SOUTHERN ENVIRONMENTAL LAW CENTER

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Buck Project Notice of Objection and Statement of Reasons – Attachments

Attachment 1 Evaluation of Areas that may be Suitable for Inclusion in the National Wilderness Preservation System, Nantahala and Pisgah National Forests-excerpt (June 2017)

Attachment 2 2013 and 2018 Field Forms

Ten-Year Summary Report of Best Management Practices Monitoring

Panther Branch Road Decommissioning Monitoring Report (2019)

Attachment 3 Excerpts from Response to FOIA 2019-FS-WO-01178-F

Attachment 4 Final Environmental Assessment, Southside Project. February, 2019.

Attachment 5 Kelly, Josh. 2013. An Assessment of the Ecosystems of the Nantahala-Pisgah National Forest and Surrounding Lands.

Attachment 6 Wiese, F. William. U.S. Forest Service., 1936. *Nantahala national forest, Georgia, North Carolina, South Carolina.* [Washington: U.S. Gov't print. off. 1936]

Wear, David N., Greis, John G. U.S. Forest Service, Southern Research Station. 2002. Southern Forest Resource Assessment.

Attachment 7 Email, Kauffman to Knapp (Jan. 16, 2018)

Executive Order 13751 (2016).

Attachment 8 Map of Buck Analysis Area Nantahala National Forest

Attachment 9 Golden-winged Warbler Working Group. 2013. Best Management Practices for Golden-winged Warbler Habitats in the Appalachian Region.

Attachment 10 Notice of Objection and Statement of Reasons, Southside Project (Aug. 27, 2018)

Attachment 11 Select Literature Cited

Attachment 12 Buck Project Map

Attachment 1

Forest Service

Nantahala and Pisgah National Forests

Updated: June 2017

Evaluation of Areas that may be Suitable for Inclusion in the National Wilderness Preservation System

maps were shared at public meetings held in Asheville and Franklin, NC in November and December 2015, and feedback was encouraged by mid-December. From January 2016 to May 2016, the forests received and reviewed additional public input on the inventory areas.

In July 2016, the Evaluation Report was shared with the public along with initial identification of Areas for Analysis in the Forest Plan DEIS by Alternative. The public was asked to provide feedback on the Evaluation report as well as the initial list of areas identified for analysis (Step 3). Public comments included both site specific comments of individual areas as well as comments on the evaluation process and documentation of wilderness characteristics.

This 2017 Evaluation Report is an updated evaluation of wilderness characteristics for the 53 inventory areas (the Shining Rock area was divided into two separate areas, bringing the total to 53), with consideration of public comments that were received in 2016 and early 2017. Updates to this report include:

- Providing narrative in the introduction that describes how individual wilderness characteristics were evaluated;
- Clarifying consideration of impacts to naturalness, including adding an appendix that describes assumptions about the effects to naturalness from recent timber harvest, wildlife openings, roads, trails, nonnative invasive species, and other past management;
- Reviewing and updating narratives for consistency in analysis of impacts to naturalness, including clarifying the pervasiveness of impacts in each area;
- Updating area narratives to identify the presence of threatened and endangered species, and rare and unique habitats where raised in public comments;
- Updating area maps to clarify that we evaluated each full inventory area by showing the complete area map, and not reducing the boundaries in size during this step;
- Revising narrative conclusion paragraphs to be a summary instead and removing statements regarding whether the area possesses overall wilderness characteristics;

The intent of this document is to clearly and efficiently describe and document the wilderness characteristics associated with each area. This document does not make any proposals about which areas will be included in the range of alternatives to be analyzed in the DEIS.

Summary of Public Input

The Forest Service received extensive public input including individual unique comments, as well as form letter submissions. Comments were received through the forest plan website, email, and postal mail during the comment period.

Public input generally fell into the following categories:

1. Views on recommending additional wilderness areas.
    a. Stakeholders in favor of recommending additional wilderness areas generally cited an area's natural qualities, opportunities for primitive recreation, or other unique features of value.
    b. Stakeholders opposed to recommending additional wilderness areas generally cited the lack of wilderness characteristics in areas with recent management activities,

Name: Southern Nantahala Extension Area

Acres: 4,298 acres

Description of Area

Location & Access

The Southern Nantahala Extension area is adjacent to the congressionally designated Southern Nantahala Wilderness on the Nantahala Ranger District of the Nantahala NF. The area is located in Macon County, NC and is bordered on the north by NFSR67. The area is less than 100 feet across at its narrowest point and there is a protrusion in the northeast that is approximately 650 feet across where the area abuts Ball Creek Road (NFSR 83).

Numerous trails through this area provide access to the Southern Nantahala Wilderness to the south including Kimsey Creek, Big Indian Loop, Little Indian, the Appalachian Trail, Lower Trail Ridge, and Timber Ridge Trail. There are several miles of closed roads off of NFSR71 on the western boundary. The Standing Indian Campground also provides access to the area off of NFSR424.

Surroundings

This area is adjacent to the Southern Nantahala Wilderness along the southern boundary and bordered by national forest system lands to the north. The northern border is irregular and follows NFSR67. Standing Indian campground is located on the northern border off of NFSR424. The western boundary is defined by Deep Gap Road (NFSR72), which separates this area from the Chunky Gal Extension inventory area.

Topography & Vegetation

Standing Indian Mountain, part of a south-facing horseshoe-shaped massif that forms the Tallulah River basin, dominates the area. To the north, ridges radiate from the closed end toward the upper Nantahala River. There are several peaks over 4,000 feet in the area. Scream Ridge is the dominant ridge in the southeastern part of the area.

The area primarily includes acidic cove, rich cove, and mesic oak ecozones with some areas of old growth forest. The area contains Southern Appalachian bogs and swamp-bog complexes.

Current Uses

Current uses in this area include horseback riding, fishing, hunting, hiking, and traditional gathering of forest products. Approximately half of the area is currently managed for backcountry recreation with approximately seven miles of closed maintenance level 1 and 2 road; these roads are maintained as linear wildlife fields and frequently used by hunters, hikers, and equestrians. There are mowed wildlife fields on Scream Ridge. There are many miles of hiking trails in the area including Kimsey Creek, Big Indian Loop, Little Indian, Lower Trail Ridge, and Timber Ridge Trail. The Appalachian Trail runs along the far eastern boundary of the area coming north from Georgia. Trails near Standing Indian campground are also used extensively by recreationists in the area.

Evaluation of Wilderness Characteristics

Apparent Naturalness

The Southern Nantahala Extension area has been logged in the recent past in the Park Creek area and there are remnants of old logging roads and dispersed campsites throughout the area. Several hiking and horse trails run through the area. There are approximately 20 acres of wildlife fields that are maintained by regular mowing and represent a departure from naturalness.

Opportunities for Solitude or Primitive & Unconfined Recreation

Contiguous to the Southern Nantahala Wilderness, this area provides opportunities for solitude and primitive recreation. The area currently managed as an Inventoried Roadless Area (1,783 acres) provides the best opportunity for solitude away from sights and sounds of open roads. Trails in the area adjacent to the Standing Indian Campground are extensively used, thereby detracting from the opportunity for solitude in their immediate area during high use seasons.

Other Values - Unique or Outstanding Qualities

This area contains southern Appalachian bogs and swamp-bog complexes as well as forests with old growth character. Approximately 800 acres of the Nantahala River, an eligible Wild and Scenic River, are within the northern section of the area.

Size & Manageability

If recommended, this area would be an extension of the Southern Nantahala Wilderness with the eastern boundary defined by NFSR 67 and NFSR 83. The area east of Scream Ridge and outside of the Inventoried Roadless Area has a lower degree of wilderness characteristics compared to the area currently managed as an IRA.

Summary

Recent vegetation management and existing wildlife fields have minor impacts to naturalness in parts of the Southern Nantahala Extension Area. Opportunities for solitude or primitive and unconfined recreation are impacted in the northern portion of the area by the adjacent developed campground, dispersed campsites, and the high recreation use. The best opportunity for managing for wilderness characteristics are in the southeastern sections that are less accessible and are within the designated Inventoried Roadless Areas.

Name: Boteler Peak

Acres: 10,524 acres

Description of Area

Location & Access

The Boteler Peak area is in Clay County about 10 miles east of Hayesville, NC on the Tusquitee Ranger District of the Nantahala National Forest. It is located between Tusquitee Road (SR1307) to the north, and US 64 to the south. Access to the east side of area is from the Chunky Gal Trail (NFST 77) with a trailhead off of US 64. The west side of the area can be accessed from Nelson Ridge Road (NFSR 351) which forms part of the northwestern border.

Surroundings

Most of the southern, western, and northwestern boundaries of the Boteler Peak area are adjacent to private lands, while those to the east are bordered by NFS lands. The area is bordered by open roads to northwest and east. All adjacent NFS lands, as well as private lands to the northwest, are generally forested; however, private lands to the west and south are developed with residential, commercial, and agricultural uses. To the south is the community of Shooting Creek, which is along US64 and has a concentration of development. Chatuge Lake is to the southwest about a mile from area boundaries.

Topography & Vegetation

Most of the area has steep terrain that drops off from high elevation ridges down to the valleys below. Elevations range from approximately 5,010 feet at Boteler Peak down to approximately 2,000 feet where Pounding Mill Creek flows out of the area toward Shooting Creek on the southwest side.

The defining feature of the area is the main ridge running east to west through the area, which is formed by Boteler Peak, The Pinnacle, Birch Knob, and Piney Top. Another high ridge is along Vineyard Mountain, running from The Pinnacle south toward Shooting Creek. These steep south facing slopes contain additional minor ridges and valleys and feeder streams to Shooting Creek which flows to Chatuge Lake (Hiwassee River Basin). The steep north facing slopes of the Boteler Peak ridge circle around Perry Gap to envelop a portion of the Tusquitee Creek watershed. The eastern slopes are somewhat gentler and drain to Buck Creek, a tributary to the Nantahala River to the north (Little Tennessee River Basin).

A range of ecozones are represented in the area, including rich cove, mesic oak, acidic cove, pine-oak/heath, dry oak, and high elevation red oak. Some of these ecozones contain rare plant species and have old growth characteristics.

Current Uses

The Boteler Peak area is managed for backcountry recreation, scenery, wildlife, timber, botanical special interest, and rock hounding. The area has been logged in the recent past with 155 acres harvested within the last 20 years and 986 acres that were cut 21-40 years ago. Vegetation and wildlife management activities are located primarily in the northern sections of the area. Much of the area is popular for hunting, fishing, hiking, backpacking, scenery, nature viewing, and gathering forest products. Approximately 59 acres is managed as a Special Interest Area for its botanical and geological values and is one of the few rock hounding areas on the Nantahala and Pisgah National Forests. The Chunky Gal Trail traverses the area's eastern boundary, from the northwest near Tusquitee Bald to the Appalachian Trail to the southeast at White Oak Stamp.

Evaluation of Wilderness Characteristics

Apparent Naturalness

Approximately 40% (4,195 acres) of the proposed area includes the designated Boteler Peak Inventoried Roadless Area, which overlaps most of the 3,216 acres managed for backcountry recreation. This core area has natural appearing forests with little evidence of man. However, areas to the north and east have recent timber harvests, maintained wildlife fields, low maintenance level roads, and the Corundum Knob/Buck Creek rock hounding area. There are approximately four miles of closed maintenance level 1 and 2 NFS roads in the area, some of which are maintained as a linear wildlife opening or access to mowed wildlife fields affecting naturalness. Along the eastern boundary on Bruce Ridge Road (NFSR 6237), there is a communication tower and a cleared utility corridor. All of these features show evidence of human modification and adversely affect naturalness.

Opportunities for Solitude or Primitive & Unconfined Recreation

There are opportunities for solitude in the area, especially in the interior of the Inventoried Roadless Area. However, concentrated development on private lands to the west, and in the Shooting Creek community to the south have sights and sounds of civilization which adversely affect solitude from many of the high ridges and south and west facing slopes. These developments include a high density housing development, a golf course, small farms, and a manufacturing plant visible to the south and southwest.

The area has opportunities for primitive recreation. Chunky Gal Trail, along the eastern boundary, is designated for hiking. Additionally, hunting, fishing, and rock hounding are popular activities in the area; however, some of the narrow arms of the boundary configuration to the north and south would confine recreation users to narrow strips (less than a quarter of a mile wide in some sections) of National Forest land.

Other Values - Unique or Outstanding Qualities

The area contains forests with old growth characteristics, provides clean water, has a diversity of wildlife, and rare plants are present. The area also contains rock outcrops providing rare habitats of serpentine woodland, and the whole area serves as a scenic backdrop for Shooting Creek, Chatuge Lake, and the US64 corridor. However, with exception of the serpentine barren/woodland, these attributes are not necessarily outstanding within the context of the Southern Appalachian Mountains. There are two State Natural Heritage Areas located in the Boteler Peak area.

Size & Manageability

Although much of the area (especially the core Inventoried Roadless Area) is managed to provide primitive recreation, sights and sounds of civilization from outside the area affect solitude. The Boteler Peak area's irregular shape with several narrow protrusions would confine recreation users and make management to preserve wilderness characteristics difficult. In addition to the various protrusions, Barnett Creek Road (NFSR 6236), an open road, is cherry-stemmed into the area along the east side; allowing vehicles access to the rock hounding area at Corundum Knob. Sights and sounds of civilization are evident along the boundaries, especially to the south, west, and northwest. There are 1,057 acres of outstanding or reserved subsurface mineral rights.

Summary

The Boteler Peak area has natural appearing forests, and opportunities for solitude and primitive and unconfined recreation in the interior of the area; however, naturalness is adversely affected in areas of recent timber management, closed roads and wildlife habitat improvements. Solitude is affected by sights and sounds of civilization where evident from ridgetops and many southern and western facing slopes. The irregular boundary configuration limits opportunities for unconfined recreation in those narrow arms of NFS lands. While the core Inventoried Roadless Area contains stronger characteristics than the Boteler Peak area as a whole, the Inventoried Roadless Area alone may not be of a sufficient size and configuration to make its preservation and use in an unimpaired condition practicable.

Name: Chunky Gal Extension

Acres: 7,785 acres

Description of Area

Location & Access

The Chunky Gal area is in Clay County, NC, on the Tusquitee Ranger District of the Nantahala National Forest. The area is adjacent to the congressionally designated Southern Nantahala Wilderness and is located between US64 to the north and west, Deep Gap Road (NFSR71) to the east, and the Shooting Creek community to the west. Access to the area is from US64, NFSR71, and SR1169 as well as Chunky Gal Trail, Appalachian National Scenic Trail, and Bly Gap Trail. Several closed low maintenance level NFS roads also provide equestrian, mountain bike, and foot travel access to the area.

Surroundings

The area's boundaries provide a relatively consolidated block of NFS land, and although it is long and narrow in shape, much of the area is adjacent to Southern Nantahala Wilderness or other NFS lands. The northwestern portion of the area forms a large "peninsula" encircled by US64 and NFSR71; the latter of which is seasonally open to vehicular traffic. The northeastern boundary along NFSR71 separates the area from another potential addition to wilderness inventory area called "Southern Nantahala Extension".

The exception to adjacency of NFS lands are private tracts to the west and southwest in Giesky Creek and Eagle Fork Creek communities, and at Kitty Ridge/Ravenrock Ridge where a residence sits immediately adjacent to the boundary. Uses in these areas are a mix of forested lands, residential developments, and agriculture. Further to the west in the Shooting Creek community, there is a dense concentration of commercial, agricultural, and residential development. There is one non-federal inholding within the area near Sharptop Ridge.

Topography & Vegetation

The defining features of the area are Chunky Gal Mountain, which bisects the area from north to south, and Yellow Mountain paralleling it to the east. Most of the area has steep terrain with elevations ranging from over 5,000 feet on Yellow Mountain to approximately 2,330 feet at Dave Barrett Creek. Views to the west into the Shooting Creek valley are not shielded by landforms in the northern part of the area near Riley Knob, but are shielded to some degree further south toward Whiteoak Stamp.

Portions of the area have old growth characteristics and there is a rare high-elevation bog at Whiteoak Stamp. A broad range of ecozones are represented in the area, including northern hardwood, high elevation red oak, acidic cove, rich cove, mesic oak, and pine-oak-heath.

Current Uses

The Chunky Gal Extension area is managed for backcountry recreation, scenery, wildlife habitat, timber, and botanical special interest area. Approximately 3,983 acres are identified as an Inventoried Roadless Area; 2,563 acres of which are currently managed as backcountry. Approximately 800 acres are managed as the Riley Knob and Whiteoak Stamp botanical Special Interest Areas. A portion of the area is also managed as a scenic corridor for the Appalachian National Scenic Trail.

The area is popular for hunting, fishing, hiking, backpacking, and gathering forest products. There are three NFS trails in the area designated as hike-only: Chunky Gal Trail (NFST77), the Appalachian National Scenic Trail (NFST1), and Bly Gap Trail (NFST84).

There is recent timber management in the area with 240 acres in the 21-40 year age class and 67 acres in the 0-20 year age class. These activities are located to the east off NFSR71 and to the southwest off of NFSR6230 and 6230C; the latter of which are closed to public vehicular traffic. There are also 6.8 acres of maintained wildlife fields and a total of 4.8 miles of closed low maintenance level NFS road in the area.

Evaluation of Wilderness Characteristics

Apparent Naturalness

Portions of the Chunky Gal area have natural appearing forests, and the Special Interest Areas at Riley Knob and Whiteoak Stamp are maintained for old growth characteristics and intact high-elevation bog habitat, respectively. Much of the area has been managed for backcountry recreation and is untouched by recent timber or wildlife management. This is particularly true in the Inventoried Roadless Areas at Chunky Gal Mountain and Sharptop Ridge.

Between Chunky Gal Mountain and Yellow Mountain is a closed low maintenance level road (NFSR71D) which is maintained as a linear wildlife opening over its entire length, and bisects the area almost to Southern Nantahala Wilderness. There are also recent timber management activities in the Yellow Mountain area. To the southwest, between Sharptop Ridge and Bly Gap Trail, are other NFS roads and recent timber harvests. These human modifications adversely affect naturalness in their immediate vicinities but do not affect apparent naturalness of the area as a whole.

Opportunities for Solitude or Primitive & Unconfined Recreation

The area offers opportunities for solitude, primarily in parts of the Chunky Gal Mountain and Sharptop Ridge IRAs. However, the adjacent US64 and NFSR71 encircle the area’s northern third and impact solitude with the sights and sounds of vehicles. Other impacts to solitude in this northern area are agricultural, commercial, and residential uses visible to the west in Shooting Creek community. Further to the southwest in the Eagle Fork Creek area, there are also views of private developments and farmlands. Other impacts to solitude come from the heavy use along the Appalachian Trail in the through-hiking seasons of spring and fall. These impacts are largely confined to the immediate vicinity of the trail. Outside these peak use seasons, visitor encounters would be less likely.

The area offers many opportunities for primitive recreation, such as hiking, backpacking, hunting, and fishing. In areas adjacent to Southern Nantahala Wilderness, recreation users are unconfined with unfettered access to thousands of acres of wild and unroaded NFS lands. Conversely, the area’s northern “peninsula” encircled by US64 and NFSR71 confine recreation users to this relatively narrow strip of land. This boundary configuration and shape affects much of the northern area and is not conducive to providing unconfined recreation.

Other Values - Unique or Outstanding Qualities

Although the area serves as a scenic backdrop for US64 and nearby communities, most of the area possesses common characteristics within the context of the Southern Appalachian Mountains. However, there are over 450 acres of unique old growth White Oak forest and high-elevation bog identified as Special Interest Areas within the Chunky Gal Extension area.

Size & Manageability

The Chunky Gal Extension area is approximately 7,785 acres in size and most of the southeastern border is adjacent to the Southern Nantahala Wilderness. The northern portion of the area is a long and relatively narrow "peninsula" encircled by US64 and NFSR71. Although the majority of area boundaries are adjacent to NFS lands, sights and sounds of US64 and nearby communities are evident from much of the area; especially in the northern third. This northern boundary configuration and adjacent land use adversely affect opportunities for unconfined recreation and for solitude. There is also a private inholding east of Sharptop Ridge; approximately five miles of closed low maintenance level NFS road being maintained as linear wildlife openings; and approximately 293 acres of outstanding or reserved subsurface mineral rights in the area. These conditions adversely affects management for wilderness characteristics from certain locations within the area.

Two portions of the area adjacent to the existing wilderness (including parts of the IRAs) could be managed to preserve wilderness characteristics of apparent naturalness and opportunities for solitude or primitive and unconfined recreation. While these parts of the IRA would each be less than 5,000 acres, they would be considered as extensions to the existing Southern Nantahala wilderness.

Summary

The Chunky Gal Extension inventory area includes low maintenance level NFS roads, recent timber harvests, and maintained wildlife fields that detract from naturalness in their immediate vicinity. The northern boundary's shape and configuration confine recreation users to a relatively small area surrounded by a state highway. Opportunities for solitude are adversely affected in this northern area by sights and sounds of the adjacent highway and highly developed communities to the west.

The southwest portion of the area, adjacent to the Southern Nantahala Wilderness (Sharptop Ridge Inventoried Roadless Area), and the Chunky Gal Inventoried Roadless Area, have a higher degree of wilderness characteristics compared to the northern portion outside the IRA. While these areas are less than 5,000 acres, they are of sufficient size as to make practicable their preservation and use in an unimpaired condition because they are adjacent to an existing wilderness.

Area Name:

Criterion 1- Apparent Naturalness: The degree to which an area generally appears to be affected primarily by the forces of nature, with the imprints of man's work substantially unnoticeable.

Considerations	Narrative
1a) Within the area, do ecological conditions appear natural or to be noticeably modified by human intervention? • Describe the natural appearance of the area. Consider the composition of plant and animal communities, water, and soil.	

1b) Describe deviations from the natural condition and the extent to which they occur, including evidence of past management activities. • Are vegetation management, timber harvest, or restoration treatments substantially noticeable? Describe the type and extent of vegetation management activities and associated landscape modifications; including existence of recent even-aged harvests, plantation style forest, low maintenance-level roads, skid roads, logging decks, cable yarder landings, etc. • Are there maintained wildlife fields or linear wildlife openings, straightened or modified stream channels, modifications from past agricultural practices, etc. • Are there concentrations of invasive plants and/or animals within the area which appear substantially unnatural? Describe species, locations, and extent of occurrences.	
1c) Describe the presence and extent of improvements in the area, including the type of improvement, approximate size of affected area, and whether structures may be considered historic (>50 years old). • Does the area contain constructed improvements such as airstrips, heliports/landing zones, vertical structures (towers), utility corridors, buildings, dams, water tanks, penstocks, remnants of past occupation, etc.? • Are there recreation improvements within the area that are substantially noticeable modifications to the landscape; such as highly developed trails, day-use or overnight developed recreation sites, recreation structures, access roads, etc.?	

1d) Other (Include any additional information related to criterion 1)	

Attachment 2

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Pisgah (B)Date: 3/12/13 Time: 0945 (C)Project Name: Baldwin Fields Thin
(D)Reviewer: Jones, Dodd (E)Compartment #_____ (F)6th level HUC #__________________
(G)Activity: Harvest Type (w/ method):_____ Site Prep:_____ Temporary Rd:____ System Rd #: 5090
(H)Status: Active Harvest: CTM/T Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 1 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 4 photos -unit
3 photos - road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →		
13. Pesticides Applied Properly	NA →		////////
14. Fertilizers Applied Properly	NA →		////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA →	~~X~~	////////
16. Total # Observed 0 # Acceptable 0	////////	////////	////////
17. Intermittent Crossings Acceptable	4	4	////////
18. Total # Observed 1 # Acceptable 1	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA →		////////

(II)ROADS ONLY System_5090_ Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed_1_ # Acceptable_1_	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA		////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: GRD (B)Date: 7/25/13 Time: 1030 (C)Project Name: Roses Creek T.S.
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd:____ System Rd #: 118
(H)Status: Active Harvest: x Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: # 5 (J)GPS: N 35. 84765, W 81. 85659, Elevation:_____ft, (± 15 ft), Pt. #: ~~+5~~

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y X N_____	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	NA	NA	NA
11. Rehab Stable w/in 30 Days: Log Decks			
12. Excessive soil/debris on Public Roads			
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed 0 # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed 0 # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

from unit 5 down to State road - Fish Hatchery Rd.

(II)ROADS ONLY System 118 Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	~~4~~ 4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 6 # Acceptable 6	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 7 # Acceptable 7	////////	////////	////////
37. Grade Carried Across Crossing	3	~~4~~ 3	2
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	2	2	////////

Inter	Peren	Fish Pass Y/N
7	6	~~3/3~~ 1/3

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

37. FSR 118 is an old system road, thus not constructed by the timber sale. The road does dip over many of the stream crossings. Contractor has rocked the crossing as mitigation, but 2 locations where sediment from road goes into stream. This probably would not have happen under average precipitation conditions. This is a high rainfall year.

44. Three ~~Two~~ fish ~~passage culverts~~ barring streams need replacement to pass aquatics.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: GRD (B)Date: 7/25/13 Time: 0930 (C)Project Name: Roses Creek T.S.
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #_____
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest: x Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: # 6 (J)GPS: N___._____, W___._____, Elevation:_____ft, (± ___ft), Pt. #:_____

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	5 ~~4~~	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	NA		////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed 0 # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed 0 # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

10 Slash was used well on skid ~~roads~~/trails rather than water bars. This practice reduces soil disturbance and is very effective at controlling erosion.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 7/25/13 Time: 1200 (C)Project Name: Roses Creek TS
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:_____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo X Closed: 6mo+_____
(I)Harvest Unit Evaluated: # 8 (J)GPS: N___.______, W___.______, Elevation:_____ft, (±___ft), Pt. #:_____

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Tusquitee (B)Date: 3/14/13 Time: 1130 (C)Project Name: Thunderstruck
(D)Reviewer: Dodd, Jones, Burrell (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd: X System Rd #:_____
(H)Status: Active Harvest: X Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: # 7 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 12-18 unit + temp road. 19 landing

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	3	3	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →	→	→
13. Pesticides Applied Properly	NA →	→	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	4	4	////////
16. Total # Observed 1 # Acceptable ~~0~~ 1	////////	////////	////////
17. Intermittent Crossings Acceptable	NA →	→	////////
18. Total # Observed 0 # Acceptable 0	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	* 3
23. Ground Cover w/in 10 Days	4	4	* 3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	* 3
25. Flow Not Obstructed; Fish Can Pass	NA →	→	////////

(II)ROADS ONLY System_____ Temporary X	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	4	4	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA →	→	////////
34. Total # Observed 0 # Acceptable 0	////////	////////	////////
35. Intermittent Crossings Acceptable	3	3	////////
36. Total # Observed 1 # Acceptable 0	////////	////////	////////
37. Grade Carried Across Crossing	3	3	2
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA →	→	////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

1 Unit should have been skylined rather than ground-based and log deck is to close to perennial channel.

* Recommend obliterating most skid roads, especially at the stream crossing.

15+16 — Major departure on the perennial xing. Bobby Burrell will make corrections next week early and send photos for documentation, after corrections will finish rating.

35 crossing needs to be pulled and slopes seeded + mulched

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Tusquitee (B)Date: 3/14/13 Time: 1000 (C)Project Name: THUNDERSTRUCK
(D)Reviewer: Dodd, Jones, Burrell (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd:____ System Rd #: 350 B
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 4 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 1-5, 7 unit
6,8-11 road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	* 3	* 3	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 350B Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	3	3	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA →		////////
34. Total # Observed 0 # Acceptable 0	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 2 # Acceptable 2	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA →		////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

P	
A	NA

I	
A	NA
||	

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

1 - * The choice to tractor log the unit over skyline was not the best practice. As a result there are multiple skid roads and excessive ground disturbance. Therefore, recommend obliterating a majority of the skid roads to restore site production, and slope stability.

- On 350B we concur with Bobby Burrell on stabilizing the switchback with grading, gravel, and waterbars.

31 verticle cuts on road near intermittent channel, but no corrective action and no sediment to channel.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Tusquitee (B)Date: 3/14/13 Time: 1300 (C)Project Name: Thunderstruck
(D)Reviewer: Dodd, James (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method):_____ Site Prep:_____ Temporary Rd:____ System Rd #: 350
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: # — (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: ~~19-20~~ 20-21

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site			////////
2. Breaks in Grade Used			////////
3. Barriers Used if w/in 300ft P/I Channel			
4. Drainage NOT to stream channel			
5. No Skidding in Channels or Waterbodies			
6. Shade Strips in Place P_____ I_____			////////
7. No Logging Debris in P/I channel			////////
8. Harvesting in MA18 (SMZ) Y_____ N_____	////////	////////	////////
9. Violation w/in MA18 (SMZ)			
10. Rehab Stable w/in 30 Days: Skid Trails			
11. Rehab Stable w/in 30 Days: Log Decks			
12. Excessive soil/debris on Public Roads			
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable			////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 350 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA	NA	////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			NA
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Tusquitee (B)Date: 3/14/15 Time: 1500 (C)Project Name: BIG COVE
(D)Reviewer: Jones, Dodd, Burrell (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd:____ System Rd #: 6148
(H)Status: Active Harvest: ~~CTM/T~~ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 5 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 22-26 unit 27-29 road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	3	3	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 6148 Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	* 3	3	////////
34. Total # Observed 1 # Acceptable 0	////////	////////	////////
35. Intermittent Crossings Acceptable	NA →		////////
36. Total # Observed 0 # Acceptable —	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA →		////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

1 Unit slope is very steep and unit should have been skylined. Skid roads are present across the slope, stacked up the hill ~225' apart. We feel that the unit is set up for mass wasting due to stacked roads.

33 One stream crossing. Culvert is undersized and prone to plug

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Nantahala (B)Date: 3/15/13 Time: 1545 (C)Project Name: Fatback
(D)Reviewer: Dodd, Jones (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 12 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 32-34

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: NANTAHALA (B)Date: 3/15/13 Time: 1530 (C)Project Name: Fatback
(D)Reviewer: Dodd, Jones, Dryman, Kilker (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo X Closed: 6mo+_____
(I)Harvest Unit Evaluated: # 11 (J)GPS: N___._______, W___._______, Elevation:_____ft, (± ___ft), Pt. #: 29-31

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: NANTAHALA (B)Date: 3/15/13 Time: 1330 (C)Project Name: FAT BACK
(D)Reviewer: DODD + DACI (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:_____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 7 (J)GPS: N___.______, W___.______, Elevation:_____ft, (±___ft), Pt. #: 17-19

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Nantahala (B)Date: 3/15/2013 Time: 1400 (C)Project Name: Fatback
(D)Reviewer: Dodd, James, Dryman, Killian (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd:____ System Rd #: 415A
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 8 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 20-25 unit 26-28 road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →		
13. Pesticides Applied Properly	NA →		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	4	4	////////
16. Total # Observed 2 # Acceptable 2	////////	////////	////////
17. Intermittent Crossings Acceptable	4	4	////////
18. Total # Observed 1 # Acceptable 1	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA →		////////

(II)ROADS ONLY System 415A Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4 +	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	3	3	////////
34. Total # Observed 2 # Acceptable 1	////////	////////	////////
35. Intermittent Crossings Acceptable	NA →		////////
36. Total # Observed 0 # Acceptable —	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	2	2	////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Nantahala (B)Date: 3/15/13 Time: 1115 (C)Project Name: HORSESHOE
(D)Reviewer: Dodd, Jones, Drymon, Killian (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/S Site Prep:_____ Temporary Rd:____ System Rd #: 714
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 11 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 7-8-9 unit
10-16 road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 7/4 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 21 # Acceptable 18	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 11 # Acceptable 10	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	
44. Flow Not Obstructed; Fish Can Pass	2	1	////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

PHOTOS ~~||||~~ ||

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

P

A	NA
~~||||~~ ~~||||~~ ~~||||~~ |||	|||

I

A	NA
~~||||~~ ~~||||~~		

F

Y	N

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: NANTAHALA (B)Date: 3/15/13 Time: 1045 (C)Project Name: HORSESHOE
(D)Reviewer: DODD, JONES, ... (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): S/CT Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 9 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: PHOTO # 6

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Nantahala (B)Date: 3/15/13 Time: 0945 (C)Project Name: Horseshoe T.S.
(D)Reviewer: Dodd, Jones, Dryman, Kilhain (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTA/S/T Site Prep:_____ Temporary Rd: X System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 7 (J)GPS: N___.______, W___.______, Elevation:_____ft, (±___ft), Pt. #: 1-4 unit

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed 0 # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable	~~5~~ 4	5	////////
18. Total # Observed 2 # Acceptable 2	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA		////////

(II)ROADS ONLY System_____ Temporary__X__	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	4	4	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA	NA	////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			NA
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

(17) pulled culverts on old system road.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Nantahala (B)Date: 3/15/2013 Time: 1000 (C)Project Name: Horseshoe
(D)Reviewer: Jones, Dodd, Killian, Dryman (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method):_____ Site Prep:_____ Temporary Rd:____ System Rd #: 714E
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: # — (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 5

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site			////////
2. Breaks in Grade Used			////////
3. Barriers Used if w/in 300ft P/I Channel			
4. Drainage NOT to stream channel			
5. No Skidding in Channels or Waterbodies			
6. Shade Strips in Place P_____ I_____			////////
7. No Logging Debris in P/I channel			////////
8. Harvesting in MA18 (SMZ) Y_____ N_____	////////	////////	////////
9. Violation w/in MA18 (SMZ)			
10. Rehab Stable w/in 30 Days: Skid Trails			
11. Rehab Stable w/in 30 Days: Log Decks			
12. Excessive soil/debris on Public Roads			
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable			////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 714E Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in (MA18) (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed 0 # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 1 # Acceptable 1	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA		////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

I

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Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Cheoah (B)Date: 3/13/2013 Time: 1115 (C)Project Name: Rose T.S.
(D)Reviewer: Jones & Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/S/T Site Prep:_____ Temporary Rd:____ System Rd #: 2630A
(H)Status: Active Harvest: CTM/S/T Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: # 4 (J)GPS: N___._______, W___._______, Elevation:_____ft, (±___ft), Pt. #: 18-25

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	~~X~~ 4	~~X~~ 5	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	NA		////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable			////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 2630A Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

10 Logger placed slash on watered skid road. This practice helps in erosion control till grass grows & beyond
29 Good filter wind-rows Slash is above and beyond required practices

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Cheoah (B)Date: 3/13/13 Time: 1045 (C)Project Name: Rose T.S.
(D)Reviewer: Jones & Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/S Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 2 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 12-17
26-27

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

10 Potential for mass wasting on skid road that was cut into unit near the top.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Cheoah (B)Date: 3/13/13 Time: 0945 (C)Project Name: Rose T.S.
(D)Reviewer: Jones & Dodd & Eller (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): CTM/S Site Prep:_____ Temporary Rd:____ System Rd #: 2630
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 11 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 5 photos of unit (1-5)
6-11, 28-32 of road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System <u>2630</u> Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 3 # Acceptable 1	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 2 # Acceptable 2	////////	////////	////////
37. Grade Carried Across Crossing	2	2	2
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA →		////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

P		I	
A	NA	A	NA
I	II	II	

photos 29-31 of unacceptable xing on perennial
Sediment delivery from road surface at grade dip.
and undersized pipe.
photo 32 - unacceptable xing on perennial due to grade dip over culvert.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Comments: (1) Terry plans to lay more gravel down on road after haul has ended. This is a good idea that we recommend to reduce water on road and rutting. Concentrate rock on rolling dips and low spots.

(26) the road was located mostly high on hill slope and above many stream channels.

