences for current and future generations. In the context of climate change, risk can arise from the dynamic interactions among climate-related **hazards**[6] (see Working Group I), the **exposure**[7] and **vulnerability**[8] of affected human and ecological systems. The risk that can be introduced by human responses to climate change is a new aspect considered in the risk concept. This report identifies 127 key risks[9]. {1.3, 16.5}

The vulnerability of exposed human and natural systems is a component of risk, but also, independently, an important focus in the literature. Approaches to analysing and assessing vulnerability have evolved since previous IPCC assessments. Vulnerability is widely understood to differ within communities and across societies, regions and countries, also changing through time.

Adaptation[10] plays a key role in reducing exposure and vulnerability to climate change. Adaptation in ecological systems includes autonomous adjustments through ecological and evolutionary processes. In human systems, adaptation can be anticipatory or reactive, as well as incremental and/ or transformational. The latter changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts. Adaptation is subject to hard and soft limits[11].

Resilience[12] in the literature has a wide range of meanings. Adaptation is often organized around resilience as bouncing back and returning to a previous state after a disturbance. More broadly the term describes not just the ability to maintain essential function, identity and structure, but also the capacity for transformation.

This report recognises the value of diverse forms of **knowledge** such as scientific, as well as Indigenous knowledge and local knowledge in understanding and evaluating climate adaptation processes and actions to reduce risks from human-induced climate change. AR6 highlights adaptation solutions which are effective, **feasible**[13], and conform to principles of **justice**[14]. The term climate justice, while used in different ways in different contexts by different communities, generally includes three principles: *distributive justice* which refers to the allocation of burdens and benefits among individuals, nations and generations; *procedural justice* which refers to who decides and participates in decision-making; and *recognition* which entails basic respect and robust engagement with and fair consideration of diverse cultures and perspectives.

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[6] Hazard is defined as the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. Physical climate conditions that may be associated with hazards are assessed in Working Group I as climatic impact-drivers.

[7] Exposure is defined as the presence of people; livelihoods; species or ecosystems; environmental functions, services and resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected.

[8] Vulnerability in this report is defined as the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

[9] Key risks have potentially severe adverse consequences for humans and social-ecological systems resulting from the interaction of climate related hazards with vulnerabilities of societies and systems exposed.

[10] Adaptation is defined, in human systems, as the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities. In natural systems, adaptation is the process of adjustment to actual climate and its effects; human intervention may facilitate this.

[11] Adaptation Limits: The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions.

- Hard adaptation limit - No adaptive actions are possible to avoid intolerable risks.
- Soft adaptation limit - Options may exist but are currently not available to avoid intolerable risks through adaptive action.

[12] Resilience in this report is defined as the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation.

[13] Feasibility refers to the potential for an adaptation option to be implemented.

[14] Justice is concerned with setting out the moral or legal principles of fairness and equity in the way people are treated, often based on the ethics and values of society. *Social justice* comprises just or fair relations within society that seek to address the distribution of wealth, access to resources, opportunity and support according to principles of justice and fairness. *Climate justice* comprises justice that links development and human rights to achieve a rights-based approach to addressing climate change.

Effectiveness refers to the extent to which an action reduces vulnerability and climate-related risk, increases resilience, and avoids maladaptation[15].

This report has a particular focus on transformation[16] and system transitions in energy; land, ocean, coastal and freshwater ecosystems; urban, rural and infrastructure; and industry and society. These transitions make possible the adaptation required for high levels of human health and wellbeing, economic and social resilience, ecosystem health[17], and planetary health[18] (Figure SPM.1). These system transitions are also important for achieving the low global warming levels (WGIII) that would avoid many limits to adaptation[11]. The report also assesses economic and non-economic losses and damages[19]. This report labels the process of implementing mitigation and adaptation together in support of sustainable development for all as climate resilient development[20].

[START BOX SPM.1 HERE]

Box SPM.1: AR6 Common Climate Dimensions, Global Warming Levels and Reference Periods

Assessments of climate risks consider possible future climate change, societal development and responses. This report assesses literature including that based on climate model simulations that are part of the fifth and sixth Coupled Model Intercomparison Project phase (CMIP5, CMIP6) of the World Climate Research Programme. Future projections are driven by emissions and/or concentrations from illustrative Representative Concentration Pathways (RCPs)[21] and Shared Socio-economic Pathways (SSPs)[22] scenarios, respectively[23]. Climate impacts literature is based primarily on climate projections assessed in AR5 or earlier, or assumed global warming levels, though some recent impacts literature uses newer projections based on the CMIP6 exercise. Given differences in the impacts literature regarding socioeconomic details and assumptions, WGII chapters contextualize impacts with respect to exposure, vulnerability and adaptation as appropriate for their literature, this includes assessments regarding sustainable development and climate resilient development. There are many emissions and socioeconomic pathways that are consistent with a given global warming outcome. These represent a broad range of possibilities as available in the literature assessed that affect future climate change exposure and vulnerability. Where available, WGII also assesses literature that is based on an integrative SSP-RCP framework where climate projections obtained under the RCP scenarios are analysed against the backdrop of various illustrative SSPs[22]. The WGII assessment combines multiple lines of evidence including impacts modelling driven by climate projections, observations, and process understanding. {1.2, 16.5, 18.2, CCB CLIMATE, WGI SPM.C, WGI Box SPM.1, WGI 1.6, WGI Ch.12, AR5 WGI}

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[15] Maladaptation refers to actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.

[16] Transformation refers to a change in the fundamental attributes of natural and human systems.

[17] Ecosystem health: a metaphor used to describe the condition of an ecosystem, by analogy with human health. Note that there is no universally accepted benchmark for a healthy ecosystem. Rather, the apparent health status of an ecosystem is judged on the ecosystem's resilience to change, with details depending upon which metrics (such as species richness and abundance) are employed in judging it and which societal aspirations are driving the assessment.

[18] Planetary health: a concept based on the understanding that human health and human civilisation depend on ecosystem health and the wise stewardship of ecosystems.

[19] In this report, the term 'losses and damages' refers to adverse observed impacts and/or projected risks and can be economic and/or non-economic.

[20] In the WGII report, climate resilient development refers to the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development for all.

[21] RCP-based scenarios are referred to as RCPy, where 'y' refers to the level of radiative forcing (in watts per square meter, or $W\ m^{-2}$) resulting from the scenario in the year 2100.

[22] SSP-based scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway describing the socio-economic trends underlying the scenarios, and 'y' refers to the level of radiative forcing (in watts per square meter, or $W\ m^{-2}$) resulting from the scenario in the year 2100.

[23] IPCC is neutral with regard to the assumptions underlying the SSPs, which do not cover all possible scenarios. Alternative scenarios may be considered or developed.

A common set of reference years and time periods are adopted for assessing climate change and its impacts and risks: the reference period 1850–1900 approximates pre-industrial global surface temperature, and three future reference periods cover the near-term (2021–2040), mid-term (2041–2060) and long-term (2081–2100). {CCB CLIMATE}

Common levels of global warming relative to 1850-1900 are used to contextualize and facilitate analysis, synthesis and communication of assessed past, present and future climate change impacts and risks considering multiple lines of evidence. Robust geographical patterns of many variables can be identified at a given level of global warming, common to all scenarios considered and independent of timing when the global warming level is reached. {16.5, CCB CLIMATE, WGI 4.2, WGI CCB11.1, WGI Box SPM.1}

WGI assessed increase in global surface temperature is 1.09 [0.95 to 1.20][24] °C in 2011-2020 above 1850-1900. The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C).[25] Considering all five illustrative scenarios assessed by WGI, there is at least a greater than 50% likelihood that global warming will reach or exceed 1.5°C in the near-term, even for the very low greenhouse gas emissions scenario[26]. {WGI CCB 2.3, WGI SPM A1.2, WGI SPM B1.3, WGI Table SPM.1}

[END BOX SPM.1 HERE]

SPM.B: Observed and Projected Impacts and Risks

Since AR5, the knowledge base on observed and projected impacts and risks generated by climate hazards, exposure and vulnerability has increased with impacts attributed to climate change and key risks identified across the report. Impacts and risks are expressed in terms of their damages, harms, economic, and non-economic losses. Risks from observed vulnerabilities and responses to climate change are highlighted. Risks are projected for the near-term (2021-2040), the mid (2041-2060) and long term (2081-2100), at different global warming levels and for pathways that overshoot 1.5°C global warming level for multiple decades[27]. Complex risks result from multiple climate hazards occurring concurrently, and from multiple risks interacting, compounding overall risk and resulting in risks transmitting through interconnected systems and across regions.

Observed Impacts from Climate Change

SPM.B.1 Human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability. Some development and adaptation efforts have reduced vulnerability. Across sectors and regions the most vulnerable people and systems are observed to be disproportionately affected. The rise in weather

[24] In the WGI report, square brackets [x to y] are used to provide the assessed *very likely* range, or 90% interval.

[25] Since AR5, methodological advances and new datasets have provided a more complete spatial representation of changes in surface temperature, including in the Arctic. These and other improvements have also increased the estimate of global surface temperature change by approximately 0.1°C, but this increase does not represent additional physical warming since AR5.

[26] Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century under the intermediate, high and very high greenhouse gas emissions scenarios considered in this report (SSP2-4.5, SSP3-7.0 and SSP5-8.5, respectively). Under the five illustrative scenarios, in the near term (2021–2040), the 1.5°C global warming level is *very likely* to be exceeded under the very high greenhouse gas emissions scenario (SSP5-8.5), *likely* to be exceeded under the intermediate and high greenhouse gas emissions scenarios (SSP2-4.5 and SSP3-7.0), *more likely than not* to be exceeded under the low greenhouse gas emissions scenario (SSP1-2.6) and *more likely than not* to be reached under the very low greenhouse gas emissions scenario (SSP1-1.9). Furthermore, for the very low greenhouse gas emissions scenario (SSP1-1.9), it is *more likely than not* that global surface temperature would decline back to below 1.5°C toward the end of the 21st century, with a temporary overshoot of no more than 0.1°C above 1.5°C global warming.

[27] Overshoot: In this report, pathways that first exceed a specified global warming level (usually 1.5°C, by more than 0.1°C), and then return to or below that level again before the end of a specified period of time (e.g., before 2100). Sometimes the magnitude and likelihood of the overshoot is also characterized. The overshoot duration can vary from at least one decade up to several decades.

and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt. (*high confidence*) (Figure SPM.2) {1.3, 2.3, 2.4, 2.6, 3.3, 3.4, 3.5, 4.2, 4.3, 5.2, 5.12, 6.2, 7.2, 8.2, 9.6, 9.8, 9.10, 9.11, 10.4, 11.3, 12.3, 12.4, 13.10, 14.4, 14.5, 15.3, 16.2, CCP1.2, CCP3.2, CCP4.1, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCB EXTREMES, CCB ILLNESS, CCB SLR, CCB NATURAL, CCB DISASTER, CCB MIGRATE, Figure TS.5, TS B1

SPM.B.1.1 Widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure have resulted from observed increases in the frequency and intensity of climate and weather extremes, including hot extremes on land and in the ocean, heavy precipitation events, drought and fire weather (*high confidence*). Increasingly since AR5, these observed impacts have been attributed[28] to human-induced climate change particularly through increased frequency and severity of extreme events. These include increased heat-related human mortality (*medium confidence*), warm-water coral bleaching and mortality (*high confidence*), and increased drought related tree mortality (*high confidence*). Observed increases in areas burned by wildfires have been attributed to human-induced climate change in some regions (*medium* to *high confidence*). Adverse impacts from tropical cyclones, with related losses and damages[19], have increased due to sea level rise and the increase in heavy precipitation (*medium confidence*). Impacts in natural and human systems from slow-onset processes[29] such as ocean acidification, sea level rise or regional decreases in precipitation have also been attributed to human induced climate change (*high confidence*). {1.3, 2.3, 2.4, 2.5, 3.2, 3.4, 3.5, 3.6, 4.2, 5.2, 5.4, 5.6, 5.12, 7.2, 9.6, 9.8, 9.7, 9.8, 9.11, 11.3, Box 11.1, Box 11.2, Table 11.9, 12.3, 12.4, 13.3, 13.5, 13.10, 14.2,14.5, 15.7, 15.8, 16.2, Box CCP5.1, CCP1.2, CCP2.2, CCP7.3, CCB EXTREME, CCB ILLNESS, CCB DISASTER, WG1 9, WGI 11.3-11.8, WGI SPM.3, SROCC Ch. 4}

SPM.B.1.2 Climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems (*high confidence*). The extent and magnitude of climate change impacts are larger than estimated in previous assessments (*high confidence*). Widespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, as well as shifts in seasonal timing have occurred due to climate change (*high confidence*), with adverse socioeconomic consequences (*high confidence*). Approximately half of the species assessed globally have shifted polewards or, on land, also to higher elevations (*very high confidence*). Hundreds of local losses of species have been driven by increases in the magnitude of heat extremes (*high confidence*), as well as mass mortality events on land and in the ocean (*very high confidence*) and loss of kelp forests (*high confidence*). Some losses are already irreversible, such as the first species extinctions driven by climate change (*medium confidence*). Other impacts are approaching irreversibility such as the impacts of hydrological changes resulting from the retreat of glaciers, or the changes in some mountain (*medium confidence*) and Arctic ecosystems driven by permafrost thaw (*high confidence*). (Figure SPM.2a). {2.3, 2.4, 3.4, 3.5, 4.2, 4.3, 4.5, 9.6, 10.4, 11.3, 12.3, 12.8, 13.3, 13.4, 13.10, 14.4, 14.5, 14.6, 15.3, 16.2, CCP1.2; CCP3.2, CCP4.1, CCP5.2, CCP6.1, CCP6.2, CCP7.2, CCP7.3, CCP5.2, Figure CCP5.4, CCB PALEO, CCB EXTREMES, CCB ILLNESS, CCB SLR, CCB NATURAL, CCB MOVING PLATE, Figure TS.5, TS B1, SROCC 2.3}

[28] Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence. {Annex II Glossary, CWGB ATTRIB}

[29] Impacts of climate change are caused by slow onset and extreme events. Slow onset events are described among the climatic-impact drivers of the WGI AR6 and refer to the risks and impacts associated with e.g., increasing temperature means, desertification, decreasing precipitation, loss of biodiversity, land and forest degradation, glacial retreat and related impacts, ocean acidification, sea level rise and salinization (https://interactive-atlas.ipcc.ch).