(37) The two sites where road ~~runoff~~ drains off road to perennial channels is really Minor in impact but requires corrective action with gravel and ~~role d~~ rolling dips.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Pisgah (B)Date: 3/12/13 Time: 0900 (C)Project Name: Progress Energy Enka Settlement
(D)Reviewer: Jones, Dodd (E)Compartment #_____ (F)6th level HUC #__________________
(G)Activity: Harvest Type (w/ method): CTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 1 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 3 photos

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4 ~~NA~~	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time:_____ (C)Project Name: Mulberry Globe Stewardship
(D)Reviewer: Jones, Eldridge, Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/S/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 10 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 11-13

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time: 1200 (C)Project Name: Mulberry Globe Stewardship
(D)Reviewer: Eldridge, Jones, Dodd (E)Compartment #_____ (F)6th level HUC #__________________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ x
(I)Harvest Unit Evaluated: # 13 (J)GPS: N___.______, W___.______, Elevation:_____ft, (±___ft), Pt. #: 17 - 20 skid road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA →		////////
16. Total # Observed 0 # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable	~~4~~	~~4~~	////////
18. Total # Observed ~~2~~ # Acceptable ~~2~~	////////	////////	////////
19. Grade Carried Across Crossing	~~4~~	~~4~~	~~3~~ NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

~~18 removed culverts from skid road/old system road~~

3+10 - silt fence used effecively where skid road comes close to creek, photo taken.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time: 1105 (C)Project Name: Mulberry Globe Stewl.
(D)Reviewer: Dodd, Eldridge, Jones (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/S/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 14 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 8-10

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time: 1040 (C)Project Name: Mulberry Globe Stew
(D)Reviewer: Dodd, Eldridge, Jones (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/S Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 15 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 4-7

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/2013 Time: 1010 (C)Project Name: Mulberry Globe Stewardship
(D)Reviewer: Dodd, Eldridge, Jones (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/S Site Prep:_____ Temporary Rd:____ System Rd #: 188
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 16 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 1-3 unit # 14,15,16 road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 18~~8~~ Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	3	3	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 7 # Acceptable 5	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 2 # Acceptable 2	////////	////////	////////
37. Grade Carried Across Crossing	3	3	2
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	2	1	////////

Int. = 2
Per. = ~~8~~ 7
Non Acc = 2 xings, perennial
Fish = 1, not accept. 2 photos
due to velocity

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

1 good grass growth in unit.

28 Lower portion of road parallels Frankum Cr.

37 One stream xing, grade dips & runoff drains to channel.

44 One fish passage crossing. It was a barrier to passage due to velocity.

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time: 1440 (C)Project Name: Mulberry Globe Stewardship
(D)Reviewer: Eldridge, Dodd, Jones (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:____ System Rd #: 4071
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 18 (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 2 photos

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	~~4~~ 3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	~~3~~ 4	~~3~~ 4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 4071 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 5 # Acceptable 3	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 6 # Acceptable 6	////////	////////	////////
37. Grade Carried Across Crossing	3	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	2	2	////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

P		I		F	
A	N	A	N	P	N
111	11	~~1111~~ 1		1	11
3	2	6	0	1	2

PICTURES

TIME 1450 1
1505 1
~~1545~~ 1515 111
1525 1 (FORD)
1535 11 (PLUGGED CUL)

8

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time: 1500 (C)Project Name: Mulberry Globe Stew.
(D)Reviewer: Dodd, Eldridge, Jones (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 19 (J)GPS: N___.______, W___.______, Elevation:_____ft, (±___ft), Pt. #: 2 photos

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Grandfather (B)Date: 3/11/13 Time: 1515 (C)Project Name: Mulberry Globe Steward
(D)Reviewer: Jones, Dodd, Eldridge (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:_____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ x
(I)Harvest Unit Evaluated: # 20 (J)GPS: N___._______, W___._______, Elevation:_____ft, (± ___ft), Pt. #: 1 photo

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N x	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	4	4	////////
14. Fertilizers Applied Properly	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			NA
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Uwharrie (B)Date: 4/18/2013 Time: 1806 (C)Project Name: Buckhorn
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #__________________
(G)Activity: Harvest Type (w/ method): CC/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 4 (J)GPS: N___._______, W___._______, Elevation:_____ft, (± ___ft), Pt. #:_____

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly	NA		////////
14. Fertilizers Applied Properly	NA		////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA	NA	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Uwharrie (B)Date: 4/18/2013 Time: 1758 (C)Project Name: Buckhorn
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #_____
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 2 (J)GPS: N 35. 28831, W 079. 83306, Elevation: 473 ft, (± — ft), Pt. #:_____

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →		
13. Pesticides Applied Properly	NA →		////////
14. Fertilizers Applied Properly	NA →		////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	4	4	////////
16. Total # Observed 1 # Acceptable 1	////////	////////	////////
17. Intermittent Crossings Acceptable	NA →		////////
18. Total # Observed 0 # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA →		////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Uwharrie (B)Date: 4/18/2013 Time: 1745 (C)Project Name: Buckhorn
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method): LTM/T Site Prep:_____ Temporary Rd: ✓ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(I)Harvest Unit Evaluated: # 3 (J)GPS: N35. 29050° W079. 82862° Elevation: 488 ft, (± — ft), Pt. #:_____

1 photo of temp road

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →	→	→
13. Pesticides Applied Properly	NA →	→	////////
14. Fertilizers Applied Properly	NA →	→	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA →	→	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary__✓_	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	4	4	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA	NA	////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

National Forests in North Carolina
S&G Implementation and Effectiveness Field Form
Version 3.6 (3/19/2012)

(A)District: Uwharrie (B)Date: 4/18/2013 Time: 1915 (C)Project Name: Buckhorn
(D)Reviewer: B. Dodd (E)Compartment #_____ (F)6th level HUC #__________
(G)Activity: Harvest Type (w/ method):_____ Site Prep:_____ Temporary Rd:____ System Rd #:_____
(H)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+_____
(I)Harvest Unit Evaluated: #______ (J)GPS: N___.______, W___.______, Elevation:_____ft, (± ___ft), Pt. #: 3 photos

(K)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site			////////
2. Breaks in Grade Used			////////
3. Barriers Used if w/in 300ft P/I Channel			
4. Drainage NOT to stream channel			
5. No Skidding in Channels or Waterbodies			
6. Shade Strips in Place P_____ I_____			////////
7. No Logging Debris in P/I channel			////////
8. Harvesting in MA18 (SMZ) Y_____ N_____	////////	////////	////////
9. Violation w/in MA18 (SMZ)			
10. Rehab Stable w/in 30 Days: Skid Trails			
11. Rehab Stable w/in 30 Days: Log Decks			
12. Excessive soil/debris on Public Roads			
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable			////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	—	—	—
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed_1_ # Acceptable_1_	////////	////////	////////
35. Intermittent Crossings Acceptable	NA →		////////
36. Total # Observed_0_ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing	3	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	4	4	////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

37 Grade not carried across, but road was graveled and well drained

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Cheoah RD (B)Date: 3/23/2018 Time: 1130 (C)Project Name: ~~Cove Creek T.S.~~ Cable Cove T.S
(D)Reviewer(s): D. Jones, B Dodd, T. Dakar, T Ellor (E)6th level HUC #________
(F)Activity: Harvest Type (w/method):________ Site Prep:________ Temporary Rd:____ System Rd #: ——
(G)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo X Closed: 6mo+_____
(H)Harvest Unit Evaluated: # 1 (I)GPS: N35 . 41730 , W83. 76096 , Elevation: 2805 ft, (± __ft), Pt. #:_____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System___ Temporary___	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#1 Slopes are > 50% and there are 3 skid roads stacked on the slope.
Recommend: Using an excavator - trackhoe to pull the fill slope onto the skid road and cover with slash.

Road_____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Cheoah RD (B)Date: 3/23/2018 Time: 1030 (C)Project Name: ~~Cove Creek T.S.~~ Cable Cove T.S.
(D)Reviewer(s): D. Jnur, B. Dodd, T. Decker, T. Eller (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Skyline LTM Site Prep:____ Temporary Rd: X System Rd #: ~~2621~~
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo X Closed: 6mo+____
(H)Harvest Unit Evaluated: # 2 (I)GPS: N35.41771, W 83.75697, Elevation: 2588 ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary__X__	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	3	3	3
32. Temp Roads Only. Rehab w/in 30 Days	4	4	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed_1_ # Acceptable_1_	////////	////////	////////
35. Intermittent Crossings Acceptable	NA		////////
36. Total # Observed_0_ # Acceptable_—_	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA →		////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

1st Crossing: Consider removing 24" pipe in temp road.

#26 * Temp Road: Look at adding to K-V plan – pull fill onto inside of road cut. Since there are cracks in fill and a small slide going into a dry draw.

Road temp – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement
1st	X				—	—	~~Yes~~ Remove pipe
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Cheoah RD (B)Date: 3/23/2018 Time: 1100 (C)Project Name: Cable Cove T.S.
(D)Reviewer(s): D. Jones B. Dodd (E)6th level HUC #______
(F)Activity: Harvest Type (w/method):______ Site Prep:____ Temporary Rd:____ System Rd #: 2621
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+____
(H)Harvest Unit Evaluated: #____ (I)GPS: N__.____, W__.____, Elevation:____ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site			////////
2. Breaks in Grade Used			////////
3. Barriers Used if w/in 300ft P/I Channel			
4. Drainage NOT to stream channel			
5. No Skidding in Channels or Waterbodies			
6. Shade Strips in Place P____ I____			////////
7. No Logging Debris in P/I channel			////////
8. Harvesting in MA18 (SMZ) Y____ N____	////////	////////	////////
9. Violation w/in MA18 (SMZ)			
10. Rehab Stable w/in 30 Days: Skid Trails			
11. Rehab Stable w/in 30 Days: Log Decks			
12. Excessive soil/debris on Public Roads			
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up			////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable			////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 2621 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 3 # Acceptable 2	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 2 # Acceptable 2	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA		////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#34 3rd xing – hole in fill over pipe needs fixing.

Road 2621 – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement
1st	X						NO
2nd			X				NO
3rd				X			Yes – 35.42070 83.76496
4th	X						No
5th			X				NO
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Croatan (B)Date: 3/19/2018 Time: 1245 (C)Project Name: Hairy T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #____________
(F)Activity: Harvest Type (w/method):____________ Site Prep:______ Temporary Rd: X System Rd #:______
(G)Status: Active Harvest:______ Active Site Prep: X Closed: 0-6mo N Closed: 6mo+______
(H)Harvest Unit Evaluated: # 1 (I)GPS: N 34.82480, W 77.14911, Elevation: 12 ft, (±__ft), Pt. #:______

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N N	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary__X__	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	4	4	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road _____ – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Croatan (B)Date: 3/19/2018 Time: 1300 (C)Project Name: Hairy T.S.
(D)Reviewer(s): D.Jones (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground CTM Site Prep: ___ Temporary Rd: ___ System Rd #: —
(G)Status: Active Harvest: ___ Active Site Prep: ___ Closed: 0-6mo ___ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 3 (I)GPS: N 34.81791, W 77.14629 Elevation: 13 ft, (± __ft), Pt. #: ___

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P___ I___	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y___ N x	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →	→	→
13. Pesticides Applied Properly	↓		////////
14. Fertilizers Applied Properly	↓		////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA →	→	////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable	↓		////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing	↓		
20. Channel Disturbed Once/Least Possible	↓		
21. Stable Banks/Protected From Accelerated Erosion	↓		////////
22. Minimum Runoff Into Channel	↓		
23. Ground Cover w/in 10 Days	↓		
24. Seeding Area 25 Feet+ w/in 15 Days	↓		
25. Flow Not Obstructed; Fish Can Pass	↓		////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
- 4. Meets or exceeds requirements of S&G's or FPGRWQ.
- 3. Minor departure but no corrective action needed.
- 2. Major departure, corrective action required.
- 1. Gross departure, corrective action required.
- NA Not applicable or not reviewed.

Effectiveness Rating
- 5. Improvement over prior conditions.
- 4. Adequate resource protection.
- 3. Minor/temporary impact, no corrective action needed.
- 2. Major short-term impacts, corrective action needed.
- 1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
- 3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
- 2. Non-critical visible sediment flow reaches stream channel.
- 1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road_____ – Stream Crossings

Crossing	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Croatan (B)Date: 3/19/2018 Time: 1220 (C)Project Name: Hairy T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Ground CTM Site Prep:____ Temporary Rd:____ System Rd #: ——
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 5 (I)GPS: N 34.80924, W 77.15971, Elevation: 22 ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA	~~3~~	~~3~~
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road _____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Croatan (B)Date: 3/19/2018 Time: 1140 (C)Project Name: Red Belly Pipeline
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Grand CTM Site Prep:___ Temporary Rd:___ System Rd #: 120
(G)Status: Active Harvest:___ Active Site Prep:___ Closed: 0-6mo___ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 1 (I)GPS: N34. 81171, W77. 15890, Elevation: 35 ft, (± __ft), Pt. #:___

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P___ I___	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y___ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 120 Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	~~4~~ 3	~~4~~ 3	////////
34. Total # Observed 1 # Acceptable 0	////////	////////	////////
35. Intermittent Crossings Acceptable	NA		////////
36. Total # Observed 0 # Acceptable -	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	4	4	////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

33

Crossing #1: bottom of inlet is rusted out, needs replacement

Road 120 – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement
1st				1	X		Yes
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

GPS
34.82209°
77.14874°

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Croatan (B)Date: 3/19/18 Time: 1130 (C)Project Name: Red Belly Pipeline
(D)Reviewer(s): D. Jones + B Dodd (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground LTM Site Prep: Temporary Rd: System Rd #: —
(G)Status: Active Harvest: X Active Site Prep: Closed: 0-6mo Closed: 6mo+
(H)Harvest Unit Evaluated: # 2 (I)GPS: N 34.81129, W 77.16851, Elevation: 35 ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P___ I___	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y___ N x	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road_____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Croatan (B)Date: 3/19/18 Time: 1100 (C)Project Name: Red belly Pipeline
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground LTM Site Prep: Temporary Rd: System Rd #:
(G)Status: Active Harvest: Active Site Prep: Closed: 0-6mo Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 3 (I)GPS: N 34.81308, W 77.17191, Elevation: 44 ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road_____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Croatan (B)Date: 3/19/2018 Time: 1000 (C)Project Name: Red Belly Pipeline
(D)Reviewer(s): D. k. Jones & Brady Dodd (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Ground CT/4 Site Prep:____ Temporary Rd:____ System Rd #: 146
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+ x
(H)Harvest Unit Evaluated: # 4 (I)GPS: N 34.31512, W 077.17508, Elevation: 92? ft, (± __ft), Pt. #: —

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P x I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N x	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA ~~4~~	~~4~~	~~3~~
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	4	4	////////
16. Total # Observed 1 # Acceptable 1	////////	////////	////////
17. Intermittent Crossings Acceptable	NA		////////
18. Total # Observed 0 # Acceptable 0	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA		////////

(II)ROADS ONLY System 146 Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 1 # Acceptable 1	////////	////////	////////
35. Intermittent Crossings Acceptable	NA —		////////
36. Total # Observed 0 # Acceptable –	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA →		////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road 146 – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement
1st	–	–	1			x	No
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
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(A)District: Croatan (B)Date: 3/19/2018 Time: 1345 (C)Project Name: Redhead T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground CTM Site Prep: Temporary Rd: System Rd #: 175
(G)Status: Active Harvest: Active Site Prep: Closed: 0-6mo Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 5 (I)GPS: N34.79063 W77.08365 Elevation: — 25 ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 175 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road ____ – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Nantahala RD (B)Date: 3/22/2018 Time: 1000 (C)Project Name: Roughbear T.S.
(D)Reviewer(s): D. Jones, B. Dodd + S. Dryman (E)6th level HUC #______
(F)Activity: Harvest Type (w/method): Ground LTM Site Prep:____ Temporary Rd:____ System Rd #: 713
(G)Status: Active Harvest:____ Active Site Prep: x Closed: 0-6mo____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 1 (I)GPS: N 35. 17612, W 83. 49245, Elevation: 2903 ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_713_ Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed_3_ # Acceptable_3_	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed_2_# Acceptable_2_	////////	////////	////////
37. Grade Carried Across Crossing	3	3	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA		////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road _713_ – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement
1st	X				—	—	No
2nd			X		—	—	No
3rd			X		—	—	No
4th	X				—	—	NO
5th			X		—	—	NO
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
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(A)District: Nantahala RD (B)Date: 3/22/2018 Time: 1115 (C)Project Name: Roughbear T.S.
(D)Reviewer(s): D. Jones, B Dodd, Sam Dryman (E)6th level HUC #
(F)Activity: Harvest Type (w/method): GmA LTM Site Prep: X Temporary Rd: System Rd #: 316
(G)Status: Active Harvest: Active Site Prep: Closed: 0-6mo Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 2 (I)GPS: N35.17076, W83.53397, Elevation: 2953ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →		
13. Pesticides Applied Properly	↓		////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	4	4	////////
16. Total # Observed 1 # Acceptable 1	////////	////////	////////
17. Intermittent Crossings Acceptable	NA		////////
18. Total # Observed 0 # Acceptable —	////////	////////	////////
19. Grade Carried Across Crossing	4	4	3
20. Channel Disturbed Once/Least Possible	4	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA		////////

(II)ROADS ONLY System 316 Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA →		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 1 # Acceptable 1 Bridge over Camp Br. Cr	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 1 # Acceptable 1	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass Camp Br. Creek	4	4	////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#8 Watershed Improvement work planned to obliterate old road used as skid road within valley bottom.

Road 316 – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement	
1st	X				—	—	No	
2nd			X		X		No	Camp Br. Cr.
3rd								
4th								
5th								
6th								
7th								
8th								
9th								
10th								
Total								

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(A)District: Nantahala RD (B)Date: 3/22/2018 Time: 1130 (C)Project Name: Rough Bear T.S.
(D)Reviewer(s): D. Jones, B. Dodd, S. Dejima (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Ground Thinning CTM Site Prep: X Temporary Rd:____ System Rd #: —
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 3 (I)GPS: N 35 . 17036 , W 83 . 53483 , Elevation: 3033 ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	Y	Y	////////
2. Breaks in Grade Used	Y	Y	////////
3. Barriers Used if w/in 300ft P/I Channel	Y	Y	3
4. Drainage NOT to stream channel	Y	Y	3
5. No Skidding in Channels or Waterbodies	Y	Y	3
6. Shade Strips in Place P — I —	Y	Y	////////
7. No Logging Debris in P/I channel	Y	Y	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	Y	Y	3
10. Rehab Stable w/in 30 Days: Skid Trails	Y	Y	3
11. Rehab Stable w/in 30 Days: Log Decks	Y	Y	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	Y	Y	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	Y	Y	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

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Road_____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Nantahala RD (B)Date: 3/22/2018 Time: 1215 (C)Project Name: Roughbear T.S.
(D)Reviewer(s): D. Jones, B. Dodd, S. Dyman, B. Killian (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Skyline LTM Site Prep:____ Temporary Rd:____ System Rd #: —
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 6 (I)GPS: N35.15302, W83.54371, Elevation: 3059 ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks - Hot deck	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating
4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating
5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):
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Road _____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Nantahala (B)Date: 3/22/2018 Time: 1400 (C)Project Name: Roughbar T.S.
(D)Reviewer(s): D. Jones, B. Dodd, S. Dryman, B. Killian (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Skyline/Grnd Site Prep: Temporary Rd: System Rd #: 388
(G)Status: Active Harvest: Active Site Prep: Closed: 0-6mo Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 7 (I)GPS: N35.14954, W83.51911, Elevation: 3187 ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y N x	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed ___ # Acceptable ___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed ___ # Acceptable ___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 388 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 8 # Acceptable 8	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 1 # Acceptable 1	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
~~43.~~ Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	2	1	////////

Implementation Rating
- 4. Meets or exceeds requirements of S&G's or FPGRWQ.
- 3. Minor departure but no corrective action needed.
- 2. Major departure, corrective action required.
- 1. Gross departure, corrective action required.
- NA Not applicable or not reviewed.

Effectiveness Rating
- 5. Improvement over prior conditions.
- 4. Adequate resource protection.
- 3. Minor/temporary impact, no corrective action needed.
- 2. Major short-term impacts, corrective action needed.
- 1. Major long-term impacts, corrective action needed.

Visible Sediment Rating
- 3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
- 2. Non-critical visible sediment flow reaches stream channel.
- 1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#44

6th Crossing: Needs assessment by fisheries for priority to replace for Aquatic Organism passage.

9th Crossing: Need repair of footer that has scoured underneath.

Road 388 – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement	
1st			X		—	—	No	
2nd			X		—	—	NO	
3rd			X		—	—	No	
4th	X				—	—	No	
5th			X		—	—	No	
6th			X			X	Yes	35.14948 83.55265
7th			X		—	—	No	
8th			X		—	—	No	
9th			X		X		Need repair of footer	35.15819 83.56087
10th								
Total								

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(A)District: Nantahala RD (B)Date: 3/22/2018 Time: 1300 (C)Project Name: Roughbear T.S.
(D)Reviewer(s): D. Jone, B. Dodd, S. Dymon, B. Killian (E)6th level HUC #________
(F)Activity: Harvest Type (w/method): Skyline CTM Site Prep:_____ Temporary Rd:____ System Rd #: 387
(G)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 9 (I)GPS: N35.15516, W83.51166, Elevation: 3142ft, (± __ft), Pt. #:_____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly	4	4	////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_381_ Temporary_____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed_0_ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed_1_ # Acceptable_1_	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	NA		////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road 381 – Stream Crossings

Crossing	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st	X				—		NO
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Pisgah RD (B)Date: 3/21/2018 Time: 1430 (C)Project Name: Mince Cove T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #______
(F)Activity: Harvest Type (w/method): Skyline LTM Site Prep:______ Temporary Rd:____ System Rd #: 5051
(G)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo X Closed: 6mo+_____
(H)Harvest Unit Evaluated: # 4 (I)GPS: N 35.40699, W 82.67687, Elevation: 3423 ft, (± __ft), Pt. #:_____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	4
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 5051 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road 5051 – Stream Crossings

Crossing	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Pisgah RD (B)Date: 3/21/2018 Time: 1300 (C)Project Name: Scott Mountain T.S
(D)Reviewer(s): D. Jones + B. Cook (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground CTM-Winch Site Prep:____ Temporary Rd:____ System Rd #: ----
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 1 (I)GPS: N 35 . 51826 , W 82 . 65012 , Elevation: 2194ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

- 4. Meets or exceeds requirements of S&G's or FPGRWQ.
- 3. Minor departure but no corrective action needed.
- 2. Major departure, corrective action required.
- 1. Gross departure, corrective action required.
- NA Not applicable or not reviewed.

Effectiveness Rating

- 5. Improvement over prior conditions.
- 4. Adequate resource protection.
- 3. Minor/temporary impact, no corrective action needed.
- 2. Major short-term impacts, corrective action needed.
- 1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

- 3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
- 2. Non-critical visible sediment flow reaches stream channel.
- 1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road _____ – Stream Crossings							
	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Pisgah RD (B)Date: 3/21/2018 Time: 1200 (C)Project Name: Scott Mountain TS
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): GROUND CTM-Winch Site Prep:____ Temporary Rd:____ System Rd #:____
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo X Closed: 6mo+____
(H)Harvest Unit Evaluated: # 2 (I)GPS: N 35.51388, W 82.64346, Elevation: 2278ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I___	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y___ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

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Road _____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Pisgah RD (B)Date: 3/21/2018 Time: 1100 (C)Project Name: Scott Mountain T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground CTM Winch Site Prep: Temporary Rd: System Rd #: —
(G)Status: Active Harvest: Active Site Prep: Closed: 0-6mo X Closed: 6mo+
(H)Harvest Unit Evaluated: # 3 (I)GPS: N35.51053, W82.64473, Elevation: 2470 ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y___ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_____	////////	////////	////////
26. Best Located to Protect Site			////////
27. Breaks in Grade Used			////////
28. Located in MA18 (SMZ)			
29. Drainage Not to Stream Channel			
30. Barrier Used if w/in 300 Feet P/I Channel			
31. No Vertical Cuts if w/in 300 Feet P/I Channel			
32. Temp Roads Only. Rehab w/in 30 Days			
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

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____

Road _____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not-Acceptable	Acceptable	Not-Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Pisgah RD (B)Date: 3/21/2018 Time: 1045 (C)Project Name: Scott Mountain T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Ground CTM-Winch Site Prep:____ Temporary Rd:____ System Rd #: 5096
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo____ Closed: 6mo+____
(H)Harvest Unit Evaluated: # 4 (I)GPS: N35.50728, W82.64481, Elevation: 2512ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P____ I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N x	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 5096 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	4	4	////////
34. Total # Observed 3 # Acceptable 3	////////	////////	////////
35. Intermittent Crossings Acceptable	4	4	////////
36. Total # Observed 2 # Acceptable 2	////////	////////	////////
37. Grade Carried Across Crossing	4	4	3
38. Channel Disturbed Once/Least Possible	4	4	////////
39. Stable Banks/Protected From Accelerated Erosion	4	4	3
40. Minimum Runoff Into Channel	4	4	3
41. Ground Cover w/in 10 Days	4	4	3
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	4	1	////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#44 Crossing replaced adequately for S&Gs, but not for passage of aquatics

Road 5096 – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement
1st			X		—	—	No
2nd			X			X	Yes 35.51606/82.64150
3rd			X		—	—	No
4th	X				—	—	No
5th	X				—	—	No
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
Standards and Guides (S&G) Implementation and Effectiveness Field Form
Version 5.1 (4/10/2017)

(A)District: Uwharrie (B)Date: 3/20/2018 Time: 1645 (C)Project Name: Cove T.S.
(D)Reviewer(s): D. Jone + B. Dodd (E)6th level HUC # ~~on separate sheet~~ 576 extension
(F)Activity: Harvest Type (w/method): Ground LTM Site Prep:_____ Temporary Rd: X System Rd #: ~~576 extension~~
(G)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo X Closed: 6mo+_____
(H)Harvest Unit Evaluated: # 1 (I)GPS: N35.43152, W80.03687, Elevation: 445 ft, (±__ft), Pt. #:_____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary_X__	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	* 3	* 3	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#32 Temp. road is from landing to FS 576 ~ 200' long. It has been left with bare soil without seeding. However no soil movement to a stream

Road_____ – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
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Version 5.1 (4/10/2017)

(A)District: Uwharrie (B)Date: 3/20/2018 Time: 1510 (C)Project Name: Cove T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #________
(F)Activity: Harvest Type (w/method): Ground CTM Site Prep:______ Temporary Rd:____ System Rd #: 576
(G)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo X Closed: 6mo+_____
(H)Harvest Unit Evaluated: # 2 (I)GPS: N 35. 42421, W 80.06831, Elevation: 685 ft, (± __ft), Pt. #:_____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P_____ I_____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y_____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 576 Temporary ____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	~~4~~ 3	3	////////
28. Located in MA18 (SMZ)	3	3	2
29. Drainage Not to Stream Channel	2	2	2
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	1	1	////////
34. Total # Observed 5 # Acceptable 0	////////	////////	////////
35. Intermittent Crossings Acceptable	NA		////////
36. Total # Observed 0 # Acceptable —	////////	////////	////////
37. Grade Carried Across Crossing	2	2	2
38. Channel Disturbed Once/Least Possible	2	2	////////
39. Stable Banks/Protected From Accelerated Erosion	3	3	2
* 40. Minimum Runoff Into Channel	2	1	1
41. Ground Cover w/in 10 Days	~~4~~ 3	~~4~~ 2	2
42. Same Day if w/in 25 Feet of Crossing	4	4	3
43. Areas 25 Feet+ w/in 15 Days	4	4	3
44. Flow Not Obstructed; Fish Can Pass	4	4	////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.

NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Crossings #1&2 within 55' of one another. There is long lengths of road and ditchline draining in to them, and the road surface is sloughing off into the inlet of #1 and both sides/ends of #2. Grade dips over both. #3 Road grade dips over pipe and pipe is too short, thus fill/over inlet is sloughing into channel. #4 Same as #3, Long road ditch leading to outlet. Also at #3 + #4 cleaned out soil material is piled on banks near inlet & outlet. #5 crossing also eroding fill over culvert ends and excessive road & ditchline drainage & sediment.

#40 These sites are all leading to critical visible sediment to these streams.

Road 576 – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement	GPS
1st				X	—	—	Yes	35.42951 080.06631
2nd				X	—	—	Yes	35.42975 080.06623
3rd				X	—	—	Yes	35.43292 080.05736
4th				X	—	—	Yes	35.43258 080.05681
5th				X	—	—	Yes	35.42901 080.04118
6th			X		X		No its a bridge	35.42880 80.02163
7th								
8th								
9th								
10th								
Total								

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Version 5.1 (4/10/2017)

(A)District: Uwharrie (B)Date: 3/20/2018 Time: 4:30 (C)Project Name: Cove T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Ground CTM Site Prep:____ Temporary Rd:____ System Rd #: 597A
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo X Closed: 6mo+____
(H)Harvest Unit Evaluated: # 3 (I)GPS: N 35.44904, W 80.07567, Elevation: 571 ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 5974 Temporary____	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road ____ – Stream Crossings

Crossing	Intermittent Crossings Acceptable	Intermittent Crossings Not-Acceptable	Perennial Crossings Acceptable	Perennial Crossings Not-Acceptable	Fish Passage Yes	Fish Passage No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

National Forests in North Carolina
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Version 5.1 (4/10/2017)

(A)District: Uwharrie (B)Date: 3/20/2018 Time: 1230 (C)Project Name: Reservation T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #
(F)Activity: Harvest Type (w/method): Ground LTM Site Prep: Temporary Rd: System Rd #: 6507
(G)Status: Active Harvest: Active Site Prep: Closed: 0-6mo X Closed: 6mo+
(H)Harvest Unit Evaluated: # 3 (I)GPS: N 35.51441, W 80.09602, Elevation: 701 ft, (± ft), Pt. #:

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P___ I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y___ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA →	→	→
13. Pesticides Applied Properly	↓		////////
14. Fertilizers Applied Properly	↓		////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA →	→	////////
16. Total # Observed 0 # Acceptable –	////////	////////	////////
17. Intermittent Crossings Acceptable	4	4	////////
18. Total # Observed 3 # Acceptable 3	////////	////////	////////
19. Grade Carried Across Crossing	* 3	4	3
20. Channel Disturbed Once/Least Possible	* 3	4	3
21. Stable Banks/Protected From Accelerated Erosion	4	4	////////
22. Minimum Runoff Into Channel	4	4	3
23. Ground Cover w/in 10 Days	4	4	3
24. Seeding Area 25 Feet+ w/in 15 Days	4	4	3
25. Flow Not Obstructed; Fish Can Pass	NA →	→	////////

(II)ROADS ONLY System 6S07 Temporary —	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

- 4. Meets or exceeds requirements of S&G's or FPGRWQ.
- 3. Minor departure but no corrective action needed.
- 2. Major departure, corrective action required.
- 1. Gross departure, corrective action required.
- NA Not applicable or not reviewed.

Effectiveness Rating

- 5. Improvement over prior conditions.
- 4. Adequate resource protection.
- 3. Minor/temporary impact, no corrective action needed.
- 2. Major short-term impacts, corrective action needed.
- 1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

- 3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
- 2. Non-critical visible sediment flow reaches stream channel.
- 1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

#19 erosion was controlled where grade came down to channel.

#20 2 xings within 100' of each other on same channel. erosion controlled.

Road ____ – Stream Crossings							
	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs Replacement
Crossing	Acceptable	Not Acceptable	Acceptable	Not Acceptable	Yes	No	
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Uwharrie (B)Date: 3/20/2018 Time: 1600 (C)Project Name: Reservation T.S.
(D)Reviewer(s): D. Jone + B. Dodd (E)6th level HUC #____
(F)Activity: Harvest Type (w/method): Ground Site Prep:____ Temporary Rd: X System Rd #:____
(G)Status: Active Harvest:____ Active Site Prep:____ Closed: 0-6mo X Closed: 6mo+____
(H)Harvest Unit Evaluated: # 4 (I)GPS: N 35.42899, W 80.04436, Elevation: — ft, (± __ft), Pt. #:____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I____	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System_____ Temporary__x__	////////	////////	////////
26. Best Located to Protect Site	4	4	////////
27. Breaks in Grade Used	4	4	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	4	4	3
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable	NA		////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

4. Meets or exceeds requirements of S&G's or FPGRWQ.
3. Minor departure but no corrective action needed.
2. Major departure, corrective action required.
1. Gross departure, corrective action required.
NA Not applicable or not reviewed.

Effectiveness Rating

5. Improvement over prior conditions.
4. Adequate resource protection.
3. Minor/temporary impact, no corrective action needed.
2. Major short-term impacts, corrective action needed.
1. Major long term impacts, corrective action needed.

Visible Sediment Rating

3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
2. Non-critical visible sediment flow reaches stream channel.
1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road_____ – Stream Crossings

	Intermittent Crossings		Perennial Crossings		Fish Passage		Needs
Crossing	Acceptable	Not Acceptable	Acceptable	Not Acceptable	Yes	No	Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

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(A)District: Uwharrie (B)Date: 3/20/2018 Time: 1345 (C)Project Name: Reservation T.S.
(D)Reviewer(s): D. Jones + B. Dodd (E)6th level HUC #________
(F)Activity: Harvest Type (w/method): Ground LTM/Thin Site Prep:______ Temporary Rd:____ System Rd #: 6621
(G)Status: Active Harvest:_____ Active Site Prep:_____ Closed: 0-6mo_____ Closed: 6mo+ X
(H)Harvest Unit Evaluated: # 5 (I)GPS: N35.44941, W80.03390, Elevation: 476 ft, (± __ft), Pt. #:_____

(J)Applicable S&G or Mitigating Measures	Implement	Effective	Visual Sediment
(I)HARVEST AREA INCLUDING SKID TRAIL/LOG DECK	////////	////////	////////
1. Best Located to Protect Site	4	4	////////
2. Breaks in Grade Used	4	4	////////
3. Barriers Used if w/in 300ft P/I Channel	4	4	3
4. Drainage NOT to stream channel	4	4	3
5. No Skidding in Channels or Waterbodies	4	4	3
6. Shade Strips in Place P X I X	4	4	////////
7. No Logging Debris in P/I channel	4	4	////////
8. Harvesting in MA18 (SMZ) Y____ N X	////////	////////	////////
9. Violation w/in MA18 (SMZ)	4	4	3
10. Rehab Stable w/in 30 Days: Skid Trails	4	4	3
11. Rehab Stable w/in 30 Days: Log Decks	4	4	3
12. Excessive soil/debris on Public Roads	NA		
13. Pesticides Applied Properly			////////
14. Fertilizers Applied Properly			////////
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	4	4	////////
(Ia)STREAM CROSSINGS	////////	////////	////////
15. Perennial Crossings Acceptable	NA		////////
16. Total # Observed___ # Acceptable___	////////	////////	////////
17. Intermittent Crossings Acceptable			////////
18. Total # Observed___ # Acceptable___	////////	////////	////////
19. Grade Carried Across Crossing			
20. Channel Disturbed Once/Least Possible			
21. Stable Banks/Protected From Accelerated Erosion			////////
22. Minimum Runoff Into Channel			
23. Ground Cover w/in 10 Days			
24. Seeding Area 25 Feet+ w/in 15 Days			
25. Flow Not Obstructed; Fish Can Pass			////////

(II)ROADS ONLY System 662 Temporary_____	////////	////////	////////
26. Best Located to Protect Site	Y	Y	////////
27. Breaks in Grade Used	Y	Y	////////
28. Located in MA18 (SMZ)	4	4	3
29. Drainage Not to Stream Channel	4	4	3
30. Barrier Used if w/in 300 Feet P/I Channel	4	4	3
31. No Vertical Cuts if w/in 300 Feet P/I Channel	4	4	3
32. Temp Roads Only. Rehab w/in 30 Days	NA		
(IIa)STREAM CROSSINGS	////////	////////	////////
33. Perennial Crossings Acceptable			////////
34. Total # Observed___ # Acceptable___	////////	////////	////////
35. Intermittent Crossings Acceptable			////////
36. Total # Observed___ # Acceptable___	////////	////////	////////
37. Grade Carried Across Crossing			
38. Channel Disturbed Once/Least Possible			////////
39. Stable Banks/Protected From Accelerated Erosion			
40. Minimum Runoff Into Channel			
41. Ground Cover w/in 10 Days			
42. Same Day if w/in 25 Feet of Crossing			
43. Areas 25 Feet+ w/in 15 Days			
44. Flow Not Obstructed; Fish Can Pass			////////

Implementation Rating

- 4. Meets or exceeds requirements of S&G's or FPGRWQ.
- 3. Minor departure but no corrective action needed.
- 2. Major departure, corrective action required.
- 1. Gross departure, corrective action required.
- NA Not applicable or not reviewed.

Effectiveness Rating

- 5. Improvement over prior conditions.
- 4. Adequate resource protection.
- 3. Minor/temporary impact, no corrective action needed.
- 2. Major short-term impacts, corrective action needed.
- 1. Major long-term impacts, corrective action needed.

Visible Sediment Rating

- 3. No visible sediment to stream channel. Visible sediment defined by NC Regulations (.0102(19)).
- 2. Non-critical visible sediment flow reaches stream channel.
- 1. Critical visible sediment flow reaches stream channel. Document with photo if possible.

Corrective Action Summary/Comments (indicate line number):

Road _____ – Stream Crossings

Crossing	Intermittent Crossings: Acceptable	Intermittent Crossings: Not-Acceptable	Perennial Crossings: Acceptable	Perennial Crossings: Not-Acceptable	Fish Passage: Yes	Fish Passage: No	Needs Replacement
1st							
2nd							
3rd							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
Total							

Best Management Practices Monitoring

Ten Year Summary Report (2009-2018)
National Forests in North Carolina

May 2018

Brady Dodd, Forest Hydrologist
Dick Jones, Hydrologist Consultant

Best Management Practices Monitoring - Ten Year Summary Report (2009-2018)

National Forests in North Carolina

Monitoring Action

Each year from 2009 through 2018, Brady Dodd, North Carolina Forest Hydrologist and Dick Jones, Hydrologist Consultant conducted Best Management Practice (BMP) monitoring on the National Forests in North Carolina. The monitoring was done to determine whether or not BMPs were implemented and effective in controlling pollutants (primarily sediment) during timber sale and road construction and maintenance activities. The monitoring is also intended to provide feedback to engineers and sale administrators to improve practices, thus protecting water quality during future land disturbing activities.

Two hundred twenty-eight harvest units and 150 roads from 63 different timber sales were selected for review.[1] A field form was developed that included basic location information, activity descriptions, harvest and road standards and guidelines, implementation and effectiveness rates and visible sediment delivery classifications (See National Forests in North Carolina, S&G Implementation and Effectiveness Field Form, Version 5.1 (4/10/2017) and USDA Forest Service Instructions for Completing the S&G Implementation and Effectiveness Field Form, National Forests in North Carolina, 2017). BMPs were selected from the following four authorities:

N/P LRMP – The Nantahala Pisgah Land and Resource Management Plan.

NC FPGRWQ – The North Carolina Forest Practice Guidelines Related to Water Quality regulations (15 NCAC 1I .0101-.0209).

N.C.G.S. Ch. 143-215.85(b). BMPs for a Fluid Spills.

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[1] 2009 - Baldwin Gap, Case Camp Ridge, Eagle Fork and Locust Cove timber sales. 2010 - Baldwin Gap, Farmers Branch, Peachtree, Shadline, Shinwhite and Slipoff timber sales. 2011 - Baldwin Gap, Chestnut Mountain, Fires Creek, Pressley Fields, Shope Creek and Slipoff Timber Sales. 2012 - Pressley Fields, Sheep Knob, Horseshoe, Farmer Branch, Thunderstruck, Stateline and Stinger Timber Sales and Mulberry Globe Stewardship. 2013 - Rose, Big Cove, Thunderstruck, Fatback, Buckhorn, Roses Creek and Baldwin Fields timber sales, Progress Energy Enka Settlement and Mulberry Globe Stewardship. 2014 - Macedonia, Brushy Ridge, Roses Creek, Rose, Flicker and Sapsucker timber sales, Miller Mountain and Bear Creek stewardships. 2015 - Cottonmouth, Brushy Ridge, Devil's Cove, White Bull, Ryefield, West Buffalo, Roses Creek and Big Cove timber sales. 2016 - Hairy, Millis Circle, Roses Creek, Brushy Ridge, Dylan, Horse Bridge, Haystack, West Buffalo, Fishtrap Reoffer, Ollie Creek and Northwest timber sales. 2017 - Big Swamp, Redhead, Cottonmouth, Millis Circle, Hadnot, Bad Fork, Foster Creek, Mince Cove, Panther Branch, Haystack, Horse Bridge, Dylan, and Cable Cove Timber Sales and Bear Creek Stewardship. 2018 – Red Belly Pipeline, Cove, Reservation, Scott Mountain, and Roughbear Timber Sales.

7730 Letter – The 7730/2520 letter dated November 28, 1990, signed by Forest Supervisor Bjorn Dahl to the Forest Management Team concerning “Specified Road Construction and Water Quality.”

Accomplishments/Findings

A summary of the BMP monitoring results done over the last ten years (2009 through 2018) is presented in Table 1. A total of 4,426 individual BMPs were checked for implementation and effectiveness. Of these, 2,658 BMPs were related to sediment delivery to streams. The overall implementation rate was 95.8 percent (4,238 out of 4,426 times the practice met or exceeded the BMP rules). In 122 instances (2.8%), there was a minor departure from the rules; 60 times (1.4%) there was a major departure from the rules and six times (0.1%) there was a gross departure from the rules. The overall effectiveness rate was 96.1 percent; 4,253 out of 4,426 times the practice prevented the pollutant from impacting the aquatic resource. In 95 instances (2.1%), there was a minor or temporary impact to the resource. Sixty times (1.4%), there was a major short-term impact that requires corrective action. Eighteen times (0.4%), there was a major long-term impact. The 18 “major long-term impact” ratings were related to legacy system road problems (Rules 26, 28, 29, 33 and 40) and fish passage obstructions (Rule 44). These identified problems all preceded the timber sale activities.

The last observation was to determine if visible sediment was entering streams. In 2,588 of 2,658 BMP checks (97.4%), visible sediment was not entering the stream channel. In 63 instances (2.4%), non-critical visible sediment reached the stream; seven times (0.3%); critical visible sediment flow reached the stream channel. A <u>non-critical</u> amount of visible sediment is a low volume, short term sediment source that does not adversely affect aquatic habitats. A <u>critical</u> amount of visible sediment is a large volume, which may be deposited over a long term. The component structure of the stream is altered, which adversely affects aquatic habitats. A stream that has a critical sediment source is obvious, even to the casual observer.

By determining implementation rates, we are attempting to answers the question, “Have the rules been properly applied?” By determining effectiveness, we are attempting to answers the question, “Were the rules effective in preventing a pollutant from impacting water quality?”

TABLE 1 – 2009-2018 BEST MANAGEMENT PRACTICES MONITORING SUMMARY

	Implementation				**Effectiveness**					**Visible Sediment**		
Rule	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
HARVEST AREA INCLUDING SKID TRAILS/LOG DECK												
1. Best Located to Protect Site	217	8	3			219	7	2				
2. Breaks in Grade Used	224					224						
3. Barriers Used if W/I 300ft P/I Channel	211	2				212	1			213		
4. Drainage not to Stream Channel	225	3				224	2	2		225	2	1
5. No Skidding in Channels or	224	2				225	1			226		

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
Waterbodies												
6. Shade Strips in Place	203	4	1			204	3	1				
7. No Logging Debris in P/I Channel	221					221						
9. Violation W/I MA-18 (SMZ)	219	3	1			220	2	1		223		
10. Rehab Stable W/I 30 Days: Skid Trails	210		3		4	204	2	3		212	1	
11. Rehab Stable W/I 30 Days: Landings	209	5	1		1	205	8	1		213	2	
12. Excessive Soil/Debris on Public Roads	37					37				37		
13. Pesticides Applied Property	59					59						
14. Fertilizers Applied Properly	132					232						
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	51					50	1					
SKID TRAIL STREAM CROSSINGS												
15. Perennial Crossings Acceptable	9		1		1	8		1				
17. Intermittent Crossings Acceptable	14	1			1	13	1					
19. Grade Carried Across Crossing	19	5				21	3			21	3	
20. Channel Disturbed Once/Least Possible	22	1	1			23		1		23	1	
21. Stable Banks/Protected From Accelerated Erosion	24				1	23						
22. Minimum Runoff Into Channel	22	2				22	2			22	2	
23. Ground Cover W/I 10 Days	22					22				22		
24. Seeding Area 25 Feet+ W/I 15 Days	21					21				21		
25. Flow Not Obstructed/ Fish Pass	4				3	1						
ROADS												
26. Best Located to Protect Site	150	1		1		150	1		1			
27. Breaks in Grade Used	150	3	1		2	149	2	1				
28. Located in MA-18 (SMZ)	147	5		1		150	2		1	148	4	1
29. Drainage Not to Stream Channel	143	6	4	1		144	5	4	1	144	8	2
30. Barrier Used if W/I 300ft P/I Channel	142	1	2			142	1	2		144	1	
31. No Vertical Cuts if W/I 300ft P/I Channel	133	11				137	7			141	3	
32. Temporary Roads Only. Rehab W/I 30 Days	22	3			1	21	3			25		
ROAD STREAM CROSSINGS												
33. Perennial Crossings Acceptable	62	16	6	1		63	13	7	2			
35. Intermittent Crossings Acceptable	55	5	2			53	3	6				
37. Grade Carried Across Crossing	66	24	7			72	18	7		73	23	1
38. Channel Disturbed Once/Least Possible	94	1	1			94	1	1				
39. Stable Banks/Protected From Accelerated Erosion	91	3	3			91	2	4		91	6	
40. Minimum Runoff Into Channel	91	2	4			91	2	3	1	90	5	2
41. Ground Cover W/I 10 Days	91	1				90	1	1		90	2	
42. Same Day if W/I 25ft of Crossing	92					92				92		
43. Areas 25ft+ W/I 15 Days	92					92				92		

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
44. Flow Not Obstructed; Fish Can Pass	18	4	19	2		18	1	12	12			
Total	**4238**	**122**	**60**	**6**	**14**	**4239**	**95**	**60**	**18**	**2588**	**63**	**7**
Percent in Class	**95.8%**	**2.8%**	**1.4%**	**0.1%**	**0.3%**	**95.8%**	**2.1%**	**1.4%**	**0.4%**	**97.4%**	**2.4%**	**0.3%**

Table 2 summarizes harvest practices, including skid trails and log decks, but not skid trail stream crossings which is presented in Table 3. Of the 2,478 BMPs checked in this category between 2009 and 2018, 2,442 (98.5%) met or exceeded the rules. Twenty-seven practices (1.1%) had a minor departure from the rules and nine practices (0.4%) had a major departure from the rules. Of the 2,478 BMPs checked, 2,141 (98.5%) provided adequate resource protection while 27 practices (1.1%) had a minor or temporary impact to the aquatic resource. Ten practices (0.4%) had a major short-term impact to the resource. Generally, the harvest area BMPs, including skid trails and log decks were adequately applied and were effective to prevent pollutants from impacting water quality. Only five practices (0.4%) delivered non-critical sediment to the stream and one practice (0.1%) delivered critical visible sediment to a stream. Detailed information of each of the practices can be found in the individual 2009 - 2018 BMP reports.

TABLE 2 – HARVEST AREA INCLUDING SKID TRAILS AND LOG DECKS (2009-2018)

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
HARVEST AREA INCLUDING SKID TRAILS/LOG DECK												
1. Best Located to Protect Site	217	8	3			219	7	2				
2. Breaks in Grade Used	224					224						
3. Barriers Used if W/I 300ft P/I Channel	211	2				212	1			186		
4. Drainage not to Stream Channel	225	3				224	2	2		225	2	1
5. No Skidding in Channels or Waterbodies	224	2				225	1			226		
6. Shade Strips in Place	203	4	1			204	3	1				
7. No Logging Debris in P/I Channel	221					221						
9. Violation W/I MA-18 (SMZ)	219	3	1			220	2	1		223		
10. Rehab Stable W/I 30 Days: Skid Trails	210		3		4	204	2	3		212	1	
11. Rehab Stable W/I 30 Days:	209	5	1		1	205	8	1		213	2	

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
Landings												
12. Excessive Soil/Debris on Public Roads	37					37				37		
13. Pesticides Applied Properly	59					59						
14. Fertilizers Applied Properly	132					132						
14.a. Solid Waste, Oils and Other Fluids Cleaned Up	51					50	1					
Total	**2442**	**27**	**9**	**0**	**5**	**2436**	**27**	**10**	**0**	**1349**	**5**	**1**
Percent in Class	**98.5%**	**1.1%**	**0.4%**	**0.0%**	**0.2%**	**98.3%**	**1.1%**	**0.4%**	**0.0%**	**99.6%**	**0.4%**	**0.1%**

Table 3 summarizes the skid trail stream crossing rules. One hundred sixty-eight practices in this category were checked for implementation and effectiveness between 2009 and 2018. Implementation and effectiveness rates were 93.5 and 95.3 percent, respectively. A departure from the rules contributed to non-critical visible sediment six times (5.2%) over the ten years of BMP monitoring. Harvest practices where skid trail stream crossings were used were generally implemented well in the 63 timber sales where BMPs were checked, never producing critical visible sediment to streams.

TABLE 3 – SKID TRAIL STREAM CROSSINGS (2009-2018)

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
SKID TRAIL STREAM CROSSINGS												
15. Perennial Crossings Acceptable	9		1		1	8		1				
17. Intermittent Crossings Acceptable	14	1			1	13	1					
19. Grade Carried Across Crossing	19	5				21	3			21	3	
20. Channel Disturbed Once/Least Possible	22	1	1			23		1		23	1	
21. Stable Banks/Protected From Accelerated Erosion	24				1	23						
22. Minimum Runoff Into Channel	22	2				22	2			22	2	
23. Ground Cover W/I 10 Days	22					22				22		
24. Seeding Area 25 Feet+ W/I 15 Days	21					21				21		
25. Flow Not Obstructed/ Fish Pass	4				3	1						
Total	**157**	**9**	**2**	**0**	**6**	**154**	**6**	**2**	**0**	**109**	**6**	**0**
Percent in Class	**93.5%**	**5.4%**	**1.2%**	**0.0%**	**3.6%**	**91.7%**	**3.6%**	**1.2%**	**0.0%**	**94.8%**	**5.2%**	**0.0%**

Table 4 summarizes road practices but not road-stream crossings which are presented in Table 5. Of the 927 BMPs checked in this category between 2009 and 2018, 887 (95.7%) met or exceeded the rules. Thirty practices (3.2%) had a minor departure from the rules; seven practices (0.8%) had a major departure from the rules and three practices (0.3%) had a gross departure from the rules. Of the 927 BMPs, 896 (96.6%) provided adequate or better protection while 21 (2.3%) had a minor or temporary impact to the aquatic resource; seven practices (0.8%) had a major short-term impact and three practices (0.3%) had a major long-term impact to the aquatic resource. Sixteen practices (2.6%) delivered non-critical sediment and three practices (0.5%) delivered critical visible sediment to the stream. Critical visible sediment was not delivered to streams in the *Roads* category in the last five years of monitoring.

TABLE 4 – ROADS (2009-2018)

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
ROADS												
26. Best Located to Protect Site	150	1		1		150	1		1			
27. Breaks in Grade Used	150	3	1		2	149	2	1				
28. Located in MA-18 (SMZ)	147	5		1		150	2		1	148	4	1
29. Drainage not to Stream Channel	143	6	4	1		144	5	4	1	144	8	2
30. Barrier Used if W/I 300ft P/I Channel	142	1	2			142	1	2		144	1	
31. No Vertical Cuts if W/I 300ft P/I Channel	133	11				137	7			141	3	
32. Temporary Roads Only. Rehab W/I 30 Days	22	3			1	21	3			25		
Total	**887**	**30**	**7**	**3**	**3**	**893**	**21**	**7**	**3**	**602**	**16**	**3**
Percent in Class	**95.7%**	**3.2%**	**0.8%**	**0.3%**	**0.3%**	**96.3%**	**2.3%**	**0.8%**	**0.3%**	**96.9%**	**2.6%**	**0.5%**

Table 5 summarizes the road stream crossing rules. Of the 853 practices checked, 752 (88.2%) met or exceeded the rules. Fifty-six practices (6.6%) had a minor departure from the rules; 42 practices (4.9%) had a major departure from the rules while three practices (0.4%) had a gross departure from the rules. Of the 853 practices checked, 756 (88.6%) provided adequate protection of the aquatic resource. Forty-one practices (4.8%) had a minor or temporary impact; 41 practices had a major short-term impact and 15 (1.8%) had a major long-term impact. These issues are discussed in detail in the yearly BMP monitoring reports. Of the 567 practices related to sediment, 528 (93.1%) delivered no visible sediment to streams. Thirty-six practices (6.3%) delivered non-critical sediment and three practices (0.5%) delivered critical visible sediment to the stream.

TABLE 5 – ROAD STREAM CROSSINGS (2009-2018)

Rule	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds 4	Minor Departure 3	Major Departure 2	Gross Departure 1	Improvement Over Past 5	Adequate Protection 4	Minor/Temp. Impact 3	Major Short-Term Impact 2	Major Long-Term Impact 1	No Visible Sediment 3	Non-Critical Visible 2	Critical Visible 1
ROAD STREAM CROSSINGS												
33. Perennial Crossings Acceptable	62	16	6	1		63	13	7	2			
35. Intermittent Crossings Acceptable	55	5	2			53	3	6				
37. Grade Carried Across Crossing	66	24	7			72	18	7		73	23	1
38. Channel Disturbed Once/Least Possible	94	1	1			94	1	1				
39. Stable Banks/Protected From Accelerated Erosion	91	3	3			91	2	4		91	6	
40. Minimum Runoff Into Channel	91	2	4			91	2	3	1	90	5	2
41. Ground Cover W/I 10 Days	91	1				90	1	1		90	2	
42. Same Day if W/I 25ft of Crossing	92					92				92		
43. Areas 25ft+ W/I 15 Days	92					92				92		
44. Flow Not Obstructed; Fish Can Pass	18	4	19	2		18	1	12	12			
Total	**752**	**56**	**42**	**3**	**0**	**756**	**41**	**41**	**15**	**528**	**36**	**3**
Percent in Class	**88.2%**	**6.6%**	**4.9%**	**0.4%**	**0.0%**	**88.6%**	**4.8%**	**4.8%**	**1.8%**	**93.1%**	**6.3%**	**0.5%**

A trend analysis for the past ten years is presented in the following Figures. The ten-year trend for *BMP implementation* is shown in Figure 1. The trend line indicates that in all categories (Harvest, Skid Trail Stream Crossings, Roads and Road Stream Crossings) BMP implementation is improving. The least improvement has occurred in Road Stream Crossings because these are legacy issues that can only be improved when funding becomes available to correct BMP stream crossing issues.

Figure 2 shows the ten-year trend for *BMP effectiveness*. The trend lines indicate that Harvest, Skid Trail Stream Crossings and Roads are all on an upward trend; however, the category Road Stream Crossings appears static. Again, this is most likely due to the legacy road problems that take time and money to correct.

Figure 3 shows the ten-year trend for *% No Visible Sediment to Stream*. An improving trend is shown in the categories Skid Trail Stream Crossing and Roads and a slight improving trend in Road Stream Crossings; however, an improving trend in Harvest is not shown because over the ten years of BMP monitoring it is rare that a harvest practice is ever shown to contribute visible sediment to streams.

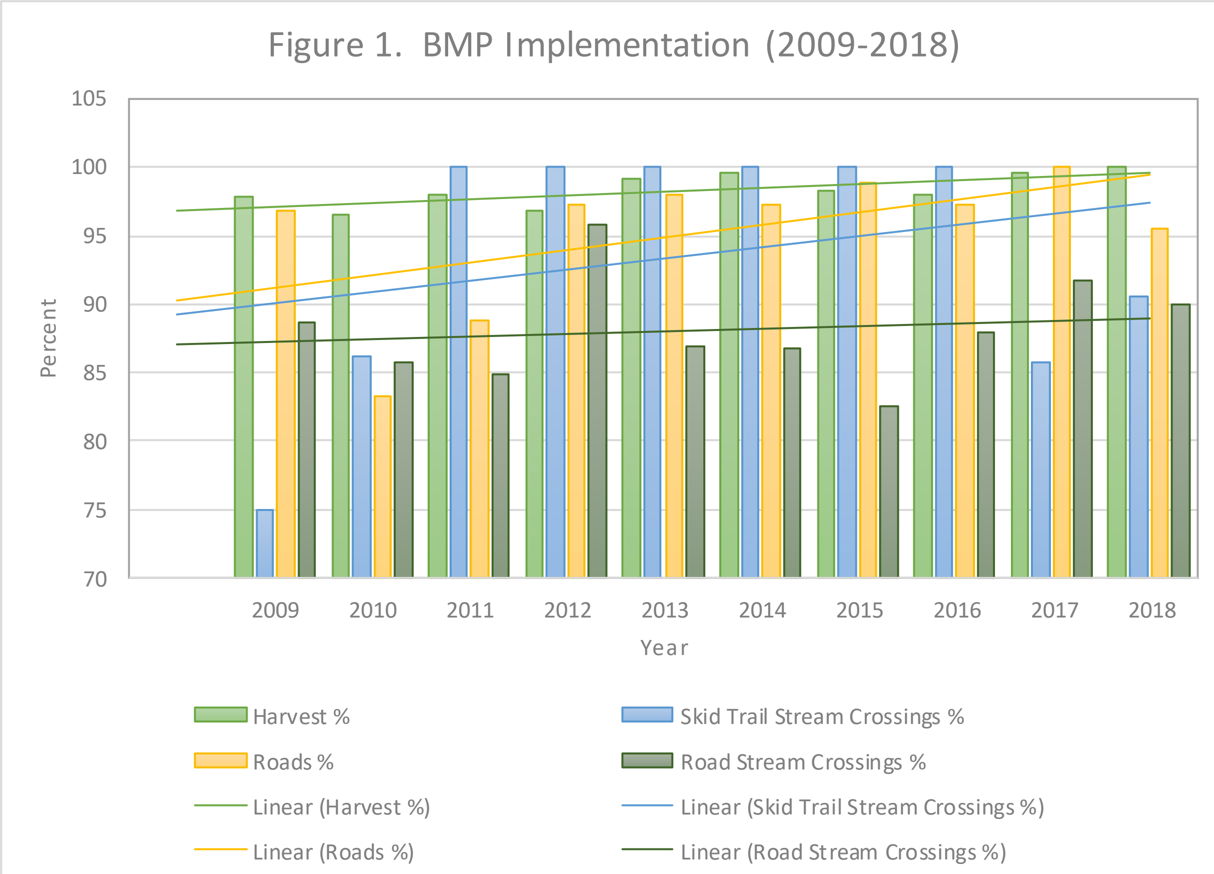
Figure 1. BMP Implementation (2009-2018)
105
100
95
90
85
80
75
70
Percent
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year
Harvest %
Skid Trail Stream Crossings %
Roads %
Road Stream Crossings %
Linear (Harvest %)
Linear (Skid Trail Stream Crossings %)
Linear (Roads %)
Linear (Road Stream Crossings %)

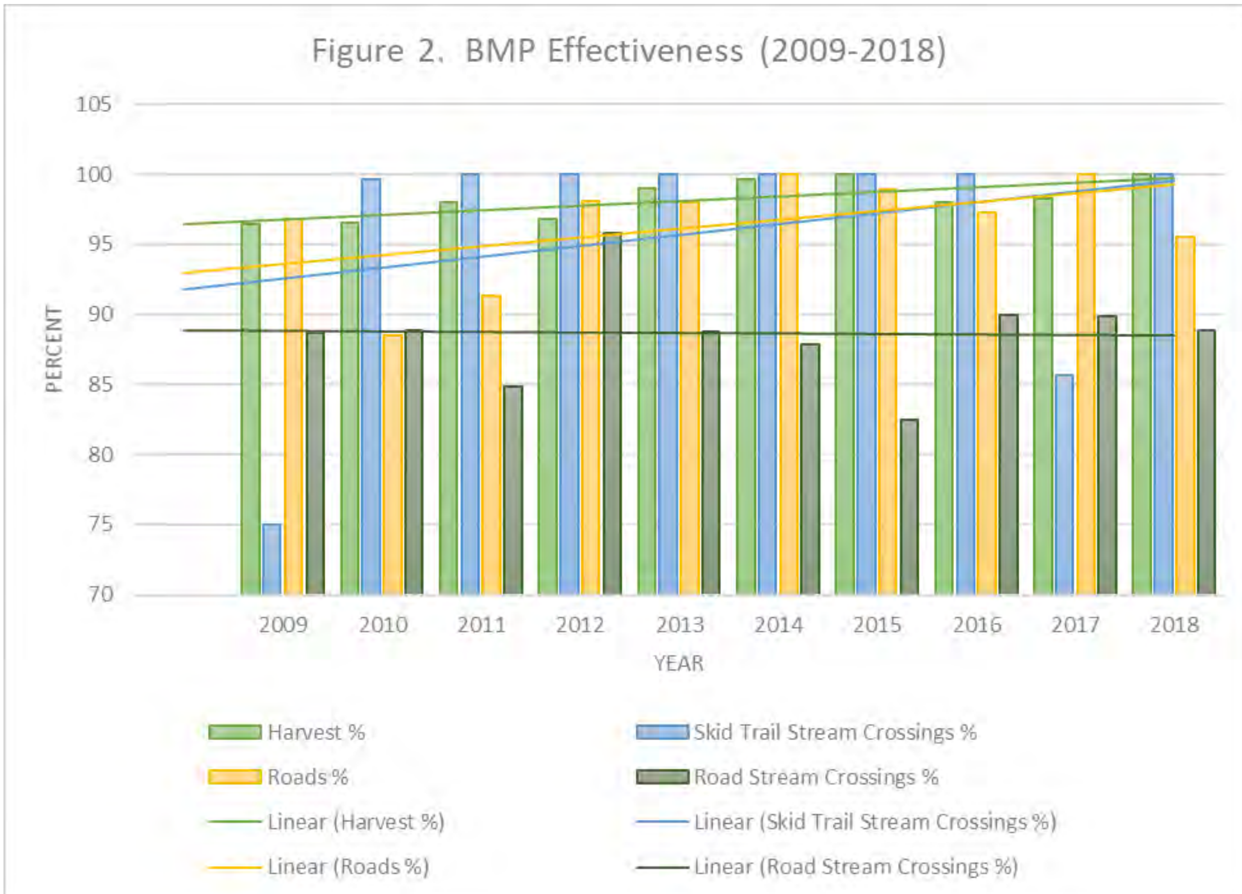

Figure 2. BMP Effectiveness (2009-2018)
105
100
95
90
85
80
75
70
PERCENT
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
YEAR
Harvest %
Skid Trail Stream Crossings %
Roads %
Road Stream Crossings %
Linear (Harvest %)
Linear (Skid Trail Stream Crossings %)
Linear (Roads %)
Linear (Road Stream Crossings %)

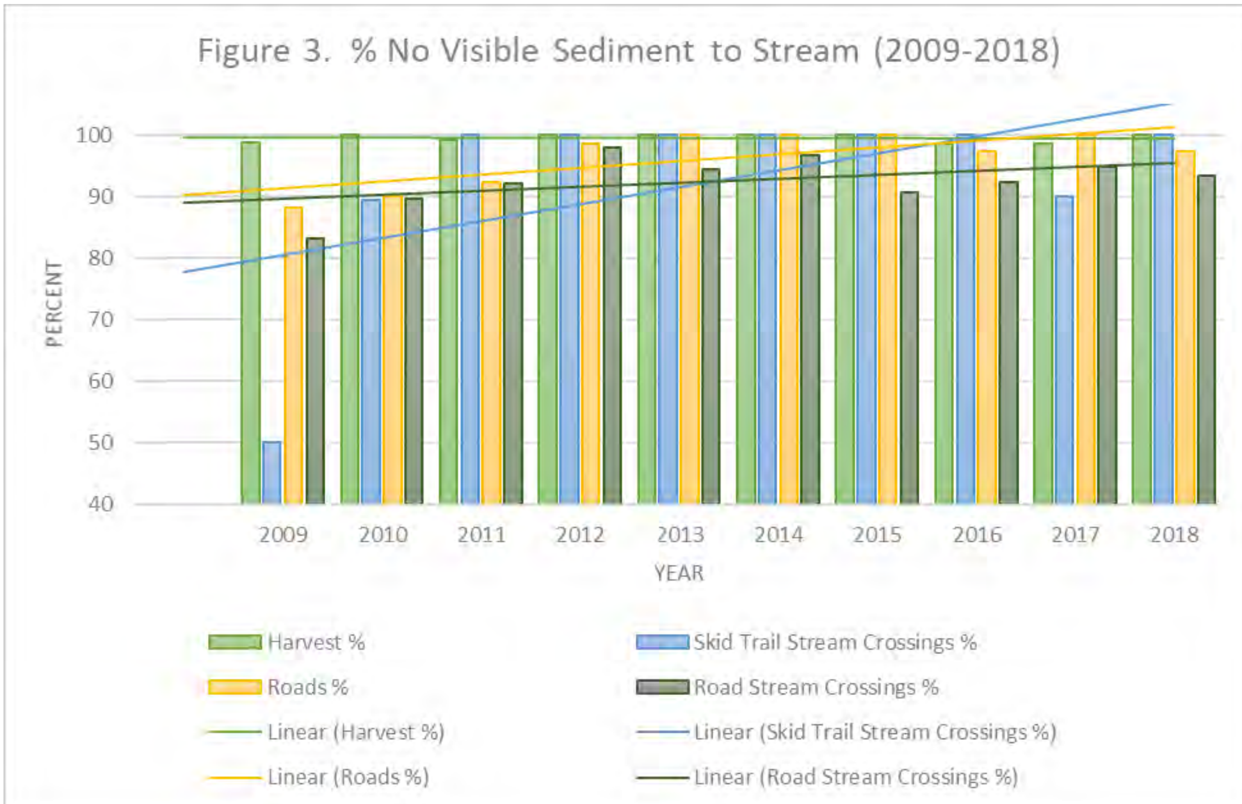

Figure 3. % No Visible Sediment to Stream (2009-2018)
100
90
80
70
60
50
40
PERCENT
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
YEAR
Harvest %
Skid Trail Stream Crossings %
Roads %
Road Stream Crossings %
Linear (Harvest %)
Linear (Skid Trail Stream Crossings %)
Linear (Roads %)
Linear (Road Stream Crossings %)

Conclusions

It was previously stated that the purpose of BMP monitoring is to answer two questions:

Have the rules been properly applied? (Implementation Monitoring); and

Were the rules effective in preventing a pollutant from impacting water quality? (Effectiveness Monitoring)

From the information collected and analyzed over the last ten years, we conclude that the Croatan, Uwharrie, Pisgah and Nantahala National Forests are implementing Best Management Practices during timber sales and they are effective in protecting streams and water quality. There has been an improving trend in BMP implementation and effectiveness and a decrease in sediment delivery to streams as shown in Figures 1 through 3.

The implementation and effectiveness rates for all harvest and road BMPs are 95.8 and 96.1 percent, respectively (See Table 1). No Visible sediment to stream channels in the ten-year period is 97.4 percent and No visible sediment and non-critical sediment together total 99.8 percent of the BMPs applied.

The six "gross departure" and 18 "major long-term impact" ratings in the 2009-2018 BMP monitoring were all related to legacy system road problems (Rules 26, 28, 29 and 33) and fish passage obstructions (Rule 44) found on existing system roads. These identified problems all preceded and were not related to the timber sale activities. When system road problems are identified they are prioritized and corrective action is taken as funding becomes available.

By avoiding skid trail stream crossings when possible (or using temporary bridges), reducing the number of existing road grade sags over streams and correcting fish migration passage problems, BMP implementation and effectiveness should continue to improve. To complete the "BMP feedback loop" this information should be used to assist engineers and sale administrators involved in future projects.

Panther Branch Road Decommissioning Monitoring Report, 2019

Pisgah Ranger District, National Forests in North Carolina

Written By: Brady N. Dodd, NFsNC Hydrologist, February 12, 2019

Background

A need arose during timber harvest to address erosion and sedimentation from the transportation network in Panther Branch T.S. Payment Units 1 and 2. Due to logger preference to use wider than typical logging equipment and a long haul truck, skid roads were constructed wider than typical, a temporary road was constructed to cut off a tight road bend in Unit 1 and road reconstruction widened the existing system road, NFSR 140A, from Unit 2 down to FSR 140. After a very wet period during logging, sediment was found entering nearby streams in Unit 1 and Unit 2.

Sale administrators required the logging contractor to strengthen mitigation measures, and conditions improved. Because of continued heavy rains, a contract was let for additional erosion control measures and hundreds of feet of silt fence was installed in critical areas. The sedimentation concern was reported to the NC Division of Water Quality by the Forest Service and they made a site visit. No violations were issued to the Forest Service since BMPs were implemented and responsive corrective actions had been taken.

During project development, the Courthouse Creek EA identified the need to decommission a section of the NFSR 140A road. Implementation of this decision began the following spring with the Panther Branch Skid Rd Decommissioning project which decommissioned 2.3 miles of NFSR140A and associated skid road within the sale area boundary from the beginning of the road at its junction with Courthouse Creek Road (FR140) to Stand 93-12 - Unit 2 (Figure 1).

Project Description

The goal of this work is to stabilize the road and skid road network to minimize adverse affects to soil productivity and water quality.

As part of the construction contract #12467018C0021 - Panther Branch Skid Rd Decommissioning, the following activities were required to stabilize constructed skid roads and a section of the temporary road (aka NFSR 140A) used in the Panther Branch Timber Sale in Units 1 and 2 (Figure 1.):

1. Recontour skid roads to reclaim soil productivity, see Figure 2 for Typicals.
    a. On the system road the crawler tractor will rip the compacted road surface to eliminate compaction before the trackhoe relocates fill material onto the cut slope and old running surface.
    b. On skid roads the crawler tractor will not be used, rather the trackhoe will recontour the road back to, or near, original side slope.
    c. All final soil grades will be outslopes matching the original topography as possible.

2. On final grade, trackhoe shall pull in woody debris from margins onto disturbed soil to aid in erosion control and reduce the need for mulch. Seed, lime and fertilize all disturbed soil using the specified seed mix for either Dry or Moist-Wet sites. Mulch with Certified Weed-free wheat straw where woody debris coverage is sparse.

3. Recontour skid road crossings of stream channels and valley bottoms to stabilize these areas and reduce erosion from the sites. Seed, lime, and fertilize all disturbed soil in these "bottom" areas using the "Moist-Wet Sites/Stream Crossings" specified mix. Scatter Certified Weed-free wheat straw mulch within 50 feet of stream channel and install Coir matting on stream banks. On final grade, trackhoe shall pull in woody debris from margins onto disturbed soil to aid in erosion control and reduce the need for mulch. In the Coir matting, install live stake plantings during the dormant season.

The road and skid road decommissioning and stabilization cost $48,511 (Table 1). Contract Specifications for this project are in Appendix A. The decommissioning work will allow for future construction of a system trail that would be built to trail standards.