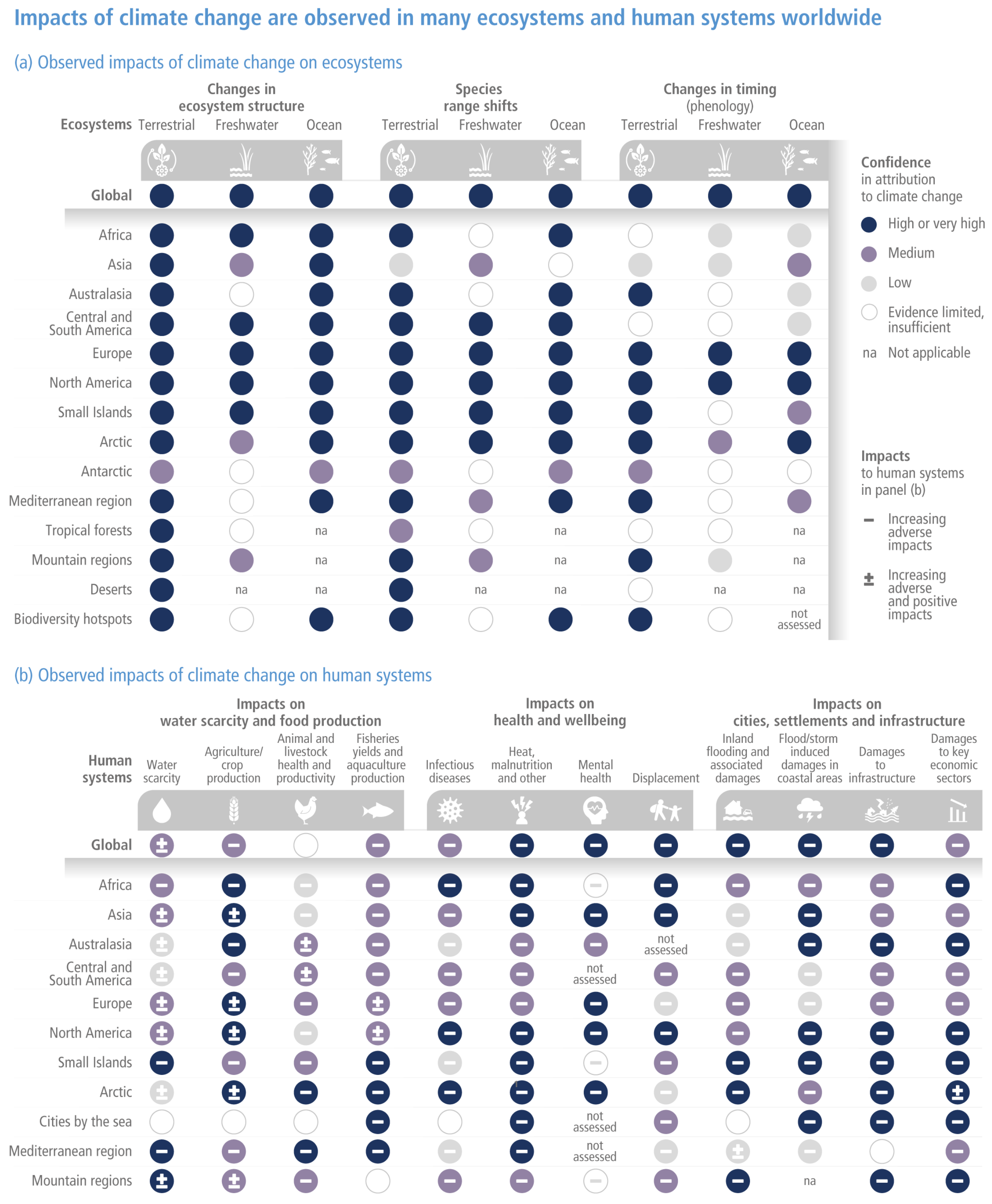

Figure SPM.2: Observed global and regional impacts on ecosystems and human systems attributed to climate change. Confidence levels reflect uncertainty in attribution of the observed impact to climate change. Global assessments focus on large studies, multi-species, meta-analyses and large reviews. For that reason they can be assessed with higher confidence than regional studies, which may often rely on smaller studies that have more limited data. Regional assessments consider evidence on impacts across an entire region and do not focus on any country in particular. (a) Climate change has already altered terrestrial, freshwater and ocean ecosystems at global scale, with multiple impacts evident at regional and local scales where there is sufficient literature to make an assessment. Impacts are evident on ecosystem structure, species geographic ranges and timing of seasonal life cycles (phenology) (for methodology and detailed references to chapters and cross-chapter papers see SMTS.1 and SMTS.1.1). (b) Climate change has already had diverse adverse impacts on human systems, including on water security and food production, health and well-being, and cities, settlements and infrastructure. The + and – symbols indicate the direction of observed impacts, with a – denoting an increasing adverse impact and a ± denoting that, within a region or globally, both adverse and positive impacts have been observed (e.g., adverse impacts in one area or food item may occur with positive impacts in another area or food item). Globally, '–' denotes an overall adverse impact; 'Water scarcity' considers, e.g., water availability in general, groundwater, water quality, demand for water, drought in cities. Impacts on food production were assessed by excluding non-climatic drivers of production increases; Global assessment for agricultural production is based on the impacts on global aggregated production; 'Reduced animal and livestock health and productivity' considers, e.g., heat stress, diseases, productivity, mortality; 'Reduced fisheries yields and aquaculture production' includes marine and freshwater fisheries/production; 'Infectious diseases' include, e.g., water-borne and vector-borne diseases; 'Heat, malnutrition and other' considers, e.g., human heat-related morbidity and mortality, labour productivity, harm from wildfire, nutritional deficiencies; 'Mental health' includes impacts from extreme weather events, cumulative events, and vicarious or anticipatory events; 'Displacement' assessments refer to evidence of displacement attributable to climate and weather extremes; 'Inland flooding and associated damages' considers, e.g., river overflows, heavy rain, glacier outbursts, urban flooding; 'Flood/storm induced damages in coastal areas' include damages due to, e.g., cyclones, sea level rise, storm surges. Damages by key economic sectors are observed impacts related to an attributable mean or extreme climate hazard or directly attributed. Key economic sectors include standard classifications and sectors of importance to regions (for methodology and detailed references to chapters and cross-chapter papers see SMTS.1 and SMTS.1.2).

SPM.B.1.3 Climate change including increases in frequency and intensity of extremes have reduced food and water security, hindering efforts to meet Sustainable Development Goals (*high confidence*). Although overall agricultural productivity has increased, climate change has slowed this growth over the past 50 years globally (*medium confidence*), related negative impacts were mainly in mid- and low latitude regions but positive impacts occurred in some high latitude regions (*high confidence*). Ocean warming and ocean acidification have adversely affected food production from shellfish aquaculture and fisheries in some oceanic regions (*high confidence*). Increasing weather and climate extreme events have exposed millions of people to acute food insecurity[30] and reduced water security, with the largest impacts observed in many locations and/or communities in Africa, Asia, Central and South America, Small Islands and the Arctic (*high confidence*). Jointly, sudden losses of food production and access to food compounded by decreased diet diversity have increased malnutrition in many communities (*high confidence*), especially for Indigenous Peoples, small-scale food producers and low-income households (*high confidence*), with children, elderly people and pregnant women particularly impacted (*high confidence*). Roughly half of the world's population currently experience severe water scarcity for at least some part of the year due to climatic and non-climatic drivers (*medium confidence*). (Figure SPM.2b) {3.5, Box 4.1, 4.3, 4.4, 5.2, 5.4, 5.8, 5.9, 5.12, 7.1, 7.2, 9.8, 10.4, 11.3, 12.3, 13.5, 14.4, 14.5, 15.3, 16.2, CCP5.2, CCP6.2}

SPM.B.1.4 Climate change has adversely affected physical health of people globally (*very high confidence)* and mental health of people in the assessed regions (*very high confidence*). Climate change impacts on health are mediated through natural and human systems, including economic and social conditions and disruptions (*high confidence*). In all regions extreme heat events have resulted in human mortality and morbidity (*very high confidence*). The occurrence of climate-related food-borne and water-borne diseases has increased (*very high confidence*). The incidence of vector-borne diseases has increased from range expansion and/or increased reproduction of disease vectors (*high confidence*). Animal and human diseases, including zoonoses, are emerging in new areas (*high confidence*). Water and food-borne disease risks have increased regionally from climate-sensitive aquatic pathogens, including *Vibrio* spp. (*high confidence*), and from toxic substances from harmful freshwater cyanobacteria (*medium confidence*). Although diarrheal diseases have decreased globally, higher temperatures, increased rain and flooding have increased the occurrence of diarrheal diseases, including cholera (*very high confidence*) and other gastrointestinal infections (*high confidence*). In assessed regions, some mental health challenges are associated with increasing temperatures (*high confidence*), trauma from weather and climate extreme events (*very high confidence*), and loss of livelihoods and culture (*high confidence*). Increased exposure to wildfire smoke, atmospheric dust, and aeroallergens have been associated with climate-sensitive cardiovascular and respiratory distress (*high confidence*). Health services have been disrupted by extreme events such as floods (*high confidence*). {4.3, 5.12, 7.2, Box 7.3, 8.2, 8.3, Figure 8.10,

[30] Acute food insecurity can occur at any time with a severity that threatens lives, livelihoods or both, regardless of the causes, context or duration, as a result of shocks risking determinants of food security and nutrition, and used to assess the need for humanitarian action (IPC Global Partners, 2019).

Box 8.6, 9.10, Figure 9.33, Figure 9.34, 10.4, 11.3, 12.3, 13.7, 14.4, 14.5, Figure 14.8, 15.3, 16.2, Table CCP5.1, CCP5.2.5, CCP6.2, Figure CCP6.3, Table CCB ILLNESS.1}

SPM.B.1.5 In urban settings, observed climate change has caused impacts on human health, livelihoods and key infrastructure (*high confidence*). Multiple climate and non-climate hazards impact cities, settlements and infrastructure and sometimes coincide, magnifying damage (*high confidence*). Hot extremes including heatwaves have intensified in cities (*high confidence*), where they have also aggravated air pollution events (*medium confidence*) and limited functioning of key infrastructure (*high confidence*). Observed impacts are concentrated amongst the economically and socially marginalized urban residents, e.g., in informal settlements (*high confidence*). Infrastructure, including transportation, water, sanitation and energy systems have been compromised by extreme and slow-onset events, with resulting economic losses, disruptions of services and impacts to wellbeing (*high confidence*). {4.3, 6.2, 7.1, 7.2, 9.9, 10.4, 11.3, 12.3, 13.6, 14.5, 15.3, CCP2.2, CCP4.2, CCP5.2}

SPM.B.1.6 Overall adverse economic impacts attributable to climate change, including slow-onset and extreme weather events, have been increasingly identified (*medium confidence*). Some positive economic effects have been identified in regions that have benefited from lower energy demand as well as comparative advantages in agricultural markets and tourism (*high confidence*). Economic damages from climate change have been detected in climate-exposed sectors, with regional effects to agriculture, forestry, fishery, energy, and tourism (*high confidence*), and through outdoor labour productivity (*high confidence*). Some extreme weather events, such as tropical cyclones, have reduced economic growth in the short-term (*high confidence*). Non-climatic factors including some patterns of settlement, and siting of infrastructure have contributed to the exposure of more assets to extreme climate hazards increasing the magnitude of the losses (*high confidence*). Individual livelihoods have been affected through changes in agricultural productivity, impacts on human health and food security, destruction of homes and infrastructure, and loss of property and income, with adverse effects on gender and social equity (*high confidence*). {3.5, 4.2, 5.12, 6.2, 7.2, 8.2, 9.6, 10.4, 13.10, 14.5, Box 14.6, 16.2, Table 16.5, 18.3, CCP6.2, CCB GENDER, CWGB ECONOMICS}

SPM.B.1.7 Climate change is contributing to humanitarian crises where climate hazards interact with high vulnerability (*high confidence*). Climate and weather extremes are increasingly driving displacement in all regions (*high confidence*), with small island states disproportionately affected (*high confidence*). Flood and drought-related acute food insecurity and malnutrition have increased in Africa (*high confidence*) and Central and South America (*high confidence*). While non-climatic factors are the dominant drivers of existing intrastate violent conflicts, in some assessed regions extreme weather and climate events have had a small, adverse impact on their length, severity or frequency, but the statistical association is weak (*medium confidence*). Through displacement and involuntary migration from extreme weather and climate events, climate change has generated and perpetuated vulnerability (*medium confidence*). {4.2, 4.3, 5.4, 7.2, 9.8, Box 9.9, Box 10.4, 12.3, 12.5, CCB MIGRATE, CCB DISASTER, 16.2}

Vulnerability and Exposure of Ecosystems and People

SPM.B.2 Vulnerability of ecosystems and people to climate change differs substantially among and within regions (*very high confidence*), driven by patterns of intersecting socio-economic development, unsustainable ocean and land use, inequity, marginalization, historical and ongoing patterns of inequity such as colonialism, and governance[31] (*high confidence*). Approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change (*high confidence*). A high proportion of species is vulnerable to climate change (*high confidence*). Human and ecosystem vulnerability are interdependent (*high confidence*). Current unsustainable development patterns are increasing exposure of ecosystems and people to climate hazards (*high confidence*). {2.3, 2.4, 3.5, 4.3, 6.2, 8.2, 8.3, 9.4, 9.7, 10.4, 12.3, 14.5, 15.3, CCP5.2, CCP6.2, CCP7.3, CCP7.4, CCB GENDER}

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[31] Governance: The structures, processes and actions through which private and public actors interact to address societal goals. This includes formal and informal institutions and the associated norms, rules, laws and procedures for deciding, managing, implementing and monitoring policies and measures at any geographic or political scale, from global to local.

SPM.B.2.1 Since AR5 there is increasing evidence that degradation and destruction of ecosystems by humans increases the vulnerability of people (*high confidence*). Unsustainable land-use and land cover change, unsustainable use of natural resources, deforestation, loss of biodiversity, pollution, and their interactions, adversely affect the capacities of ecosystems, societies, communities and individuals to adapt to climate change (*high confidence*). Loss of ecosystems and their services has cascading and long-term impacts on people globally, especially for Indigenous Peoples and local communities who are directly dependent on ecosystems, to meet basic needs (*high confidence*). {2.3, 2.5, 2.6, 3.5, 3.6, 4.2, 4.3, 4.6, 5.1, 5.4, 5.5, 5.7, 5.8, 7.2, 8.1, 8.2, 8.3, 8.4, 8.5, 9.6, 10.4, 11.3, 12.2, 12.5. 13.8, 14.4, 14.5, 15.3, CCP1.2, CCP1.3, CCP2.2, CCP3, CCP4.3, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCP7.4, CCB ILLNESS, CCB MOVING PLATE, CCB SLR}

SPM.B.2.2 Non-climatic human-induced factors exacerbate current ecosystem vulnerability to climate change (*very high confidence*). Globally, and even within protected areas, unsustainable use of natural resources, habitat fragmentation, and ecosystem damage by pollutants increase ecosystem vulnerability to climate change (*high confidence*). Globally, less than 15% of the land, 21% of the freshwater and 8% of the ocean are protected areas. In most protected areas, there is insufficient stewardship to contribute to reducing damage from, or increasing resilience to, climate change (*high confidence*). {2.4, 2.5, 2.6, 3.4, 3.6, 4.2, 4.3, 5.8, 9.6, 11.3, 12.3, 13.3, 13.4, 14.5, 15.3, CCP1.2 Figure CCP1.15, CCP2.1, CCP2.2, CCP4.2, CCP5.2, CCP 6.2, CCP7.2, CCP7.3, CCB NATURAL}

SPM.B.2.3 Future vulnerability of ecosystems to climate change will be strongly influenced by the past, present and future development of human society, including from overall unsustainable consumption and production, and increasing demographic pressures, as well as persistent unsustainable use and management of land, ocean, and water (*high confidence*). Projected climate change, combined with non-climatic drivers, will cause loss and degradation of much of the world's forests (*high confidence*), coral reefs and low-lying coastal wetlands (*very high confidence*). While agricultural development contributes to food security, unsustainable agricultural expansion, driven in part by unbalanced diets[32], increases ecosystem and human vulnerability and leads to competition for land and/or water resources (*high confidence*). {2.2, 2.3, 2.4, 2.6, 3.4, 3.5, 3.6, 4.3, 4.5, 5.6, 5.12, 5.13, 7.2, 12.3, 13.3, 13.4, 13.10, 14.5, CCP1.2, CCP2.2, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCB NATURAL, CCB HEALTH}

SPM.B.2.4 Regions and people with considerable development constraints have high vulnerability to climatic hazards (*high confidence*). Global hotspots of high human vulnerability are found particularly in West-, Central- and East Africa, South Asia, Central and South America, Small Island Developing States and the Arctic (*high confidence*). Vulnerability is higher in locations with poverty, governance challenges and limited access to basic services and resources, violent conflict and high levels of climate-sensitive livelihoods (e.g., smallholder farmers, pastoralists, fishing communities) (*high confidence*). Between 2010-2020, human mortality from floods, droughts and storms was 15 times higher in highly vulnerable regions, compared to regions with very low vulnerability (*high confidence*). Vulnerability at different spatial levels is exacerbated by inequity and marginalization linked to gender, ethnicity, low income or combinations thereof (*high confidence*), especially for many Indigenous Peoples and local communities (*high confidence*). Present development challenges causing high vulnerability are influenced by historical and ongoing patterns of inequity such as colonialism, especially for many Indigenous Peoples and local communities (*high confidence*). {4.2, 5.12, 6.2, 6.4, 7.1, 7.2, Box 7.1, 8.2, 8.3, Box 8.4, Figure 8.6, Box 9.1, 9.4, 9.7, 9.9, 10.3, 10.4, 10.6, 12.3, 12.5, Box 13.2, 14.4, 15.3, 15.6, 16.2, CCP6.2, CCP7.4}

SPM.B.2.5 Future human vulnerability will continue to concentrate where the capacities of local, municipal and national governments, communities and the private sector are least able to provide infrastructures and basic services (*high confidence*). Under the global trend of urbanization, human vulnerability will also concentrate in informal settlements and rapidly growing smaller settlements (*high confidence*). In rural areas vulnerability will be heightened by compounding processes including high emigration, reduced habitability and high reliance on climate-sensitive livelihoods (*high confidence*). Key infrastructure systems including sanitation, water, health, transport, communications and energy will be increasingly vulnerable if design

[32] Balanced diets feature plant-based foods, such as those based on coarse grains, legumes fruits and vegetables, nuts and seeds, and animal-source foods produced in resilient, sustainable and low-greenhouse gas emissions systems, as described in SRCCL.