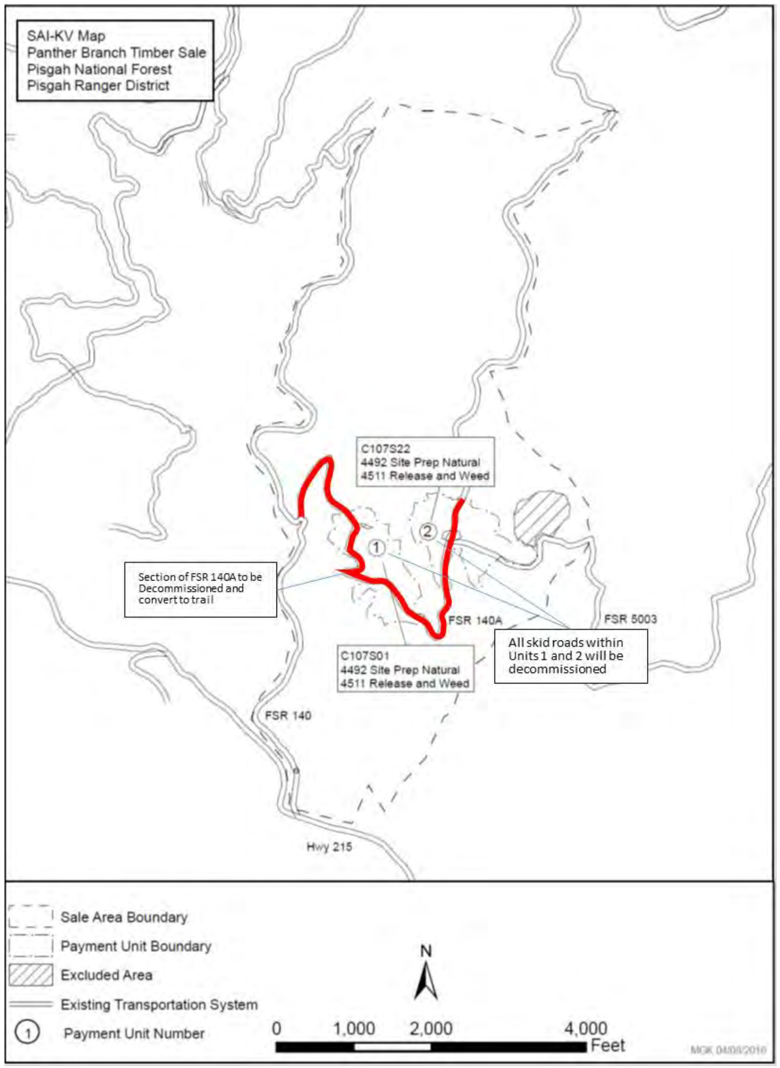

Figure 1. Location map of the section of NFSR 140A road decommissioned. Decommissioned skid roads are spurred off this road.

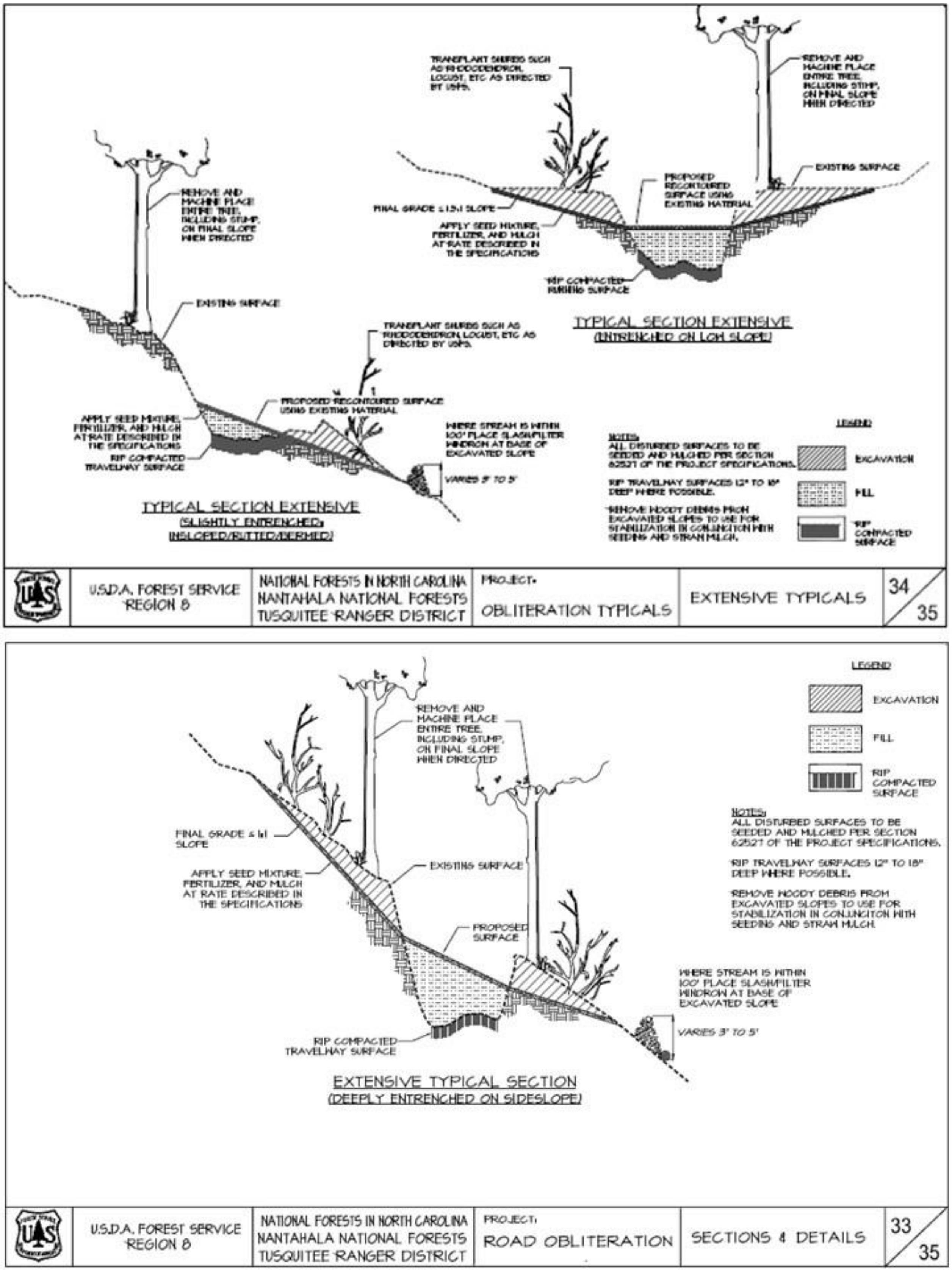

Figure 2. Typical cross sections of skid road & road recontouring.

Table 1. Cost of road and skid road decommissioning.

Description	Measurement	Quantity	Unit	Unit Price	Totals
ITEM 1. PANTHER BRANCH T.S. UNITS #1 AND #2 - SKID ROAD DECOMMISSIONING					
1A. EQUIPMENT & LABOR					
Track hoe w/ hydraulic thumb & operator	AQ	122.8	hours	150.00	$18,420
Mobilization - Trackhoe	AQ	1	each	3,500.00	$3,500
Dump Truck & operator	AQ	0	hours	110.00	$0
Crawler tractor/dozer w/attachements & operator	AQ	23.2	hours	130.00	$3,016
Mobilization - Crawler Tractor	AQ	1	each	3,500.00	$3,500
1B. EROSION & SEDIMENT CONTROL - MATERIALS w/ INSTALLATION					
Seed (see spec.)	CQ	15	acre	414.00	$6,210
Mulch (certified weed-free wheat-straw)	AQ	5	acre	684.00	$3,420
Lime (pelletized, 100 lbs/acre)	CQ	15	acre	254.00	$3,810
Fertilizer (10/10/10, 50 lbs/acre)	CQ	15	acre	261.00	$3,915
Coir matting (700 series)	AQ	1000	linear feet	2.22	$2,220
Live stake plantings (staked in Coir matting)	AQ	0	each	2.86	$0
Culvert hauled off site	AQ	1	lump sum	500.00	$500
			Item 1. Total Costs:		**$48,511**

Photo Monitoring Results

As seen in the following set of photos, the goal as stated above "…to stabilize the road and skid road network to minimize adverse affects to soil productivity and water quality" is currently being met. Recontoured slopes are largely stable without notable amounts of erosion with the exception of two sites addressed in the following recommendations section. At these site the "monitoring feedback" portion of all monitoring efforts is in action. The erosion and sedimentation concerns from these sites is currently being addressed through Pisgah Ranger District resources, and effectiveness of mitigation actions will be assessed in the near future. **Overall, obliteration of these approximately 2.3 miles of system road and skid road has been highly effective at controling loss of soil and restoring soil productivity and water quality.**

Panther Branch Decommissioning 2018 – Unit 2, Photo Point #1


April 9, 2018


April 10, 2018


April 16, 2018


November 26, 2018

Panther Branch Decommissioning 2018 – FSR 140A, Photo Point #5


April 9, 2018


April 11, 2018


November 26, 2018

Panther Branch Decommissioning 2018 – Unit 1, Photo Point #7

Panther Branch Decommissioning 2018 – Unit 1, Photo Point #18

Panther Branch Decommissioning 2018 – Unit 1, Photo Point #12/20

Panther Branch Decommissioning 2018 – FSR 140A, Culvert Removal, Photo Point #32

Panther Branch Decommissioning 2018 – FSR 140A, Photo Point #30

Photo Monitoring Recommendations

Based on a review of site conditions on November 26, 2018 the following mitigation measures are recommended in Table 2, their locations in Figure 3 and the following photos:

Table 2. Panther Branch road decommissioning project monitoring recommendations.

SITE #	RECOMMENDATION
1	Plant live stakes on streambanks at site of culvert removal & channel reconstruction (GPS: $35^0$15'38.28"N $82^0$53'13.72"W) (PHOTO 1).
2	Sow grass seed on bare soil above stream channel (GPS: $35^0$15'22.33"N $82^0$53'06.77"W) (PHOTO 2).
3	Sow grass seed on bare soil on log landing (GPS: $35^0$15'30.16"N $82^0$53'10.37"W).
4	Down slope from Site# 2 clean out sediment stored behind silt fence (PHOTO 3). Also, in this same drainage, clean out sediment stored behind other lengths of silt fence

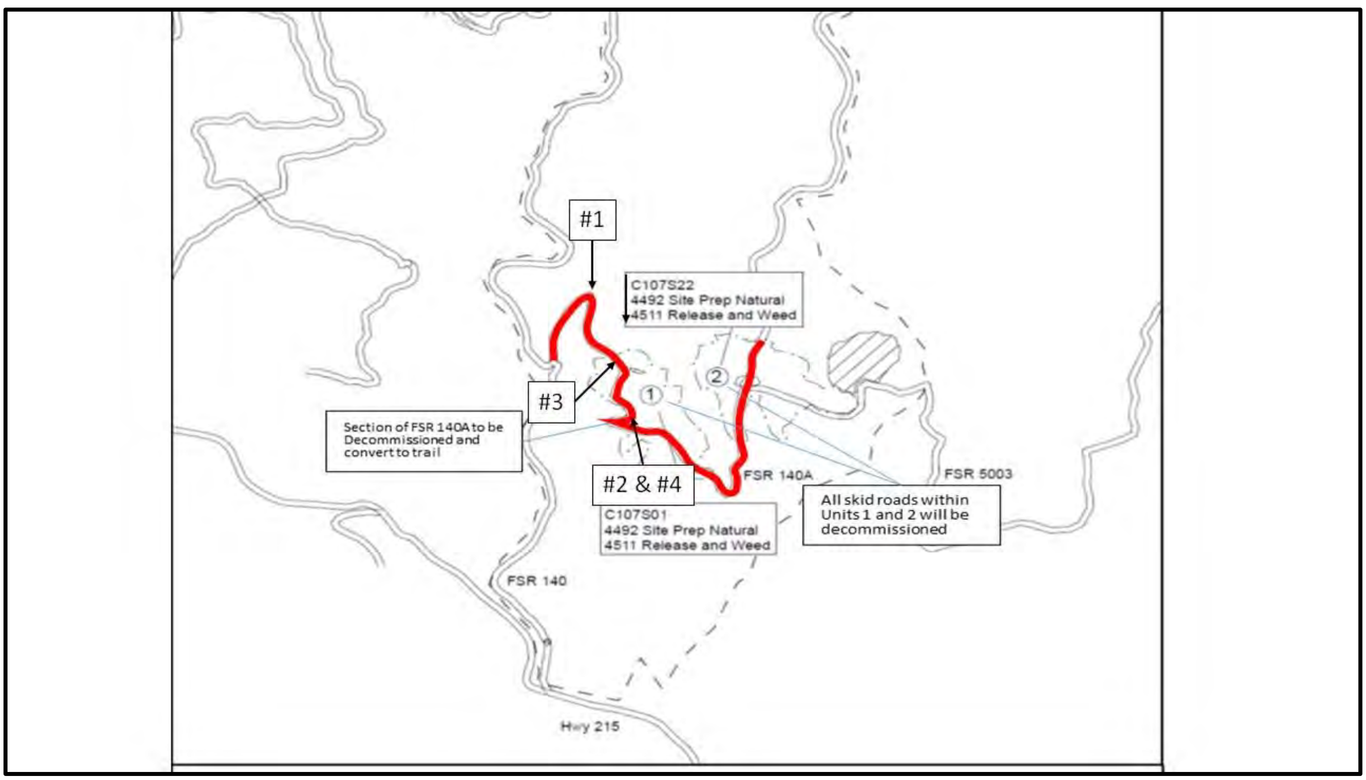

Figure 3. Location of site recommendations, refer to Table 2 above for details.


PHOTO 1


PHOTO 2


PHOTO 3

APPENDIX A

EQUIPMENT AND EROSION CONTROL CONTRACT SPECIFICATIONS

A) **Manner of Construction -** Excavation will be done in a manner which will minimize sedimentation in the stream channel. Silt fence will be installed downstream of the construction area to reduce the risk of sediment entering the stream.

B) **Equipment Operator Performance** - Equipment operators shall be experienced and competent in the use of the equipment to which they are assigned. They shall be expected to demonstrate a level of proficiency with the equipment which enables them to be productive in all aspects of erosion control work.
Operators will be instructed by the construction inspector as to the desired result of construction activities. Operators will be responsible for determining how best to use equipment to achieve the desired results.

C) **Environmental Considerations** - Earth moving equipment will cross and operate in the streamflow only when necessary and only when directed to do so by the construction inspector. Equipment shall be new or of low hours and be maintained to prevent fuel, oil and lubricant spills in the vicinity of the stream. Refueling, repairs and lubrication will be performed at a safe distances from the stream and only at locations approved by the construction inspector where water is controlled by runoff control measures.

D) Equipment Specifications

1. Hydraulic Excavator:
   - Track mounted, hydraulic powered.
   - Excavator:
     - Min weight – 47,000 lbs
     - Min. Reach – 30 feet
     - Min Digging Depth – 13 feet
     - Min Bucket size – 1.0 cu yd.
     - Min 138 HP
     - Equipped with hydraulic thumb, with experienced operator as described above.

(More than 1 excavator may be required. Unit price bid should be for one excavator for one hour of running time).

2. Dump Truck:
   - Sixteen cubic yard capacity minimum.

3. Dozer/Crawler Tracktor:
   - Dozer to of sufficient size/weight to efficiently pull a subsoiler rear attachment through the soil and a discer to prepare the surface for planting seed.
     - Min. wieght – 12,800
     - Min. net power: 125 hp
   - Attachments:
     - Subsoiler/Ripper:

1. Min. 3 shanks/rippers
2. Min. 18" Raised tooth ground clearance
3. 21" Ground penetration

Seed/Mulch/Lime/Fertilizer:

Description

Seeding, liming, fertilizer and mulching shall occur within 24 hours of ground disturbing activities. Seed, lime and fertilizer shall be applied in a manner that provides an even coverage and be immediately covered with certified weed-free wheat straw mulch. Mulch shall be applied in quantities to cover at least 50 percent of the ground surface. On stream banks, Coir matting/blanket shall be placed to hold mulch, seed, and soil in place. Below are native grass species to be sown, their seeding density and their location, determined by dry or moist-wet sites.

Specification for Seed/Fertilizer/Lime

Item	Type	Application Rate	Lbs needed for area
Seed	*Creeping Red Fescue*	5 lbs/acre	75
	Virginia Wild Rye	15 lbs/acre	225
	Annual Winter Rye	20 lbs/acre	300
	Black Locust	10 lbs/acre	150
	*River oats**	1 lbs/acre	5
	*Deer tongue**	2 lbs/acre	10
Lime	*pelletized*	100 lbs/acre	1,500
Fertilizer	*10/10/10*	50 lbs/acre	750
*These species to be sown over 5 acres the other "Types" over 15 acres.			

Scientific Name	Common Name	Application Rate
Dry Sites:		
Festuca rubra	Creeping red fescue	5 lbs/acre
Elymus virginicus	Virginia wild rye	15lbs/acre
Secale cereale	**Winter rye - Annual**	20 lbs/acre
Robinia pseudoacacia	**Black locust**	10 lbs/acre
Moist-Wet Sites/Stream Crossings:		
Festuca rubra	Creeping red fescue	5 lbs/acre
Elymus virginicus	Virginia wild rye	15lbs/acre
Secale cereale	**Winter rye - Annual**	20 lbs/acre
Uniola latifolia (Chasmanthium latifolium)	River oats	1 lbs/acre
Dichanthelium clandestinum	Deertongue	2 lbs/acre

Materials
All materials shall meet the approval of the Designer.

Basis of Payment
Payment for installation of seed and mulch will be paid for as outlined. This payment shall be considered full compensation for all labor, equipment, furnishing materials, hauling, rehandling, sorting, materials, and incidentals necessary to seed, lime, fertilize and mulch.

Payment will be made under:
Seed ……..ACRE
Mulch…….ACRE
Lime……..ACRE
Fertilizer……….ACRE

Matting

Materials
All materials shall meet the approval of the Designer and include Coir fiber mat 700, hardwood stakes, and live stakes (see "Live Stake Planting" Specs).

Installation
At all stream crossings, Coir fiber mat 700 shall be used on upper and lower stream banks (above and below the bankfull elevation). The matting shall be fastened in place using hardwood stakes. During the following plant dormant season, live stakes shall be planted in the matting from water's edge to just above bankfull. Species include silky dogwood (Cornus ammonum), black willow (Salix nigra), silky willow (Salix sericea), common elderberry (Sambucus canadensis), and ninebark (Physocarpus opulifolius) from a local source (see plant list below).

Place the matting upon final grading, following seed and mulch application. Provide a smooth soil surface free from stones, clods, or debris which will prevent the contact of the matting with the soil. Unroll the matting on the contour, starting at the bottom of the slope and apply without stretching such that it will lie smoothly but loosely on the soil surface. Stake the matting according to the manufactures recommended pattern for specific product and slope. Where one roll of matting ends and a second roll begins, install matting end-over-end with approximately 6 inches of overlap. Stake through overlapped area using 5 stakes. Install stakes across the matting at ends, junctions, and trenches approximately 1.3 feet apart.

Basis of Payment
Payment for installation of matting will be paid for as outlined. This payment shall be considered full compensation for all labor, equipment, furnishing materials, hauling, stockpiling, rehandling, sorting, fitting, materials, and incidentals necessary to install matting.

Payment will be made under:
Matting ……………………………………………………………………………………………………….LINEAR FEET

Live Stake Plantings

Description
Live stake planting shall occur during plant dormancy. Below is a list of woody vegetation species to be

planted on stream banks and in the Coir matting.

Scientific Name	Common Name	Percent of plantings	Spacing (feet)
Live Stake Species:			
Cornus ammonum	silky dogwood	20	3
Salix nigra	black willow	20	3
Salix sericea	silky willow	20	3
Sambucus canadensis	common elderberry	20	3
Physocarpus opulifolius	ninebark	20	3

Materials
All materials shall meet the approval of the Designer.

Basis of Payment
Payment for installation of plantings will be paid for as outlined. This payment shall be considered full compensation for all labor, equipment, furnishing materials, hauling, rehandling, sorting, materials, and incidentals necessary to plant.

Payment will be made under:
Live Stake Plantings………EACH

Attachment 3

Forest Service

Washington Office

1400 Independence Avenue, SW
Washington, D.C. 20250

File Code: 1920 **Date:** MAY 18 2018
Route To:

Subject: Implementation Strategy for Improving Forest Conditions

To: Regional Foresters

REPLY DUE JUNE 8, 2018

With passage of the Fiscal Year 2018 Omnibus Bill, the U. S. Department of Agriculture's Forest Service has received a suite of new authorities to accelerate the scope and scale of improving forest conditions and reducing fire risk. The need for this work is clear – and we are moving out now to implement these new authorities. We will use them to continue protecting lives, homes, communities and wildland resources from the impacts of wildfire. Our objective is to improve forest conditions, build capacity through our partners, and shift our cultural approach to accomplish our work.

We have before us an opportunity to demonstrate to Congress and to the American people that their confidence in the Forest Service is justified. To meet this challenge, we cannot simply continue business as usual. We must make improvements based on the principles of transparency, collaboration, and creative thinking at a landscape level.

To that end, I am directing each Region to develop an implementation strategy with an executive narrative describing the major aspects of your implementation plan for the remainder of Fiscal Year 2018 through Fiscal Year 2020 and into the future. To assist, we have enclosed an overview of the 2018 Omnibus authorities.

Each Region's implementation strategy should define the following:

- Objectives for improving forest conditions;
- Efforts to build capacity through Good Neighbor agreements;
- Suggested new policies; and,
- Innovative organizational structural changes or actions you have implemented that could be shared and replicated in other Regions.

The development of your implementation strategy should be framed by considering the following 2018 Omnibus Authorities:

- Categorical Exclusions for Wildfire Resiliency Projects;
- Healthy Forest Restoration Act (HFRA) project definitions expanding its use;
- Application of Roads authorities in Good Neighbor Agreements;
- The 20-year stewardship pilot authorities;
- The 2014 Farm Bill and Healthy Forest Restoration Act authorities;
- Regional approaches to apply expanded KV and trust fund authorities;

- A risk-based strategic wildland fuels investment approach;
- Opportunities to expand Good Neighbor Agreements; and,
- Forest products modernization and environmental analysis and decision making efforts.

From your strategy, I am asking each Region to submit to the Deputy Chief, National Forest System, a three-page executive narrative detailing each objective with established timeframes and considerations.

In addition, each Region should complete the enclosed template titled "Forest Service five-year plan by Region/Forest Fiscal Year 2018 – Fiscal Year 2022." This information will allow our scientists to incorporate data into current models to guide decisions on where best to make investments for future work. This product will inform modeling scenarios that will be used at a national level to make decisions about financial and target allocations. The Forest Service Communication Plan, 2018 Omnibus Highlights, is enclosed for your reference.

Finally, a cross-Deputy Team will be established with the objective of ensuring coordinated direction and support to facilitate national policy interpretation, initiate potential cross-regional hiring opportunities, and coordinate future strategic risk mapping aggregation and resource allocation decisions.

Thank you for the work you have accomplished to date. I appreciate the continued emphasis placed on this essential work in order to insure the Forest Service delivers more of the benefits Americans rely on from their Forests.

Victoria Christiansen

VICTORIA CHRISTIANSEN
Interim Chief

Enclosures

USDA United States Department of Agriculture

Topic: Summary of Five Year Availability of Regional Projects
Date: May 17, 2018

Contact: Allen Rowley, Director, FMRMVE
Phone: 202-205-1523
Email: arowley@fs.fed.us

Issue:
For outyear planning the Washington Office (WO) needs to understand the status of regional plans that contribute improving forest conditions on our National Forests. As the Agency continues to implement new authorities and new methodologies, it is to understand the outputs from current project planning efforts and their effect on the pace and scale of restoration in the upcoming years.

There is also concurrent research into scenario planning to help identify the highest priority treatment areas to improve foest conditions.

Background:
The chief issued a letter on May 18, 2018 requesting each region to submit their strategies for improving forest conditions. The request included descriptions of how the Regions would implement 2014 Farm Bill and 2018 Omnibus Bill authorities, along with other new policies put in place over the past year. As part of their response, regions were asked to identify the volume and acres available under NEPA decisions and what may be available under pending decisions. The table below presents a summary of their responses. Not only will this data be useful in understanding how much area is ready for treatment, it also can be used to study where treatments should be targeted. As stated in the letter: "*This information will allow our scientists to incorporate data into current models to guide decisions on where best to make investments for future work. This product will inform modeling scenarios that will be used at a national level to make decisions about financial and target allocations.*"

All Regions Five Year Plan FY 2018 - FY 2022											
				Completed		Available (NEPA completed only)				Pending	
Region	Year	National Timber Target (MBF)	Sum of Regional Timber Target (MBF)	#EA/EIS	#CE	Available Harvest Acres	Available Volume (CCF)	Available Volume (MBF)	Available Hazardous Fuels treatment acres	NEPA Pending #	Pending NEPA (acres)
All	2018	3,400,000	3,429,000	204	249	239,157	6,396,261	3,397,256	3,638,217	130	2,131,683
	2019	3,700,000	3,412,000	109	77	145,576	4,316,616	2,347,115	2,565,755	156	2,177,281
	2020	4,000,000	3,568,900	97	67	77,476	2,112,934	1,085,234	2,593,342	144	1,342,740
	2021	4,100,000	3,694,900	78	70	67,750	2,114,793	1,087,030	2,654,704	137	1,112,787
	2022	4,200,000	3,812,400	74	68	68,436	2,100,173	1,079,790	2,439,486	128	1,059,404

Observations:
Some observations from this summary are:

- The FY18 timber volume targets are what was assigned to each of the regions. Actual accomplishments may vary.
- FY19-22 targets are regional estimates based on projected national targets. Any shortfall will be addressed as annual targets are set. The WO has not set regional targets for out years at this time.
- NEPA documents (and associated treatment acres and volumes) for all years do not support the targets. This was expected since under the current situation many forests are completing NEPA the same year as the planned sale. Any previously completed NEPA analysis and decision have been used up to meet targets over the past few years.
- The annual hazardous fuels acres targets are estimated from the regions fall short of the planned national targets.
- Additional work is needed to gain efficiencies from new authorities in developing shelf stock for prescribed fire projects and timber sales.
- Current work in developing a more flexible year round workforce for both suppression and prescribed fire should continue in order to meet hazardous fuels targets.
- Efficiencies can gained through agreements and implementing cross boundary prescribed fire projects.

Forest Service

Southern Region

1720 Peachtree Road, NW
Atlanta, GA 30309

Fax: 404-347-4448

File Code: 1920 **Date:** June 8, 2018
Route To:

Subject: Region 8 Implementation Strategy for Improving Forest Conditions

To: Deputy Chief, National Forest System

Enclosed is the Southern Region Implementation Strategy for Improving Forest Conditions. We recognize that our work in the Southern Region requires an all-lands approach considering that private land ownership is intermixed with national forest land throughout the Region. We are engaging our partners, stakeholders and state foresters in this conversation to incorporate their views into our strategies.

The Southern Region is leading the Forest Service in innovation with Good Neighbor Authority, use of stewardship, expansion of Knutson-Vandenberg, and utilization of Farm Bill Insect and Disease Categorical Exclusion Authorities. Each of these tools are critical to our ability to consistently deliver 50% of the acres treated by prescribed fire and nearly 20% of the timber volume sold for the agency.

We appreciate the close coordination with the Washington Office in providing leadership, guidance, policies, and funding to support these activities. The important work on Forest Products Modernization and Environmental Analysis and Decision Making, among other national initiatives, is critical to improving forest conditions throughout the South and the agency.

We look forward to the efficiencies gained by implementing this strategy. If you have any questions or would like additional information, please contact José V. Castro at 404-347-7396, or via email at jcastro@fs.fed.us.

Ken Arney
KEN ARNEY
Acting Regional Forester

Enclosure

cc: Frank R Beum, Jose' V Castro, Peter Gaulke, Jeff Matthews

Southern Region Implementation Strategy for Improving Forest Conditions

The Southern Region has identified three objectives for Improving Forest Conditions:

1. Increasing the pace and scale of restoration to move towards a desired future condition of a more resilient landscape, while accomplishing resource management in an ecologically and economically efficient manner.
2. Providing for public safety and the protection of life and property through sound land management.
3. Providing for clean drinking water and ecosystem restoration. The above mentioned tools and the authorities in the 2018 Omnibus will be instrumental in carrying out these objectives and fulfilling the commitment to the American public for stewarding the land.

The Southern Region continues to focus on applying restoration and improving conditions to increase forest health and resiliency. Building on our integrated approach, ecological and watershed restoration objectives are achieved through prescribed fire, hazardous fuel reduction, vegetation management, treatment of invasive species, stream restoration, soil and water quality improvement, and management of roads and trails. This focus on restoration improves habitat and water quality.

Collaborative restoration at the landscape and watershed scales are the best strategies to achieve these goals. The Region is investing in multiple programs such as Joint Chiefs, using the Water Condition Framework to select priority watersheds and to guide watershed restoration, increasing the use of stewardship contracting, and supporting regional restoration initiatives for longleaf pine and Southern Appalachian forests.

Below is the Regional aggregate table for the 5-year plan. A breakdown for individual forests is not ready at this time, but could be provided prior to the end of the fiscal year (FY), if needed. The Region intends to increase timber volume sold from 680 MMBF in FY 2018 to 780 MMBF in FY 2021, and then maintain that level. Hazardous fuels treatments are planned to increase by 16% over the next 5 years.

USFS - Five Year Plans by Region/Forest FY2018-FY2023

Regional aggregate

			Completed		Available				Pending	
Region	Year	FY18 Timber Target	#EA/EIS	#CE	Harvest Acres	Available Volume (CCF)	Available Volume (MBF)	Available Hazardous Fuels treatment acres	NEPA Pending #	Pending NEPA (acres)
	2018	680	31	105	78,000	12,466,000	680,000	1,550,000		
	2019	710			54,000	858,000	468,000	1,600,000		
	2020	740						1,650,000		
#	2021	780						1,700,000		
	2022	780						1,750,000		
	2023	780						1,800,000		
	All	4,470	31	105	132,000	13,324,000	1,148,000	10,050,000	0	0

The Southern Region has depleted much of its shelf volume over the last 2 years of increasing timber outputs. As a result, the majority of forests have about 6-9 months of shelf volume remaining, but are actively working in an improved efficient manner to prepare future National Environmental Protection Agency (NEPA) documents. Between current decisions and NEPA that is in progress, FY 2019 is covered, but FY 2020 will need additional completed NEPA analysis and signed decisions.

The Southern Region leads the country in the number of executed Good Neighbor Authority (GNA) Agreements with 36, which includes 15 Master Agreements (8 with state forestry agencies), 19 Supplemental Project Agreements, and 2 Stand-alone Agreements. We will reach out to our GNA partners by the end of FY 18 to update our agreements to incorporate the recent addition of road maintenance activities wherever appropriate. The Chattahoochee-Oconee National Forests and the Georgia Forestry Commission have the first

GNA agreement that includes timber removal. Several other forests are following suit and building on that success, are beginning to implement their own agreements with timber removal to bolster capacity.

All Forests within the Region utilize stewardship contracting authorities and its use continues to grow each year. With the increase in contract and agreement length to 20 years, there is an opportunity to make investments in local communities to develop infrastructure and markets for products where none currently exists. We will work with our stewardship partners to increase contract and agreement length to 20 years wherever appropriate by the end of FY 18. Longer agreement lengths will make it easier for partners to complete work within timeframes because they are not restricted by the expiration date of master stewardship agreements.

We recognize there are changes happening at all levels of the Agency, Department and Government. Our focus is to "right size" the Environmental Analysis and Decision Making (EADM) effort to the Region, its issues, processes and procedures, partners, and culture. We do not discuss the EADM work as NEPA work. We recognize that in order to impact our delivery of programs in a meaningful and lasting way, all resources and disciplines need to engage in this work, not simply NEPA or planning.

The Region is promoting the use of NEPA efficiency tools, such as: templates, checklists, and several new examples of focused EA's, while offering EADM-centric training, in an effort to increase capacity for the analysis necessary to implement projects geared towards improving forest conditions. Through this training, which has engaged many line officers, concerns have been raised about needing support from the Washington Office while implementing the NEPA efficiencies. To help foster support and increase relationships with partners, the Region is working with partners such as the Southern Environmental Law Center (SELC) to open up the dialogue related to landscape scale analysis from a NEPA risk and uncertainty perspective.

A combination of NEPA tools including the use of Supplemental Information Reports, Farm Bill Section 603 and Title VI of the Healthy Forests Restoration Act (HFRA) are actively being used. We are also initiating a region-wide formal consultation on red-cockaded woodpecker (RCW) to cover all management activities within the range of the RCW. This will allow us to increase the pace and scale of longleaf and shortleaf pine restoration, including timber harvest and prescribed burning.

The Southern Region is home to 271 federally listed species and hundreds of at-risk species. Many of these species are found in fire adapted ecosystems with vast acreage in need of restoration. Conservation actions for these species can be achieved through increased timber harvest and an increase in fuels treatments, both with prescribed fire and mechanical means. These consultation efforts would result in Biological Opinions that the forests could tier to at the project level. Additional training, on Biological Assessments and Biological Evaluations, is being providing which also dovetails with the efforts of the Endangered Species Act Taskforce.

In FY 2018, all Forests prepared a restoration strategy that will guide analysis and decision making in order to measurably reduce the risk to resource values, move towards natural range of variation desired conditions, and provide public benefits. Forests are being asked to consider how landscape scale restoration can be achieved across boundaries to maximize and leverage both staffing and funding capacity. A sub-regional preliminary assessment of how longleaf pine restoration could be accelerated by working at the multi-forest scale has been conducted by comparing acres analyzed and carried forward into a NEPA decision against acres implemented and time taken to move through the analysis process.

The Forest Service and the Natural Resources Conservation Service work cooperatively to improve the health and resiliency of national forests and adjacent privately owned lands. Through Joint Chiefs' Landscape Restoration Partnership, the two agencies have worked to reduce wildfire threats, restore ecosystems, improve water quality, and enhance wildlife habitat. Since 2014, the Southern Region has initiated 12 projects in support of restoring landscape function and resiliency across boundaries with interagency and private partners.

In an effort to maximize the use of trust funds as part of the integrated approach to both funding and accomplishing restoration work on the ground, the Region is embracing the expansion of KV authority. The Acting Regional Forester issued a letter directing forests to use the new FS 2400-50 Sale Area Improvement (SAI) Plan form for all new sales and revisions to existing SAI plans. A webinar was held with Forests on May 31 to explain the expansion of the KV policy and to answer questions. The Region is stressing to Forests that expansion of KV is a great new opportunity. In FY 2017, there was an extensive effort made to clean-up KV activities planned in previous fiscal years that had yet to be accomplished, yielding approximately $20 million in funds being transferred to CWK2. The region invested over $14 million into the FY18 program of work to fill in the gap in funding from what the WO provided to accomplish the targets. The Region also invested $3 million in surveys to advance the NEPA process along for out-year projects. The Region is increasing efforts to spend CWKV funds in two to three years when possible after sale closure rather than five years.

The revised integrated budget process in Region 8 works within the existing budget structure to integrate projects and funding in the way programs such as fire, timber, wildlife, forest health, watersheds, ecosystems, and other natural resource programs have to work together in the South.

The Region is developing a strike team for timber sale marking, and utilizing timber sale pipeline funding as seed money to get it started. The Nature Conservancy is discussing a pilot project on one National Forest to bolster capacity for project development and sale preparation through a stewardship agreement, modeled after their success using Job Corps students on burning crews. The Region is exploring the potential reorganization of sale administration, sale preparation, and timber sale accounting duties to fill critical vacancies and be more efficient.

The Region has put a region-wide BPA in place with several cultural resource management contracting firms for additional capacity in identifying and evaluating effects to historic properties within project areas, as well as providing options for other aspects of planning, preparation, and implementation of projects. Many of the forests in the Region have re-negotiated or are in the process of re-negotiating older Section 106 programmatic agreements with their State Historic Preservation Offices and affected Tribal Historic Preservation Offices. For larger, multi-year projects, we utilize phased compliance agreements per 36CFR800.4(b)(2). These allow us to complete the identification of historic properties and required consultation after the NEPA decision is signed but prior to project implementation.

The principle goals of the National Wildland Fire Cohesive Strategy are managing vegetation and fuels, protecting homes, communities, and other values at risk, managing human-caused ignitions, and effectively and efficiently responding to wildfire. These goals are being emphasized in all prescribed fire and mechanical fuels treatment projects that are planned and implemented within the Region. Approximately 10% of the annual hazardous fuels reduction prescribed fire treatment acres are accomplished utilizing the categorical exclusion for wildfire resiliency. We utilize the Southern Wildfire Risk Assessment Wildland Urban Interface Risk Index and the National Forest Health Risk mapping systems to identify areas within and adjacent to National Forest boundaries that are at high risk of damaging wildfires. Treatment options are prioritized within these high risk areas.