standards do not account for changing climate conditions (*high confidence*). Vulnerability will also rapidly rise in low-lying Small Island Developing States and atolls in the context of sea level rise and in some mountain regions, already characterised by high vulnerability due to high dependence on climate-sensitive livelihoods, rising population displacement, the accelerating loss of ecosystem services and limited adaptive capacities (*high confidence*). Future exposure to climatic hazards is also increasing globally due to socio-economic development trends including migration, growing inequality and urbanization *(high confidence*). {4.5, 5.5, 6.2, 7.2, 8.3, 9.9, 9.11, 10.3, 10.4, 12.3, 12.5, 13.6, 14.5, 15.3, 15.4, 16.5, CCP2.3, CCP4.3, CCP5.2, CCP5.3, CCP5.4, CCP6.2, CCB MIGRATE}

Risks in the near term (2021-2040)

SPM.B.3 Global warming, reaching 1.5°C in the near-term, would cause unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans (*very high confidence*). The level of risk will depend on concurrent near-term trends in vulnerability, exposure, level of socioeconomic development and adaptation (*high confidence*). Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all (*very high confidence*). (Figure SPM.3, Box SPM.1) {WGI Table SPM.1, 16.4, 16.5, 16.6, CCP1.2, CCP5.3, CCB SLR, WGI SPM B1.3}

SPM.B.3.1 Near-term warming and increased frequency, severity and duration of extreme events will place many terrestrial, freshwater, coastal and marine ecosystems at high or very high risks of biodiversity loss (*medium to very high confidence*, depending on ecosystem). Near-term risks for biodiversity loss are moderate to high in forest ecosystems (*medium confidence*), kelp and seagrass ecosystems (*high* to *very high confidence*), and high to very high in Arctic sea-ice and terrestrial ecosystems (*high confidence*) and warm-water coral reefs (*very high confidence*). Continued and accelerating sea level rise will encroach on coastal settlements and infrastructure (*high confidence*) and commit low-lying coastal ecosystems to submergence and loss (*medium confidence*). If trends in urbanisation in exposed areas continue, this will exacerbate the impacts, with more challenges where energy, water and other services are constrained (*medium confidence*). The number of people at risk from climate change and associated loss of biodiversity will progressively increase (*medium confidence*). Violent conflict and, separately, migration patterns, in the near-term will be driven by socio-economic conditions and governance more than by climate change (*medium confidence*). (Figure SPM.3) {2.5, 3.4, 4.6, 6.2, 7.3, 8.7, 9.2, 9.9, 11.6, 12.5, 13.6, 13.10, 14.6, 15.3, 16.5, 16.6, CCP1.2, CCP2.1, CCP2.2, CCP5.3, CCP6.2, CCP6.3, CCB SLR, CCB MIGRATE}

SPM.B.3.2 In the near term, climate-associated risks to natural and human systems depend more strongly on changes in their vulnerability and exposure than on differences in climate hazards between emissions scenarios (*high confidence*). Regional differences exist, and risks are highest where species and people exist close to their upper thermal limits, along coastlines, in close association with ice or seasonal rivers (*high confidence*). Risks are also high where multiple non-climate drivers persist or where vulnerability is otherwise elevated (*high confidence*). Many of these risks are unavoidable in the near-term, irrespective of emission scenario (*high confidence*). Several risks can be moderated with adaptation (*high confidence*). (Figure SPM.3, Section C) {2.5, 3.3, 3.4, 4.5, 6.2, 7.1, 7.3, 8.2, 11.6, 12.4, 13.6, 13.7, 13.10, 14.5, 16.4, 16.5, CCP2.2, CCP4.3, CCP5.3, CCB SLR, WGI Table SPM.1}

SPM.B.3.3 Levels of risk for all Reasons for Concern (RFC) are assessed to become high to very high at lower global warming levels than in AR5 (*high confidence*). Between 1.2°C and 4.5°C global warming level very high risks emerge in all five RFCs compared to just two RFCs in AR5 (*high confidence*). Two of these transitions from high to very high risk are associated with near-term warming: risks to unique and threatened systems at a median value of 1.5°C [1.2 to 2.0] °C (*high confidence*) and risks associated with extreme weather events at a median value of 2°C [1.8 to 2.5] °C (*medium confidence*). Some key risks contributing to the RFCs are projected to lead to widespread, pervasive, and potentially irreversible impacts at global warming levels of 1.5–2°C if exposure and vulnerability are high and adaptation is low (*medium confidence*). Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all (*very high confidence*). (Figure SPM.3b) {16.5, 16.6, CCB SLR}

Mid to Long-term Risks (2041–2100)

SPM.B.4 Beyond 2040 and depending on the level of global warming, climate change will lead to numerous risks to natural and human systems (*high confidence*). For 127 identified key risks, assessed mid- and long-term impacts are up to multiple times higher than currently observed (*high confidence*). The magnitude and rate of climate change and associated risks depend strongly on near-term mitigation and adaptation actions, and projected adverse impacts and related losses and damages escalate with every increment of global warming (*very high confidence*). (Figure SPM.3) {2.5, 3.4, 4.4, 5.2, 6.2, 7.3, 8.4, 9.2, 10.2, 11.6, 12.4, 13.2, 13.3, 13.4, 13.5, 13.6, 13.7, 13.8, 14.6, 15.3, 16.5, 16.6, CCP1.2; CCP2.2, CCP3.3, CCP4.3, CCP5.3, CCP6.3, CCP7.3}

SPM.B.4.1 Biodiversity loss, and degradation, damages to and transformation of ecosystems are already key risks for every region due to past global warming and will continue to escalate with every increment of global warming (*very high confidence*). In terrestrial ecosystems, 3 to 14% of species assessed[33] will *likely* face very high risk of extinction[34] at global warming levels of 1.5°C, increasing up to 3 to 18% at 2°C, 3 to 29% at 3°C, 3 to 39% at 4°C, and 3 to 48% at 5°C. In ocean and coastal ecosystems, risk of biodiversity loss ranges between moderate and very high by 1.5°C global warming level and is moderate to very high by 2°C but with more ecosystems at high and very high risk (*high confidence*), and increases to high to very high across most ocean and coastal ecosystems by 3°C (*medium* to *high confidence*, depending on ecosystem). Very high extinction risk for endemic species in biodiversity hotspots is projected to at least double from 2% between 1.5°C and 2°C global warming levels and to increase at least tenfold if warming rises from 1.5°C to 3°C (*medium confidence*). (Figure SPM.3c, d, f) {2.4, 2.5, 3.4, 3.5,12.3, 12.5, Table 12.6, 13.4, 13.10, 16.4, 16.6, CCP1.2, Figure CCP1.6; Figure CCP1.7, CCP5.3, CCP6.3, CCB PALEO}

SPM.B.4.2 Risks in physical water availability and water-related hazards will continue to increase by the mid- to long-term in all assessed regions, with greater risk at higher global warming levels (*high confidence*). At approximately 2°C global warming, snowmelt water availability for irrigation is projected to decline in some snowmelt dependent river basins by up to 20%, and global glacier mass loss of 18 ± 13% is projected to diminish water availability for agriculture, hydropower, and human settlements in the mid- to long-term, with these changes projected to double with 4°C global warming (*medium confidence*). In small islands, groundwater availability is threatened by climate change (*high confidence*). Changes to streamflow magnitude, timing and associated extremes are projected to adversely impact freshwater ecosystems in many watersheds by the mid- to long-term across all assessed scenarios (*medium confidence*). Projected increases in direct flood damages are higher by 1.4 to 2 times at 2°C and 2.5 to 3.9 times at 3°C compared to 1.5°C global warming without adaptation (*medium confidence*). At global warming of 4°C, approximately 10% of the global land area is projected to face increases in both extreme high and low river flows in the same location, with implications for planning for all water use sectors (*medium confidence*). Challenges for water management will be exacerbated in the near, mid and long term, depending on the magnitude, rate and regional details of future climate change and will be particularly challenging for regions with constrained resources for water management (*high confidence*). {2.3, Box 4.2, 4.4, 4.5, Figure 4.20, 15.3, CCB DISASTER, CCP5.3, SROCC 2.3}

SPM.B.4.3 Climate change will increasingly put pressure on food production and access, especially in vulnerable regions, undermining food security and nutrition (*high confidence*). Increases in frequency, intensity and severity of droughts, floods and heatwaves, and continued sea level rise will increase risks to food security (*high confidence*) in vulnerable regions from moderate to high between 1.5°C and 2°C global warming level, with no or low levels of adaptation (*medium confidence*). At 2°C or higher global warming level in the mid-term, food security risks due to climate change will be more severe, leading to malnutrition and micro-nutrient deficiencies, concentrated in Sub-Saharan Africa, South Asia, Central and South America and Small Islands (*high confidence)*. Global warming will progressively weaken soil health and ecosystem

[33] Numbers of species assessed are in the tens of thousands globally.

[34] The term 'very high risks of extinction' is used here consistently with the IUCN categories and criteria and equates with 'critically endangered'.

services such as pollination, increase pressure from pests and diseases, and reduce marine animal biomass, undermining food productivity in many regions on land and in the ocean (*medium confidence*). At 3ºC or higher global warming level in the long term, areas exposed to climate-related hazards will expand substantially compared with 2ºC or lower global warming level (*high confidence*), exacerbating regional disparity in food security risks (*high confidence*). (Figure SPM.3) {1.1, 3.3, CCB SLR, 4.5, 5.2, 5.4, 5.5, 5.8, 5.9, 5.12, CCB MOVING PLATE, 7.3, 8.3, 9.11,13.5,15.3, 16.5, 16.6}

SPM.B.4.4 Climate change and related extreme events will significantly increase ill health and premature deaths from the near- to long-term (*high confidence*). Globally, population exposure to heatwaves will continue to increase with additional warming, with strong geographical differences in heat-related mortality without additional adaptation (*very high confidence*). Climate-sensitive food-borne, water-borne, and vector-borne disease risks are projected to increase under all levels of warming without additional adaptation (*high confidence*). In particular, dengue risk will increase with longer seasons and a wider geographic distribution in Asia, Europe, Central and South America and sub-Saharan Africa, potentially putting additional billions of people at risk by the end of the century (*high confidence*). Mental health challenges, including anxiety and stress, are expected to increase under further global warming in all assessed regions, particularly for children, adolescents, elderly, and those with underlying health conditions (*very high confidence*). {4.5, 5.12, Box 5.10, 7.3, Fig 7.9, 8.4, 9.10, Fig 9.32, Fig 9.35, 10.4, Fig 10.11, 11.3, 12.3, Fig 12.5, Fig 12.6, 13.7, Fig 13.23, Fig 13.24, 14.5, 15.3, CCP6.2}

SPM.B.4.5 Climate change risks to cities, settlements and key infrastructure will rise rapidly in the mid- and long-term with further global warming, especially in places already exposed to high temperatures, along coastlines, or with high vulnerabilities (*high confidence*). Globally, population change in low-lying cities and settlements will lead to approximately a billion people projected to be at risk from coastal-specific climate hazards in the mid-term under all scenarios, including in Small Islands (*high confidence*). The population potentially exposed to a 100-year coastal flood is projected to increase by about 20% if global mean sea level rises by 0.15 m relative to 2020 levels; this exposed population doubles at a 0.75 m rise in mean sea level and triples at 1.4 m without population change and additional adaptation (*medium confidence*). Sea level rise poses an existential threat for some Small Islands and some low-lying coasts (*medium confidence*). By 2100 the value of global assets within the future 1-in-100 year coastal floodplains is projected to be between US$7.9 and US$12.7 trillion (2011 value) under RCP4.5, rising to between US$8.8 and US$14.2 trillion under RCP8.5 (*medium confidence*). Costs for maintenance and reconstruction of urban infrastructure, including building, transportation, and energy will increase with global warming level (*medium confidence*), the associated functional disruptions are projected to be substantial particularly for cities, settlements and infrastructure located on permafrost in cold regions and on coasts (*high confidence*). {6.2, 9.9, 10.4, 13.6, 13.10, 15.3, 16.5, CCP2.1, CCP2.2, CCP5.3, CCP6.2, CCB SLR, SROCC 2.3, SROCC CCB9}

SPM.B.4.6 Projected estimates of global aggregate net economic damages generally increase non-linearly with global warming levels (*high confidence*).[35] The wide range of global estimates, and the lack of comparability between methodologies, does not allow for identification of a robust range of estimates (*high confidence*). The existence of higher estimates than assessed in AR5 indicates that global aggregate economic impacts could be higher than previous estimates (*low confidence*).[36] Significant regional variation in aggregate economic damages from climate change is projected (*high confidence*) with estimated economic damages per capita for developing countries often higher as a fraction of income (*high confidence*). Economic damages, including both those represented and those not represented in economic markets, are projected to be lower at 1.5°C than at 3°C or higher global warming levels (*high confidence*). {4.4, 9.11, 11.5, 13.10, Box 14.6, 16.5, CWGB ECONOMICS}

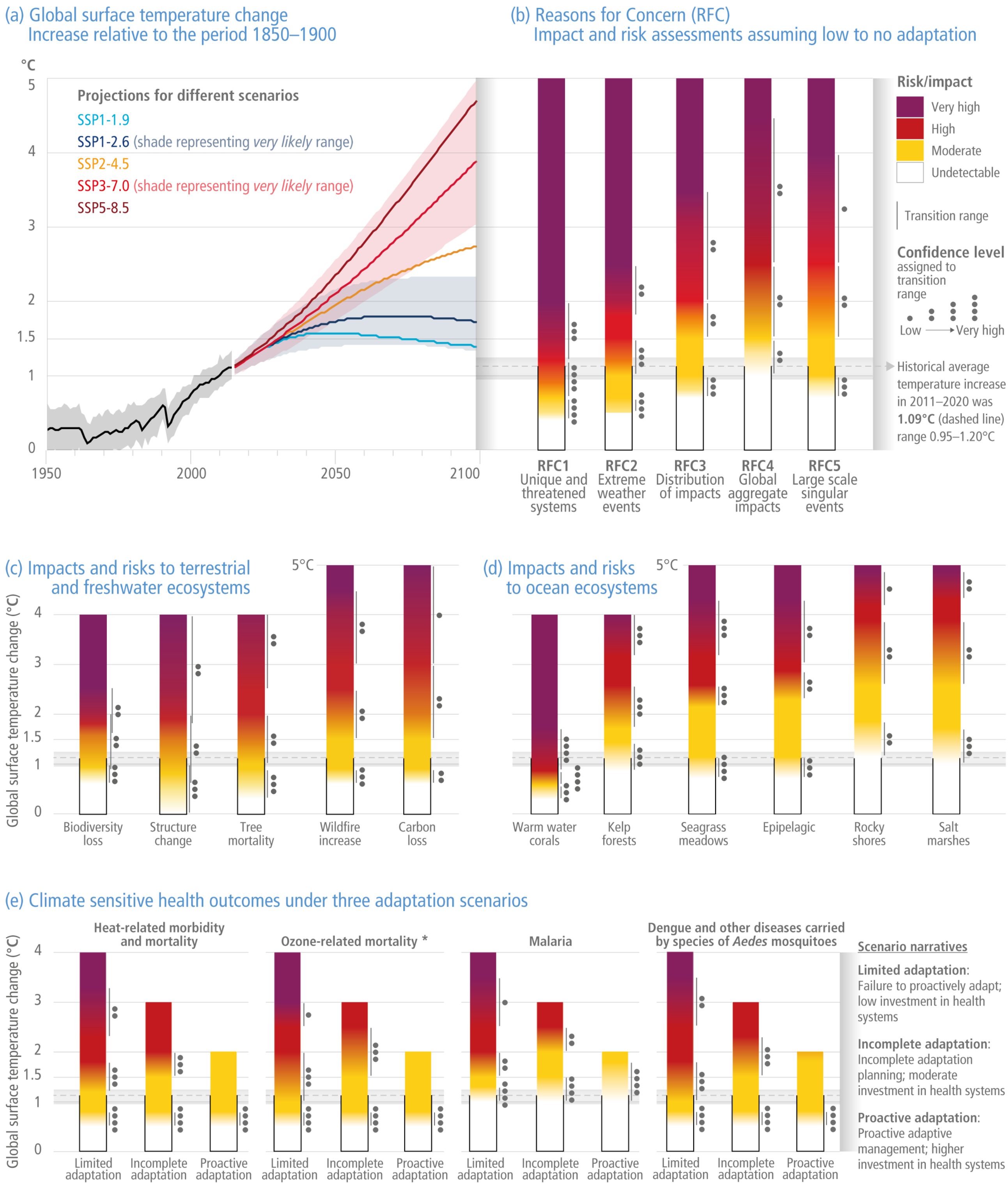
SPM.B.4.7 In the mid- to long-term, displacement will increase with intensification of heavy precipitation and associated flooding, tropical cyclones, drought and, increasingly, sea level rise (*high confidence*). At progressive levels of warming, involuntary migration from regions with high exposure and low adaptive

[35] The assessment found estimated rates of increase in projected global economic damages that were both greater than linear and less than linear as global warming level increases. There is evidence that some regions could benefit from low levels of warming (*high confidence*). {CWGB ECONOMICS}

[36] *Low confidence* assigned due to the assessed lack of comparability and robustness of global aggregate economic damage estimates. {CWGB ECONOMICS}

capacity would occur (*medium confidence*). Compared to other socioeconomic factors the influence of climate on conflict is assessed as relatively weak (*high confidence*). Along long-term socioeconomic pathways that reduce non-climatic drivers, risk of violent conflict would decline (*medium confidence*). At higher global warming levels, impacts of weather and climate extremes, particularly drought, by increasing vulnerability will increasingly affect violent intrastate conflict (*medium confidence*). {7.3, 16.5, CCB MIGRATE, TSB7.4}

Global and regional risks for increasing levels of global warming



* Mortality projections include demographic trends but do not include future efforts to improve air quality that reduce ozone concentrations.

(f) Examples of regional key risks

Absence of risk diagrams does not imply absence of risks within a region. The development of synthetic diagrams for Small Islands, Asia and Central and South America was limited due to the paucity of adequately downscaled climate projections, with uncertainty in the direction of change, the diversity of climatologies and socioeconomic contexts across countries within a region, and the resulting few numbers of impact and risk projections for different warming levels.

The risks listed are of at least *medium confidence* level:

Small Islands
- Loss of terrestrial, marine and coastal biodiversity and ecosystem services
- Loss of lives and assets, risk to food security and economic disruption due to destruction of settlements and infrastructure
- Economic decline and livelihood failure of fisheries, agriculture, tourism and from biodiversity loss from traditional agroecosystems
- Reduced habitability of reef and non-reef islands leading to increased displacement
- Risk to water security in almost every small island

North America
- Climate-sensitive mental health outcomes, human mortality and morbidity due to increasing average temperature, weather and climate extremes, and compound climate hazards
- Risk of degradation of marine, coastal and terrestrial ecosystems, including loss of biodiversity, function, and protective services
- Risk to freshwater resources with consequences for ecosystems, reduced surface water availability for irrigated agriculture, other human uses, and degraded water quality
- Risk to food and nutritional security through changes in agriculture, livestock, hunting, fisheries, and aquaculture productivity and access
- Risks to well-being, livelihoods and economic activities from cascading and compounding climate hazards, including risks to coastal cities, settlements and infrastructure from sea-level rise

Europe
- Risks to people, economies and infrastructures due to coastal and inland flooding
- Stress and mortality to people due to increasing temperatures and heat extremes
- Marine and terrestrial ecosystems disruptions
- Water scarcity to multiple interconnected sectors
- Losses in crop production, due to compound heat and dry conditions, and extreme weather

Central and South America
- Risk to water security
- Severe health effects due to increasing epidemics, in particular vector-borne diseases
- Coral reef ecosystems degradation due to coral bleaching
- Risk to food security due to frequent/extreme droughts
- Damages to life and infrastructure due to floods, landslides, sea level rise, storm surges and coastal erosion

Australasia
- Degradation of tropical shallow coral reefs and associated biodiversity and ecosystem service values
- Loss of human and natural systems in low-lying coastal areas due to sea-level rise
- Impact on livelihoods and incomes due to decline in agricultural production
- Increase in heat-related mortality and morbidity for people and wildlife
- Loss of alpine biodiversity in Australia due to less snow

Asia
- Urban infrastructure damage and impacts on human well-being and health due to flooding, especially in coastal cities and settlements
- Biodiversity loss and habitat shifts as well as associated disruptions in dependent human systems across freshwater, land, and ocean ecosystems
- More frequent, extensive coral bleaching and subsequent coral mortality induced by ocean warming and acidification, sea level rise, marine heat waves and resource extraction
- Decline in coastal fishery resources due to sea level rise, decrease in precipitation in some parts and increase in temperature
- Risk to food and water security due to increased temperature extremes, rainfall variability and drought

Africa
- Species extinction and reduction or irreversible loss of ecosystems and their services, including freshwater, land and ocean ecosystems
- Risk to food security, risk of malnutrition (micronutrient deficiency), and loss of livelihood due to reduced food production from crops, livestock and fisheries
- Risks to marine ecosystem health and to livelihoods in coastal communities
- Increased human mortality and morbidity due to increased heat and infectious diseases (including vector-borne and diarrhoeal diseases)
- Reduced economic output and growth, and increased inequality and poverty rates
- Increased risk to water and energy security due to drought and heat

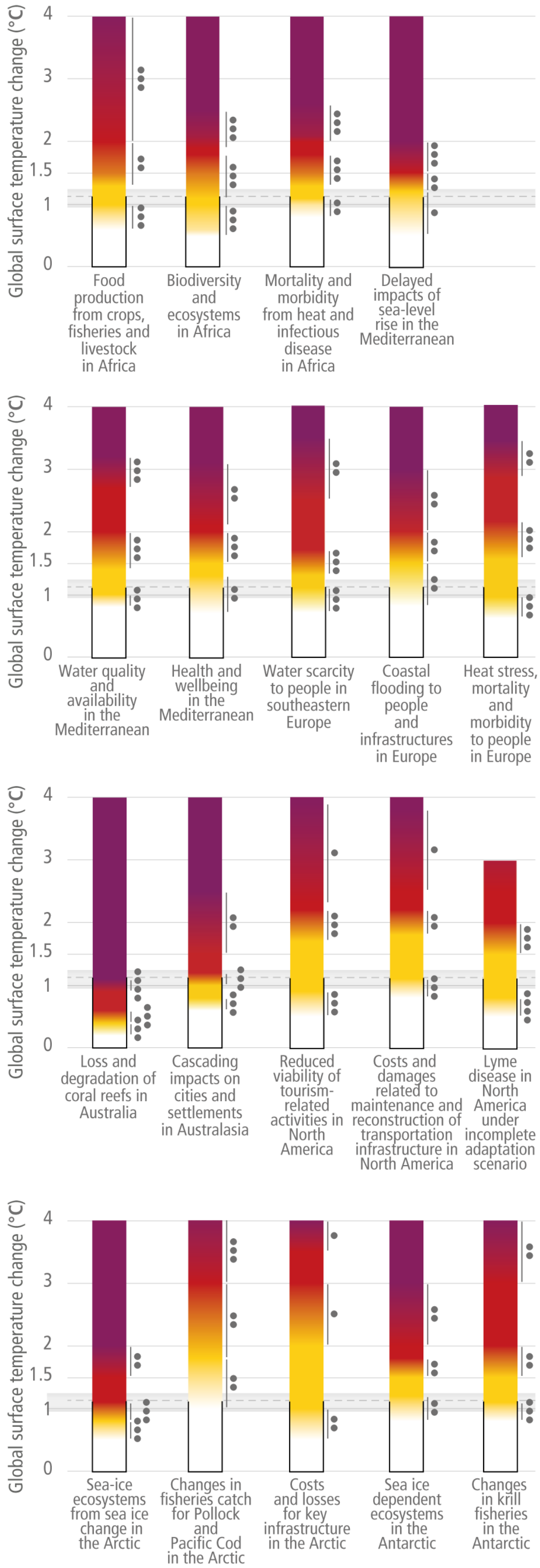


Figure SPM.3: Synthetic diagrams of global and sectoral assessments and examples of regional key risks. Diagrams show the change in the levels of impacts and risks assessed for global warming of 0-5°C global surface temperature change relative to pre-industrial period (1850-1900) over the range. (a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining CMIP6 model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-

7.0 (WGI Figure SPM.8). Assessments were carried out at the global scale for (b), (c), (d) and (e). (b) The Reasons for Concern (RFC) framework communicates scientific understanding about accrual of risk for five broad categories. Diagrams are shown for each RFC, assuming low to no adaptation (i.e., adaptation is fragmented, localized and comprises incremental adjustments to existing practices). However, the transition to a very high risk level has an emphasis on irreversibility and adaptation limits. Undetectable risk level (white) indicates no associated impacts are detectable and attributable to climate change; moderate risk (yellow) indicates associated impacts are both detectable and attributable to climate change with at least *medium confidence*, also accounting for the other specific criteria for key risks; high risk (red) indicates severe and widespread impacts that are judged to be high on one or more criteria for assessing key risks; and very high risk level (purple) indicates very high risk of severe impacts and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks. The horizontal line denotes the present global warming of 1.09°C which is used to separate the observed, past impacts below the line from the future projected risks above it. RFC1: Unique and threatened systems: ecological and human systems that have restricted geographic ranges constrained by climate-related conditions and have high endemism or other distinctive properties. Examples include coral reefs, the Arctic and its Indigenous Peoples, mountain glaciers and biodiversity hotspots. RFC2: Extreme weather events: risks/impacts to human health, livelihoods, assets and ecosystems from extreme weather events such as heatwaves, heavy rain, drought and associated wildfires, and coastal flooding. RFC3: Distribution of impacts: risks/impacts that disproportionately affect particular groups due to uneven distribution of physical climate change hazards, exposure or vulnerability. RFC4: Global aggregate impacts: impacts to socio-ecological systems that can be aggregated globally into a single metric, such as monetary damages, lives affected, species lost or ecosystem degradation at a global scale. RFC5: Large-scale singular events: relatively large, abrupt and sometimes irreversible changes in systems caused by global warming, such as ice sheet disintegration or thermohaline circulation slowing. Assessment methods are described in SM16.6 and are identical to AR5, but are enhanced by a structured approach to improve robustness and facilitate comparison between AR5 and AR6. Risks for (c) terrestrial and freshwater ecosystems and (d) ocean ecosystems. For c) and d), diagrams shown for each risk assume low to no adaptation. The transition to a very high risk level has an emphasis on irreversibility and adaptation limits. (e) Climate-sensitive human health outcomes under three scenarios of adaptation effectiveness. The assessed projections were based on a range of scenarios, including SRES, CMIP5, and ISIMIP, and, in some cases, demographic trends. The diagrams are truncated at the nearest whole ºC within the range of temperature change in 2100 under three SSP scenarios in panel (a). (f) Examples of regional key risks. Risks identified are of at least *medium confidence* level. Key risks are identified based on the magnitude of adverse consequences (pervasiveness of the consequences, degree of change, irreversibility of consequences, potential for impact thresholds or tipping points, potential for cascading effects beyond system boundaries); likelihood of adverse consequences; temporal characteristics of the risk; and ability to respond to the risk, e.g., by adaptation. The full set of 127 assessed global and regional key risks is given in SM16.7. Diagrams are provided for some risks. The development of synthetic diagrams for Small Islands, Asia and Central and South America were limited by the availability of adequately downscaled climate projections, with uncertainty in the direction of change, the diversity of climatologies and socio-economic contexts across countries within a region, and the resulting low number of impact and risk projections for different warming levels. Absence of risks diagrams does not imply absence of risks within a region. (Box SPM.1) {16.5, 16.6, Figure 16.15, SM16.3, SM16.4, SM16.5, SM16.6 (methodologies), SM16.7, Figure 2.11, Figure SM3.1, Figure 7.9, Figure 9.6, Figure 11.6, Figure 13.28, Figure CCP6.5, Figure CCP4.8, Figure CCP4.10, Figure TS.4, WGI Figure SPM.8, WGI SPM A.1.2, Box SPM.1, WGI Ch. 2}

Complex, Compound and Cascading Risks

SPM.B.5 Climate change impacts and risks are becoming increasingly complex and more difficult to manage. Multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions. Some responses to climate change result in new impacts and risks. (*high confidence*) {1.3, 2.4, Box 2.2, Box 9.5, 11.5, 13.5, 14.6, Box 15.1, CCP1.2, CCP2.2, CCB DISASTER, CCB INTERREG, CCB SRM, CCB COVID}

SPM.B.5.1 Concurrent and repeated climate hazards occur in all regions, increasing impacts and risks to health, ecosystems, infrastructure, livelihoods and food (*high confidence*). Multiple risks interact, generating new sources of vulnerability to climate hazards, and compounding overall risk (*high confidence*). Increasing concurrence of heat and drought events are causing crop production losses and tree mortality (*high confidence*). Above 1.5°C global warming increasing concurrent climate extremes will increase risk of simultaneous crop losses of maize in major food-producing regions, with this risk increasing further with higher global warming levels (*medium confidence*). Future sea level rise combined with storm surge and heavy rainfall will increase compound flood risks (*high confidence*). Risks to health and food production will be made more severe from the interaction of sudden food production losses from heat and drought, exacerbated by heat-induced labour productivity losses (*high confidence*). These interacting impacts will increase food prices, reduce household incomes, and lead to health risks of malnutrition and climate-related mortality with no or low levels of adaptation, especially in tropical regions (*high confidence*). Risks to food safety from climate change will further compound the risks to health by increasing food contamination of crops from mycotoxins and contamination of seafood from harmful algal blooms, mycotoxins, and chemical contaminants (*high confidence*). {5.2, 5.4, 5.8, 5.9, 5.11, 5.12, 7.2, 7.3, 9.8, 9.11, 10.4, 11.3, 11.5, 12.3, 13.5, 14.5, 15.3, Box 15.1, 16.6, CCP1.2, CCP6.2, Figure TS10C, WG1 SPM A.3.1, A.3.2 and C.2.7}

SPM.B.5.2 Adverse impacts from climate hazards and resulting risks are cascading across sectors and regions (*high confidence*), propagating impacts along coasts and urban centres (*medium confidence*) and in mountain regions (*high confidence*). These hazards and cascading risks also trigger tipping points in sensitive ecosystems and in significantly and rapidly changing social-ecological systems impacted by ice melt, permafrost thaw and changing hydrology in polar regions (*high confidence*). Wildfires, in many regions, have affected ecosystems and species, people and their built assets, economic activity, and health (*medium to high confidence*)**.** In cities and settlements, climate impacts to key infrastructure are leading to losses and damages across water and food systems, and affect economic activity, with impacts extending beyond the area directly impacted by the climate hazard (*high confidence*). In Amazonia, and in some mountain regions, cascading impacts from climatic (e.g., heat) and non-climatic stressors (e.g., land use change) will result in irreversible and severe losses of ecosystem services and biodiversity at 2°C global warming level and beyond (*medium confidence*). Unavoidable sea level rise will bring cascading and compounding impacts resulting in losses of coastal ecosystems and ecosystem services, groundwater salinisation, flooding and damages to coastal infrastructure that cascade into risks to livelihoods, settlements, health, well-being, food and water security, and cultural values in the near to long-term (*high confidence*). (Figure SPM.3) {2.5, 3.4, 3.5, Box 7.3, Box 8.7, Box 9.4, Box 11.1, 11.5, 12.3, 13.9, 14.6, 15.3, 16.5, 16.6, CCP1.2, CCP2.2, CCP5.2, CCP5.3, CCP6.2, CCP6.3, Box CCP6.1, Box CCP6.2, CCB EXTREMES, Figure TS.10, WGI SPM Figure SPM.8d}

SPM.B.5.3 Weather and climate extremes are causing economic and societal impacts across national boundaries through supply-chains, markets, and natural resource flows, with increasing transboundary risks projected across the water, energy and food sectors (*high confidence*). Supply chains that rely on specialized commodities and key infrastructure can be disrupted by weather and climate extreme events. Climate change causes the redistribution of marine fish stocks, increasing risk of transboundary management conflicts among fisheries users, and negatively affecting equitable distribution of food provisioning services as fish stocks shift from lower to higher latitude regions, thereby increasing the need for climate-informed transboundary management and cooperation (*high confidence*). Precipitation and water availability changes increases the risk of planned infrastructure projects, such as hydropower in some regions, having reduced productivity for food and energy sectors including across countries that share river basins (*medium confidence*). {Figure TS.10e-f, 3.4, 3.5, 4.5, 5.8, 5.13, 6.2, 9.4, Box 9.5,14.5, Box 14.5, Box 14.6, CCP5.3, CCB EXTREMES, CCB MOVING PLATE, CCB INTERREG, CCB DISASTER}

SPM B.5.4 Risks arise from some responses that are intended to reduce the risks of climate change, including risks from maladaptation and adverse side effects of some emission reduction and carbon dioxide removal measures (*high confidence*). Deployment of afforestation of naturally unforested land, or poorly implemented bioenergy, with or without carbon capture and storage, can compound climate-related risks to biodiversity, water and food security, and livelihoods, especially if implemented at large scales, especially in regions with insecure land tenure (*high confidence*). {Box 2.2, 4.1, 4.7, 5.13, Table 5.18, Box 9.3, Box 13.2, CCB NATURAL, CWGB BIOECONOMY}