Southern Region Five Year Plan FY 2018 - FY 2022										
			Completed		Available (NEPA completed only)				Pending	
Region	Year	Timber Target (MBF)	EA/EIS	CE	Available Harvest Acres	Available Volume (CCF)	Available Volume (MBF)	Available Hazardous Fuels treatment acres	NEPA Pending #	Pending NEPA (acres)
8	2018	680,000	31	105	78,000	1,246,600	680,000	1,550,000	0	0
	2019	710,000	0	0	54,000	858,000	468,000	1,600,000	0	0
	2020	740,000	0	0	0	0	0	1,650,000	0	0
	2021	780,000	0	0	0	0	0	1,700,000	0	0
	2022	780,000	0	0	0	0	0	1,750,000	0	0
	ALL	3,690,000	31	105	132,000	2,104,600	1,148,000	8,250,000	0	0

Attachment 4

United States
Department of
Agriculture

Forest
Service

February 2019

Final Environmental Assessment

Southside Project

Nantahala Ranger District, Nantahala National Forest
Jackson and Macon Counties, North Carolina

For Information Contact: Steverson Moffat
123 Woodland Drive, Murphy NC 28906
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www.fs.usda.gov/nfsnc

Non-native invasive plant control and prevention efforts in the Southside project area will focus on the following areas:

- All off-road logging equipment will be clean and free of soil and vegetation prior to entering stands. Off-road logging and earth moving equipment will be re-cleaned if moved away from the sale area and then brought back to the sale area.
- All areas of soil disturbance (log landing and temporary road construction) will be seeded with a weed-free seed mix.
- All tracked and some of the non-tracked NNIP will be prioritized for treatment prior to timber harvest activities to avoid further spread. The amount of control accomplished will be based on time and funding available. The following is the order of priority for accomplishing treatments:
    - The few smaller populations of lesser periwinkle (*Vinca minor*), kudzu (*Pueraria montana*), and Chinese yam (*Dioscorea polystachya*).
    - The woody species that occur in smaller discrete population such as Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), and Japanese meadowsweet (*Spiraea japonica*).
    - The moderate sized woody vine populations of oriental bittersweet (*Celastrus orbiculatus*) and the large grass Chinese silver grass (*Miscanthus sinensis*).
    - The small, local populations of non-FS tracked English Ivy (*Hedera helix*), Hosta (*Hosta sp.*), and winged euonymus (*Euonymus alata*).
    - The more widespread tracked NNIP species populations of Japanese stilt-grass (*Microstegium vimineum*), autumn olive (*Elaeagnus umbellata*), and multiflora rose (*Rosa multiflora*).
    - Both Sericea lespedeza (*Lespedeza cuneata*) and shrubby bushclover (*Lespedeza bicolor*), which were formerly planted for wildlife benefit and soil stabilization.
    - All other NNIP listed in table 3.6.1.1 that have not yet been mentioned above.
- Stands will be prioritized for treatment for at least two years post timber harvest to control any NNIP that was introduced to the site or expanded due to the additional soil disturbance and light availability.

3.6.2 North Carolina Natural Heritage Natural Areas

The Whitewater River Falls and Gorge, Dulany Bog, Slick Rock, and Chattooga River Gorge/Ellicott Rock are known research natural areas or botanical special interest areas recognized by the current Land and Resource Management Plan (LRMP) within the Southside botanical Analysis Area (AA). The Fodderstacks, Hawkins Rockhouse, Blackrock Mountain/Granite City, and Terrapin Mountain Natural Heritage Natural Areas (NHNA) are located in the Southside botanical AA. Activities proposed for the Southside treatment units would have no negative effects to these NHNAs. These NHNAs are not identified as Special Interest Areas by the LRMP.

In October 2017, Gary Kauffman, Botanist for the National Forests in North Carolina and Wesley Knapp, the western regional Ecologist/Botanist for the North Carolina Natural Heritage Program visited the NHNA complexes in the Southside project area including stands proposed for treatment in the project area with the goal of reviewing current conditions in the NHNAs and to determine if boundary adjustments were needed. As a result of this field review, the North Carolina Natural Heritage Program modified the boundary of the Whitewater River Falls and Gorge NHNA to exclude compartment/stand 41-44 since it has more recent group selections harvests which do not meet natural area criteria. The Whitewater River Falls and Gorge NHNA boundary was modified in other areas to exclude young and mid-seral habitat which was determined both based on the field review as well as canopy height LiDAR data from 2005. In addition, the North Carolina Natural Heritage Program recommended that white pine be removed from compartment/stand 41-53 while maintaining and promoting a Montane-Oak Hickory Forest through limited timber harvest, tree planting, and prescribed fire.

A portion of the Blackrock Mountain/Granite City NHNA (1,741 acres) was located within compartment/stand 31/18. Compartment 31 Stand 18 is proposed for a two-aged harvest in the Southside project. On April 4, 2018 Matt Bushman (Nantahala National Forest Botanist), Gary Kauffman, and Wesley Knapp visited compartment/stand 31-18 and the Blackrock Mountain/Granite City NHNA. The goal of this visit was to review the current conditions of the NHNA and determine if boundary adjustments were needed. As a result of this review the North Carolina Natural Heritage Program modified the boundary of the Blackrock Mountain/Granite City NHNA to exclude younger forest and previously disturbed forested areas with roads. This boundary modification excluded compartment/stand 31-18 from the Blackrock Mountain/Granite City NHNA. Therefore activities proposed in compartment/stand 31-18 would not affect the Blackrock/Granite City NHNA.

A portion of the Whitewater River Falls and Gorge NHNA (1,552 acres) is located within compartment/stand 41-53. The 1,552 acre Whitewater River Falls and Gorge NHNA is connected to the 303 acre Whitewater River Falls and Gorge RHA identified as a Special Interest Area in the LRMP. No activities are planned in the 303 acre Whitewater River Falls and Gorge Special Interest Area identified in the LRMP. Stand 41-53 is proposed for a two aged shelterwood treatment to emphasize oak, remove white pine and apply prescribed fire to the stand to promote Montane-Oak Hickory Forest, actions encouraged and supported by the North Carolina Natural Heritage Program.

The activities proposed in the Southside project would not negatively impact the core values of the Whitewater River Falls and Gorge NHNA, which are listed as waterfalls, spray cliffs, grottos, cliffs, dry rocky outcrops, and rare plants in the Whitewater River gorge in the Transylvania County Natural Area Inventory (2008). In addition to the rocky habitats the Natural Area Inventory also lists forested communities on the banks and slopes above the Whitewater River as being intact and contain a number of rare plants. Potential federally listed, Federally Endangered, Federally Threatened, Region 8 Sensitive, and Forest Concern (PETS FC) plants that occur in the stands proposed for management in the project area are listed in the Southside Biological Evaluation (BE). The BE details the protective measures and project design criteria for each of the PETS FC plants that occur in the Southside project area. These measures and design criteria protect the rare plant occurrences in the Southside project area and address the rare plant concerns in the Whitewater River Falls and Gorge NHNA.

Table 3.3.1: Sensitive Wildlife Species with potential to occur in the Southside Analysis Area

Name	Type	Habitat Description	Habitat within Proposed Treatment Units (Yes/No)	Analyzed Further?
green salamander *(Aneides aeneus)*	Amphibian	Green salamanders prefer moist, shady crevices in cliffs and rock faces.	No	Yes
Seepage salamander *(Desmognathus aeneus)*	Amphibian	Seeps, springs, or streams in forests in extreme southwestern counties	Yes	Yes
Eastern Small-footed bat *(Myotis leibii)*	Mammal	Winters in caves.	Yes	Yes
Tri-colored bat (*Perimyotis subflavus*)	Mammal	During summer, roost in leaf clusters of canopy trees. Winter hibernacula are caves and mine shafts	Yes	Yes
Monarch butterfly (*Danaus plexipplus*)		Larvae feed on milkweed, adults feed on a variety of flowering plants	Yes	Yes
Bog turtle *(Glyptemys muhlenbergii)*	Reptile	Bogs, wet pastures, wet thickets	No	No

*Habitat descriptions were taken from the LRMP unless otherwise cited.

3.3.1 Effects of Alternatives on Sensitive Wildlife Species

GREEN SALAMANDER (Aneides aeneus)

The green salamander inhabits the damp, shaded crevices of cliffs or rock outcrops in disjointed subpopulations in North Carolina in Macon, Jackson, and Transylvania counties. In November 2017, wildlife staff from both the U. S. Forest Service and North Carolina Wildlife Resources Commission conducted site visits to proposed units and nearby known green salamander sites to document presence/absence of the species or its habitat and to determine if proposed activities near known salamander populations would impact sites adjacent to exiting populations. One new green salamander site was discovered during these field visits just within the boundary of stand 35-42 (Brushy Mountain). Because this rock outcrop is located at the edge of a proposed treatment unit, a 100 meter buffer will be established to protect this site from increased insolation.

In November 2018, the North Carolina Wildlife Resources Commission conducted surveys in the Southside AA and encountered additional green salamanders at rock outcrops near stand 35-42 and adjacent to the outcrop where the individual green salamander was discovered in fall 2017. To further conserve habitat for this species, additional 100 meter buffers will be established to provide shade, cover, and foraging areas.

Other currently occupied or historical green salamander sites in or near proposed units were either products of incorrect geolocations or proposed project activities would not impact sites due to distance from the unit, terrain features, etc.

Direct and Indirect Effects: **Alternative A** would have no direct or indirect effects on the green salamander because existing conditions would not change.

Alternative B and Alternative C: Although green salamanders spend several months of the year in rock crevices that would not be impacted by timber harvest, this species does occupy habitat in the canopy top near brood rearing/wintering rock outcrops. Timber harvest may potentially affect this species through crushing. However, since the salamander occurs in fairly localized areas, the likelihood of these effects is minimal. Implementation of 100 meter buffers around documented green salamander denning areas adjacent to stand 35-42 will minimize direct and indirect effects to individual salamanders. Because other areas adjacent to the brood rearing/wintering rock outcrops near stand 35-42 are not proposed for silvicultural treatments, there will be connectivity of undisturbed habitat in the analysis area for growing season foraging. Prescribed fire in this environment should not impact shaded rock outcrops used by this species, especially since prescribed burns normally take place during dormant months when the species is deep in rock crevices away from flames and smoke.

Cumulative Effects: In the absence of direct and indirect effects, there would be no effects on these salamanders resulting from **Alternative A**.

Alternative B and Alternative C: Past silvicultural treatments and prescribed burning within the wildlife analysis area would have had effects greater to the proposed harvest and prescribed burning. Prescribed fire would not have had a measurable impact on salamander populations and would not have affected available habitat. Though harvest may potentially alter microhabitat conditions around treated stands, these effects are ephemeral as stands age and several proposed units with known green salamander populations in or near them were either dropped or buffers were recommended. In fact, one new, previously undocumented green salamander site was discovered within an older timber harvest that is adjacent to a proposed stand. This site has been recommended to be buffered to avoid negative impacts to the small, isolated rock outcropping, but past harvest has apparently not eliminated this site as habitat for green salamanders.

Determination of Effect: **Alternative A** would have no impact on the green salamander because existing conditions would not change.

Alternative B and Alternative C: These alternatives may impact individuals but are not likely to lead toward federal listing or a decrease in viability across the forest for the green salamander.

Attachment 5

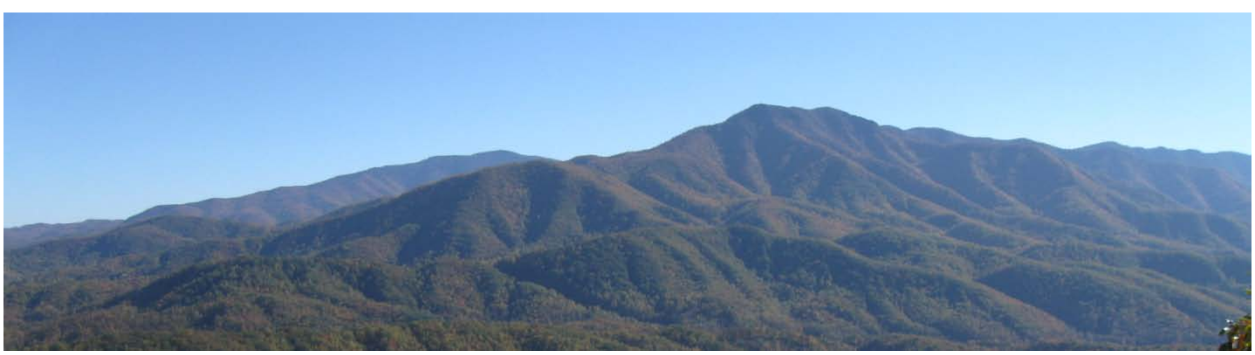
WESTERN NORTH CAROLINA ALLIANCE

An Assessment of the Ecosystems of Nantahala-Pisgah National Forest & Surrounding Lands

A Synthesis of the eCAP Methodology and LiDAR Vegetation Analysis

Josh Kelly

12/17/2013



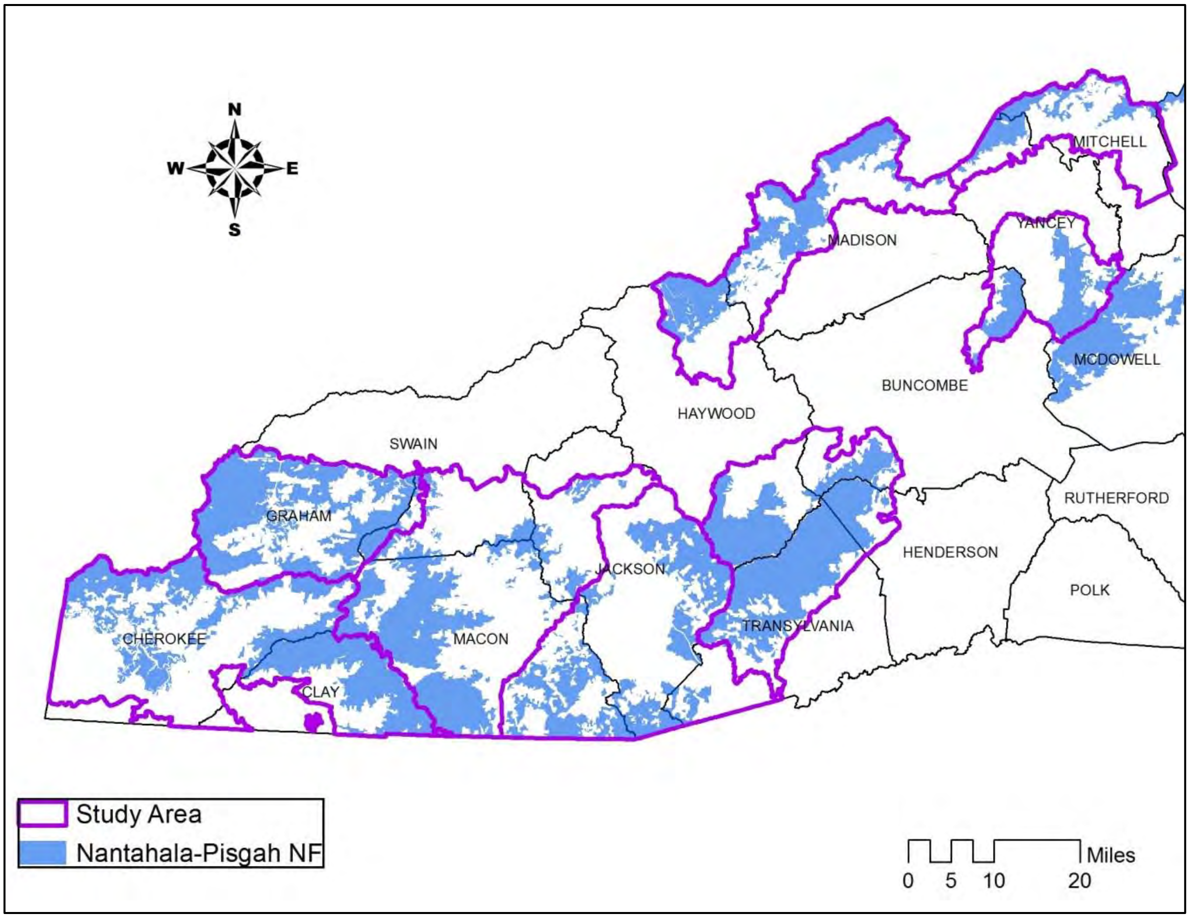
Abstract

Ecological restoration has become one of the guiding principles of National Forest management. However, it can be difficult to identify a reference or desired condition as a restoration goal, and furthermore, accurately assessing ecosystem condition is dependent of the quality of the data available. LANDFIRE Biophysical Settings are computer models that combine scientific research, historical information, and expert opinion to describe the disturbance probabilities of ecosystems and simulate a Natural Range of Variation as a restoration target. Ecological zone maps are the most accurate ecosystem maps available for the Southern Blue Ridge Ecoregion and can be cross-walked to LANDFIRE Biophysical Settings. Light Detection and Ranging (LiDAR) data are recognized as one of the most comprehensive and accurate data for measuring vegetation structure. A study area including the overlap of the 2005 Phase III North Carolina LiDAR data and the proclamation boundary of Nantahala-Pisgah National Forest was analyzed with the use of ecological zone maps, LANDFIRE Biophysical Settings, and LiDAR vegetation models. In total, over 700,000 hectares (1,760,000 acres) of forest were evaluated using LiDAR measured height and US Forest Service stand records to estimate forest age. LiDAR measurements of canopy cover and shrub density were used to evaluate canopy closure. Of 11 forest ecosystems evaluated, five were found to be highly departed from reference conditions. In general, ecosystems with a more frequent historical fire return interval were more departed from reference conditions than mesic forests and ecosystems with greater timber value were more disturbed than ecosystems with less economic value. For oak, cove and spruce ecosystems the Natural Range of Variation included a much higher proportion of old forests than the 2005 conditions, while the converse was true for shortleaf pine and pine-oak/heath ecosystems. Both oak and pine ecosystems had canopies that were much more closed than the reference models, while the canopies of cove ecosystems were more open than the reference models. This study indicates that increased fire management and the continued restoration of old-growth conditions on public land would be ecologically beneficial.

Introduction

The Southern Blue Ridge Ecoregion has long been appreciated as an area of great scenic beauty and unique biodiversity. Nantahala-Pisgah National Forest totals nearly 1.1 million acres in the Southern Blue Ridge Mountains of North Carolina and includes all of the representative ecosystems of the region. National Forest management has been the subject of vigorous debates since at least the 1980's with environmental concerns typically countering timber industry demand for tree cutting (Newfont 2012). In 2012, Nanthala-Pisgah National Forest began a three year process of Forest Plan Revision, which could be an opportunity for either further conflict between interest groups, or for groups to work together to identify common interests that meet the needs of a broad constituency. Ecological restoration has emerged as a strategy for land management that can improve the health and resilience of ecosystems, identify situations in which timber cutting could be beneficial and pursue management activities that align with environmental interests, thus providing hope of decreasing conflict over management of these important conservation lands.

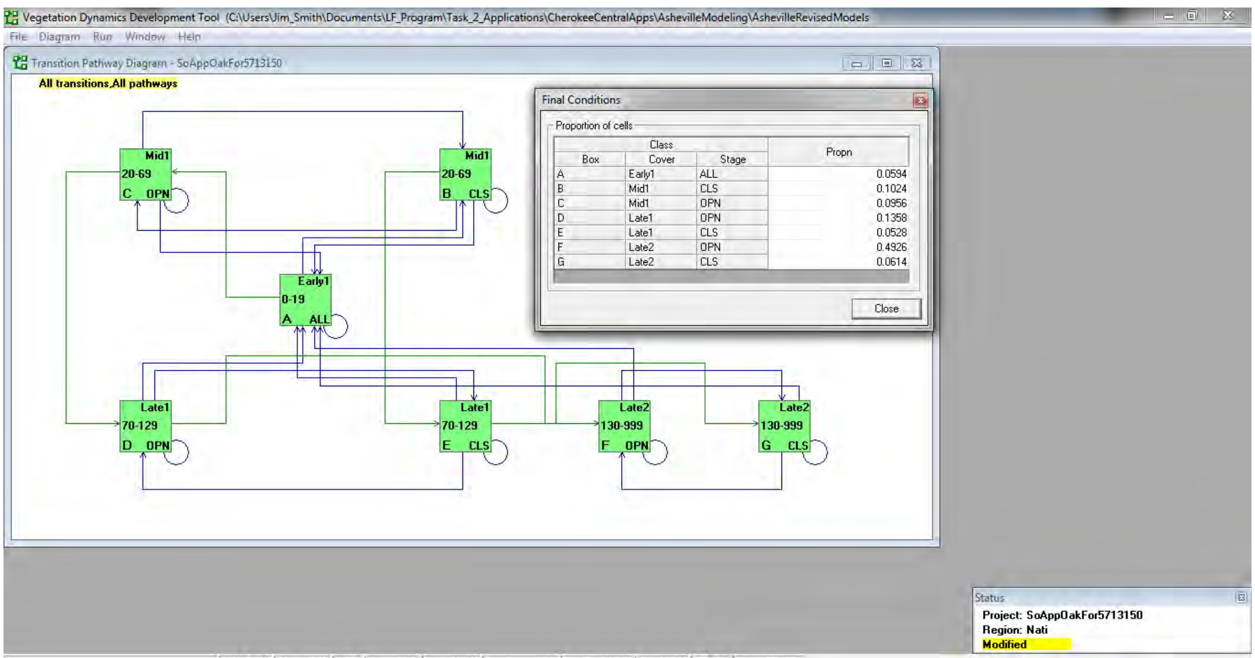
Figure 1: Study area defined by the overlap of the Nanthala-Pisgah National Forest Proclamation Boundary and Phase III LiDAR data from North Carolina



One difficulty in ecological restoration can be identifying a condition or set of conditions to restore ecosystems to. This can be especially challenging in areas in which it is believed that human influence has caused significant and, in some cases undesired, change in ecosystems such as in much of eastern North America. LANDFIRE Biophysical Setting models are viable options for addressing the challenges associated with choosing a reference condition. Biophysical Setting models have been developed for each ecosystem in the U.S. by regional panels of experts that define the probabilities of disturbances such as fire, wind, ice, insects, disease, and other natural dynamics. The disturbances are used as "transitions" between S-classes - successional and structural conditions defined in the models as "states". After the state and transition framework of the model has been created and probabilities entered into Vegetation Dynamics Development Tool software, the models are run through a thousand year simulation that predicts the percentages of the various S-classes that would be expected for each ecosystem, which becomes the reference, or natural range of variation for each ecosystem (Landfire 2013).

LiDAR technology has emerged as perhaps the most precise and accurate way to measure the physical structure of large forested areas and has been used to accurately measure tree height, canopy closure, basal area, and even coarse woody debris (Hopkins et al. 2009; Lefsky et al. 1999; Suarez et al. 2004; Wulder et al. 2012; Zimble et al. 2003). The acquisition of raw LiDAR data by the state of North Carolina between 2001 and 2005 provides the opportunity for analyzing the condition of vegetation over a large area at a resolution not previously possible. The Phase III data, acquired in 2005, have four times the density of points per unit area as the Phase II data from 2003, allowing especially fine-scale analysis of forests.

Figure 1: The seven box (S-class) state and transition model for Southern Appalachian Oak Forest viewed in the Vegetation Dynamics Development Tool. **Image credit: Jim Smith**



Analyzing the physical structure of ecosystems requires a reliable map of where ecosystems occur. Fortunately, Nantahala-Pisgah National Forest and the Southern Blue Ridge Fire Learning Network have invested substantial resources into mapping the ecological zones of the study area, not once, but three times (Simon et al. 2007; Simon 2011). The resultant map products are accurate, consistent over millions of hectares, and facilitate the analysis of vegetation across a gradient of productivity in which each ecosystem has a discreet potential for tree growth and height.

The eCAP methodology developed by The Nature Conservancy uses Biophysical Settings, ecosystem mapping, an assessment of current ecosystem conditions, and scenario forecasting to guide land management - all but the scenario forecasting are included in this study, producing a measure of ecological departure for the ecosystems in question (Low et al. 2010). Ecological departure is calculated by comparing the current percentage of s-classes to the reference condition in each ecosystem. By identifying the most departed ecosystems and the S-classes leading to the departure of each ecosystem, land managers can prioritize activities so as to decrease the departure of ecosystems from the natural range of variation. The intent of this study is to help identify a "need for change" in the Nantahala-Pisgah Forest Plan Revision and to facilitate ecologically sound management on National Forest and other lands.

Methodology

LiDAR Processing

Raw LiDAR data covering the purchase boundary of Nantahala-Pisgah National Forest were acquired from the Click website (http://lidar.cr.usgs.gov/). LiDAR point clouds were processed into canopy height, canopy cover, and shrub density models with the use of Fusion© Software, a free software package from the University of Washington and the USFS Northwest Research Station. The LiDAR data from the USGS are projected in NC State Plane FIPS 3200(feet), so all LiDAR models are in units of feet. Canopy height models were produced at 20' pixel size with values <0' and >190' being excluded from analysis as the tallest known tree in the ecoregion is 192' tall (http://www.ents-bbs.org/viewtopic.php?f=74&t=2423). Canopy cover and shrub density models were produced at 40' pixel size. Canopy cover was defined as occurring above 15' in height and shrub density was calculated below 15' in height. LiDAR models created in Fusion© were imported into ArcMap as ASCI files and converted to raster format.

GIS Analysis

Ecozones were first lumped into broader types that could be cross-walked to Biophysial Settings (see Table 1). A total of 11 ecosystems were then evaluated separately. Agricultural and developed areas were excluded from the analysis using GAP land cover data. LiDAR vegetation models were extracted to the boundaries of each ecosystem, reclassified into broad categories, and intersected. The intersected master file was then clipped to a layer of Forest Service ownership, creating master files for Forest Service and "All Lands".

Taking inspiration from previous studies, LiDAR canopy height models were reclassified to serve as a surrogate for height (Weber & Boss 2009). This analysis includes lands other than Forest Service lands, and those ownerships have no systematic age data. Additionally, even Forest Service data often overlooks natural disturbances like wind throw, landslides, insect outbreaks, disease, or individual tree mortality if they occur at a scale smaller than the stand level. Broad categories of height were defined for Early, Mid, and Late S-Classes for each ecosystem. As a first attempt, site-index growth curves were selected for each ecosystem as a guide for choosing height breaks. For example, the break between early and mid S-classes occurs at 20 years and the break between mid and late S-classes occurs at 70 years in the Southern Appalachian Oak BpS (Dry Mesic Oak Ecozone). Tracing a growth curve for white oak at site index 70, the site index most often listed for this forest type, yields a height of just over 30' at 20 years and approximately 85' at 70 years (Carmean 1971). However, the results of this methodology grossly underestimated the quantity of the late successional S-class on National Forest, where fairly reliable age data are available.

Table 1: Crosswalk between LANDFIRE Biophysical Settings and Ecozones analyzed in this study.

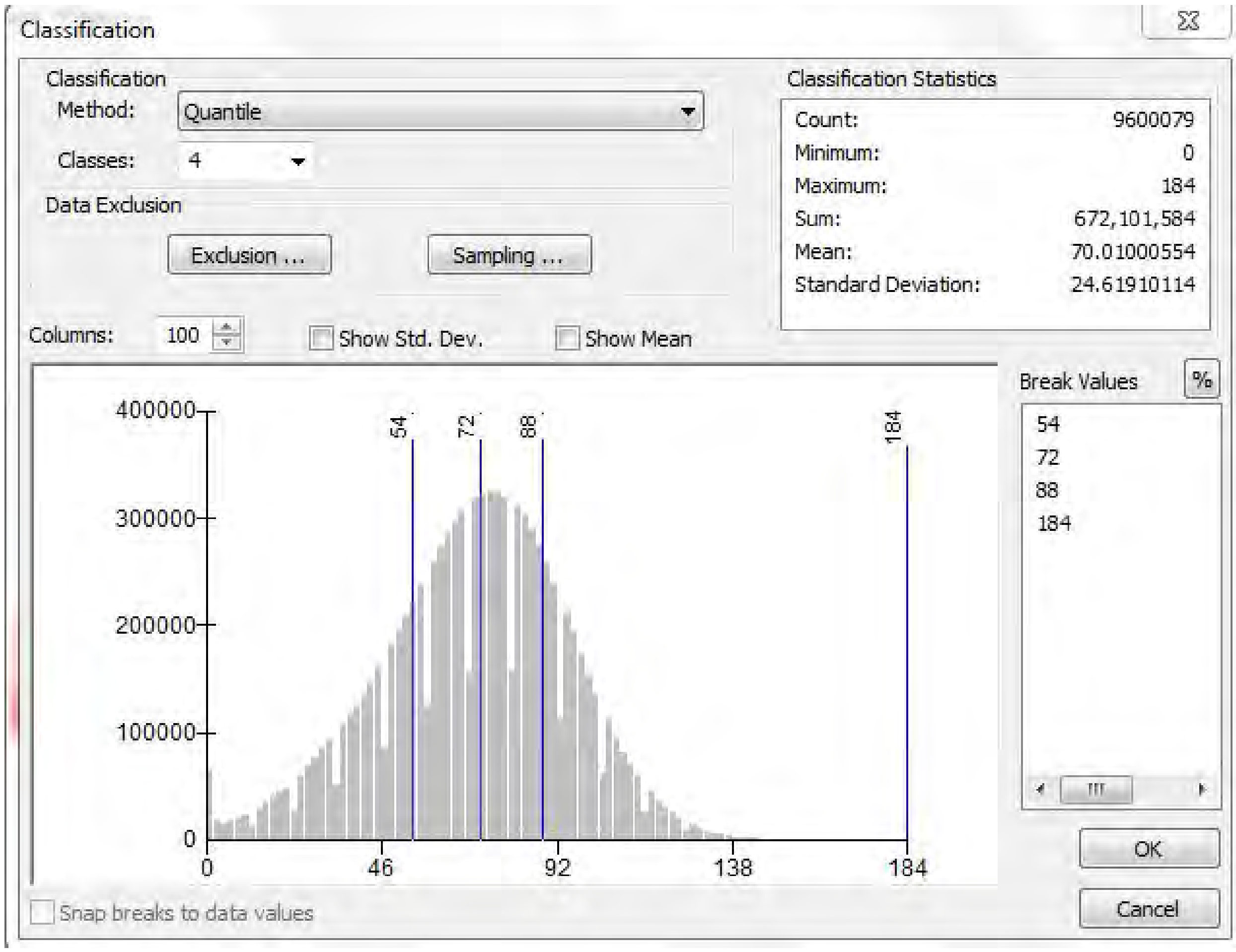
Biophysical Setting	Ecozone(s)	Gridcode
Central and Southern Appalachian Spruce-Fir Forest	Spruce-Fir	1
Southern Appalachian Northern Hardwoods Forest	Northern Hardwoods Slope Northern Hardwoods Cove	2 3
Southern Blue Ridge Cove Forest	Acidic Cove Forest Rich Cove Forest Oak Rhodo	4 5 29
Southern Appalachian Mesic Oak Forest*	High Elevation Red Oak*	8
Southern Appalachian Mesic Oak Forest	Montane Oak-Hickory Slope Montane Oak Rich Montane Oak-Hickory Cove	9 24 28
Allegheny Cumberland Dry Oak-Pine Forest	Dry Oak Evergreen Heath Dry Oak Deciduous Heath	10 11
Southern Appalachian Oak Forest	Dry Mesic Oak Forest	13
Southern Appalachian Low Elevation Pine Forest	Low Elevation Pine Shortleaf Pine-Oak/Heath	16 31
Southern Appalachian Montane Pine Forest & Woodland	Pine-Oak/Heath	18

* High Elevation Red Oak Forest lacks an acceptable LANDFIRE Biophysical Setting, so Mesic Oak was used as its reference.

There are many logical reasons why the site index approach failed. First, the pixel size for the LiDAR canopy height model employed is smaller than the crown of a large tree. So, while the tree may reach the height predicted, not all the pixels of the crown would be classified as the correct age. Second, not all of the species making up the canopy of the forest grow as rapidly as the site index species. Species like black gum and sourwood would tend be older than the site index height approach would indicate. Third, not all of the forests sampled are even aged. Old growth forest and forest approaching old growth conditions will in most cases have all age classes and an uneven canopy. Many stands also have been high-graded, leaving deformed trees and less-than-ideal growing conditions for the residual trees. Ecosystem mapping errors may also contribute because while the mapping products used are the best available, they are still incorrect in approximately 20% of all locations.

The method finally adopted was to examine the distribution of LiDAR heights within each ecosystem on National Forest Land. Because age data are available for Forest Service ownership, the percentage of late successional and old-growth forest within an ecosystem was compared with the distribution of LiDAR points. So, for Dry Mesic Oak Hickory Forest, where Forest Service stand data record 74% of the stands being greater than 70 years in age, the height break chosen was 55' (See Figure 2). An obvious consequence of this methodology is that it will overestimate the age of some trees. Height is what is actually being measured, after all. However, concentrated areas of consistently tall canopy are classified correctly, and the percentages of late-seral and old-growth forest on Forest Service Land are within 5% of Forest Service stand data in all ecosystems when using this method.

Figure 2: The quantile distribution of heights within National Forest ownership in the Dry-Mesic Oak-Hickory ecosystem. Because 74% of Forest Service ownership is >70 years of age, 55' was used as the height associated with age ≥70 in this ecosystem.



Old-growth forest was analyzed in systems in which LANDFIRE BpS models have been revised to include old-growth S-classes. Ecosystems not yet modeled for old-growth S-Classes are: Southern Appalachian Montane Pine Forest and Woodland, Southern Appalachian Low Elevation Pine Forest, Southern Appalachian Northern Hardwoods Forest, and Southern Appalachian Spruce Forest. Old-growth was not detected by LiDAR, but by Forest Service stand age. The age used for the old-growth threshold was 130 years for oak forests and 140 years for Cove Forests; both ages consistent with and informed by the "Guidance for Conserving and Restoring Old-Growth Forest Communities in the Southern Region" (USDA Forest Service 1998). Because no records for age are available for other lands, no old-growth was indentified on those lands.

For each ecosystem, the LiDAR canopy height raster reclassified into Early, Mid, and Late S-Classes was intersected with the canopy cover raster re-classified as open (≤60%) or closed (> 60%) and a shrub density raster re-classified as low (≤50%) or high (>50%). The result was the creation of at least 5 different condition classes for each ecosystem, and up to 13 condition classes for ecosystems where shrub density was analyzed and old-growth s-classes were modeled.

Table 2: Physical Metrics used to define S-classes in this analysis

Ecozone/Ecosystem	Max Early-Seral Height	Max Mid-Seral Height	Old-Growth Age	Canopy Cover Classes	Shrub Density Classes
Spruce	23’ (<35 yrs.)	60’ (65 yrs.)	No BpS Model	<60% = Open	Not Analyzed
NH Cove	33’ (<25 yrs.)	59’ (75 yrs.)	No BpS Model	<60% = Open	Not Analyzed
NH Slope*	25’ (<25 yrs.)	55’ (75 yrs.)	No Bps Model	<60% = Open	Not Analyzed
High Elevation Red Oak	20’ (<20 yrs.)	42’ (70 yrs.)	130 years	<60% = Open	>50% = High Shrub Cover
Acidic Cove**	33’ (<10 yrs.)	97’ (100 yrs.)	140 years	<60% = Open	>50% = Acidic Cove
Rich Cove**	33’ (<10 yrs.)	97’ (100 yrs.)	140 years	<60% = Open	<50%= Rich Cove
Mesic Oak	33’ (<20 yrs.)	60’ (70 yrs.)	130 years	<60% = Open	>50% = High Shrub Cover
Dry Mesic Oak	33’ (<20 yrs.)	55’ (70 yrs.)	130 years	<60% = Open	>50% = High Shrub Cover
Dry Oak	25’ (<20 yrs.)	49’ (70 yrs.)	130 years	<60% = Open	>50% = High Shrub Cover
Shortleaf Pine	27’ (<20 yrs.)	57’ (70 yrs.)	No BpS Model	<60% = Open	>50% = High Shrub Cover
Pine-Oak Heath	20’ (<20 yrs.)	40’ (70 yrs.)	No BpS Model	<60% = Open	>50% = High Shrub Cover

* Modeled separately from NH Cove Forest because of productivity differences in these ecosystems.