SPM B.5.5 Solar radiation modification approaches, if they were to be implemented, introduce a widespread range of new risks to people and ecosystems, which are not well understood (*high confidence*). Solar radiation modification approaches have potential to offset warming and ameliorate some climate hazards, but substantial residual climate change or overcompensating change would occur at regional scales and seasonal timescales (*high confidence*). Large uncertainties and knowledge gaps are associated with the potential of solar radiation modification approaches to reduce climate change risks. Solar radiation modification would not stop atmospheric CO_2 concentrations from increasing or reduce resulting ocean acidification under continued anthropogenic emissions (*high confidence*). {XWGB SRM}

Impacts of Temporary Overshoot

SPM.B.6 If global warming transiently exceeds 1.5°C in the coming decades or later (overshoot)[37], then many human and natural systems will face additional severe risks, compared to remaining below 1.5°C (*high confidence*). Depending on the magnitude and duration of overshoot, some impacts will cause release of additional greenhouse gases (*medium confidence*) and some will be irreversible, even if global warming is reduced (*high confidence*). (Figure SPM.3) {2.5, 3.4, 12.3, 16.6, CCB SLR, CCB DEEP, Box SPM.1}

SPM.B.6.1 While model-based assessments of the impacts of overshoot pathways are limited, observations and current understanding of processes permit assessment of impacts from overshoot. Additional warming, e.g., above 1.5°C during an overshoot period this century, will result in irreversible impacts on certain ecosystems with low resilience, such as polar, mountain, and coastal ecosystems, impacted by ice-sheet, glacier melt, or by accelerating and higher committed sea level rise (*high confidence*).[38] Risks to human systems will increase, including those to infrastructure, low-lying coastal settlements, some ecosystem-based adaptation measures, and associated livelihoods (*high confidence*), cultural and spiritual values (*medium confidence*). Projected impacts are less severe with shorter duration and lower levels of overshoot (*medium confidence*). {2.5, 3.4, 12.3, 13.2, 16.5, 16.6, CCP 1.2, CCP5.3, CCP6.1, CCP6.2, CCP2.2, CCB SLR, Box TS4, SROCC 2.3, SROCC 5.4, WG1 SPM B5 and C3}

SPM.B.6.2 Risk of severe impacts increase with every additional increment of global warming during overshoot (*high confidence*). In high-carbon ecosystems (currently storing 3,000 to 4,000 GtC)[39] such impacts are already observed and are projected to increase with every additional increment of global warming, such as increased wildfires, mass mortality of trees, drying of peatlands, and thawing of permafrost, weakening natural land carbon sinks and increasing releases of greenhouse gases (*medium confidence*). The resulting contribution to a potential amplification of global warming indicates that a return to a given global warming level or below would be more challenging (*medium confidence*). {2.4, 2.5, CCP4.2, WG1 SPM B.4.3, SROCC 5.4}

SPM.C: Adaptation Measures and Enabling Conditions

Adaptation, in response to current climate change, is reducing climate risks and vulnerability mostly via adjustment of existing systems. Many adaptation options exist and are used to help manage projected climate change impacts, but their implementation depends upon the capacity and effectiveness of governance and decision-making processes. These and other enabling conditions can also support Climate Resilient Development (Section D).

Current Adaptation and its Benefits

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[37] In this report, overshoot pathways exceed 1.5°C global warming and then return to that level, or below, after several decades.

[38] Despite limited evidence specifically on the impacts of a temporary overshoot of 1.5°C, a much broader evidence base from process understanding and the impacts of higher global warming levels allows a high confidence statement on the irreversibility of some impacts that would be incurred following such an overshoot.

[39] At the global scale, terrestrial ecosystems currently remove more carbon from the atmosphere (-3.4 ± 0.9 Gt yr^{-1}) than they emit ($+1.6 \pm 0.7$ Gt yr^{-1}), a net sink of -1.9 ± 1.1 Gt yr^{-1}. However, recent climate change has shifted some systems in some regions from being net carbon sinks to net carbon sources.

SPM.C.1 Progress in adaptation planning and implementation has been observed across all sectors and regions, generating multiple benefits (*very high confidence*). However, adaptation progress is unevenly distributed with observed adaptation gaps[40] (*high confidence*). Many initiatives prioritize immediate and near-term climate risk reduction which reduces the opportunity for transformational adaptation (*high confidence*). {2.6, 5.14, 7.4, 10.4, 12.5, 13.11, 14.7, 16.3, 17.3, CCP5.2, CCP5.4}

SPM.C.1.1 Adaptation planning and implementation have continued to increase across all regions (*very high confidence*). Growing public and political awareness of climate impacts and risks has resulted in at least 170 countries and many cities including adaptation in their climate policies and planning processes (*high confidence*). Decision support tools and climate services are increasingly being used (*very high confidence*). Pilot projects and local experiments are being implemented in different sectors (*high confidence*). Adaptation can generate multiple additional benefits such as improving agricultural productivity, innovation, health and well-being, food security, livelihood, and biodiversity conservation as well as reduction of risks and damages (*very high confidence*). {1.4, CCB ADAPT, 2.6, CCB NATURE, 3.5, 3.6, 4.7, 4.8, 5.4, 5.6, 5.10, 6.4.2, 7.4, 8.5, 9.3, 9.6, 10.4, 12.5, 13.11, 15.5, 16.3, 17.2, 17.3, 17.5 CCP5.4}

SPM.C.1.2 Despite progress, adaptation gaps exist between current levels of adaptation and levels needed to respond to impacts and reduce climate risks (*high confidence*). Most observed adaptation is fragmented, small in scale, incremental, sector-specific, designed to respond to current impacts or near-term risks, and focused more on planning rather than implementation (*high confidence*). Observed adaptation is unequally distributed across regions *(high confidence)*, and gaps are partially driven by widening disparities between the estimated costs of adaptation and documented finance allocated to adaptation (*high confidence*). The largest adaptation gaps exist among lower income population groups (*high confidence*). At current rates of adaptation planning and implementation the adaptation gap will continue to grow (*high confidence*). As adaptation options often have long implementation times, long-term planning and accelerated implementation, particularly in the next decade, is important to close adaptation gaps, recognising that constraints remain for some regions (*high confidence*). {1.1, 1.4, 5.6, 6.3, Figure 6.4, 7.4, 8.3, 10.4, 11.3, 11.7, 15.2, Box 13.1, 13.11, 15.5, Box16.1, Figure 16.4, Figure 16.5, 16.3, 16.5, 17.4, 18.2, CCP2.4, CCP5.4, CCB FINANCE, CCB SLR}

[40] Adaptation gaps are defined as the difference between actually implemented adaptation and a societally set goal, determined largely by preferences related to tolerated climate change impacts and reflecting resource limitations and competing priorities.

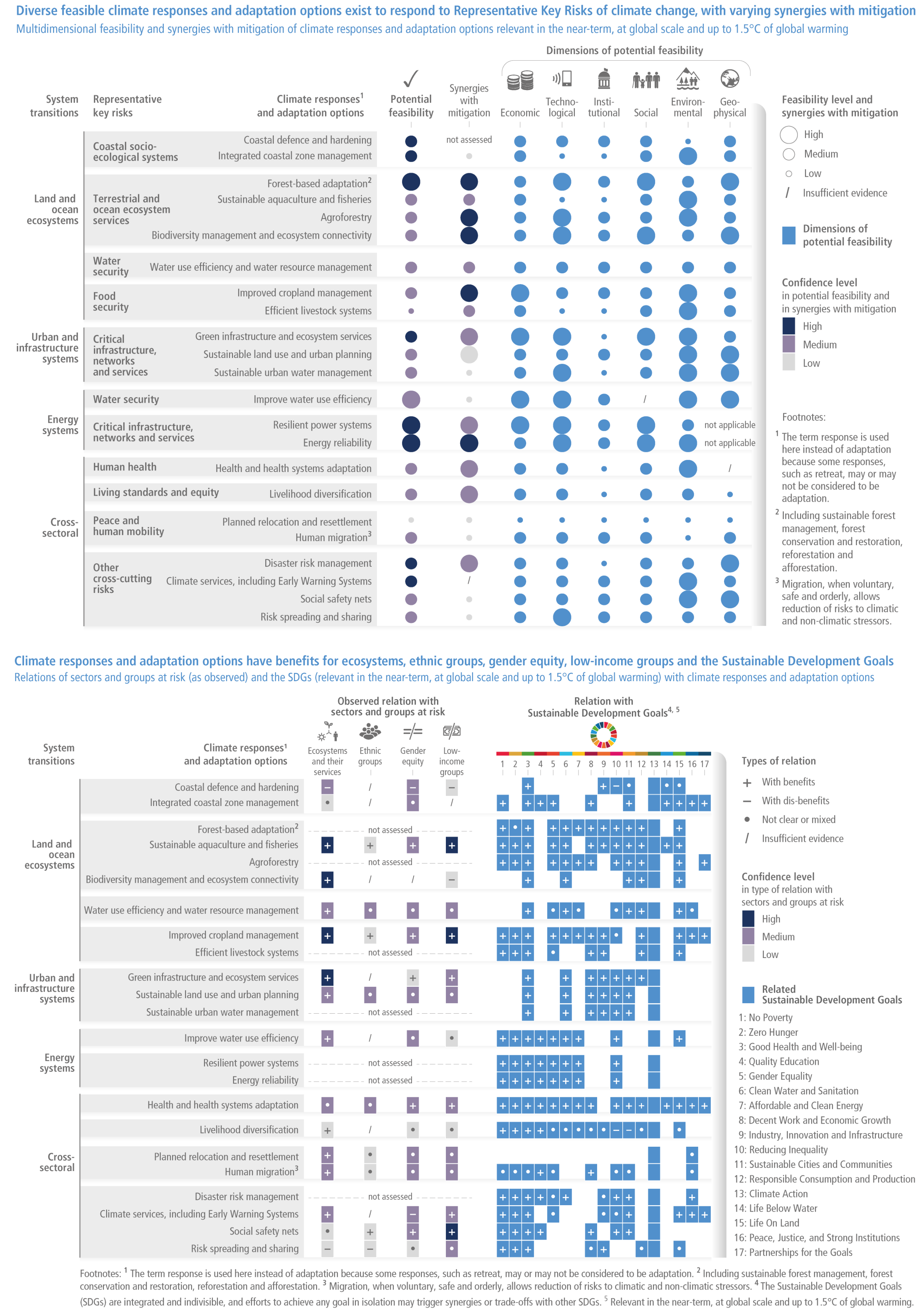

Figure SPM.4: (a) Climate responses and adaptation options, organized by System Transitions and Representative Key Risks (RKRs), are assessed for their multidimensional feasibility at global scale, in the near term and up to 1.5°C global warming. As literature above 1.5°C is limited, feasibility at higher levels of warming may change, which is currently not possible to assess robustly. Climate responses and adaptation options at global scale are drawn from a set of options assessed in AR6 that have robust evidence across the feasibility dimensions. This figure shows the six feasibility dimensions (economic, technological, institutional, social, environmental and geophysical) that are used to calculate the potential feasibility of climate responses and adaptation options, along with their synergies with mitigation. For potential feasibility and feasibility dimensions, the figure shows high, medium, or low feasibility. Synergies with mitigation are identified as high, medium, and low. Insufficient evidence is denoted by a dash. {CCB FEASIB., Table SMCCB FEASIB.1.1; SR1.5 4.SM.4.3}

Figure SPM.4: (b) Climate responses and adaptation options, organized by System Transitions and Representative Key Risks, are assessed at global scale for their likely ability to reduce risks for ecosystems and social groups at risk, as well as their relation with the 17 Sustainable Development Goals (SDGs). Climate responses and adaptation options are assessed for observed benefits (+) to ecosystems and their services, ethnic groups, gender equity, and low-income groups, or observed dis-benefits (-) for these systems and groups. Where there is highly diverging evidence of benefits/ dis-benefits across the scientific literature, e.g., based on differences between regions, it is shown as not clear or mixed (•). Insufficient evidence is shown by a dash. The relation with the SDGs is assessed as having benefits (+), dis-benefits (-) or not clear or mixed (•) based on the impacts of the climate response and adaptation option on each SDG. Areas not coloured indicate there is no evidence of a relation or no interaction with the respective SDG. The climate responses and adaptation options are drawn from two assessments. For comparability of climate responses and adaptation options see Table SM17.5. {17.2, 17.5; CCB FEASIB}

Future Adaptation Options and their Feasibility

SPM.C.2 There are feasible[41] and effective[42] adaptation options which can reduce risks to people and nature. The feasibility of implementing adaptation options in the near-term differs across sectors and regions (*very high confidence*). The effectiveness of adaptation to reduce climate risk is documented for specific contexts, sectors and regions (*high confidence*) and will decrease with increasing warming (*high confidence*). Integrated, multi-sectoral solutions that address social inequities, differentiate responses based on climate risk and cut across systems, increase the feasibility and effectiveness of adaptation in multiple sectors (*high confidence*). (Figure SPM.4) {Figure TS.6e, 1.4, 3.6, 4.7, 5.12, 6.3, 7.4, 11.3, 11.7, 13.2, 15.5, 17.6, CCB FEASIB, CCP2.3}

Land, Ocean and Ecosystems Transition

SPM.C.2.1 Adaptation to water-related risks and impacts make up the majority of all documented adaptation (*high confidence*). For inland flooding, combinations of non-structural measures like early warning systems and structural measures like levees have reduced loss of lives (*medium confidence*). Enhancing natural water retention such as by restoring wetlands and rivers, land use planning such as no build zones or upstream forest management, can further reduce flood risk (*medium confidence*). On-farm water management, water storage, soil moisture conservation and irrigation are some of the most common adaptation responses and provide economic, institutional or ecological benefits and reduce vulnerability (*high confidence*). Irrigation is effective in reducing drought risk and climate impacts in many regions and has several livelihood benefits, but needs appropriate management to avoid potential adverse outcomes, which can include accelerated depletion of groundwater and other water sources and increased soil salinization (*medium confidence*). Large scale irrigation can also alter local to regional temperature and precipitation patterns (*high confidence*), including both alleviating and exacerbating temperature extremes (*medium confidence*). The effectiveness of most water-related adaptation options to reduce projected risks declines with increasing warming (*high confidence*). {4.1,

[41] In this report, feasibility refers to the potential for a mitigation or adaptation option to be implemented. Factors influencing feasibility are context-dependent, temporally dynamic, and may vary between different groups and actors. Feasibility depends on geophysical, environmental-ecological, technological, economic, socio-cultural and institutional factors that enable or constrain the implementation of an option. The feasibility of options may change when different options are combined and increase when enabling conditions are strengthened.

[42] Effectiveness refers to the extent to which an adaptation option is anticipated or observed to reduce climate-related risk.

4.6, 4.7, Box 4.3, Box 4.6, Box 4.7, Figure 4.28, Figure 4.29, Table 4.9, 9.3, 9.7, 11.3, 12.5, 13.1, 13.2, 16.3, CCP5.4, Figure 4.22}

SPM.C.2.2 Effective adaptation options, together with supportive public policies enhance food availability and stability and reduce climate risk for food systems while increasing their sustainability (*medium confidence*). Effective options include cultivar improvements, agroforestry, community-based adaptation, farm and landscape diversification, and urban agriculture (*high confidence*). Institutional feasibility, adaptation limits of crops and cost effectiveness also influence the effectiveness of the adaptation options (*limited evidence*, *medium agreement*). Agroecological principles and practices, ecosystem-based management in fisheries and aquaculture, and other approaches that work with natural processes support food security, nutrition, health and well-being, livelihoods and biodiversity, sustainability and ecosystem services (*high confidence*). These services include pest control, pollination, buffering of temperature extremes, and carbon sequestration and storage (*high confidence*). Trade-offs and barriers associated with such approaches include costs of establishment, access to inputs and viable markets, new knowledge and management (*high confidence*) and their potential effectiveness varies by socio-economic context, ecosystem zone, species combinations and institutional support (*medium confidence*). Integrated, multi-sectoral solutions that address social inequities and differentiate responses based on climate risk and local situation will enhance food security and nutrition (*high confidence*). Adaptation strategies which reduce food loss and waste or support balanced diets[33] (as described in the IPCC Special Report on Climate Change and Land) contribute to nutrition, health, biodiversity and other environmental benefits (*high confidence*). {3.2, 4.7, 4.6, Box 4.3, 5.4, 5.5, 5.6, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, 7.4, Box 5.10, Box 5.13, 6.3, 10.4, 12.5, 13.5, 13.10, 14.5, CWGB BIOECONOMY, CCB MOVING PLATE, CCB NATURAL, CCB FEASIB, CCP5.4, CCB HEALTH}

SPM.C.2.3 Adaptation for natural forests[43] includes conservation, protection and restoration measures. In managed forests[44], adaptation options include sustainable forest management, diversifying and adjusting tree species compositions to build resilience, and managing increased risks from pests and diseases and wildfires. Restoring natural forests and drained peatlands and improving sustainability of managed forests, generally enhances the resilience of carbon stocks and sinks. Cooperation, and inclusive decision making, with local communities and Indigenous Peoples, as well as recognition of inherent rights of Indigenous Peoples, is integral to successful forest adaptation in many areas. (*high confidence*) {2.6, Box 2.2, CCB NATURAL, CCB FEASIB, CCB INDIG, 5.6, 5.13, 11.4, 12.5, 13.5, Box 14.1, Box 14.2, Table 5.23, Box CCP7.1, CCP7.5}.