** Acidic Cove and Rich Cove were separated in this analysis by shrub density; high shrub density being defined as Acidic Cove.

After ecosystems were analyzed and acreage of each condition class was tabulated, the 2005 condition – the time of LiDAR acquisition – of each ecosystem was compared to the respective LANDFIRE Biophysical Setting model to calculate a departure from the Natural Range of Variation. Because Biophysical Setting (BpS) models do not have specific S-classes for shrub density, areas of high shrub density were aggregated with closed canopied S-classes. High shrub density generally corresponds to areas of evergreen shrubs in the genera *Rhododendron*, *Kalmia*, and *Luecothoë* . These evergreen shrubs tend to exclude many herbs and shade intolerant tree seedlings and such environments are considered to be ecologically analogous to a closed canopy in this study. The percentages of S-classes measured with LiDAR were compared with the percentages of S-classes from the Natural Range of Variation described by BpS models to calculate ecological departure with the following equation:

$$100\% - \sum_{i=1}^{n} \min\{Current_i, NRV_i\}$$

Ecosystems with a departure scores ≤33% were considered to be in good condition, those with scores 33% ≥ and ≤ 66% are considered to be in fair condition, and scores > 66% reflect poor ecosystem conditions.

Results

Five of 11 ecozones/ecosystems analyzed were found to be > 66% departed from reference conditions. The most departed ecosystem analyzed was Dry Oak Forest and the least departed ecosystem was Northern Hardwoods Forest. The most common cause of departure was too much of an ecosystem falling into one age class, generally either the middle or late age classes. Coincident with the overabundance of those age classes was an under-abundance of old-growth in every ecosystem where it was modeled. Six of the eight most departed ecosystems also had much less open canopied forest than their reference conditions.

Table 3: Ecological Departure of Ecosystems in the Nantahala-Pisgah National Forest and surrounding lands by ownership

Ecosystem	National Forest	Other Lands	All Lands	Drivers of Departure
Dry Oak Forest	84%	80%	80%	Too much closed canopy, lacks old-growth
Pine-Oak/Heath*	83%	74%	79%	Too much closed canopy, too much late-seral
Shortleaf Pine-Oak*	83%	63%	71%	Too much closed canopy, too much late-seral, lacks early-seral
Dry Mesic Oak-Hickory	70%	71%	71%	Too much closed canopy, lacks old-growth
Mesic Oak-Hickory	70%	74%	72%	Too much closed canopy, lacks old-growth
High Elevation Red Oak Forest	63%	75%	65%	Too much closed canopy, lacks old-growth
Rich Cove Forest	54%	56%	55%	Lacks old-growth
Acid Cove Forest	55%	57%	56%	Lacks old-growth
Spruce-Fir Forest*	34%	43%	39%	Too much mid-seral, too little late-seral; questions about species composition
Northern Hardwoods Cove*	6%	14%	10%	No significant departure, but old-growth not modeled
Northern Hardwoods Slope*	3%	7%	4%	No significant departure, but old-growth not modeled

* Old-Growth S-classes not included in these models

There were consistent differences in the departure of ecosystems across land-ownership. All ecosystems had a greater proportion of closed canopy and were generally older (or, at least, taller) on National Forest land than on other lands, the majority of which are private. So, for dry oak and pine ecosystems in which woodland conditions make up a substantial portion of the reference models, other lands generally had a lower departure from the reference than Forest Service land because of a greater percentage of open canopied forest. For ecosystems in which woodland conditions are less common in the reference models National Forest lands are less departed from the reference than other lands. In every ecosystem, National Forest lands contain a greater percentage of late-seral and old-growth than on other lands, which led to lower departures in Rich Cove, Acidic Cove, High Elevation Red Oak, Mesic-Oak Hickory, and Spruce-Fir ecosystems.

Despite some differences in the proportion of S-classes between National Forest and other lands, the basic trend of ecological departure between land ownerships is remarkably consistent. Ecosystems that are departed on National Forest also tend to be similarly departed on other lands. Only three ecosystems differ by more than 10% in the departure metric between National Forest and Other Lands: Shortleaf Pine-Oak, Pine-Oak/Heath, High Elevation Red Oak. In Pine-Oak/Heath and Shortleaf-Pine Oak Forests, the greater abundance of early and open S-classes on other lands decreases their departure. High Elevation Red Oak Forests display a different trend. This ecosystem has large amounts of late-successional and old-growth forest in its LANFIRE BpS reference model, and National Forest lands have a much greater proportion of late-successional and old-growth s-classes in every ecosystem than do other lands.

Discussion

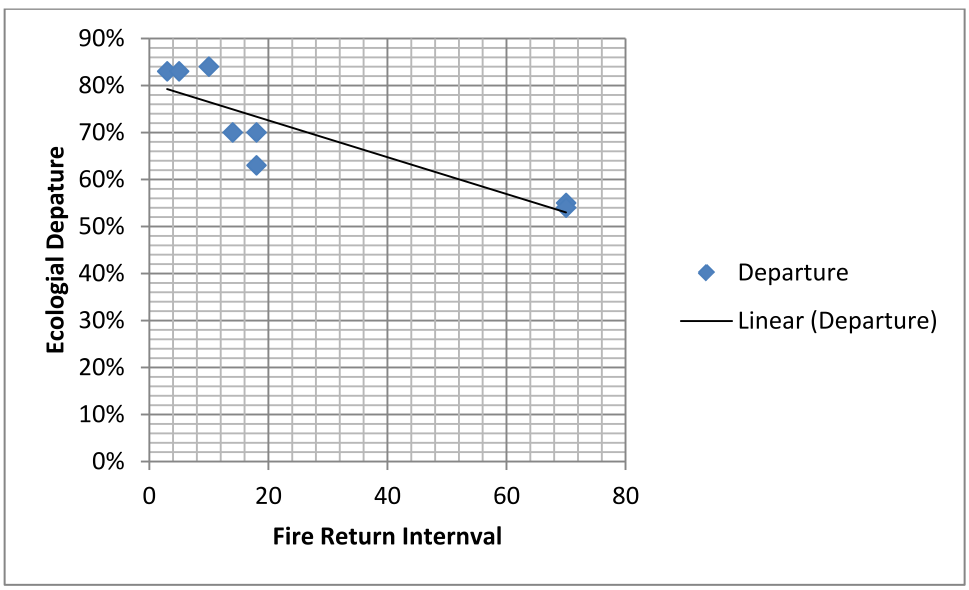
Caution is advised when evaluating the results of this study. There are several potential sources of error, the least of which are errors in LiDAR measurements. Ecological zone mapping is evaluated as no more than 80% accurate in most ecosystems, so mapping errors of ecosystem boundaries have surely occurred. National land cover data is produced at 30 meter pixel size, by far the coarsest pixel size used in this study, so it is likely that misclassification has occurred within pixels defined as forest in this study. Finally, LANDFIRE Biophysical Settings models are works-in-progress and should not be taken as absolute truth. Only the models for Southern Blue Ridge Cove Forest and Southern Appalachian Montane Pine-Forest and Woodland have had sufficient research into their ecology and historical disturbance patterns to not require further studies bolstering them. Even with the comparatively detailed knowledge of those two ecosystems, revisions could certainly be made to all models that would improve their utility and accuracy as reference conditions.

So, rather than focusing on the precision of the results of this study, it is recommended that both LANDFIRE BpS models and the results presented here be evaluated generally. For example, some readers will likely disagree that over 50% of the Mesic-Oak Hickory Forests would have been open-canopied woodlands in their Natural Range of Variation. However, most experts would agree that the 5% of open canopy present in this system on Nantahala-Pisgah National Forest is below an objective

Natural Range of Variation and that efforts should be made to increase woodlands in this ecosystem. Likewise, it is doubtful that there is consensus that 59% of the canopy space of Mesic Oak-Hickory ecosystem would be older than 130 years in age under a natural range of variation, yet it would seem that consensus among experts would be that the 9% of old-growth in this system on National Forests is far below a pre-European Settlement levels.

Identifying the overabundant/under-represented s-classes in each ecosystem is fairly straightforward; simply comparing the current condition to the reference accomplishes that. Less clear are the processes -some of them historical and some of them ongoing - that lead to ecological departure. An ecologist examining Table 3 would note that there seems to be a moisture gradient associated with the ecological departure scores, where drier ecosystems tend to be more departed than wetter ecosystems. An obvious hypothesis is that the departure of many ecological systems is due to a fire regime that is out of line with the reference. Since there is abundant evidence that fire suppression has altered ecosystems across North America, a logical hypothesis is that a lack of fire is leading to the lack of early and open S-classes in dry forests.

Figure 3: Historical fire return interval plotted vs. ecosystem departure from reference conditions for the eight most departed ecosystems on Nantahala-Pisgah National Forest.



A scatter plot of the mean fire return interval used in reference models vs. ecological departure can be used to test the hypothesis that fire return interval is associated with high ecological departure. Ecosystems with the most frequent fire return intervals are the most departed from reference condition. Fitting a line to the scatter plot, with fire return interval on the x-axis and % departure on the y-axis reveals a negative slope with increasing fire return interval. This pattern is present when plotting the eight most departed ecosystems on Forest Service land and the slope of the line only increases when all ecosystems are considered. This lends credence to the hypothesis that the high departure of the most fire dependent ecosystems on Nantahala-Pisgah National Forest is tied to a lack of fire in previous decades.

When looking at ecosystem departure on "All Lands", National Forest land and other lands have a complementary role. The increased disturbance present on other lands from human activities adds a significant component of early and open S-classes to ecosystems in which they are lacking. The markedly older demographics of ecosystems on National Forest land provide the majority of the rare and under-represented old-growth S-classes on the landscape. From this analysis, an "All Lands" approach emphasizes the importance of National Forests in providing old-growth forest structure, while other lands provide the majority of early and open structure, which unfortunately is not allocated proportional to ecosystem needs.

Table 4: Comparison of the percentage of closed-canopy forest across ecosystems vs. reference models indicates that some ecosystems, like Cove Forests are too disturbed, while several others lack disturbance

Ecosystem	National Forest Land	Other Lands	All Lands	Reference Model
Shortleaf Pine-Oak	85%	65%	74%	3%
Pine-Oak/Heath	92%	82%	87%	8%
Dry Oak Forest	88%	84%	86%	10%
Dry-Mesic Oak-Hickory	88%	78%	82%	22%
Mesic Oak-Hickory	88%	75%	86%	42%
High Elevation Red Oak	91%	84%	89%	42%
Spruce-Fir Forest	73%	73%	73%	72%
Northern Hardwoods	89%	77%	84%	89%
Rich Cove Forest*	84%	68%	75%	96%
Acidic Cove Forest*	94%	88%	91%	96%

* Mid-open S-class not modeled in this ecosystem but analyzed with LiDAR

If the percentages of early and open S-classes are compared across ecosystems, a striking pattern is recognizable (see Appendix A). Some ecosystems in which the reference models predict the least disturbance are the most disturbed ecosystems, regardless of ownership, though this pattern in especially strong outside of Forest Service ownership on "other lands". It is important to note that early and open S-classes require disturbance for their creation and maintenance, so they can be used as proxy to evaluate disturbance processes. The ecosystems predicted by Landfire BpS models to have the highest percentages of early and open S-classes are those in which fire was historically most frequent. The ecosystems predicted to have the least early and open S-classes are those that receive the least frequent fires and occupy the landforms most protected from weather events, namely Cove Forests. High elevation forests, like Northern Hardwoods Forest and Spruce-Fir Forest that experience very infrequent fire but frequent severe storm events are intermediate in the amounts of early and open S-classes predicted by reference models. In the context of Cove Forests being among the most disturbed ecosystems when looking at "All Lands", the value of the older, less disturbed Cove Forests on National Forest lands is magnified. With so little of ecosystems such as Rich Cove Forest, Acidic Cove Forest, Mesic-Oak Hickory Forest, Dry-Mesic Oak-Hickory Forest, and Northern Hardwoods Cove Forest reaching old-growth or even late-successional stage on other lands, the need to increase the amount of old-growth in those ecosystems on National Forest lands is enhanced.

When looking at xeric forests with lower economic value, a different trend emerges. Those forests are more disturbed on other lands than on National Forest Lands, likely with some benefits to those ecosystems. However, the disturbances occurring on other lands are still not sufficient to bring those ecosystems into good ecological condition compared to reference models. It is indicative of the economic incentives involved in land management that Rich Cove Forest, predicted to be the least disturbed ecosystem in reference models, is among the top three disturbed ecosystems among all ownerships, while Pine-Oak/Heath Forest with its lack of economic value is among least disturbed of all ecosystems across ownerships, despite having one of the highest rates of historical disturbance.

The lack of management occurring in systems like Pine-Oak/Heath as of 2005 is indicative of a need for change in the management of Nanthala-Pisgah National Forest. Most vegetation management under the 1994 Revised Land and Resource Management Plan focused on creating disturbance and early successional habitat through timber management. Because some of the ecosystems that require the most disturbance in the form of fire, like Dry Oak Forest and Pine-Oak/Heath Forest, have little economic incentive for timber management, they have been neglected under the priorities of the last management plan. Even ecosystems that do have economic incentives for vegetation management – like Dry-Mesic Oak-Hickory Forest, Mesic Oak-Hickory Forest, High Elevation Red Oak Forest, and Shortleaf Pine-Oak Forest – are lacking the important process of fire that influences physical structure and species composition.

Management Implications

The evaluation of the ecological departure of ecosystems in Nanthala-Pisgah National Forest has the potential to clarify the priorities of vegetation management of the forest. In the 1987 Plan, most rationales for vegetation management revolved around the creation of early successional habitat (ESH) in a system in which logging was generally the only acknowledged source of ESH. As the Forest Service has evolved over the years, there has been more openness to considering ESH created from natural disturbances but no practical way until the advent of LiDAR to measure it. The results of this study indicate that, from a vegetation dynamics point of view, most ecosystems currently have enough early development, though not necessarily sufficient levels of early successional habitat for disturbance dependent wildlife species (Litvaitis 2001). There is also concern for species composition issues due to the interruption of the process of fire in the early development that does occur in the analysis area.

This is one of the first studies that attempts to answer the questions of how much early development is currently present and what is the proper proportion of various structural and successional conditions of the ecosystems in the Southern Blue Ridge. The results of this study indicate that cove forests and economically valuable oak-hickory forests actually have more ESH than their reference models, especially when all lands are considered. As previously noted, yellow pine oriented systems do seem to lack early development and fire seems to be lacking from at least six ecosystems. The greatest lack of disturbance associated s-classes in the six most ecologically departed ecosystems is a lack of open habitat – forest structure with between 40% and 60% canopy cover.

While the exact percentage of open-habitats in oak and pine forests is far from settled, the reference models in this study indicate a minimum of 40% open habitat (High Elevation Red Oak) and up to 97% open habitat in yellow pine forests (see Appendix A). The large differences between reference and current conditions indicate that current conditions in these ecosystems are far too closed and that opening the canopy of oak and pine ecosystems by 10% through fire and mechanical means would still fall into the range of conservative managementFor the Dry Oak, Pine-Oak/Heath, and Shortleaf Pine-Oak ecosystems a conservative approach could easily be to open up 20% of the ecosystem.

Table 4: Acreage of the six ecosystems lacking open canopy structure on the Nantahala-Pisgah National Forest portion of the study area

Ecosystem	Total Acres	10% of Acres
Dry Oak Forest	~32,000	3,200
Pine-Oak/Heath	~55,400	5,540
Shortleaf Pine-Oak*	~28,700	2,870
Dry-Mesic Oak-Hickory*	~80,500	8,050
Mesic Oak-Hickory*	~146,000	14,600
High Elevation Red Oak*	~36,000	3,600

*Ecosystems with positive revenue potential

In total, 37,860 acres of National Forest within the study area could be converted to an open canopied structural condition over the next planning period under through prescribed fire, wildfire, and mechanical means. Of those acres, there are approximately 29,000 acres of potential mechanical work that could be revenue positive and help fund other programs on the forest. So, under a conservative, ecological restoration management approach, the next Nantahala-Pisgah Forest Plan could prioritize between 1,400 and 2,900 acres of commercial thinning, annually, in the ecosystems listed above in conjunction with a prescribed fire program to influence the species composition and maintain the open structure created. While this would represent an increase in the amount of logging occurring on the Nantahala-Pisgah relative to contemporary levels, there is evidence to support this activity being ecologically beneficial. The prioritization of activity by ecosystem and s-class would likewise tend to assuage groups and individuals with environmental concerns about logging on public land. The timber harvest and prescribed fire activities in these ecosystems would also likely benefit declining disturbance dependent species (Hunter et al. 2001).

It is important to emphasize that continued restoration of old-growth forests is supported by this study to an equal degree as the need for more open canopied forest. Because most ecosystems are so far below their natural range of variation for old-growth, it is recommended that all old-growth and forests nearing old-growth status, forests over 120 years of age being a possible threshold, be protected and restored on National Forest Land. Because old-growth takes so long to develop, it is important that National Forest managers be strategic when creating disturbances so that old-growth structure is not negatively impacted by management decisions.

By prioritizing vegetation management based on the needs of each ecosystem and focusing on management of ecosystems with the greatest ecological need, Nantahala-Pisgah National Forest has the opportunity to usher in an era of near consensus regarding silviculture, ecological restoration, and vegetation management of the forest. The benefits in terms of wildlife, local economic activity, maintaining traditions of woodcraft, the ecosystem services provided by the forest, and increasing the resilience of ecosystems to coming challenges would be measurable and significant.

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Appendix A: S-Class Distributions in the Ecosystems of Nantahala Pisgah National Forest

S-Class Distribution of Dry Oak Forest Compared to the Natural Range of Variation of Allegheny-Cumberland Dry Oak Pine Forest and Woodland BpS (5713170), revised 11-2012.

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-19)	5%	9%	7%	6%
Mid-Open (20-69)	1%	2%	1%	13%
Mid-Closed (20-69)	17%	13%	15%	4%
Late-Open (70-129)	2%	6%	4%	18%
Late-Closed (70-129)	66%	71%	69%	3%
Old-Growth Open (130+)	0.2%		0.1%	57%
Old-Growth Closed (130+)	8%		4%	1%

S-Class Distribution of Pine-Oak/Heath Forest Compared to the Natural Range of Variation of Southern Appalachian Montane Pine Forest and Woodland BpS (5713520)

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-15)	5%	9%	7%	12%
Mid-Open (16-70)	1%	2%	1%	25%
Mid-Closed (16-70)	15%	11%	13%	3%
Late-Open (71+)	3%	8%	6%	55%
Late-Closed (71+)	77%	70%	74%	5%

S-Class Distribution of Shortleaf-Oak Forest Compared to the Natural Range of Variation of Southern Appalachian Low Elevation Pine Forest BpS (5713530)

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-10)	10%	24%	18%	32%
Mid-Open (11-30)	2%	6%	4%	32%
Mid-Closed (11-30)	28%	27%	27%	2%
Late-Open (30+)	2%	5%	4%	33%
Late-Closed (30+)	58%	39%	47%	1%

S-Class Distribution of Dry-Mesic Oak-Hickory Forest Compared to the Natural Range of Variation of Southern Appalachian Oak Forest BpS (5713150)

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-19)	8%	14%	12%	6%
Mid Open (20-70)	1%	2%	2%	10%
Mid Closed (20-70)	17%	16%	16%	10%
Late Open (71-129)	3%	5%	5%	14%
Late Closed (71-129)	67%	62%	64%	5%
Old-Growth Open (130+)	0.2%		0.1%	49%
Old-Growth Closed (130+)	4%		2%	6%

S-Class Distribution of Mesic Oak-Hickory Forest Compared to the Natural Range of Variation of Mesic Appalachian Oak Forest BpS, created 11-2012.

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-19)	7%	14%	11%	5%
Mid-Open (20-70)	1%	4%	3%	7%
Mid-Closed (20-70)	22%	20%	21%	6%
Late-Open (71-129)	4%	8%	6%	6%
Late-Closed (71-129)	56%	55%	55%	5%
Old-Growth Open (130+)	0.5%		0.2%	39%
Old-Growth Closed (130+)	9%		4%	31%

S-Class Distribution of High Elevation Red Oak Forest Compared to the Natural Range of Variation of Mesic Appalachian Oak Forest BpS; created 11-2012.

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-19)	4%	6%	4%	5%
Mid-Open (20-70)	2%	3%	2%	7%
Mid-Closed (20-70)	17%	18%	17%	6%
Late-Open (71-129)	3%	7%	4%	6%
Late-Closed (71-129)	56%	66%	59%	5%
Old-Growth Open (130+)	1%		0.6%	39%
Old-Growth Closed (130+)	17%		13%	31%

S-Class Distribution of Acidic Cove Forest Compared to the Natural Range of Variation of Southern and Central Appalachian Cove Forest BpS (5713180); revised 11-2012

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-9)	5%	13%	9%	4%
Mid (10-99)	83%	77%	80%	29%
Late Open (100-139)	1%	1%	1%	1%
Late Closed (100-139)	10%	9%	10%	10%
Old-Growth (140+)	1%		0.6%	56%

S-Class Distribution of Rich Cove Forest Compared to the Natural Range of Variation of Southern and Central Appalachian Cove Forest BpS (5713180); revised 11-2012.

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-9)	7%	15%	12%	4%
Mid (10-99)	67%	69%	68%	29%
Late Open (100-139)	2%	2%	2%	1%
Late Closed (100-139)	21%	13%	17%	10%
Old-Growth (140+)	3%		1%	56%

S-Class Distribution of Spruce-Fir Forest Compared to the Natural Range of Variation. Central and Southern Appalachian Spruce-Fir Forest BpS (5713500)

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-35)	18%	18%	18%	18%
Mid-Open (36-65)	6%	8%	6%	11%
Mid-Closed (26-65)	36%	56%	41%	13%
Late-Open (66 +)	5%	1%	4%	0%
Late-Closed (66 +)	37%	17%	31%	58%

S-Class Distribution of Northern Hardwood Cove Forest Compared to the Natural Range of Variation of Southern Appalachian Northern Hardwood Forest BpS (5713090)

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-24)	5%	9%	7%	9%
Mid Closed (25-75)	24%	27%	26%	18%
Late Open (76+)	3%	9%	6%	4%
Late Closed (76+)	67%	55%	61%	69%

S-Class Distribution of Northern Hardwood Slope Forest Compared to the Natural Range of Variation Southern Appalachian Northern Hardwood Forest BpS (5713090)

S-Class	National Forest	Other Lands	All Lands	Natural Range of Variation
Early (0-24)	12%	9%	11%	9%
Mid-Open (25-75)	3%	4%	3%	0%
Mid-Closed (25-75)	15%	11%	14%	18%
Late-Open (76+)	3%	11%	5%	4%
Late-Closed (76+)	68%	65%	66%	69%

Works Cited

Clark, Matthew, David Clark and Dar Roberts. 2004. Small-footprint LiDAR estimation of sub-canopy elevation and tree height in a tropical rain forest landscape. *Remote Sensing of Environment* 91 68-89

Harding, D.J., Ma Lefsky, G.G. Parker, and J.B. Blair. 2001. Laser altimeter canopy height methods and validation for closed-canopy broadleaf forests. *Remote Sensing of* Environment 76: 283-297

Hopkinson, Chris, and Laura Chasmer. 2009. Testing LiDAR Models of Fractional Cover Across Multiple Forest Ecozones. *Remote Sensing of Environment* 113 (1) (January 15): 275–288.

Hunter, William C., David Buehler, Ronald Canterbury, John Confer, and Paul Hamel. 2001. Conservation of disturbance dependent birds in eastern North America. Wildlife Society Bulletin, 29(2): 440-455

Hyde, P., R. Dubayah, B. Peterson, J.B. Blair, M. Hofton, C. Hunsaker, R. Knox, and W. Walker. 2005. Mapping Forest Structure for Wildlife Habitat Analysis Using Waveform Lidar: Validation of Montane Ecosystems. *Remote Sensing of Environment* 96 (3–4) (June 30): 427–437. doi:10.1016/j.rse.2005.03.005.

Junttila, Virpi, Andrew O. Finley, John B. Bradford, and Tuomo Kauranne. 2013. "Strategies for Minimizing Sample Size for Use in Airborne LiDAR-based Forest Inventory." *Forest Ecology and Management* 292 (0) (March 15): 75–85

Kane, Van R., Jonathan D. Bakker, Robert J. McGaughey, James A. Lutz, Rolf F. Gersonde, and Jerry F. Franklin. 2010. Examining conifer canopy structural complexity across forest ages and elevations with LiDAR data. *Canadian Journal Of Forest Research* 40, no. 4: 774-787. Lefsky, Michael A., D. Harding, W.B. Cohen, G. Parker, and H.H. Shugart. 1999. Surface LiDAR Remote Sensing of Basal Area and Biomass in Deciduous Forests of Eastern Maryland. *Remote Sensing of Environment* 67: 83-98

Litvaitis, John A. 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin. 29(2): 466-473.

Lefsky, Michael A., Warren B. Cohen, and Geoffrey G. Parker. 2002. Lidar remote sensing for ecosystem studies. Bioscience52, no. 1: 19-30.

Loudermilk, E.L., W.P. Cropper Jr., R.J. Mitchell, and H. Lee. 2011. Longleaf Pine (Pinus Palustris) and Hardwood Dynamics in a Fire-maintained Ecosystem: A Simulation Approach. *Ecological Modelling* 222 (15) (August 10): 2733–2750.

Lovell, J.L., D.L.B. Jupp, G.J. Newnham, and D.S. Culvenor. 2011. Measuring Tree Stem Diameters Using Intensity Profiles from Ground-based Scanning Lidar from a Fixed Viewpoint. ISPRS *Journal of Photogrammetry and Remote Sensing* 66 (1) (January): 46–55. Marek K. Jakubowski, Qinghua Guo, Maggi Kelly, Tradeoffs between lidar pulse density and forest measurement accuracy, *Remote Sensing of Environment*, Volume 130, 15 March 2013, Pages 245-253,

Low, Greg, Provencher, and Abele. 2010. Enhanced Conservation Action Planning: Assessing Landscape Condition and Predicting Benefits of Conservation Strategies. *Journal of Conservation Planning* Vol. 6 (2010) 36—60

Martinuzzi, Sebastián, Lee A. Vierling, William A. Gould, Michael J. Falkowski, Jeffrey S. Evans, Andrew T. Hudak, and Kerri T. Vierling. 2009. Mapping Snags and Understory Shrubs for a LiDAR-based Assessment of Wildlife Habitat Suitability. *Remote Sensing of Environment* 113 (12) (December 15): 2533–2546.

Newfont, Katherine. 2012. Blue Ridge Commons: Environmental Activism and Forest History in Western North Carolina. University of Georgia Press: Athens, Georgia.

Richardson, Jeffrey J, and L. Monika Moskal. 2011. Strengths and Limitations of Assessing Forest Density and Spatial Configuration with Aerial LiDAR. Remote Sensing of *Environment* 115 (10) (October 17): 2640–2651

Simon, Steven A.; Collins, Thomas K.; Kauffman, Gary L.; McNab, W. Henry; Ulrey, Christopher J. 2005., "Ecological Zones in the Southern Appalachians; First Approximation", *Res. Pap. SRS-41.* Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 41 p

Simon, Steven A. 2011. Ecological Zones in the Southern Appalachians; Third Approximation. *Report to Nanthalal-Pisgah National Forest.*

Stephens, Peter R., Mark O. Kimberley, Peter N. Beets, Thomas S.H. Paul, Nigel Searles, Alan Bell, Cris Brack, and James Broadley. 2012. Airborne Scanning LiDAR in a Double Sampling Forest Carbon Inventory. *Remote Sensing of Urban Environments* 117 (0) (February 15): 348–357.

Suarez, Juan C., Carlos Ontiveros, Steve Smith, and Stewart Snape. 2004. The Use of Airborne LiDAR and Aerial Photography in the Estimation of Invidual Tree Heights in Forestry. *7th AGILE Conference on Geographic Information Science 19 April – 1 May 2004, Heraklion, Greece*

Vega, Cedric and Benoit St- Onge. 2009. Mapping site index and age by linking a time series of canopy height models with growth curves. *Forest Ecology and Management.* 257: 951-959.

Weber, Theodore C., and Daniel E. Boss. 2009. Use of LiDAR and Supplemental Data to Estimate Forest Maturity in Charles County, MD, USA. *Forest Ecology and Management* 258 (9) (October 10): 2068–2075. doi:10.1016/j.foreco.2009.08.001.

Wulder, Michael A., Joanne C. White, Ross F. Nelson, Erik Næsset, Hans Ole Ørka, Nicholas C. Coops, Thomas Hilker, Christopher W. Bater, and Terje Gobakken. 2012. Lidar Sampling for Large-area Forest Characterization: A Review. *Remote Sensing of Environment* 121 (0) (June): 196–209.

Zimble, Daniel A., David L. Evans, George C. Carlson, Robert C. Parker, Stephen C. Grado, and Patrick D. Gerard. 2003. Characterizing Vertical Forest Structure Using Small-footprint Airborne LiDAR. *Remote Sensing of Environment* 87 (2–3) (October 15): 171–182.

Webinar Link:
https://nethope.webex.com/nethope/lsr.php?AT=pb&SP=MC&rID=67037897&rKey=02d57cfd6f3f0e0b

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Attachment 6

Nantahala National Forest

GEORGIA • NORTH CAROLINA • SOUTH CAROLINA

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

NANTAHALA NATIONAL FOREST

By
F. W. WIESE

HIGH in the picturesque Blue Ridge Mountains, where the three States of North Carolina, South Carolina, and Georgia join, lies the beautiful Nantahala National Forest. Five hundred thousand acres in extent, the heavily forested coves and slopes, once the primeval home of the Cherokee Nation, have been purchased by the Federal Government and made into a national forest in order that its historic charm and rich resources may be conserved and developed for the use and enjoyment of the people of three converging commonwealths. It lies approximately 150 miles northeast of Atlanta, Ga., and 75 miles southwest of Asheville, N. C., and is readily accessible by railroad and improved highways. The Nantahala is noted for its scenic attractiveness, climaxed in May and June when the laurel, azalea, and rhododendron present an unrivaled wild-flower spectacle, and again in the fall when the gold and red of turning leaves set the mountain slopes blazing with color. Throughout the year its numerous waterfalls, fed by springs, remain lovely, and it is impossible to travel very far in the forest by trail or motor road without seeing one of them.

EARLY DAYS IN THE NANTAHALA AREA

Before the arrival of the white man, the Cherokee Indian Nation thrived in the primeval mountain region now known as the Nantahala National Forest. It was a storehouse from which the Indians obtained their food, shelter, and clothing. Deer, bear, turkey, grouse, quail, raccoon, and opossum were found in abundance. Large trout thrived in the swift, cold streams. The mountains formed a protecting wall from tribes of marauding neighbors and furnished the Cherokee with raw materials for implements of war and peace. The brilliant

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Lake Santeetlah.

stones he quarried were used in resplendent personal adornment. Little wonder that he relinquished this land to the white man only after a long and bitter struggle.

The first traders from Virginia came into the area between 1666 and 1676. Soon traders from South Carolina penetrated the mountain fastnesses, and trading with the Indians became an established practice. Under the treaty of May 20, 1777, the first of this rich region to be acquired by the white race was ceded to South Carolina and Georgia by the Indians. Large numbers of grants from the ceded Indian lands were issued to revolutionary soldiers by the State of South Carolina as bounties in payment for their services or to encourage their enlistment in the war between Great Britain and the United States.

Following the consummation of the treaty in 1777, endless negotiations were conducted in further attempts by the Government to acquire more land. Numerous treaties were concluded, ceding to the whites parcels of land in east Tennessee,

Primitive logging.

north Georgia, and western North Carolina, but the Indians clung tenaciously to their rich holdings in the territory now known as the Nantahala National Forest. Finally, after much negotiation and conflict, the Indians realized that they could hold out no longer, and on February 27, 1819, during President Jackson's administration, a treaty was concluded which established the crest of the Nantahala Mountains as the eastern boundary of the Cherokee Nation. It was not until 1835, however, when the main body of the Cherokee Nation was moved west of the Mississippi River, that the last of the lands was acquired by the whites. The Indians who hid in the mountains rather than leave the land of their fathers were later established on the Qualla Reservation, where their descendants live today.

The settlement of the Tennessee Valley began as soon as the Cherokees left. Cabins and houses were built which are to this day owned and occupied by the descendants of the original purchasers and settlers.

Like the Indian, the early settler obtained most of the necessities of life from the forest. It provided the material for his house and its furnishings, barns, wagons, and implements, sheltered the game which supplied his meat, and provided mast for his hogs and forage for his cattle. Homes were built of material laboriously removed from the forest; logs were hewed, shingles rived, and flooring was split from straight-grained logs by the most primitive methods. Later, small watermills were introduced, which enabled the settlers to manufacture material for use in their homes much more easily and made possible larger and better houses.

EXPLOITATION OF TIMBER RESOURCES

After the first railroad penetrated the Nantahala area in 1887, portable sawmills and bandmills rapidly appeared to harvest the rich crop of timber, and the exploitation and abuse of the forest began. The best of the timber was cut from the rich coves and the more undesirable species left standing. The cut-over areas were left to reseed and reproduce to undesirable species. Cut-over and culled areas were burned each spring and fall with the idea of improving the range for the large herds of cattle and droves of hogs that roamed the woods. The repeated burning not only killed the young trees and hollowed the bases of old timber, but it destroyed the fertile bed of leaf litter and humus in which the seed of the new crop might sprout, removed the blanket of leaves which protected the mineral soil from the sun, wind, frost, and erosion, and allowed the soil to wash down with the torrents of water from excessive rain, in some places exposing the bare rock on which nothing could grow.

WORK OF RESTORATION

In response to an insistent demand of far-sighted conservationists, the Weeks law, passed by Congress in 1911, launched the Federal Government upon a program of national-forest purchases in the East and South. The inclusion of the Nantahala region in such a program followed naturally. The

Tennessee and Savannah Rivers, two of the most important eastern waterways, have their sources in these highlands. Nowhere was there greater or more urgent need for governmental protection of the mountain watersheds against wanton timber waste, burning, and soil erosion. The work of acquiring and consolidating the Nantahala National Forest commenced promptly after the passage of the law and appropriation of funds and has gone forward steadily.

When acquired, these timberlands were generally in a low state of productivity as a result of repeated fires; the best timber had been removed from the more accessible areas without regard to the protection of young growth; and the ground had been left covered with masses of inflammable material. Unrestricted fires were resulting in soil erosion and rapid run-off after rain, which was noticeable in the flow of many streams, flood water during wet seasons, and very low water in dry weather. The bulk of the remaining timber could not be marketed because of the lack of roads and consequently had not been touched.

As soon as these timberlands were put under administration by the Forest Service, work on these unsatisfactory conditions was begun. Today they are being remedied by the application of fire-control methods, improved systems of logging, the construction of roads, and the practice of scientific forestry in developing and cutting the timber. The results of 20 years of such management are noticeable in the flow of many streams, which carry less mud and silt after rains, and in the improvement of the forested areas, particularly the increase in vigorous young growth. Examples of the latter are found in the heavy stands of young white pine in the vicinity of Highlands, N. C., and in the excellent yellow poplar reproduction in the coves and on northern exposures. Both of these species are of high timber value and are easily destroyed by fire.

SERVICE TO THE PUBLIC

The fundamental policy of national forest administration is to make the highest use of all of the resources of these areas in

the public interest. In carrying out this policy, the protection and development of the forests is so planned and executed that each resource is developed for the benefit of the public.

Originally the national forests were created to protect watersheds and to provide a timber supply, but it was soon recognized that they were valuable also for their wildlife, for grazing, and as public playgrounds. Plans now provide for the coordinated development of these resources and each particular area is devoted to the purposes it can best serve.

While timber is grown and harvested on most of the areas they are never stripped clean of forest growth. Cutting is done under scientific forestry methods which leave the younger trees to mature and a portion of the crop to provide seed for new growth. Many areas which have high recreational value are left uncut, and in some locations original timber stands are being preserved in their natural state so that people may see what our original forests looked like.

Harvesting of timber crops can be coordinated with recreational use, and this is being done on the national forests. The Nantahala National Forest, like the others, is not only being made to contribute to local industries and permanent community development, but it is also becoming a play ground where people may go and forget their business and every day troubles. In this way the national forests make the greatest possible contribution to our social and economic welfare.

FINANCIAL RETURNS

The activities of the forest from which money returns are received include timber sales, grazing, water power, and special uses, such as land rentals and mining permits. In accordance with an act of March 4, 1907, 25 percent of the gross receipts of the forest is paid to the county in which the forest land is located for the benefit of public schools and roads. An additional 10 percent is expended by the Forest Service in the construction and maintenance of roads and trails within such counties.

TREES AND FLOWERS

There are more than 100 different species of native trees alone in the Nantahala National Forest. In addition, there are hundreds of herbaceous plants and shrubs. The tree growth and plant vegetation range from the typical southern types to the northern types and form a botanical paradise, the scientific interest of which is unexcelled elsewhere in the United States.

The timber trees of importance in the Nantahala include yellow poplar, white and red oaks, hard and soft maples, white pine, pitch pine, shortleaf pine, hemlock, basswood, cucumber, and ash.

The azaleas ranging in color from white to dark orange, the rhododendron with its gorgeous blossoms, the mountain laurel, dogwood, red bud, and countless others present a spectacle when in bloom that attracts thousands of visitors each year.

Orchids, lilies, hellebores, passion flowers, cove flowers, bluets, columbines, trilliums, asters, violets, hepatica, ferns, lichens, and mosses abound in unrivaled variety and profusion. During the flowering season, the various stages of development and bloom may be noticed as one travels from the lower elevations in the forest to the high mountain peaks.

FLOWERING SEASONS

April—Dogwood (also in May), red bud, shad bush (at low altitudes).

May—Azalea (at low altitudes), yellow poplar, mountain laurel (at low altitudes), wild crab, orchids, magnolia (mountain).

Forest Service roads are well marked.

June—Rhododendron (Catawba and maximum), laurel, empresstree (Paulownia), azalea (at high altitudes).

July—Rhododendron (maximum), on Wayah Creek, Cullasaja, Highlands, Rabun Bald.

Throughout the summer months there is a wide display of the smaller flowering plants.

HOW IS THE FISHING?

The Forest Service is restocking the ideal trout streams to insure a full supply of game fish for sportsmen. A Federal fish hatchery under construction within the forest assures the propagation of rainbow, speckled, and brook trout for future stocking of the streams. Rearing pools located at advantageous positions along the streams facilitate this work.

No fee is charged by the Forest Service for the privilege of fishing within the forest boundaries, but fishermen must comply with the State and county laws governing the territory in which they are fishing. Where streams are closed to fishing, they are posted and patroled and the regulations are strictly enforced.

Fishermen should visit the ranger in charge of each district to acquaint themselves with current regulations.

HUNTING

The Forest Service maintains a staff of game experts whose duty it is to work out for each national forest a management program which will permit the best development of the wildlife resources of the area. Where certain species of animals once plentiful in the region have become rare or disappeared entirely, a condition common in the southern national forests, such species will be restocked and with reasonable protection should again become plentiful. Deer, once abundant in the Nantahala area but now depleted by hunting, should in a few years again roam the forest in large numbers.

The Wayah State Game Refuge has been established by the State of North Carolina in cooperation with the Nantahala National Forest for the purpose of providing an area in which native game animals may breed and distribute themselves naturally to adjacent areas. Deer, wild turkey, ruffed grouse, fox, gray squirrel, quail, and wildcat may be found throughout the forest.

Hunting is governed by State and county laws in the same manner as is fishing.

CAMPGROUNDS AND PICNIC AREAS—LOCATION

The Nantahala National Forest offers campgrounds and picnic areas for free public use. Sanitary facilities, pure, protected water, fireplaces, firewood, and tables are provided. The only conditions imposed upon the users are that they comply with the common sense sanitary and fire regulations posted in each area. Leave the campgrounds the way you would like to find them, and be sure your camp fire is really out.

Arrowood Glade.—Wayah Bald Road. Picnic use only. Near Franklin, N. C.

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Gorge Dell.—United States Highway 19 in Nantahala Gorge. Picnic use only.

Van Hook Glade.—United States Highway 64, near Highlands, N. C. Camping and picnicking.

Warwoman Dell.—Clayton-Pine Mountain Road near Clayton, Ga. Picnic use only.

Buck Creek Glade.—United States Highway 64. West of Franklin, N. C. Camping and picnicking.

MOUNTAINEERING

A network of excellent trails embracing many points of interest in the Nantahala National Forest offers opportunities to the devotees of strenuous and continuous foot travel in the mountains. Primitive wilderness areas, spectacular waterfalls, and rugged mountain peaks provide diversified scenic attractions.

The Appalachian Trail passes through the Georgia and North Carolina portions of the Nantahala National Forest along the crest of the Blue Ridge, Nantahala, and Snowbird Ranges and traverses some of the most interesting mountain peaks in the forest—Standing Indian, Wayah Bald, Wesser, Burningtown, and Tellico Bald.

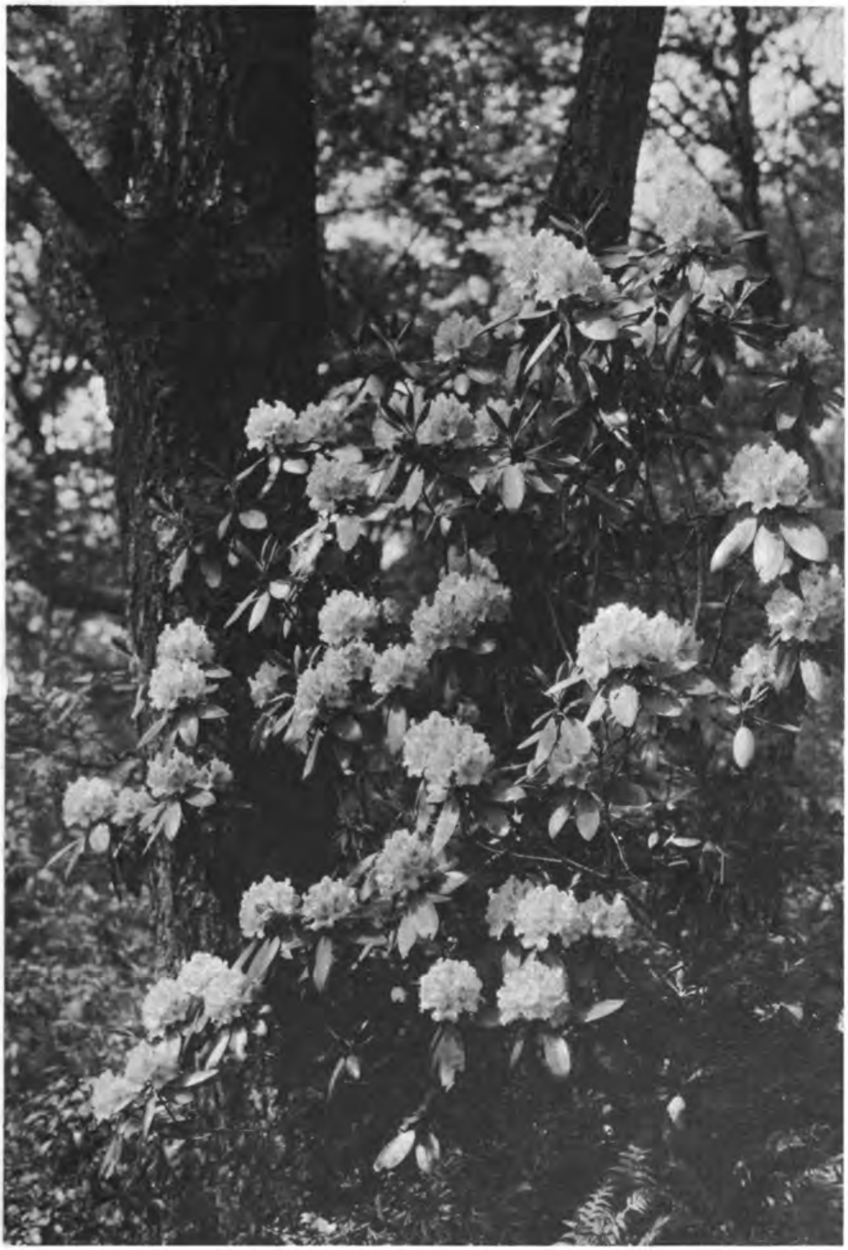
Standing Indian, in North Carolina, with an elevation of 5,500 feet, also may be reached from the Georgia side by a trail up the Tallulah River.

Rabun Bald, in Georgia, affording excellent views in the forest at an elevation of 4,750 feet, may be reached by a Forest Service trail near Clayton, Ga., or a short trail branching from the Dillard-Highlands Road.

Whiteside Cliff, with its spectacular cliff and panoramic view of the Bull Pen Valley, may be reached over the Kelsey Trail from Highlands, N. C.

Big Stamp Knob, near Andrews, N. C., is accessible by a trail up McClelland Creek.

Pickens Nose, an inspiring spectacle of jagged rock, is reached by Betty's Creek Road from Dillard, Ga., and by a foot trail.



Standing Indian Mountain is a favorite haunt of the purple rhododendron.

Yellow Mountain, elevation 5,145 feet, reached by Yellow Mountain Trail from the Buck Creek or Highlands Road in North Carolina.

POINTS OF SPECIAL INTEREST

In North Carolina: Cullasaja River Gorge, Nantahala Gorge, Wayah Bald, Satulah Mountain, Whiteside Cliff.

In Georgia: Pickens Nose, Glassy Mountain, Lake Nacoochee, Rabun Bald, Tallulah Gorge.

In South Carolina: Round Mountain, Fish Hatchery, Blue Ridge Tunnel, Tomasse Falls.

The recreational attractions of the Nantahala National Forest include camping, boating, fishing, bathing, hiking, horseback riding, and motoring.

All of the natural attractions of the forest cannot be seen and enjoyed in one short stay. The settlements nestled back in the mountains, the large areas of unbroken timberland, remote

Keeping the lonely watch for fires on Round Mountain.

The Wayah Game Refuge protects numerous deer.

waterfalls, and enticing streams and mountain peaks offer much of interest to those who enjoy exploring off the beaten track.

MOTOR ROUTES THROUGH THE NANTAHALA

The Nantahala National Forest is accessible by the following highways: North, U. S. Highway 19; east, U. S. Highway 64; south, U. S. Highway 23; and west, U. S. Highway 76. These routes, which are all-weather highways, traverse the forest through some of the best scenery it has to offer.

U. S. Highway 64 follows the course of the Cullasaja River and affords fine views of the deep gorge and spectacular waterfalls. A trail from the road to Dry Falls has been constructed by the Forest Service to a ledge of rock beneath the brink of the falls where one may view the gorge below through the sparkling sheet of water. On this route also is the Van Hook Glade, in the shade of towering white pines, an ideal spot for a picnic or for pitching a tent.

The road winds under Bridal Veil Falls and past Lake Sequoyah, named after the originator of the Cherokee alphabet, to what is said to be the highest incorporated town in the East, Highlands, N. C. From this town extensive tours may be arranged on foot or by automobile to Rabun Bald, Satulah Mountain, Yellow Mountain, Whiteside Cliff, the Bull Pen, or Horse Cove, and other points of interest.

U. S. Highway 19 connects Bryson City and Andrews, N. C., and winds through the famous Nantahala Gorge. Along this route exceptional vistas of the Great Smoky Mountains and the gorge may be obtained. Side trips may be made to the Winding Stair Road, a Forest Service development, with its breath-taking glimpses of the gorge below, to Lake Santeetlah nestled at the foot of the Snow Bird Mountains, to the marble quarry at Marble, and to Big Stamp Tower up McClelland Creek. A picnic area has been laid out by the Forest Service in the Nantahala Gorge. Here under a variety of more than 20 different trees typical of the northern and southern forests with a profusion of naturally established shrubs and flowering plants, one may enjoy a luncheon beside the swift moving waters of the Nantahala River.

U. S. Highway 23 is the main route from Asheville, N. C., to Atlanta, Ga., and divides the forest in a northern and southern direction. This road crosses Rabun Gap, the divide between the watersheds of the Tennessee and Savannah Rivers, and passes the famous Tallulah Gorge. From the road side trips may be made to Lakes Rabun, Nacoochee, and Burton in Georgia, with their established tourist and summer home facilities, to Glassy Mountain by motor road for a vista of Lake Burton; to Highlands by the Dillard-Highland Road, to Pickens Nose by the Betty's Creek Road from Dillard, or to the Warwoman Dell on the Warwoman Road from Clayton, Ga., with its facilities for picnicking. Here a bit of history is perpetuated by the nature trail on the bed of the historic Blue Ridge Railroad right-of-way.

U. S. Highway 76 and U. S. Highway 64 connect Greenville, S. C., with Highlands, N. C., and furnish a contrast of views from the Piedmont Plateau to the Blue Ridge. A side trip may be made from Highlands to the old railroad tunnel near Wal-

Fishing streams are constantly being improved.

Bridalveil Falls on the Cullasaja River Road.

halla, completed solely by hand labor during the old slave days, to the Federal fish hatchery near Mountain Rest; or to the rough, picturesque country in the Bull Pen section.

FOREST SERVICE ROADS

In addition to the State and Federal highway system, the Nantahala National Forest has developed within its boundaries over 200 miles of improved roads. This auxiliary road system, constructed as a means of fire control, leads the traveler away from the beaten path to intimate glimpses of virgin timber, remote waterfalls, the homes of mountaineers, and to the secluded retreats of wild animals and deep pools harboring rainbow and speckled trout.

The following roads will attract all lovers of outdoor life:

The Wayah Bald Road, 4.7 miles southwest of Franklin off U. S. Highway 64. This is a scenic mountain drive and leads to Arrowood Glade with its picnic facilities and rearing pools, the Wayah Game Refuge, the Wayah Bald tower with its panoramic view of four States, and the Winding Stair portion of the road which terminates in the Nantahala Gorge on U. S. Highway 19.

The Dillard-Highlands Road, which connects U. S. Highway 23 at Dillard, Ga., with U. S. Highway 64 at Highlands, N. C., winds through a mountainous country and presents a variety of vistas of waterfalls, including Glen Falls and Middle Creek Falls, and makes accessible the swift trout streams of the area. Rabun Bald, affording a panoramic view of three States, is accessible from this road.

The Bridge Creek Road, which branches from U. S. Highway 23 at Tiger, Ga., leads to the beautiful lake region of the forest. The road to Glassy Mountain Lookout, a branch

of this forest road, furnishes an excellent view of the lakes below, nestled at the foot of the Blue Ridge Mountains.

The Lake Rabun Road from U. S. Highway 23 at Lakemont, Ga., leads to many interesting drives along the shores of Lake Rabun, Lake Burton, and Lake Nacoochee. Facilities for boating, swimming, fishing, and overnight stops are available.

The Pine Mountain or Warwoman Road, east of Clayton, Ga., leads to a delightful scenic section of the forest. Warwoman Dell, equipped with picnic facilities, is just off this road. The historic tunnels and masonry work of the Blue Ridge Railroad constructed in ante-bellum days, Pine Mountain, once the center of a gold rush, and the headwaters of the Chattooga River are all accessible from this road. Numerous natural camp sites are available along the way.

Wade Hampton Memorial Highway from Mountain Rest in South Carolina through the Bull Pen section in North Carolina to Cashiers, N. C., offers numerous scenic side trips over improved forest roads. The Federal Fish Hatchery along the Memorial Highway is of especial interest.

There are other improved roads not listed here, but they are well marked with standard Forest Service signs to guide the visitor to recreational opportunities and point the way through the forest.

WHERE TO STAY

Hotel and housekeeping accommodations throughout the forest are operated by private enterprise—in North Carolina at Franklin, Highlands, and Andrews; and in Georgia at Clayton and in the vicinity of Lake Rabun. The rates for accommodations vary according to the location and conveniences offered, but are on a reasonable basis.

HOW THE FOREST IS ADMINISTERED

The pivotal positions in each national forest are those of forest supervisor and district ranger, each forest being divided into districts for the purpose of administration. District rangers for the Nantahala are located at Clayton, Ga., Franklin, N. C., and Andrews, N. C. The forest supervisor has his headquarters at Franklin.

The keynote of national forest administration is service. Forest officers are the guardians of this great public property. Their principal functions are to protect the forest and make its resources available for the maximum benefit of the citizens of the country. No entrance fees are charged, but it is necessary for the Forest Service to impose certain requirements with regard to fire protection and sanitation. Such requirements are rigidly enforced, but their observance is clearly essential and causes visitors neither hardship nor inconvenience.

The public is invited to use and enjoy the Nantahala National Forest, and visitors will be afforded every courtesy and consideration by its officers. For additional information concerning the Nantahala or other national forests in the Southern Region, address the forest supervisor of the unit in which you are interested or the regional forester at Atlanta, Ga.

THE LEGEND OF THE BALDS

Many of the mountains, streams, and localities in the Nantahala National Forest bear the original Indian names, or are associated by name with some incident connected with the Indians or characteristic ascribed to them by the pioneers. Thus, legendary backgrounds have been built up through the years. One of the most interesting tales is that which alleges to explain the origin of the "balds", the local name for the characteristic treeless mountain tops of the Southern Appalachians. Scientists have been unable to arrive at a satisfactory explanation of why trees do not grow in these tiny isolated meadows found on the mountain tops, that afford fine, unobstructed panoramas of the surrounding country. The inability of the experts to solve this mystery so far has served to increase interest in the legendary background that has grown up around them, and one of the most interesting tales is that told by the Indians.

Countless moons ago, according to the Indian explanation, when the braves of the Cherokee Nation roamed the trails of the Nantahala and Blue Ridge Ranges, the peaceful villages were disturbed by the appearance of a terrible monster. On the shore of the little Tennessee, near the village of Nikwasi, one day this beast, with wide-spreading wings, long, sharp claws, and beady eyes, plunged suddenly from a clear sky into a group of happy children playing in the sand, seized a small child and flew swiftly away. Soon runners from other villages brought stories of similar raids and terror grew among the tribes.

In council, the leaders decided to clear the mountain tops of all timber so that the flight of the beast could be observed, and to place lookouts close enough together so that warning shouts

Old water mills never fail to attract visitors to the forest.

Delicate blossoms of the mountain laurel transform the forest in May and June.

could be passed along when the monster was sighted. After much toil and a long period of watching, the den of the marauder was located in the inaccessible cliffs on the southern side of the mountain now known as "Standing Indian." Two stalwart braves climbed the tallest hemlocks and from their tops looked down in horror upon a brood of young beasts to which the monster had been feeding the children. Hastily descending, the braves sought the elders gathered on the rocks below.

Smooth, insurmountable, perpendicular walls protected the den and the helpless warriors besought the aid of the Great Spirit. Their supplications were answered. Early one morning thunder roared from a clear sky and a bolt of lightning tore asunder the ancient cliffs. The earth trembled and weird screams were heard as the monster and its sinister brood were dashed to the valley below.

For many days the Indians offered thanks to the Great Spirit and received a promise from him that never again would the mountain tops be covered with timber in which a

similar beast might hide. And so, the Indians believe, the "balds" originated.

An interesting angle of the legend concerns Standing Indian Mountain, on top of which is a pillar of stone, a dismal figure with the traces of an Indian head discernible. One of the warriors stationed there, the story goes, fled when the bolt of lightning destroyed the monster and because of his lack of courage and devotion to duty was turned to stone by the Great Spirit.

DERIVATION OF NAMES

The names of many of the places and streams in the Nantahala National Forest are a corruption of Cherokee Indian names or have been applied by the mountaineers to describe a characteristic or historical incident which is alleged to have occurred there. A few selected derivations are listed below:

COWEE. KAWI'YI. "Place of the deer clan."

KEOWEE. KUWAHI'YI. "Mulberry-grove place."

OCONALUFTEE. EGWANULTI. "By the river."

SEQUOYAH. SIKWA'YI. Name of the originator of the Cherokee alphabet.

STANDING INDIAN. YUN'WI. TSULENUN'YI. "Where man stood."

TUGALOO. DUGILU'YI. "A place at the forks of a stream."

TUSQUITTEE BALD. TWUWA'UNIYTSUN'YI. "Where the water-dog laughed."

NANTAHALA. NUN'DAYELI. "Noon-day Sun." So-called from the high cliffs which shut out the view of the sun until nearly noon.

WAYAH. WA'YA. Wolf. An imitation of the animal's howl.

LICKLOG. A notched log used for salting cattle.

STILLHOUSE BRANCH. A moonshiners' retreat.

BALD PLACE. U'TAWAGUN'TA. A treeless mountain top.

TUTI'YI. "Snowbird place." Little Snow-bird Creek of Cheowa River in Graham County, N. C.

CULLASAGEE. KULSE'TSI'YI. "Honey-locust place." Also used as variation for "sugar." The local name has commonly been rendered Sugartown by the traders.

TALLULAH. TALULU'. The word is of uncertain etymology. The dulu'si frog is said to cry talulu'. The noted falls upon the Tallulah River are known to the Cherokee as Ugun'yi.

BLUE RIDGE. CATOOSA-YAR-LA. "Long middle" or "long divide" because it divides the waters of the east and west.

CARTOOGESHAYE. CAR-TOO-GE-CHA-CHE-YAH. "The village beyond" because the river emptied into the Little Tennessee just beyond the village of Naguessa.

THE CODE OF A GOOD WOODSMAN

1. BUILD a fire only when necessary; then build a small fire on a site near water after all inflammable material down to mineral soil has been removed from a spot 5 feet in diameter.

2. BEFORE leaving a fire, even for a short time, extinguish it with water and cover the ashes with earth.

3. DO NOT throw away lighted matches, cigar or cigarette ends, or pipe heels. Drop them in damp mineral soil. Step on them!

4. KEEP the camp clean. Where garbage pits and incinerators are not provided burn or bury all garbage and refuse.

5. DO NOT pollute the springs, streams, or lakes by insanitary acts.

6. DO NOT mutilate or destroy the trees and shrubbery or the signs and improvements.

7. DO NOT hunt or discharge firearms in the vicinity of forest camps and habitations.

8. YOU are permitted to hunt and fish on national forest land unless it is specifically closed and posted against such use, but subject to the State fish and game laws.

Information may be obtained from any forest officer

NANTAHALA NATIONAL FOREST

FOREST SUPERVISOR: Headquarters, Franklin, N. C.

RANGER HEADQUARTERS: Tallulah District, Clayton, Ga. Nantahala District, Andrews, N. C. Wayah District, Franklin, N. C.

PURPOSES: 1. To protect the watersheds of navigable streams. 2. To produce merchantable timber in perpetuity. 3. To put all of the forest resources to the best possible use for the greatest number of people.

ACCESSIBILITY: North-south, U. S. Highways 19, 23, and 129. East-west, U. S. Highways 64 and 76.

FOREST AREA: 400,000 acres.

FOREST SERVICE ROADS: 215 miles.

FOREST TRAILS: 300 miles.

TELEPHONE LINES: 444 miles.

FIRE TOWERS: 9.

PICNIC AND CAMP GROUNDS: 6.

Industries partially or wholly dependent on the forest resources: Sawmills, paper mills, tannic acid and extract plants, and power companies.

U. S. GOVERNMENT PRINTING OFFICE: 1936

MOTOR TOURS THROUGH THE NANTAHALA NATIONAL FOREST

From Franklin toward Dillsboro by U. S. Highway 23

Miles

0.7 Junction Cullasaja Road—U. S. 64. Turn right.
9.2 Buck Creek Road to Yellow Mountain Tower. Turn left.
10.5 Cullasaja Falls. Right.
15.2 Van Hook Glade, left. Camp and picnic grounds.
16.1 Dry Falls. Improved Forest Service trail to escarpment below falls. Right.
20.0 Highlands, N. C. Highest incorporated town in the East. Bridalveil Falls and Lake Sequoyah on this route.

From Clayton, Ga., toward Atlanta by U. S. Highway 23

3.3 Tiger, Ga., Bridge Creek Road, right, to Glassy Mountain Lookout Tower, and Lake Burton and Lake Nacoochee. Forest Service road.
5.4 Stonewall Creek Road, right. Large, unbroken forest area.
8.9 Lakemont, Ga., Lake Rabun Road, right, straight to Tallulah Gorge.

From Lakemont, Ga., on Lake Rabun Road (Forest Service Road)

5.6 Lake Rabun Beach. left. Beach and picnic area.
6.7 Crow Creek Road, left, to summer homesites. Straight ahead to Lake Burton, Hiwassee Road, and trail to Standing Indian Tower.

From Clayton, Ga., by Pine Mountain-Warwoman Road (Forest Service Road)

3.4 Warwoman Dell. Picnic area. Rearing pools. Proceed on this road to Pine Mountain, junction of State highway between Walhalla, S. C., and Highlands, N. C.

From Franklin, N. C., by U. S. Highway 64, West

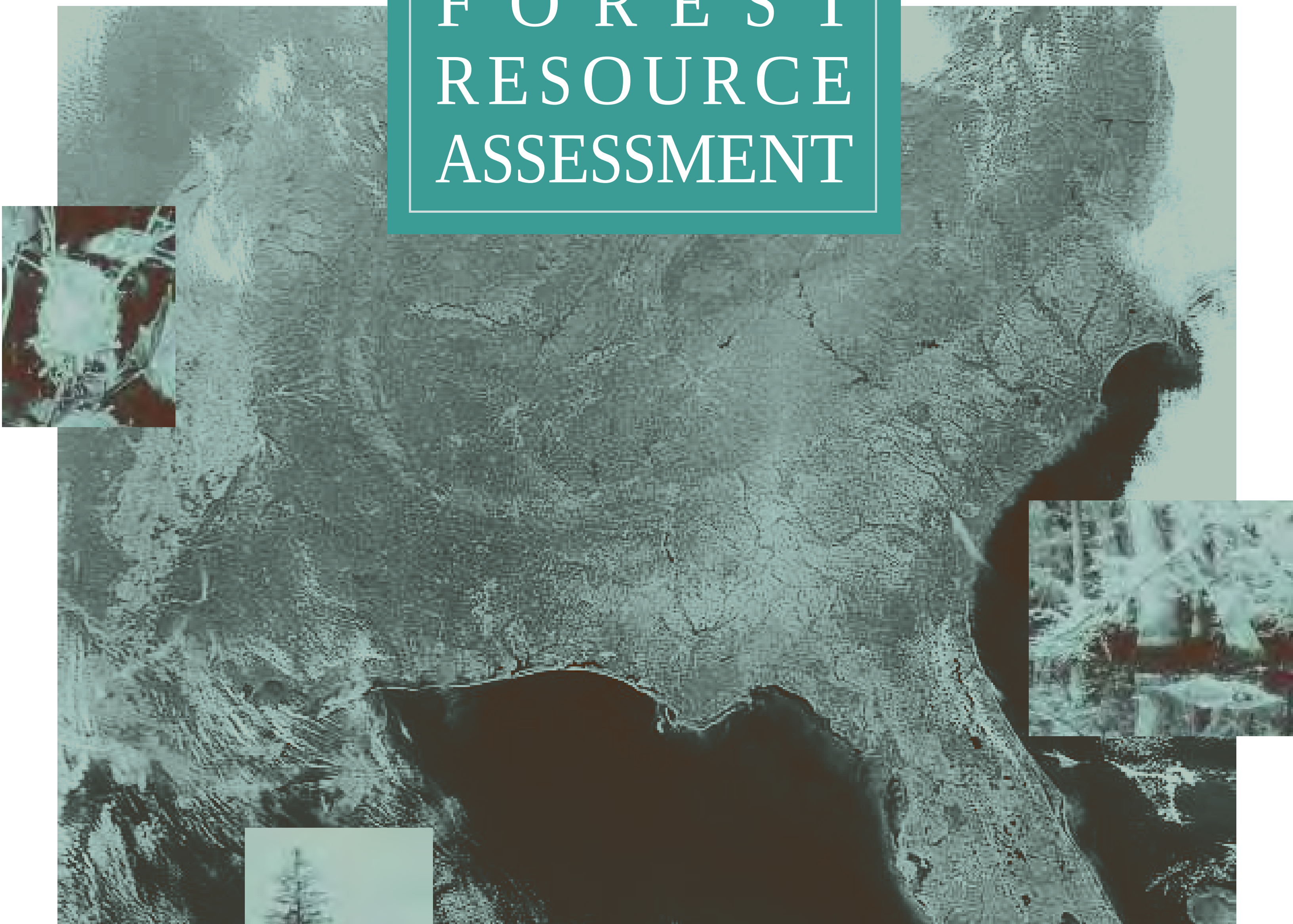
4.7 Wayah Road, right turn.
2.8 On Wayah Road, enter Wayah Game Refuge.
3.2 Enter Nantahala National Forest.
3.3 Arrowwood Glade, picnic area, right. Wayah Garage, left.
9.6 Nantahala Gap. Right turn to Wayah Bald. Left turn to camp ground.
10.6 Leave Wayah Game Refuge.
21.1 Town of Kyle.
29.5 Enter Winding Stair Road. Exceptional view of Nantahala Gorge.
32.7 Enter Nantahala Gorge. Right turn U. S. Highway 19.
38.7 Gorge Dell. Left turn public picnic area. U. S. Highway 19 leads to Bryson City and Andrews, N. C. This route affords excellent views of the Nantahala Gorge and the Great Smoky Mountains.

From Franklin, N. C., by U. S. Highway 23, toward Clayton, Ga.

0.2 Junction U. S. 64. Proceed on U. S. 23.
10.4 Buddy Gap Road, right, to Coweeta Forest Experiment Station.
14.9 Dillard-Highlands Road, left. A scenic Forest Service road.
15.9 Betty's Creek Road, right, to Pickens Nose. Forest Service road.
16.9 Rabun-Nacoochee Agricultural School. Right turn.
19.6 Rabun Gap Divide. Elevation 2,411 feet. Dividing line between the watersheds of the Tennessee and Savannah Rivers.
22.5 Tallulah Ranger District Headquarters.
22.8 Clayton, Ga.

SOUTHERN FOREST RESOURCE ASSESSMENT

■ What are the history, status, and projected future of terrestrial wildlife habitat types and species in the South? ■ What are the history, status and projected future of native plant communities in the South? ■ What are the likely effects of expanding human populations, urbanization and infrastructure development on wildlife and their habitats? ■ What are the historical and projected future impacts of forest management and access on terrestrial ecosystems in the South? ■ What conditions will be needed to maintain animal species associations in the South? ■ How have land uses changed in the South and how might changes in the future affect the area of forests? ■ What are the attitudes and values of southern residents toward forests and their management, and how have they changed over time, and do they differ by demographic groups? ■ How do current policies, regulations, and laws affect forest resources and their management? ■ What motivates private forest landowners to manage their forest land and how are their management objectives formed? ■ What role do forests play in employment and local economies in the South? ■ What are the supplies of and demands for forest-based recreation and other noncommodity uses of forests in the South? ■ How do forests and their uses influence the quality of life in the South? ■ What are the history, status and projected future demands for and supplies of wood products in the South? ■ What are the status and trends of forest management practices in the South? ■ How might existing and new technologies influence forest operations and the resultant conditions of forests? ■ What are the history, status and projected future of southern forests? ■ How have biological agents including insects and disease influenced the overall health of the South's forests and how will they likely affect it in the future? ■ How have abiotic factors, including environmental stressors such as air pollution, influenced the overall health of the South's forests, and what are future effects likely to be? ■ What are the history, status, and likely future of water quality in southern forested watersheds? ■ What are the history, status, and likely future of forested wetlands in the South? ■ How have forest management activities and other forest uses influenced water quality, aquatic habitat, and designated uses in forested watersheds? ■ What are the implementation rates and effectiveness of BMPs in the South? ■ What are the history, status, and likely future of aquatic habitats and species in the South?



About the Editors

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Cover photo: A beautiful spring day in the southeastern United States is seen in this SeaWiFS image. Several smoke plumes are visible including a rather large one that originates in Georgia, midway between the Savannah and Altamaha rivers. A good-sized plume of turbid water can also be seen flushing out of Mobile Bay. Photo courtesy of the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE.

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What are the history, status, and projected future of native plant communities in the South?

Chapter 2: The History of Native Plant Communities in the South

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Key Findings

Nowhere in America is there a greater variety of native plant communities, native plant species, or rare and endemic native plants than in the forests of the Southeast. However, this exceptional bounty of diversity is under increasing stress from habitat conversion, alterations in community composition, and exotic pest and disease species. Human activities have impacted native plant communities since the first aboriginals settled in the region, and humans are likely to remain a formative part of the southern landscape for the foreseeable future.

The human use of native plants and their communities mirror contemporary societal needs. At the beginning of the 21st century the forested plant communities of the South are producing more than ever. Although the vast majority of the region's plant communities have been altered to a greater or lesser extent, an increasingly important societal need is the conservation of natural areas and the restoration of public lands. Rare vascular plant species are not evenly distributed throughout the South. Peaks of rare species diversity occur in the Southern Appalachians, the Florida Panhandle, and the Lake Wales Ridge region of Florida. Secondary peaks of rare species diversity are located in Arkansas' Ouachita Mountains and on the Cumberland Plateau.

Introduction

Native plant communities in the South have been much studied and written about since the Bartrams explored the region in the 18th century (Bartram 1791). Bartram noted that Native Americans as well as European settlers altered native plant communities by intentional burning, land clearing for agriculture, clearcutting of timber, and introductions of exotic species from Europe and the Caribbean. The plant communities of the South were not pristine in Bartrams time, and they were not pristine when Europeans first arrived on these shores. The southern landscape had already seen 10,000 years of human history. The last 400 years, however, have brought more radical changes than any caused by Native Americans.

Todays landscape and vegetation are not only the result of a very long history of change; they are also the starting point of tomorrows vegetation. To better understand the resource at hand, it is valuable to remind ourselves of how we got here so that, perhaps, we can do better in the future. For the purposes of this Assessment, a native plant community is defined as a set of populations of plants naturally indigenous to an area that are interacting to the extent and degree that would have been observed prior to European settlement and share critical physiognomic and compositional traits.

It is somewhat arbitrary to define what is natural in terms of a pre-European timeframe, because it is impossible to separate the influences of native cultures from the historical landscape. However, even at the height of aboriginal culture in the Southeastern United States, Native Americans could not have had the impact on native vegetation to the degree that the Europeans had.

Plant communities, both native and otherwise, are defined not only by their inter- and intraspecific interactions and composition which species are present and in what numbers but also by their structure. Major structural elements include seral stage; the relative abundance, age distribution, and spatial arrangement of dominant species in each canopy layer; as well as physical metrics such as the height, size, and spatial arrangement of individuals. Natural disturbances such as hurricane blowdowns, ice storms, and drought are common events that markedly influence the structural condition of plant communities and have contributed to the perpetuation of a full spectrum of structural and seral conditions.

Methods

The literature was reviewed for information about the history of southern vegetation. There are already several reviews of this material. The better treatments of the subject include Delcourt and Delcourt (1993), Mac and others (1998), Ricketts and others (1999), and Stein and others (2000). An extensive and detailed primary literature exists on the paleobotany of the region based on palynology (the study of ancient pollen). Only a small portion of that information was used in this work, but anyone interested in further reading can consult the reviews of Watts (1980) and Delcourt and Delcourt (1998).