SPM.C.2.4 Conservation, protection and restoration of terrestrial, freshwater, coastal and ocean ecosystems, together with targeted management to adapt to unavoidable impacts of climate change, reduces the vulnerability of biodiversity to climate change (*high confidence*). The resilience of species, biological communities and ecosystem processes increases with size of natural area, by restoration of degraded areas and by reducing non-climatic stressors (*high confidence*). To be effective, conservation and restoration actions will increasingly need to be responsive, as appropriate, to ongoing changes at various scales, and plan for future changes in ecosystem structure, community composition and species' distributions, especially as 1.5°C global warming is approached and even more so if it is exceeded (*high confidence*). Adaptation options, where circumstances allow, include facilitating the movement of species to new ecologically appropriate locations, particularly through increasing connectivity between conserved or protected areas, targeted intensive management for vulnerable species and protecting refugial areas where species can survive locally (*medium confidence*). {2.3, Figure 2.1, 2,6, Table 2.6, 2.6, 3.6, Box 3.4, 4.6, Box 11.2, 12.3, 12.5, 3.3, 13.4, 14.7, Box 4.6, CCP5.4, CCB FEASIB}

SPM.C.2.5 Effective Ecosystem-based Adaptation[44] reduces a range of climate change risks to people, biodiversity and ecosystem services with multiple co-benefits (*high confidence*). Ecosystem-based Adaptation

[43] In this report, the term natural forests describes those which are subject to little or no direct human intervention, whereas the term managed forests describes those where planting or other management activities take place, including those managed for commodity production.

[44] Ecosystem based Adaptation (EbA) is recognised internationally under the Convention on Biological Diversity (CBD14/5). A related concept is Nature-based Solutions (NbS), which includes a broader range of approaches with safeguards, including those that contribute to adaptation and mitigation. The term 'Nature-based Solutions' is widely but not universally used in the scientific literature. The term is the subject of ongoing debate, with concerns that it may lead to the misunderstanding that NbS on its own can provide a global solution to climate change.

is vulnerable to climate change impacts, with effectiveness declining with increasing global warming (*high confidence*). Urban greening using trees and other vegetation can provide local cooling (*very high confidence*). Natural river systems, wetlands and upstream forest ecosystems reduce flood risk by storing water and slowing water flow, in most circumstances (*high confidence*). Coastal wetlands protect against coastal erosion and flooding associated with storms and sea level rise where sufficient space and adequate habitats are available until rates of sea level rise exceeds natural adaptive capacity to build sediment (*very high confidence*). {2.4, 2.5, 2.6, Table 2.7, 3.4, 3.5, 3.6, Figure 3.26, 4.6, Box 4.6, Box 4.7, 5.5, 5.14, Box 5.11, 6.3, 6.4, Figure 6.6, 7.4, 8.5, 8.6, 9.6, 9.8, 9.9, 10.2, 11.3, 12.5, 13.3, 13.4, 13.5, 14.5, Box 14.7, 16.3, 18.3, CCB HEALTH, CCB NATURAL, CCB MOVING PLATE, CCB FEASIB.3, CWGB BIOECONOMY, CCP5.4}

Urban, Rural and Infrastructure Transition

SPM.C.2.6 Considering climate change impacts and risks in the design and planning of urban and rural settlements and infrastructure is critical for resilience and enhancing human well-being (*high confidence*). The urgent provision of basic services, infrastructure, livelihood diversification and employment, strengthening of local and regional food systems and community-based adaptation enhance lives and livelihoods, particularly of low-income and marginalised groups (*high confidence*). Inclusive, integrated and long-term planning at local, municipal, sub-national and national scales, together with effective regulation and monitoring systems and financial and technological resources and capabilities foster urban and rural system transition (*high confidence*). Effective partnerships between governments, civil society, and private sector organizations, across scales provide infrastructure and services in ways that enhance the adaptive capacity of vulnerable people (*medium to high confidence*). {5.12, 5.13, 5.14, Box 6.3, 6.3, 6.4, Box 6.6, Table 6.6, 7.4, 12.5, 13.6, 14.5, Box14.4, Box17.4, CCB FEASIB, CCP2.3, CCP2.4, CCP5.4}

SPM.C.2.7 An increasing number of adaptation responses exist for urban systems, but their feasibility and effectiveness is constrained by institutional, financial, and technological access and capacity, and depends on coordinated and contextually appropriate responses across physical, natural and social infrastructure (*high confidence*). Globally, more financing is directed at physical infrastructure than natural and social infrastructure (*medium confidence*) and there is *limited evidence* of investment in the informal settlements hosting the most vulnerable urban residents (*medium* to *high confidence*). Ecosystem-based adaptation (e.g., urban agriculture and forestry, river restoration) has increasingly been applied in urban areas (*high confidence).* Combined ecosystem-based and structural adaptation responses are being developed, and there is growing evidence of their potential to reduce adaptation costs and contribute to flood control, sanitation, water resources management, landslide prevention and coastal protection (*medium confidence*). {3.6, Box 4.6, 5.12, 6.3, 6.4, Table 6.8, 7.4, 9.7, 9.9, 10.4, Table 10.3, 11.3, 11.7, Box 11.6, 12.5, 13.2, 13.3, 13.6, 14.5, 15.5, 17.2, Box 17.4, CCB FEASIB, CCP2.3, CCP 3.2, CCP5.4, CCB SLR, SROCC ES}

SPM C.2.8: Sea level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow onset changes and increased frequency and magnitude of extreme sea level events which will escalate in the coming decades (*high confidence*). Such adaptation challenges would occur much earlier under high rates of sea level rise, in particular if low-likelihood, high impact outcomes associated with collapsing ice sheets occur (*high confidence*). Responses to ongoing sea level rise and land subsidence in low-lying coastal cities and settlements and small islands include protection, accommodation, advance and planned relocation (*high confidence*)[45]. These responses are more effective if combined and/or sequenced, planned well ahead, aligned with sociocultural values and development priorities, and underpinned by inclusive community engagement processes (*high confidence*). {CCB SLR, CCP2.3, 6.2, 10.4, 11.7, Box 11.6, 13.2.2, 14.5.9.2, 15.5, SROCC ES: C3.2, WGI SPM B5, C3}

SPM.C.2.9 Approximately 3.4 billion people globally live in rural areas around the world, and many are highly vulnerable to climate change. Integrating climate adaptation into social protection programs, including cash transfers and public works programmes, is highly feasible and increases resilience to climate change, especially when supported by basic services and infrastructure. Social safety nets are increasingly being reconfigured to build adaptive capacities of the most vulnerable in rural and also urban communities. Social

[45] The term 'response' is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation.

safety nets that support climate change adaptation have strong co-benefits with development goals such as education, poverty alleviation, gender inclusion and food security. (*high confidence*) {5.14, 9.4, 9.10, 9.11, 12.5, 14.5, CCB GENDER, CCB FEASIB, CCP5.4}

Energy System Transition

SPM.C.2.10 Within energy system transitions, the most feasible adaptation options support infrastructure resilience, reliable power systems and efficient water use for existing and new energy generation systems (*very high confidence*). Energy generation diversification, including with renewable energy resources and generation that can be decentralised depending on context (e.g., wind, solar, small scale hydroelectric) and demand side management (e.g., storage, and energy efficiency improvements) can reduce vulnerabilities to climate change, especially in rural populations (*high confidence*). Adaptations for hydropower and thermo-electric power generation are effective in most regions up to 1.5°C to 2°C, with decreasing effectiveness at higher levels of warming (*medium confidence*). Climate responsive energy markets, updated design standards on energy assets according to current and projected climate change, smart-grid technologies, robust transmission systems and improved capacity to respond to supply deficits have high feasibility in the medium- to long-term, with mitigation co-benefits (*very high confidence*). {4.6, 4.7, Figure 4.28, Figure 4.29, 10.4, Table 11.8, Figure 13.19, Figure 13.16, 13.6, 18.3, CCB FEASIB, CWGB BIOECONOMY, CCP5.2, CCP5.4}

Cross-cutting Options

SPM.C.2.11 Strengthening the climate resiliency of health systems will protect and promote human health and wellbeing (*high confidence*). There are multiple opportunities for targeted investments and finance to protect against exposure to climate hazards, particularly for those at highest risk. Heat Health Action Plans that include early warning and response systems are effective adaptation options for extreme heat (*high confidence*). Effective adaptation options for water-borne and food-borne diseases include improving access to potable water, reducing exposure of water and sanitation systems to flooding and extreme weather events, and improved early warning systems (*very high confidence*). For vector-borne diseases, effective adaptation options include surveillance, early warning systems, and vaccine development (*very high confidence*). Effective adaptation options for reducing mental health risks under climate change include improving surveillance, access to mental health care, and monitoring of psychosocial impacts from extreme weather events (*high confidence*). Health and well-being would benefit from integrated adaptation approaches that mainstream health into food, livelihoods, social protection, infrastructure, water and sanitation policies requiring collaboration and coordination at all scales of governance (*very high confidence*). {5.12, 6.3, 7.4, 9.10, Box 9.7, 11.3, 12.5, 13.7, 14.5, CCB FEASIB, CCB ILLNESS, CCB COVID}.

SPM.C.2.12 Increasing adaptive capacities minimises the negative impacts of climate-related displacement and involuntary migration for migrants and sending and receiving areas (*high confidence*). This improves the degree of choice under which migration decisions are made, ensuring safe and orderly movements of people within and between countries (*high confidence*). Some development reduces underlying vulnerabilities associated with conflict, and adaptation contributes by reducing the impacts of climate change on climate sensitive drivers of conflict (*high confidence*). Risks to peace are reduced, for example, by supporting people in climate-sensitive economic activities (*medium confidence*) and advancing women's empowerment (*high confidence*). {7.4, 12.5, CCB MIGRATE, Box 9.8, Box 10.2, CCB FEASIB}

SPM.C.2.13 There are a range of adaptation options, such as disaster risk management, early warning systems, climate services and risk spreading and sharing that have broad applicability across sectors and provide greater benefits to other adaptation options when combined (*high confidence*). For example, climate services that are inclusive of different users and providers can improve agricultural practices, inform better water use and efficiency, and enable resilient infrastructure planning (*high confidence*). {2.6, 3.6, 4.7, 5.4, 5.5, 5.6, 5.8, 5.9, 5.12, 5.14, 9.4, 9.8, 10.4, 12.5, 13.11, CCB MOVING PLATE, CCB FEASIB, CCP5.4}

Limits to Adaptation

SPM.C.3 Soft limits to some human adaptation have been reached, but can be overcome by addressing a range of constraints, primarily financial, governance, institutional and policy constraints (*high confidence*). Hard limits to adaptation have been reached in some ecosystems (*high confidence*). With increasing global warming, losses and damages will increase and additional human and natural systems will reach adaptation limits (*high confidence*). {Figure TS.7, 1.4, 2.4, 2.5, 2.6, CCB SLR, 3.4, 3.6, 4.7, Figure 4.30, 5.5, Table 8.6, Box 10.7, 11.7, Table 11.16, 12.5 13.2, 13.5, 13.6, 13.10, 13.11, Figure 13.21, 14.5, 15.6, 16.4, Figure 16.8, Table 16.3, Table 16.4, CCP1.2, CCP1.3, CCP2.3, CCP3.3, CCP5.2, CCP5.4, CCP6.3, CCP7.3}

SPM.C.3.1 Soft limits to some human adaptation have been reached, but can be overcome by addressing a range of constraints, which primarily consist of financial, governance, institutional and policy constraints (*high confidence*). For example, individuals and households in low lying coastal areas in Australasia and Small Islands and smallholder farmers in Central and South America, Africa, Europe and Asia have reached soft limits (*medium confidence*). Inequity and poverty also constrain adaptation, leading to soft limits and resulting in disproportionate exposure and impacts for most vulnerable groups (*high confidence*). Lack of climate literacy[46] at all levels and limited availability of information and data pose further constraints to adaptation planning and implementation (*medium confidence*). {1.4, 4.7, 5.4, Table 8.6, 8.4, 9.1, 9.4, 9.5, 9.8, 11.7, 12.5 13.5, 15.3, 15.5, 15.6, 16.4, Figure 16.8, 16.4, Box 16.1, CCP5.2, CCP5.4, CCP6.3}

SPM.C.3.2 Financial constraints are important determinants of soft limits to adaptation across sectors and all regions (*high confidence*). Although global tracked climate finance has shown an upward trend since AR5, current global financial flows for adaptation, including from public and private finance sources, are insufficient for and constrain implementation of adaptation options especially in developing countries (*high confidence*). The overwhelming majority of global tracked climate finance was targeted to mitigation while a small proportion was targeted to adaptation (*very high confidence*). Adaptation finance has come predominantly from public sources (*very high confidence*). Adverse climate impacts can reduce the availability of financial resources by incurring losses and damages and through impeding national economic growth, thereby further increasing financial constraints for adaptation, particularly for developing and least developed countries (*medium confidence*). {1.4, 2.6, 3.6, 4.7, Figure 4.30, 5.14, 7.4, Table 8.6, 8.4, 9.4, 9.9, 9.11, 10.5, 12.5, 13.3, 13.11, Box 14.4, 15.6, 16.2, 16.4, Figure 16.8, Table 16.4, 17.4, 18.1, CCB FINANCE, CCP2.4, CCP5.4, CCP6.3, Figure TS 7}

SPM.C.3.3 Many natural systems are near the hard limits of their natural adaptation capacity and additional systems will reach limits with increasing global warming (*high confidence*). Ecosystems already reaching or surpassing hard adaptation limits include some warm water coral reefs, some coastal wetlands, some rainforests, and some polar and mountain ecosystems (*high confidence*). Above 1.5°C global warming level, some ecosystem-based adaptation measures will lose their effectiveness in providing benefits to people as these ecosystems will reach hard adaptation limits (*high confidence*). {1.4, 2.4, 2.6, 3.4, 3.6, CCB SLR, 9.6, Box11.2, 13.4, 14.5, 15.5, 16.4, 16.6, 17.2, CCP1.2, CCP5.2, CCP6.3, CCP7.3, Figure SPM.4}

SPM.3.4 In human systems, some coastal settlements face soft adaptation limits due to technical and financial difficulties of implementing coastal protection (*high confidence*). Above 1.5°C global warming level, limited freshwater resources pose potential hard limits for Small Islands and for regions dependent on glacier and snow-melt (*medium confidence*). By 2°C global warming level, soft limits are projected for multiple staple crops in many growing areas, particularly in tropical regions (*high confidence*). By 3°C global warming level, soft limits are projected for some water management measures for many regions, with hard limits projected for parts of Europe (*medium confidence*). Transitioning from incremental to transformational adaptation can help overcome soft adaptation limits (*high confidence*). {1.4, 4.7, 5.4, 5.8, 7.2, 7.3, 8.4, Table 8.6, 9.8, 10.4, 12.5, 13.2, 13.6, 16.4, 17.2, CCB SLR, CCP1.3. Box CCP1.1, CCP2.3, CCP3.3, CCP4.4, CCP5.3}

SPM.C.3.5 Adaptation does not prevent all losses and damages, even with effective adaptation and before reaching soft and hard limits. Losses and damages are unequally distributed across systems, regions and sectors and are not comprehensively addressed by current financial, governance and institutional arrangements, particularly in vulnerable developing countries. With increasing global warming, losses and damages increase and become increasingly difficult to avoid, while strongly concentrated among the poorest vulnerable

[46] Climate literacy encompasses being aware of climate change, its anthropogenic causes and implications.

populations. (*high confidence*) {1.4, 2.6, 3.4, 3.6, 6.3, Figure 6.4, 8.4, 13.7, 13.2, 13.10, 17.2, CCB LOSS, CCB SLR, CCP2.3, CCP4.4, CWGB ECONOMIC}

Avoiding Maladaptation

SPM.C.4 There is increased evidence of maladaptation[15] across many sectors and regions since the AR5. Maladaptive responses to climate change can create lock-ins of vulnerability, exposure and risks that are difficult and expensive to change and exacerbate existing inequalities. Maladaptation can be avoided by flexible, multi-sectoral, inclusive and long-term planning and implementation of adaptation actions with benefits to many sectors and systems. (*high confidence*) {1.3, 1.4, 2.6., Box 2.2, 3.2, 3.6, Box 4.3, Box 4.5, 4.6, 4.7, Figure 4.29, 5.6, 5.13, 8.2, 8.3, 8.4, 8.6, 9.6, 9.7, 9.8, 9.9, 9.10, 9.11, Box 9.5, Box 9.8, Box 9.9, Box 11.6, 13.11, 13.3, 13.4, 13.5, 14.5, 15.5, 15.6, 16.3, 17.3, 17.4, 17.6, 17.2, 17.5, CCP5.4, CCB NATURAL, CCB SLR, CCB DEEP, CWGB BIOECONOMY, CCP2.3, CCP2.3}

SPM.C.4.1 Actions that focus on sectors and risks in isolation and on short-term gains often lead to maladaptation if long-term impacts of the adaptation option and long-term adaptation commitment are not taken into account (*high confidence*). The implementation of these maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change (*high confidence*). For example, seawalls effectively reduce impacts to people and assets in the short-term but can also result in lock-ins and increase exposure to climate risks in the long-term unless they are integrated into a long-term adaptive plan (*high confidence*). Adaptation integrated with development reduces lock-ins and creates opportunities (e.g., infrastructure upgrading) (*medium confidence*). {1.4, 3.4, 3.6, 10.4, 11.7, Box 11.6, 13.2, 17.2, 17.5, 17.6, CCP 2.3, CCB SLR, CCB DEEP}

SPM.C.4.2 Biodiversity and ecosystem resilience to climate change are decreased by maladaptive actions, which also constrain ecosystem services. Examples of these maladaptive actions for ecosystems include fire suppression in naturally fire-adapted ecosystems or hard defences against flooding. These actions reduce space for natural processes and represent a severe form of maladaptation for the ecosystems they degrade, replace or fragment, thereby reducing their resilience to climate change and the ability to provide ecosystem services for adaptation. Considering biodiversity and autonomous adaptation in long-term planning processes reduces the risk of maladaptation. (*high confidence*) {2.4, 2.6, Table 2.7, 3.4, 3.6, 4.7, 5.6, 5.13, Table 5.21, 5.13, Box 13.2, 17.2, 17.5, Table 5.23, Box 11.2, 13.2, CCP5.4}

SPM.C.4.3 Maladaptation especially affects marginalised and vulnerable groups adversely (e.g., Indigenous Peoples, ethnic minorities, low-income households, informal settlements), reinforcing and entrenching existing inequities. Adaptation planning and implementation that do not consider adverse outcomes for different groups can lead to maladaptation, increasing exposure to risks, marginalising people from certain socio-economic or livelihood groups, and exacerbating inequity. Inclusive planning initiatives informed by cultural values, Indigenous knowledge, local knowledge, and scientific knowledge can help prevent maladaptation. (*high confidence*) (Figure SPM.4) {2.6, 3.6, 4.3, 4.6, 4.8, 5.12, 5.13, 5.14, 6.1, Box 7.1, 8.4, 11.4, 12.5, Box 13.2, 14.4, Box 14.1, 17.2, 17.5, 18.2, 17.2., CCP2.4}

SPM.C.4.4 To minimize maladaptation, multi-sectoral, multi-actor and inclusive planning with flexible pathways encourages low-regret[47] and timely actions that keep options open, ensure benefits in multiple sectors and systems and indicate the available solution space for adapting to long-term climate change (*very high confidence*). Maladaptation is also minimized by planning that accounts for the time it takes to adapt (*high confidence*), the uncertainty about the rate and magnitude of climate risk (*medium confidence*) and a wide range of potentially adverse consequences of adaptation actions (*high confidence*). {1.4, 3.6, 5.12, 5.13, 5.14, 11.6, 11.7, 17.3, 17.6, CCP2.3, CCP2.4, CCB SLR, CCB DEEP; CCP5.4}

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[47] From AR5, an option *that would generate net social and/or economic benefits under current climate change and a range of future climate change scenarios*, and represent one example of robust strategies.

Enabling Conditions

SPM.C.5 Enabling conditions are key for implementing, accelerating and sustaining adaptation in human systems and ecosystems. These include political commitment and follow-through, institutional frameworks, policies and instruments with clear goals and priorities, enhanced knowledge on impacts and solutions, mobilization of and access to adequate financial resources, monitoring and evaluation, and inclusive governance processes. (*high confidence*) {1.4, 2.6, 3.6, 4.8, 6.4, 7.4, 8.5, 9.4, 10.5, 11.4, 11.7, 12.5, 13.11, 14.7, 15.6, 17.4, 18.4, CCB INDIG, CCB FINANCE, CCP2.4, CCP5.4}

SPM.C.5.1 Political commitment and follow-through across all levels of government accelerate the implementation of adaptation actions (*high confidence*). Implementing actions can require large upfront investments of human, financial and technological resources (*high confidence*), whilst some benefits could only become visible in the next decade or beyond (*medium confidence*). Accelerating commitment and follow-through is promoted by rising public awareness, building business cases for adaptation, accountability and transparency mechanisms, monitoring and evaluation of adaptation progress, social movements, and climate-related litigation in some regions (*medium confidence*). {3.6, 4.8, 5.8, 6.4, 8.5, 9.4, 11.7, 12.5, 13.11, 17.4, 17.5, 18.4, CCB COVID, CCP2.4}

SPM.C.5.2 Institutional frameworks, policies and instruments that set clear adaptation goals and define responsibilities and commitments and that are coordinated amongst actors and governance levels, strengthen and sustain adaptation actions (*very high confidence*). Sustained adaptation actions are strengthened by mainstreaming adaptation into institutional budget and policy planning cycles, statutory planning, monitoring and evaluation frameworks and into recovery efforts from disaster events (*high confidence*). Instruments that incorporate adaptation such as policy and legal frameworks, behavioural incentives, and economic instruments that address market failures, such as climate risk disclosure, inclusive and deliberative processes strengthen adaptation actions by public and private actors (*medium confidence*). {1.4, 3.6, 4.8, 5.14, 6.3, 6.4, 7.4, 9.4, 10.4, 11.7, Box 11.6, Table 11.17, 13.10, 13.11, 14.7, 15.6, 17.3, 17.4, 17.5, 17.6, 18.4, CCB DEEP, CCP2.4, CCP5.4, CCP6.3}

SPM.C.5.3 Enhancing knowledge on risks, impacts, and their consequences, and available adaptation options promotes societal and policy responses (*high confidence*). A wide range of top-down, bottom-up and co-produced processes and sources can deepen climate knowledge and sharing, including capacity building at all scales, educational and information programmes, using the arts, participatory modelling and climate services, Indigenous knowledge and local knowledge and citizen science (*high confidence*). These measures can facilitate awareness, heighten risk perception and influence behaviours (*high confidence*). {1.3, 3.6, 4.8, 5.9, 5.14, 6.4, Table 6.8, 7.4, 9.4, 10.5, 11.1, 11.7, 12.5, 13.9, 13.11, 14.3, 15.6, 15.6, 17.4, 18.4, CCB INDIG, CCP2.4.1}.

SPMC.5.4 With adaptation finance needs estimated to be higher than those presented in AR5, enhanced mobilization of and access to financial resources are essential for implementation of adaptation and to reduce adaptation gaps (*high confidence*). Building capacity and removing some barriers to accessing finance is fundamental to accelerate adaptation, especially for vulnerable groups, regions and sectors (*high confidence*). Public and private finance instruments include inter alia grants, guarantee, equity, concessional debt, market debt, and internal budget allocation as well as savings in households and insurance. Public finance is an important enabler of adaptation (*high confidence*). Public mechanisms and finance can leverage private sector finance for adaptation by addressing real and perceived regulatory, cost and market barriers, for example via public-private partnerships (*high confidence*). Financial and technological resources enable effective and ongoing implementation of adaptation, especially when supported by institutions with a strong understanding of adaptation needs and capacity (*high confidence*). {4.8, 5.14, 6.4, Table 6.10, 7.4, 9.4, Table 11.17, 12.5, 13.11, 15.6, 17.4, 18.4, BOX 18.9, CCP5.4, CCB FINANCE}.

SPM.C.5.5 Monitoring and evaluation (M&E) of adaptation are critical for tracking progress and enabling effective adaptation (*high confidence*). M&E implementation is currently limited (*high confidence*) but has increased since AR5 at local and national levels. Although most of the monitoring of adaptation is focused towards planning and implementation, the monitoring of outcomes is critical for tracking the effectiveness and progress of adaptation *(high confidence)*. M&E facilitates learning on successful and effective adaptation measures, and signals when and where additional action may be needed. M&E systems are most effective when supported by capacities and resources and embedded in enabling governance systems (*high confidence*). {1.4, 2.6, 6.4, 7.4, 11.7, 11.8, 13.2, 13.11, 17.5, 18.4, CCB PROGRESS, CCB NATURAL, CCB ILLNESS, CCB DEEP, CCP2.4}.

SPM.C.5.6 Inclusive governance that prioritises equity and justice in adaptation planning and implementation leads to more effective and sustainable adaptation outcomes (*high confidence*). Vulnerabilities and climate risks are often reduced through carefully designed and implemented laws, policies, processes, and interventions that address context specific inequities such as based on gender, ethnicity, disability, age, location and income (*high confidence*). These approaches, which include multi-stakeholder co-learning platforms, transboundary collaborations, community-based adaptation and participatory scenario planning, focus on capacity-building, and meaningful participation of the most vulnerable and marginalised groups, and their access to key resources to adapt (*high confidence*). {1.4, 2.6, 3.6, 4.8, 5.4, 5.8, 5.9, 5.13, 6.4, 7.4, 8.5, 11.8, 12.5, 13.11, 14.7, 15.5, 15.7, 17.3, 17.5, 18.4, CCB HEALTH, CCB GENDER, CCB INDIG, CCP2.4, CCP5.4, CCP6.4}

SPM.D: Climate Resilient Development

Climate Resilient Development integrates adaptation measures and their enabling conditions (Section C) with mitigation to advance sustainable development for all. Climate resilient development involves questions of equity and system transitions in land, ocean and ecosystems; urban and infrastructure; energy; industry; and society and includes adaptations for human, ecosystem and planetary health. Pursuing climate resilient development focuses on both where people and ecosystems are co-located as well as the protection and maintenance of ecosystem function at the planetary scale. Pathways for advancing climate resilient development are development trajectories that successfully integrate mitigation and adaptation actions to advance sustainable development. Climate resilient development pathways may be temporarily coincident with any RCP and SSP scenario used throughout AR6, but do not follow any particular scenario in all places and over all time.

Conditions for Climate Resilient Development

SPM.D.1 Evidence of observed impacts, projected risks, levels and trends in vulnerability, and adaptation limits, demonstrate that worldwide climate resilient development action is more urgent than previously assessed in AR5. Comprehensive, effective, and innovative responses can harness synergies and reduce trade-offs between adaptation and mitigation to advance sustainable development. (*very high confidence*) {2.6, 3.4, 3.6, 4.2, 4.6, 7.2, 7.4, 8.3, 8.4, 9.3, 10.6, 13.3, 13.8, 13.10, 14.7, 17.2, 18.3, Figure 18.1, Table 18.5, Box 18.1}

SPM.D.1.1 There is a rapidly narrowing window of opportunity to enable climate resilient development. Multiple climate resilient development pathways are still possible by which communities, the private sector, governments, nations and the world can pursue climate resilient development – each involving and resulting from different societal choices influenced by different contexts and opportunities and constraints on system transitions. Climate resilient development pathways are progressively constrained by every increment of warming, in particular beyond 1.5°C, social and economic inequalities, the balance between adaptation and mitigation varying by national, regional and local circumstances and geographies, according to capabilities including resources, vulnerability, culture and values, past development choices leading to past emissions and future warming scenarios, bounding the climate resilient development pathways remaining, and the ways in which development trajectories are shaped by equity, and social and climate justice. (*very high confidence*) {2.6, 4.7, 4.8, 5.14, 6.4, 7.4, 8.3, 9.4, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 14.7, 15.3, 18.5, CCP2.3, CCP3.4, CCP4.4, CCP5.3, CCP5.4, Table CCP5.2, CCP6.3, CCP7.5, Figure TS14.d}

SPM.D.1.2 Opportunities for climate resilient development are not equitably distributed around the world (*very high confidence*). Climate impacts and risks exacerbate vulnerability and social and economic inequities and consequently increase persistent and acute development challenges, especially in developing regions and sub-regions, and in particularly exposed sites, including coasts, small islands, deserts, mountains and polar regions. This in turn undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities (*very high confidence*). {2.5, 4.4, 4.7, 6.3, 9.4, Box 6.4, Figure 6.5, Table 18.5, CWGB URBAN, CCB HEALTH, CCP2.2, CCP3.2, CCP3.3, CCP5.4, CCP6.2}

SPM.D.1.3 Embedding effective and equitable adaptation and mitigation in development planning can reduce vulnerability, conserve and restore ecosystems, and enable climate resilient development. This is especially challenging in localities with persistent development gaps and limited resources (*high confidence*). Dynamic trade-offs and competing priorities exist between mitigation, adaptation, and development. Integrated and inclusive system-oriented solutions based on equity and social and climate justice reduce risks and enable climate resilient development (*high confidence*). {1.4, 2.6, 3.6, 4.7, 4.8, Box 4.5, Box 4.8, 5.13, 7.4, 8.5, 9.4, 10.6, Box 9.3, Box 2.2, 12.5, 12.6, 13.3, 13.4, 13.10, 13.11, 14.7, 18.4, CCB HEALTH, SRCCL, CCB DEEP, CCP2, CCP5.4}

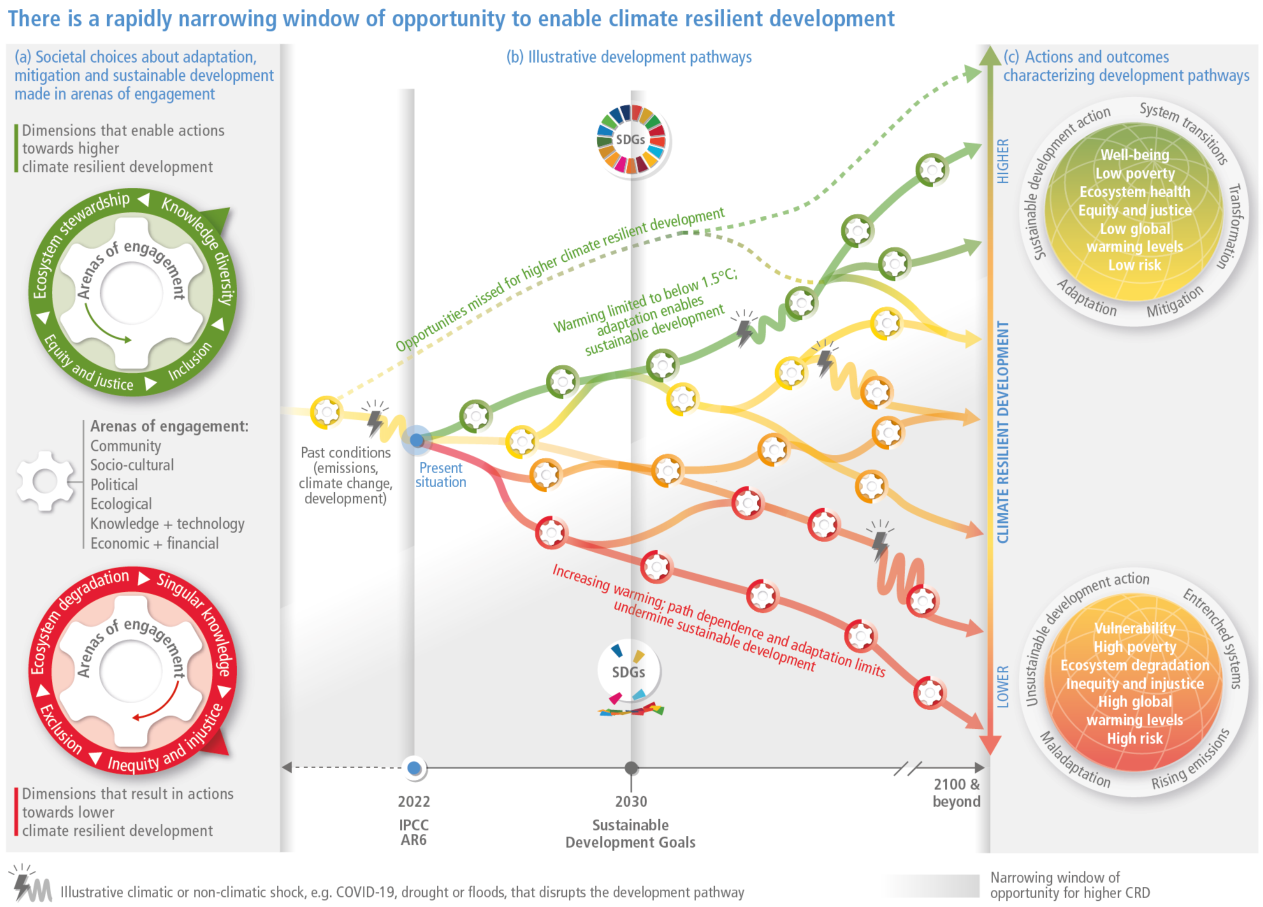

Figure SPM.5: Climate resilient development (CRD) is the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development. This figure builds on Figure SPM.9 in AR5 WGII (depicting climate resilient pathways) by describing how CRD pathways are the result of cumulative societal choices and actions within multiple arenas. Panel (a): Societal choices towards higher CRD (green cog) or lower CRD (red cog) result from interacting decisions and actions by diverse government, private sector and civil society actors, in the context of climate risks, adaptation limits and development gaps. These actors engage with adaptation, mitigation and development actions in political, economic and financial, ecological, socio-cultural, knowledge and technology, and community arenas from local to international levels. Opportunities for climate resilient development are not equitably distributed around the world. Panel (b): Cumulatively, societal choices, which are made continuously, shift global development pathways towards higher (green) or lower (red) climate resilient development. Past conditions (past emissions, climate change and development) have already eliminated some development pathways towards higher CRD (dashed green line). Panel (c): Higher CRD is characterised by outcomes that advance sustainable development for all. Climate resilient development is progressively harder to achieve with global warming levels beyond 1.5°C. Inadequate progress towards the Sustainable Development Goals (SDGs) by 2030 reduces climate resilient development prospects. There is a narrowing window of opportunity to shift pathways towards more climate resilient development futures as reflected by the adaptation limits and increasing climate risks, considering the remaining carbon budgets. (Figure SPM.2, Figure SPM.3) {2.6, 3.6, 7.2, 7.3, 7.4, 8.3, 8.4, 8.5, 16.4, 16.5, 17.3, 17.4, 17.5, 18.1, 18.2, 18.3, 18.4, Figure 18.1, Figure 18.2, Figure 18.3, Box 18.1, CCB COVID, CCB GENDER, CCB HEALTH, CCB INDIG, CCB SLR, AR6 WGI Table SPM.1 and Table SPM.2, SR1.5 Figure SPM.1, Figure TS.14b}

Enabling Climate Resilient Development

SPM.D.2 Climate resilient development is enabled when governments, civil society and the private sector make inclusive development choices that prioritise risk reduction, equity and justice, and when decision-making processes, finance and actions are integrated across governance levels, sectors and timeframes (*very high confidence*). Climate resilient development is facilitated by international cooperation and by governments at all levels working with communities, civil society, educational bodies, scientific and other institutions, media, investors and businesses; and by developing partnerships with traditionally marginalised groups, including women, youth, Indigenous Peoples, local communities and ethnic minorities (*high confidence*). These partnerships are most effective when supported by enabling political leadership, institutions, resources, including finance, as well as climate services, information and decision support tools (*high confidence*). (Figure SPM.5) {1.3, 1.4, 1.5, 2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.4, 17.6, 18.4, 18.5, CCP2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB HEALTH, CCB GENDER, CCB INDIG, CCB DEEP, CCB NATURAL, CCB SLR}

SPM.D.2.1 Climate resilient development is advanced when actors work in equitable, just and enabling ways to reconcile divergent interests, values and worldviews, toward equitable and just outcomes (*high confidence*). These practices build on diverse knowledges about climate risk and chosen development pathways account for local, regional and global climate impacts, risks, barriers and opportunities (*high confidence*). Structural vulnerabilities to climate change can be reduced through carefully designed and implemented legal, policy, and process interventions from the local to global that address inequities based on gender, ethnicity, disability, age, location and income (*very high confidence*). This includes rights-based approaches that focus on capacity-building, meaningful participation of the most vulnerable groups, and their access to key resources, including financing, to reduce risk and adapt (*high confidence).* Evidence shows that climate resilient development processes link scientific, Indigenous, local, practitioner and other forms of knowledge, and are more effective and sustainable because they are locally appropriate and lead to more legitimate, relevant and effective actions (*high confidence*). Pathways towards climate resilient development overcome jurisdictional and organizational barriers, and are founded on societal choices that accelerate and deepen key system transitions (*very high confidence*). Planning processes and decision analysis tools can help identify 'low regrets' options[47] that enable mitigation and adaptation in the face of change, complexity, deep uncertainty and divergent views (*medium confidence*). {1.3, 1.4, 1.5, 2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2-17.6, 18.2-18.4, CCP2.3-2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, Box 8.7, Box 9.2, CCB HEALTH, CCB INDIG, CCB DEEP, CCB NATURAL, CCB SLR}

SPM.D.2.2 Inclusive governance contributes to more effective and enduring adaptation outcomes and enables climate resilient development (*high confidence*). Inclusive processes strengthen the ability of governments and other stakeholders to jointly consider factors such as the rate and magnitude of change and uncertainties, associated impacts, and timescales of different climate resilient development pathways given past development choices leading to past emissions and scenarios of future global warming (*high confidence*). Associated societal choices are made continuously through interactions in arenas of engagement from local to international levels. The quality and outcome of these interactions helps determine whether development pathways shift towards or away from climate resilient development (*medium confidence*). (Figure SPM.5) {2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2-17.6, 18.2, 18.4, CCP2.3-2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB HEALTH, CCB GENDER, CCB INDIG}

SPM.D.2.3 Governance for climate resilient development is most effective when supported by formal and informal institutions and practices that are well-aligned across scales, sectors, policy domains and timeframes. Governance efforts that advance climate resilient development account for the dynamic, uncertain and context-specific nature of climate-related risk, and its interconnections with non-climate risks. Institutions[48] that enable climate resilient development are flexible and responsive to emergent risks and facilitate sustained and timely action. Governance for climate resilient development is enabled by adequate and appropriate human and technological resources, information, capacities and finance. (*high confidence*) {2.7, 3.6, 4.8, 5.14, 6.3, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2-17.6, 18.2, 18.4, CCP2.3-2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB HEALTH, CCB GENDER, CCB INDIG, CCB DEEP, CCB NATURAL, CCB SLR}

Climate Resilient Development for Natural and Human Systems

SPM.D.3 Interactions between changing urban form, exposure and vulnerability can create climate change-induced risks and losses for cities and settlements. However, the global trend of urbanisation also offers a critical opportunity in the near-term, to advance climate resilient development (*high confidence*). Integrated, inclusive planning and investment in everyday decision-making about urban infrastructure, including social, ecological and grey/physical infrastructures, can significantly increase the adaptive capacity of urban and rural settlements. Equitable outcomes contributes to multiple benefits for health and well-being and ecosystem services, including for Indigenous Peoples, marginalised and vulnerable communities (*high confidence*). Climate resilient development in urban areas also supports adaptive capacity in more rural places through maintaining peri-urban supply chains of goods and services and financial flows (*medium confidence*). Coastal cities and settlements play an especially important role in advancing climate resilient development (*high confidence*). {6.2, 6.3, 18.3, Table 6.6, Box 9.8, CCP6.2, CCP2.1. CCP2.2, CWGB URBAN}

SPM.D.3.1 Taking integrated action for climate resilience to avoid climate risk requires urgent decision making for the new built environment and retrofitting existing urban design, infrastructure and land use. Based on socioeconomic circumstances, adaptation and sustainable development actions will provide multiple benefits including for health and well-being, particularly when supported by national governments, non-governmental organisations and international agencies that work across sectors in partnerships with local communities. Equitable partnerships between local and municipal governments, the private sector, Indigenous Peoples, local communities, and civil society can, including through international cooperation, advance climate resilient development by addressing structural inequalities, insufficient financial resources, cross-city risks and the integration of Indigenous knowledge and Local knowledge. (*high confidence*) {6.2, 6.3, 6.4, 7.4, 8.5, 9.4, 10.5. 12.5, 17.4, 18.2, Table 6.6, Table 17.8, Box 18.1, CCP2.4, CCB GENDER, CCB INDIG, CCB FINANCE, CWGB URBAN}

SPM.D.3.2 Rapid global urbanisation offers opportunities for climate resilient development in diverse contexts from rural and informal settlements to large metropolitan areas (*high confidence*). Dominant models of energy intensive and market-led urbanisation, insufficient and misaligned finance and a predominant focus on grey infrastructure in the absence of integration with ecological and social approaches, risks missing opportunities for adaptation and locking in maladaptation (*high confidence*). Poor land use planning and siloed approaches to health, ecological and social planning also exacerbates, vulnerability in already marginalised

[48] Institutions: Rules, norms and conventions that guide, constrain or enable human behaviours and practices. Institutions can be formally established, for instance through laws and regulations, or informally established, for instance by traditions or customs. Institutions may spur, hinder, strengthen, weaken or distort the emergence, adoption and implementation of climate action and climate governance.

communities (*medium confidence*). Urban climate resilient development is observed to be more effective if it is responsive to regional and local land use development and adaptation gaps, and addresses the underlying drivers of vulnerability (*high confidence*). The greatest gains in well-being can be achieved by prioritizing finance to reduce climate risk for low-income and marginalized residents including people living in informal settlements (*high confidence*). {5.14, 6.1, 6.2, 6.3, 6.4, 6.5, 7.4, 8.5, 8.6, 9.8, 9.9, 10.4, 18.2, Table 17.8, Table 6.6, Figure 6.5, CCB HEALTH, CCP2.2, CCP5.4, CWGB URBAN}

SPM.D.3.3 Urban systems are critical, interconnected sites for enabling climate resilient development, especially at the coast. Coastal cities and settlements play a key role in moving toward higher climate resilient development given firstly, almost 11% of the global population – 896 million people – lived within the Low Elevation Coastal Zone[49] in 2020, potentially increasing to beyond 1 billion people by 2050, and these people, and associated development and coastal ecosystems, face escalating climate compounded risks, including sea level rise. Secondly, these coastal cities and settlements make key contributions to climate resilient development through their vital role in national economies and inland communities, global trade supply chains, cultural exchange, and centres of innovation. (*high confidence*) {6.2, Box 15.2, CCP2.1, CCP2.2, Table CCP2.4, CCB SLR}

SPM.D.4 Safeguarding biodiversity and ecosystems is fundamental to climate resilient development, in light of the threats climate change poses to them and their roles in adaptation and mitigation (*very high confidence*). Recent analyses, drawing on a range of lines of evidence, suggest that maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems (*high confidence*). {2.4, 2.5, 2.6, 3.4, Box 3.4, 3.5, 3.6, 12.5, 13.3, 13.4, 13.5, 13.10, CCB NATURAL, CCB INDIG}

SPM.D.4.1 Building the resilience of biodiversity and supporting ecosystem integrity[50] can maintain benefits for people, including livelihoods, human health and well-being and the provision of food, fibre and water, as well as contributing to disaster risk reduction and climate change adaptation and mitigation. {2.2, 2.5, 2.6, Table 2.6, Table 2.7, 3.5, 3.6, 5.8, 5.13, 5.14, 12.5, Box 5.11 CCP5.4, CCB NATURAL, CCB ILLNESS, CCB COVID, CCB GENDER, CCB INDIG, CCB MIGRATE}

SPM.D.4.2 Protecting and restoring ecosystems is essential for maintaining and enhancing the resilience of the biosphere (*very high confidence*). Degradation and loss of ecosystems is also a cause of greenhouse gas emissions and is at increasing risk of being exacerbated by climate change impacts, including droughts and wildfire *(high confidence)*. Climate resilient development avoids adaptation and mitigation measures that damage ecosystems (*high confidence*). Documented examples of adverse impacts of land-based measures intended as mitigation, when poorly implemented, include afforestation of grasslands, savannas and peatlands, and risks from bioenergy crops at large scale to water supply, food security and biodiversity (*high confidence*). {2.4, 2.5, Box 2.2, 3.4, 3.5, Box 3.4, Box 9.3, CCP7.3, CCB NATURAL, CWGB BIOECONOMY}

SPM.D.4.3 Biodiversity and ecosystem services have limited capacity to adapt to increasing global warming levels, which will make climate resilient development progressively harder to achieve beyond 1.5°C warming (*very high confidence*). Consequences of current and future global warming for climate resilient development include reduced effectiveness of EbA and approaches to climate change mitigation based on ecosystems and amplifying feedbacks to the climate system (*high confidence*). {2.4, 2.5, 2.6, 3.4, 3.5, 3.6, 12.5, 13.2, 13.3, 13.10, 14.5, 14.5, 15.3, 17.3, 17.6, Box 14.3, Box 3.4, Table 5.2, CCP5.3, CCP5.4, Figure TS.14d, CCB EXTREMES, CCB ILLNESS, CCB NATURAL, CCB SLR, SR1.5, SRCCL, SROCC}

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[49] LECZ, coastal areas below 10 m of elevation above sea level that are hydrologically connected to the sea

[50] Ecosystem integrity refers to the ability of ecosystems to maintain key ecological processes, recover from disturbance, and adapt to new conditions.

Achieving Climate Resilient Development

SPM.D.5 It is unequivocal that climate change has already disrupted human and natural systems. Past and current development trends (past emissions, development and climate change) have not advanced global climate resilient development (*very high confidence*). Societal choices and actions implemented in the next decade determine the extent to which medium- and long-term pathways will deliver higher or lower climate resilient development (*high confidence*). Importantly climate resilient development prospects are increasingly limited if current greenhouse gas emissions do not rapidly decline, especially if 1.5°C global warming is exceeded in the near term (*high confidence*). These prospects are constrained by past development, emissions and climate change, and enabled by inclusive governance, adequate and appropriate human and technological resources, information, capacities and finance (*high confidence*). {1.2, 1.4, 1.5, 2.6, 2.7, 3.6, 4.7, 4.8, 5.14, 6.4, 7.4, 8.3, 8.5, 8.6, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 13.11, 14.7, 15.3, 15.6, 15.7, 16.2, 16.4, 16.5, 16.6, 17.2-17.6, 18.2-18.5, CCP2.3-2.4, CCP3.4, CCP4.4, Table CCP5.2, CCP5.3, CCP5.4, CCP6.3, CCP6.4, CCP7.5, CCP7.6, Figure TS.14d, CCB DEEP, CCB HEALTH, CCB INDIG, CCB DEEP, CCB NATURAL, CCB SLR}

SPM.D.5.1 Climate resilient development is already challenging at current global warming levels (*high confidence*). The prospects for climate resilient development will be further limited if global warming levels exceeds 1.5°C (*high confidence*) and not be possible in some regions and sub-regions if the global warming level exceeds 2°C (*medium confidence*). Climate resilient development is most constrained in regions/subregions in which climate impacts and risks are already advanced, including low-lying coastal cities and settlements, small islands, deserts, mountains and polar regions (*high confidence*). Regions and subregions with high levels of poverty, water, food and energy insecurity, vulnerable urban environments, degraded ecosystems and rural environments, and/or few enabling conditions, face many non-climate challenges that inhibit climate resilient development which are further exacerbated by climate change (*high confidence*). {1.2, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 14.7, 15.3, CCP2.3, CCP3.4, CCP4.4, Box 6.6. CCP5.3, Table CCP5.2, CCP6.3, CCP7.5, Figure TS.14d}

SPM.D.5.2 Inclusive governance, investment aligned with climate resilient development, access to appropriate technology and rapidly scaled-up finance, and capacity building of governments at all levels, the private sector and civil society enable climate resilient development. Experience shows that climate resilient development processes are timely, anticipatory, integrative, flexible and action focused. Common goals and social learning build adaptive capacity for climate resilient development. When implementing adaptation and mitigation together, and taking trade-offs into account, multiple benefits and synergies for human well-being as well as ecosystem and planetary health can be realised. Prospects for climate resilient development are increased by inclusive processes involving local knowledge and Indigenous Knowledge as well as processes that coordinate across risks and institutions. Climate resilient development is enabled by increased international cooperation including mobilising and enhancing access to finance, particularly for vulnerable regions, sectors and groups. (*high confidence*) (Figure SPM.5) {2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2-17.6, 18.2-18.5, CCP2.3-2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB HEALTH, CCB INDIG, CCB DEEP, CCB NATURAL, CCB SLR}

SPM.D.5.3 The cumulative scientific evidence is unequivocal: Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all. (*very high confidence*) {1.2, 1.4, 1.5, 16.2, 16.4, 16.5, 16.6, 17.4, 17.5, 17.6, 18.3, 18.4, 18.5, CWGB URBAN, CCB DEEP, Table SM16.24, WGI SPM, SROCC SPM, SRCCL SPM}