Results

Prehistory of Southern Native Plant Communities

Through providing an understanding of the history of native plant communities in the South, this Assessment hopes to put into context the background against which change has occurred. It is important to understand the roles that global climate change and indigenous human cultures played in shaping the plant communities that are considered native or natural today. In this Assessment, only those works that address the Quaternary, 2 million years before present (BP), and later floras are discussed. The primary focus is on the vegetation history of the Holocene, 10,000 years BP.

For the majority of the Quaternary, the climate of the Southeast has been colder than at present (Greller 1988). During this period, there were multiple continental glaciation episodes that did not affect our region directly, but nonetheless had significant impacts on the composition of our native plant communities. These glaciations have been attributed by most to Milankovitch (1941) variations in the orbit of the Earth about the sun. The components of the Milankovitch cycle are expressed at periods of approximately 100,000, 41,000, and 21,000 years (Delcourt and Delcourt 1993). The effects of each of these cycles have been correlated with the relative severity of glacial periods and the rapidity with which glacial advances or retreats occurred.

The coastlines of the Southeastern United States achieved their present approximate position and shape during the early Quaternary (Christensen 1988). Changes in sea level associated with Quaternary glaciations have profoundly affected the vegetation of the historical Coastal Plains, though due to normal coastal processes, most of the evidence of paleocoastal plant communities has been obliterated. Likewise, the major Quaternary glaciations also profoundly impacted the depositional landscape, especially in the Mississippi Basin.

The composition of native plant communities of the Southeastern United States has changed less than that of any other region in the country during the last 20,000 years (Delcourt and Delcourt 1993). This is not to suggest that plant communities in the South have been static over that period. About 18,000 years ago, at the peak of the last major glacial period, the influence of Arctic air masses and boreal vegetation extended to about 33 N. latitude, the approximate latitude of Birmingham, AL, and Atlanta, GA (Delcourt and Delcourt 1993).

These forests were dominated by various spruce species (*Picea* spp.) and jack pine (*Pinus banksiana*); fir (*Abies* spp.) was abundant in some locations. The understories of these forests were generally typical of modern spruce-fir forests, with the exception of the absence of certain prairie elements (Wright 1981). Today, jack pine is essentially limited to boreal forest types and higher elevations in New England, Wisconsin, Minnesota, and northward. Modern boreal forests dominated by spruce and fir are similarly restricted to New England and Canada.

Temperate deciduous forests dominated the landscape south of 33 N. latitude, to about 30 N. latitude, including most of the then Gulf Coast from about 84 W. longitude. The climate of this region was similar to or slightly drier than modern conditions, based on the analysis of the species present in pollen profiles collected from lake sediments deposited during this time. Oak (*Quercus* spp.), hickory (*Carya* spp.), chestnut (*Castanea dentata*), and southern pine species were abundant. Walnuts (*Juglans* spp.), beech (*Fagus grandifolia*), sweetgum (*Liquidambar styraciflua*), alder (*Alnus* spp.), birch (*Betula* spp.), tulip tree (*Liriodendron tulipifera*), elms (*Ulmus* spp.), hornbeams (*Carpinus* spp. and *Ostrya* spp.), tilias (*Tilia* spp.), and others that are generally common in modern southern deciduous forests were also common then. Pollen of members of the grass, sedge, and sunflower plant families (Poaceae, Cyperaceae, and Asteraceae) were also common in samples from this time period (Delcourt and Delcourt 1993, Greller 1988, Watts 1980).

The vegetation south of 30 N. latitude, in peninsular Florida, was dominated by sand-scrub communities with xeric pine-oak forests in the uplands. Swamps and marshes occupied low-lying and coastal areas (Delcourt and Delcourt 1993, Greller 1988, Watts 1980). The areas that were occupied by coastal marshes at that time are now submerged because sea levels during the time of peak glacial extent were significantly lower than modern levels. The sand-scrub communities still occupy significant areas of upland central Florida (Ricketts and others 1999).

During glacial periods, extensive mesophytic forest communities, similar in character and overall composition to modern lowland and bottomland forests, occurred along major river drainages, especially the Mississippi embayment, the Alabama-Coosa-Tallapoosa Basin, the Apalachicola-Chattahoochee-Flint Basin, and the Savannah River Basin (Delcourt and Delcourt 1993, Greller 1988).

From approximately 15,000 years BP to approximately 10,000 years BP there was a gradual warming trend throughout the region, but the period of 14,000 years BP to about 12,000 years BP was marked by a high degree of climatic variability, including increased seasonality and other climatic extremes (Delcourt and Delcourt 1993). By approximately 10,000 years BP, deciduous forests had expanded northward throughout the region, with pockets of boreal elements remaining only at high elevations in the Appalachian Mountains and in a few other refuges. Broadleaf evergreen and pine forests occupied an area similar in extent to what they occupy today, primarily in the Coastal Plains. Mesophytic and bottomland forest communities continued to occupy the major river drainages of the region (Delcourt and Delcourt 1993).

Although the exact date is in question, this was also the period in which humans first colonized the Southeast. Archeologists date the earliest potential human habitation at approximately 12,500 years BP. Between 12,500 and 10,000 years BP, the human population of the region is thought to have been largely nomadic and very sparsely distributed. Human influence on the regions vegetation was almost certainly trivial and highly localized.

At about this time, many large herbivores that heretofore had been common in the region went extinct (Martin and Klein 1984). Among these animals were the mastodon, ground sloth, and giant bison. In other parts of the World where large grazing animals still exist, they are known to exert a profound influence on the composition and condition of the native plant communities. Likewise, their extinction would lead to a variety of (largely unpredictable) changes. It is not clear why this guild of plant-eating animals disappeared from the region, but overexploitation by aboriginal Americans and an inability to adjust to climatic changes are most often posited. It is certain that their disappearance altered regional patterns of vegetation (Martin and Klein 1984).

At the beginning of the Holocene (10,000 years BP), the climatic conditions in the Southeast were comparable to conditions today (Delcourt and Delcourt 1993). However, the existence of modern climatic conditions does not necessarily imply the existence of modern native plant communities. Although the major modern community types were flourishing in the Southeast by 10,000 years BP, the understory flora had not yet come to resemble modern herbaceous floras. Mixed hardwood forests dominated the majority of the upper Coastal Plains, Piedmont, and lower Mountain regions. Southern pine communities dominated the middle and lower Coastal Plains, whereas evergreens and some remnant boreal elements occupied higher elevation sites. Canopy openings in the mixed hardwood and high-elevation forest regions are thought to have been infrequent and due either to local edaphic conditions or natural disturbance (Delcourt and Delcourt 1993, Watts 1980).

Evidence of human habitation in the region becomes common at about 10,000 years BP (the Paleo-Indian period), but there is little evidence that these cultures had significant or large-scale impacts on the landscape (University of Illinois 1997).

Around 8,700 years BP to approximately 5,000 years BP, a period of significant warming and drying, often called the hypsithermal period, began impacting the vegetation of the Southeast. During the hypsithermal period, extensive expansions of prairies and savannas occurred throughout the region (Delcourt and Delcourt 1993), and xeric oak and oak-hickory forest types proliferated. Many species with more northerly affinities migrated northward and, to the extent possible, upward in elevation. Given the limited heights of the Appalachian Mountains, many of these boreal elements were extirpated during this period. Others were relegated to isolated refuges (Delcourt 1979, Delcourt and Delcourt 1998). Further retraction of boreal forest elements caused a proportional increase in pine-dominated forests in the Appalachians. The hypsithermal was also responsible for the expansion of sand and scrub habitats in central Florida (Delcourt and Delcourt 1993, Watts 1971). The grasslands and savannas of the time expanded and were also linked to the great interior plains grasslands to the west of the region. As a result, elements of the prairie flora became established throughout the region, first by simple migration, but then also by invading disjunct openings (including glades and barrens) that were forming in the canopy of more mesic forests (Delcourt and Delcourt 1993).

During most of the climatic shifts of the last 100,000 years, most plant migration in Eastern North America occurred along a more or less north-south axis. The hypsithermal was significant because it made conditions favorable for the invasion and establishment of species from the center of the continent.

With the warming and drying of the climate throughout the region, species with more mesic proclivities retreated to shrinking riparian and riverine areas.

During this period, the population density of aboriginal peoples increased substantially. The hypsithermal also saw the transition from Paleo-Indian to Archaic Indian cultures. During this period, the Archaic Indians settlements and populations tended to increase in size. Archaic Indians remained; like their Paleo-Indian ancestors, they were largely nomadic but were able to remain in some areas for extended seasons by practicing more concentrated resource usage. Increased resource use was made possible by technological advances that improved the efficiency of the harvest, collection, and processing of, for example, native plant materials. More concentrated occupation had significant but still local impacts on the abundance and regeneration of tree species (University of Illinois 1997).

At the end of the hypsithermal interval, about 5,000 years BP, all of the components of the modern southern forests were in place. As the climate cooled and precipitation increased, species migrated so that communities were reassembled in new form. The boreal elements of the early Quaternary enjoyed a modest expansion. Riparian, bottomland, and wetland plant communities expanded. Grasslands and savannas contracted and retracted westward.

Within approximately 1,000 years of the end of the hypsithermal, the distribution of species within plant communities of the Southeast had more or less stabilized and would see only minor changes until the colonization by Europeans (Delcourt and Delcourt 1993).

At about 4,000 years BP, the Archaic Indian cultures began practicing agriculture throughout the region. Technology had advanced to the point that pottery was becoming common, and the small-scale felling of trees became feasible. Some of their crop plants, such as corn and squashes (*Zea mays* and *Cucurbita* spp.), were acquired through trading with cultures from the South that had a longer tradition of agriculture (Delcourt 1987). Other crop plants were selected from local natives on the basis of desirable cultivation and harvesting traits. This period also saw increasing emphasis on some forms of passive agriculture, in which existing perennial plants were cared for to increase or improve their output of desired products such as beechnuts or cranberries. Concurrently, the Archaic Indians began using fire in a widespread manner in large portions of the region. Intentional burning of vegetation was taken up to mimic the effects of natural fires that tended to clear forest understories, thereby making travel easier and facilitating the growth of herbs and berry-producing plants that were important for both food and medicines.

Approximately concurrent with the transition from the Archaic Indian culture to the Woodland Indian culture, around 2,800 to 2,500 years BP, aboriginal groups began to establish relatively large settlements. People from these settlements visited sites to exploit specialized resources such as fish, medicinal plants, and cherts. There was a trend, however, toward more permanent occupations to maintain local agricultural plots (University of Illinois 1997). It was during this time that the Mound cultures began to develop and flourish. Woodland Indian Culture evolved into the Mississippian Indian Culture in large portions of the region approximately 1,000 years BP (University of Illinois 1997). Mississippian Culture agriculture became more highly developed, and villages, both large and small, were able to support a more specialized citizenry (Delcourt 1987). Mounds became larger and more numerous, and the amount of land needed to support these populations increased. The majority of Mississippian Culture sites are associated with wetland, riparian, or riverine habitats, and these people became quite expert at altering local hydrological patterns to keep their villages dry and their fields irrigated, and to supply community water needs. In some places, soil erosion became locally significant.

Indian use of fire in land management continued from approximately 4,000 years BP to approximately 500 or 600 years BP (Adams 1992, Cowell 1998, Delcourt and Delcourt 1997). This practice significantly affected the structure of forest stands and the relative abundance of species over large portions of the region. It is not clear to what extent fire influenced the composition or richness of regional floras.

For reasons that are unclear, approximately 500 years ago, aboriginal populations declined significantly throughout Eastern North America and more broadly throughout the Americas. Most anthropologists attribute this depopulation to the transmission and spread of pathogens brought to North America by Europeans. Some communities are known to have lost 98 percent of their population; in general it seems that approximately two-thirds of the Indian population of the Eastern United States was eliminated in a very short time. As a consequence, large areas that had been cleared, burned, and farmed by native peoples were left fallow. Thus, by the time the first European observers were reporting the nature of the vegetation of the region, it is likely to have changed significantly since the regional peak of Indian influence.

A myth has developed that prior to European culture the New World was a pristine wilderness. In fact, the vegetation conditions that the European settlers observed were changing rapidly because of aboriginal depopulation. As a result, canopy closure and forest tree density were increasing throughout the region.

When Europeans started making regular visits to the New World approximately 500 years BP, and during subsequent colonization (specifically in Florida, but also shortly afterwards northward along the Atlantic coast), they also began introducing Eurasian and nonnative tropical plant species. Exotic plants first became prevalent around permanent settlements, especially along the coasts, and then spread inland along travel routes to other suitable locations.

The earliest exotic plants to become established in the region came originally as packing material (often rough hay) in shipping crates or animal bedding material. Later, food, forage, and medicinal plants were introduced in support of the settlements (Carrier 1923). The introduction of exotic animals (especially hogs, cattle, and rats) also began at this time. These animals also have had a significant and permanent impact on the vegetation of the region.

In June of 1527, a group of Spaniards, including Cabeza de Vaca, began a 10-year expedition from Florida along the gulf coast into Texas and on into the American Southwest (Cabeza de Vaca 1542). In his account of the journey, Cabeza de Vaca reported that: (1) the natives of Florida cultivated large quantities of corn; (2) palmetto was abundant and was used commonly for food, fiber, and fuel; and (3) extensive areas of heavy timber (almost certainly longleaf pine) were present with a considerable amount of large woody debris on the ground. The chronicles of other early Spanish explorers, such as Hernando de Soto and Ponce de Leon, contain similarly superficial accounts of the existing native vegetation. The first really useful and widely available information on the natural vegetation of the Southeast was not published until more than 200 years after the Spanish exploration of the region.

Southern Native Plant Communities in Historical Times

Information about the historical native plant communities of the region can be difficult to interpret. Since the modern concept of a plant community did not evolve until the late 19th and early 20th centuries, earlier writers seldom included the kind of information we would like to have for this Assessment. Also, most common paleobotany methods have limited value in the study of historical vegetation, because they have poor resolving capabilities over the relatively short period of the last 500 years. These difficulties aside, there is currently a great deal of interest in the nature of native plant communities at the time of European settlement, largely motivated by the current trend toward restoring such plant communities in the South.

Although Europeans began to explore and settle the Southeast by the mid- and late 16th century, their impact on the native plant communities of the region was limited largely to Coastal Plain, savanna, and bottomland forests. For the most part, the earliest settlements were established in coastal areas and on broad river terraces accessible by boat and barge. Even the rare interior settlements, such as the Arkansas Post established in 1686, were built along major rivers to avail themselves of local patterns of commerce. These areas were often cleared to make way for agriculture. Some of the clearings were made for subsistence farming, but the largest were made for commercial farming and livestock production. The quantity of timber taken during this time was limited both by technology and local demand. Consequently, large areas of upland forest in the South went essentially untouched until the 19th century.

The exploitation of natural resources, such as timber and forage, increased as population increased and as an industrial base was built in North America. Improved agricultural efficiency, a growing population, and better access to European markets by the end of the 18th century provided both the motivation and the capital necessary to expand the conversion of native vegetation to agriculture (Carrier 1923). People began to move westward into the interior of the region and began to clear increasingly large tracts of land. In this era of increased trade, additional exotic species were introduced to the South, and exotic plants that had become well established moved with the expanding population.

Although the Native American population had declined significantly, these people were sufficiently common in the early 18th century to exert a continued impact on wide areas of the southern landscape through their agriculture and, more importantly, their use of fire as a means of manipulating vegetation. The aboriginal practice of burning the forests was adopted by European settlers soon after permanent settlements were established.

Like the Indians, the European settlers of the interior South tended to choose specific areas in which to build homes and farms. Relatively flat topography, access to water and timber, and proximity to trade routes via waterways or overland were important criteria for settlement sites. Such places are most typically found either along the terraces of large river systems or on the Coastal Plain. Consequently, riverine forest communities and longleaf pine communities were the first natural vegetation types in the interior South to be impacted by the expansion of European settlement. However, these native plant communities had long been inhabited by aboriginal people. In some cases, the Europeans removed the Indians by force so that they could occupy their land. Europeans selected and exploited other areas on the basis of their strategic value for military outposts or their proximity to mineral resources. These areas were less common but usually had equally significant impacts on the local vegetation.

Until the 20th century, the economy of the South was based largely on agriculture. Technology changed the kinds of crops grown, especially for the export market. From the late 18th century until the early 20th century, resin extraction from pines, especially longleaf pine, for use by American and European navies shaped the management of longleaf pine forests in the Coastal Plains. The naval stores industry, based on the processed and unprocessed resin, or tar, used to seal the hulls of ships and many other things, began to decline with the development of metal hull ships at the end of the 19th century. Large farms became common in the region by the early 19th century, due in great part to technological improvements like the invention of the cotton gin in 1793. Until the beginning of the 19th century, tobacco accounted for the majority of southern exports; thereafter and well into the 20th century, mechanized cotton production dominated the South. Large tracts of agricultural land were created out of the native plant communities of the Coastal Plain where cultivation was relatively easy. This form of land use also greatly affected longleaf pine communities, as well as a wide range of hardwood communities that existed on river terraces.

Increases in farm size had the effect of concentrating economic power in the hands of relatively few established families and companies. There was little incentive for these families to develop new centers of agriculture or diversify the crops being grown. The majority of new settlements in the interior South were based either on a subsistence economy or service to relatively small areas. Certain areas were completely converted to agriculture, with permanent and deleterious implications for the native plant communities. In areas dominated by subsistence farming, less obvious impacts to the native plant communities occurred, such as the disruption of population processes caused by fragmentation, the introduction of exotic species, impacts on rare communities such as mountain bogs and glades, and widespread alterations in forest community structure related to timber harvesting and fuel-wood gathering.

There was considerable curiosity in 17th and 18th century Europe about North American ornamental and medicinal plants. In fact, most of the botanists of this time were collectors for wealthy Europeans. These botanists, however, usually did not catalog the natural resources of the region. It was left to the early 18th century botanists from the Northeast to first explore and describe the vegetation of the Southeast. Most notable among these early explorers were John (1699-1777) and William Bartram (1739-1823).

The Bartrams made several journeys of botanical exploration and collection and published accounts of the natural history of the areas that they visited. William Bartrams Travels through North and South Carolina, Georgia, East and West Florida . . . became an international bestseller shortly after being published in 1791. This success was no doubt due in part to John Bartrams reputation and to his and Williams extensive correspondence with European botanists. William Bartram states that the purpose of his trip through the South was the discovery of rare and useful products of nature, chiefly in the vegetable kingdom, and to obtain specimens and seeds of some curious trees and shrubs (which were the principal objects of this excursion).

Although Travels through North and South Carolina, Georgia, East and West Florida . . . is full of details of soil conditions in various places, lists of species encountered, and in some cases detailed descriptions of particular species, Bartram did not generally offer useful accounts of the native plant communities. He did record the occurrence of many of the broad community types we are familiar with, including forests, savannas, glades, and swamps, described in such terms as . . . expansive green meadows or savannas, in which are to be seen glittering ponds of water, surrounded at a great distance, by high open pine forests and hommocks, and islets of oaks and bays projecting into the savannas . . . .

He also noted large areas of clearcut longleaf pine (Bartram 1791, p. 312) and expansive ancient Indian fields (Bartram 1791, p. 458). Bartram was particularly interested in the agricultural potential of the South, noting not only the areas used by the aboriginals for cropping (e.g., Bartram 1791, p. 511), but also areas that would be suitable for the cultivation of European crops as diverse as olives and oranges (Bartram 1791, p. 337). He also documents the early trade in useful native plants such as ginseng (Bartram 1791, p. 327) and rosinweed (*Silphium*) (Bartram 1791, p. 398). Bartram also offers accounts of introduced species such as barnyard grass (*Echinochloa*) (Bartram 1791, p. 430) as well as a description of Franklin tree (*Franklinia altamaha*) (Bartram 1791, p. 467), a species that is now extinct in the wild. Perhaps most remarkable about the landscapes described by Bartram is that many of these places remained unchanged until the late 19th century.

Thomas Nuttall, traveling in the Arkansas Territory around 1819 (Nuttall 1821), also described what he saw in general terms: thickets of dwarf oaks, hills of pine and oak, and scattered areas of prairie. He too noted the effect of the human hand on the landscape, mentioning annual fires set by the white settlers and extensive areas of cutover pine. Nuttall cataloged many nonwoody plants as well. As was customary at the time, he did not elaborate about the specific conditions in which these plants were growing, but simply stated this or that species was growing under oaks, along streams, or high upon a hill.

Bartram and Nuttall are the most important of the early botanical explorers of the South, but their work is of limited value in determining the nature of native plant communities in existence at the time. Their approach reflected the contemporary philosophy of natural history and botany. At the beginning of the 19th century, ecology was not yet a word, much less a science. Linneaus had developed his natural classification system only a half century earlier; there was not yet a concept of natural selection or evolution, and it was a time of global exploration and discovery. All of the major seafaring European nations were establishing colonies around the World. The purpose of this exploration was the acquisition of power and wealth, and because many plants were the source of great wealth, botanists were needed to travel to unexplored parts of the World to catalog the plant life. At the time, this was called phytogeography, a term that describes the endeavor well enough. The primary concern of phytogeographers was to identify the location and distribution of plant species. While phytogeography was a necessary step in the development of plant ecology, at the beginning of the 19th century little effort was expended on describing the interrelations among the species that were being so faithfully cataloged.

After Bartram and Nuttall, a procession of botanists and naturalists, often physicians with an interest in botany, collected plants in the areas around their homes. For the most part, these collectors did not directly contribute to the understanding of the distribution of native plant communities. However, their work would become important later, in the late 19th and early 20th centuries, as regional floras for the South were developed.

In 1835, the first railroad system in the South began operating in North Carolina, in the heart of the longleaf pine forests of the Coastal Plain (Croker 1987). The industrial revolution had brought to the South the means by which its abundant forest resources could be transported great distances and still turn a tidy profit. The longleaf pine forests of the Coastal Plains were not only a source of high-quality timber for a growing population, but also the Nations most important source of naval stores. The naval stores industry began in North Carolina and spread throughout the Coastal Plains with the railroad (Croker 1987). By 1854, the railways had reached the Mississippi River.

In the mid-19th century, clearcutting was the primary logging method employed. Modern forestry, as practiced in Europe at the time, would not become commonplace in North America until the early 20th century. In the first half of the 19th century, extensive areas of forest were leveled to create pastureland. In many places the native forest has never recovered. Forested areas surrounding major river ports were extensively cut to fuel steamboats. Vast acreages of wetlands and river terraces were drained or plowed by the mid-19th century, causing significant losses to local biodiversity in some areas. Strip mining, especially for coal to stoke hungry steamboats and railroad locomotives, became commonplace where deposits were sufficiently shallow to exploit, such as the Upper Cumberland Plateau. Strip mining eliminated forest cover and frequently altered or killed riparian and aquatic plant and animal communities downstream from the spoil piles. Although much of this activity in the region slowed during the 1860s, logging resurged quickly thereafter. By the 1880s, a broad sector of Americans, mostly in the Northeast and West, were becoming concerned about the unbridled exploitation of the Nations forest and wetland resources.

The evolution of forest protection laws and the establishment of national forests in the South parallel the development of the modern conservation movement in the United States (Williams 2000). Issues such as farmland erosion, forest clearcutting, and the hyperexploitation of buffalo were on the national conscience. The first use of the word conservation in the context of the protection of natural resources was in 1875, by John Warder, president of the American Forestry Association. The leadership of Americas conservation movement was borne by Gifford Pinchot, John Muir, Charles Sargent, and Theodore Roosevelt.

The Federal Government began setting aside tracts of land as forest reserves when Congress passed the Forest Reserve Act of 1891 (Williams 2000). This legislation allowed the President to from time to time, set apart and reserve, in any state or territory having public land bearing forests, in any part of the public lands, wholly or in part covered with timber or undergrowth, whether commercially valuable or not, as public reservations . . . . Federal forest administration was consolidated under the leadership of Gifford Pinchot in 1905 with the establishment of the U.S. Department of Agricultures Forest Service (Williams 2000). The first national forest established in the South was the Arkansas National Forest (1907). Two national forests in Florida were added to the growing system in 1908 (Ocala and Choctawhatchee). Most of the national forests throughout the South are a result of the Weeks Act of 1911. This act broadened the mandate of the Forest Service and provided for the purchase of land, largely for watershed protection. From the time of their establishment until the beginning of the Second World War, the national forests of the South served primarily as conservation areas (Williams 2000). National forest lands have since been critical refuges of functional native plant communities in the South.

At the turn of the 20th century, the logging industry in the South was producing lumber at its historical peak. So much forest land had been logged out that timber companies were finding it difficult to access merchantable trees and were beginning to close mills and move to the newly opened virgin timberlands of the Northwest. Although the First World War caused a short-lived resurgence in the demand for timber and naval stores, the conversion of the shipbuilding industry to steel by 1920 caused demand for southern timber and naval stores to fall drastically. By 1930 the majority of the Coastal Plains longleaf pine communities had been essentially cut over (Croker 1987), as had the interior shortleaf pines (*P. echinatus*). Upland hardwood forests fared somewhat better, at least in some places.

After 300 years of land conversion and alien plant introduction, it is no surprise that in the early part of the 20th century exotic plant species were common throughout the region. Some had been planted purposefully as ornamentals, as forage for livestock, or increasingly as erosion control agents by State and Federal agencies. Others were simply accidental tourists that made their way across the region without the direct assistance of people, in stocks of hay or the coats of domestic animals. Palmer (1926) notes an abundance of introduced species [and] adventive woody species in the vicinity of Hot Springs, AR. He specifically noted Japanese honeysuckle (*Lonicera japonica*), Princess tree (*Paulownia tomentosa*), and many other introduced species.

Vascular plants were not the only exotic species introduced to the United States during historical times. Among the most destructive exotics were fungal pathogens of trees. Chestnut blight (*Cryphonectria parasitica*) was introduced into this country in New York in 1904. It spread rapidly and was actively killing trees in the Southern Appalachians by the 1920s. By the early 1950s, American chestnut (*Castanea dentata*) was ecologically extinct throughout its range in Eastern America. This species once was a dominant tree of Appalachian forests. In some areas, one tree in four was a chestnut. Although loss of the chestnut was significant in terms of change in forest composition, there is some disagreement about the ecological impact of chestnut blight. Only one species extinction is suspected to have resulted from the blight (American chestnut moth, *Ectodemia castaneae*); and the greatest impacts to native plant communities seem to have been a change in tree density (a temporary result of canopy gaps created by the death of chestnuts) and a realignment of dominant overstory tree species resulting from competition (Stein and others 2000, Woods and Shanks 1959). Different trees have replaced the chestnut as the dominant canopy species in different portions of the chestnuts former range.

Dutch elm disease (*Ophiostoma ulmi* and *O. nova-ulmi*) entered the United States in 1930 in logs imported from Europe. There is differential susceptibility among *Ulmus* species, but the American elm, a common street and landscaping tree, has been the hardest hit. By the late 1970s Dutch elm disease was known to have impacted elm trees throughout the country (Schlarbaum 1997).

Butternut canker (*Sirococcus calvigigenti-juglanacearum*), which impacts *Juglans cineria*, was first observed in the United States in 1967, but it is believed to have been infecting trees for many years by that time. By 1995, the USDA Forest Service estimated that over three-quarters of all butternut trees had perished from the disease (Schlarbaum 1997).

There have been many other exotic disease-causing fungi and insects that have had significant impacts on the native plant communities of the South. Examples include white pine blister rust (*Cronartium ribicola*), the gypsy moth (*Lymantria dispar*), and the balsam wooly adelgid (*Adelges piceae*). Many introduced disease organisms are still impacting our native plant communities, and it is likely that new pests will be periodically introduced to our region. No one can tell what damage they might bring in the future. For a more thorough discussion of the impact of exotic diseases of forest trees, see chapter 17 of this report.

The study of the flora of the South was in some respects dependent on the publication of local and regional floras. Improvements in the knowledge of the botany of the region required these tools. Several local floras had been published for portions of the South, including Walters Flora Caroliniana (1788), Mohrs Flora of Alabama (1901), and Gattingers Flora of Tennessee (1901). The first comprehensive flora of the Southeast was published in 1860 by Chapman. It was an important though incomplete work. Unfortunately, it seemed to stifle further serious assessments of the local flora of the region until the early 20th century. It was not until 1903, with the publication of Smalls Manual of the Southern Flora, that the region had a comprehensive, systematic flora. Revised in 1933, Smalls Manual is a monumental work of 1,500 pages and was the standard of southern botany floras for over 50 years (Reveal and Pringle 1993). The last 20 years have seen the development of several important new floras [e.g., Smith (1994) and Wunderlin and Hansen (2000)].

The lack of specific information about native plant communities in the South from settlement times to the end of the 19th century is the product of two conspiring circumstances. First and foremost, the Southeast has been continuously occupied for longer than any other region of the United States: by the early 19th century, when the Nation became interested in its natural resources, the focus was on the wild and unknown West rather than the familiar South.

Secondly, the development of plant ecology as a modern science took place largely in Europe beginning in the early and mid-19th century. There and then the concepts of succession and plant associations were first developed into forms recognizable today. However, at the time, the study of plant ecology was a subdiscipline of plant geography. Plant geography, the description of the distribution of plants, was the primary concern of European academics, capitalists, and naturalists. In the 19th century, naturalists from many nations were traveling around North America cataloging plants. The pinnacle of plant geography studies was reached in the early 20th century and coincided with the rise of the modern study of plant ecology. The earliest focus of the fledgling field of ecology was the study of plant community succession. That research was done in the midwestern plains and eastern forests.

Henry Cowles first described the dynamic (changing) nature of vegetation. Prior to Cowles, plant geographers were content to map the current condition and extent of vegetation. Many of Cowles students went on to make important contributions to the study of succession throughout North America. E. Lucy Braun became renowned for her descriptions of virgin forests in the Eastern States, especially the

Appalachian Mountains. Her work is still read and used as a reference.

Fredrick Clements was arguably the first community ecologist in America. Working largely with prairie and old-field communities in the Midwest, Clements described much of the vegetation of North America, named many plant associations, and identified successional stages for his named communities. He described the plant community as a form of superorganism to indicate his perception of the interdependence of all of the parts of a community, and he described succession as the development or life cycle of the organism.

Clements notion of the superorganism was not universally accepted. In 1926, Henry Gleason, who conducted his research in forested communities similar to those common throughout the South, wrote an influential paper that criticized Clements views and posited that the nature of plant associations is determined by the individualistic behavior of plant species. Gleasons individualistic notion of plant communities eventually won out over Clements idea of the superorganism.

The complexity of southern forest plant communities hampered the development of a comprehensive and consistent community classification system, such as those developed early in the history of land management in the Midwest and West.

Beginning with the study of plant succession in the first quarter of the 20th century, a practical science of plant and community ecology evolved. From this point forward meaningful data became available about the nature of native plant communities. However, because the South had been settled for centuries, by the early 20th century, vast tracts of native plant communities had been converted, planted, logged over, infested with weeds, or otherwise impacted, so opportunities to study intact native communities were rare.

The Great Depression of the early 1930s was exceptionally difficult for the people of the South, but it did a lot for the native plant communities of the region. The Federal Government purchased land and established many national forests. The Civilian Conservation Corps (CCC), established in 1933 during the Franklin Roosevelt administration, did extensive reforestation in the South. The formal teaching of forest sciences in the United States had finally matured by the 1920s and 1930s, so that an abundance of well-trained foresters working for the USDA Forest Service, State forestry agencies, and the CCC itself were available to supervise and direct the work (Williams 2000). The fledgling USDA Forest Service was working to control unauthorized timber cutting on Federal land. Unfortunately, this was also the time in which widespread fire suppression activities began. Although this practice was well intentioned at the time, it eventually led to significant declines in native plant communities throughout most of the Southeast.

The timber industry in the South remained depressed until the outbreak of the Second World War. At about the same time, serious scientific research was started at government and university labs to increase the productivity of forest land. Much of this work focused on the development of improved tree selections and cultivation practices. One of the innovations that arose was the growing of pines in plantations.

Plantation cultivation of pines turned out to be exceptionally productive. Newly developed tree selections thrived in the prepared conditions of the plantation. Large tracts of cutover land, especially in the Coastal Plain and Piedmont, would eventually be converted to pine plantations. This method focused timber production on developed sites. Although those sites were forever altered, this intensive form of silviculture saved many acres of native forest from more traditional timber harvesting.

The next large threat to native plant communities in the South came from another, unlikely advancement in technology. From the time of settlement the South was largely rural, agrarian, and sparsely populated. The widespread availability of air conditioning in the 1950s and 1960s made living and conducting business much easier in the sweltering heat of southern summers. The South, therefore, began to see significant increases in immigration and urbanization. Land was developed, and large tracts were fragmented. These trends led to rapid increases in demand for building materials, electricity, and additional agricultural production.

Improvements in technology and mechanization (especially in agriculture) and decreasing Federal commodity price supports led to significant consolidations in the timber and farm industries. Former farmers migrated to cities in the North and South. In the 1940s, 42 percent of the population in the South lived on farms. By the 1950s, only 15 percent of southerners lived on farms. The majority of the population of the region became isolated from the landscape, forever changing the way southerners viewed their forests.

After the end of the Second World War, pine forests in the South, including those on State and Federal land, were predominantly managed for timber production. The birth of the modern conservation movement in the 1960s came, in part, as a reaction to concerns about public land management priorities and the lax enforcement of environmental laws.

The Current Condition of Native Plant Communities in the South

Ecosystems In the Southeastern United States, interacting aggregations of plant and animal communities and the abiotic factors affecting them are as diverse as any in the World. No place in North America has more diverse forests in terms of plants or animals, or more different types of forests. One very important source of this diversity in plant communities in the Southeast is the exceptionally high degree of endemism (occurrence restricted to a particular region or area) in the regional flora, especially in Coastal Plain conifer forests and in Appalachian forests.

In contrast, the South has the greatest absolute number of introduced plant species in North America. Florida alone reports 800 introduced species existing outside of cultivation (FLEPPC 2001).

One of the most important tools in the study of any system, including plant communities, is a comprehensive means of classifying the observed diversity. Several large-scale vegetation classification methods are in current use; the most important are those described by Kuchler (1985), Bailey (1994, 1998), and The Nature Conservancy (TNC) (1999). Each of these systems divides the region on the basis of either general physiography or potential natural vegetation. Although many other methods exist, these methods illustrate the basic philosophies of large-scale vegetation classification. Although most vegetation classification systems are in agreement on the general distribution of regional plant communities, there is still much discussion and continuing research concerning how to define the transitions between vegetative communities.

Small-scale community classification can be generally useful in understanding the dynamics of local vegetation. Hierarchical and geographically comprehensive systems such as TNCs National Vegetation Classification System (Anderson and others 1998, Grossman and others 1998) define literally thousands of plant associations based on the presence of dominant and associated species. The utility of this system (and similar systems) is its inherent flexibility.

One of the most useful qualities of TNCs National Vegetation Classification System is the assignment of rarity ranks to plant communities (Association for Biodiversity Information 2001). A comprehensive system of rarity ranks across the Nation allows for an assessment of the geography of community diversity.

According to TNC figures, the Southeastern United States has the highest number of endangered ecosystems of any region of the country. More than 30 percent of all natural plant communities throughout the Southeast are critically endangered, and the Southeast has the highest proportion of imperiled plant communities in the United States, exclusive of Hawaii (Stein and others 2000). A great number of the rare plant communities in the Southeast are inherently rare, and their rarity is a function of the great plant diversity in the region. However, the majority of rare communities in the Southeast are rare because of habitat alteration or degradation.

The majority of inherently rare plant communities are relatively small patches of plants in unique combinations, often due to the presence of equally rare edaphic conditions. These patch communities can be seen as occurring within a matrix of more common, widespread community types. Most habitat conservation activities tend to focus on the patch habitats.

Because there has not been a single consistent convention for the identification of plant communities during the majority of the history of the Southeast, it is essentially impossible to discuss the specific changes to those plant communities over time. However, this is not to say that we cannot assess the overall trends in conditions of plant communities. On the basis of conversion, alteration, and impedance of function, more than 99 percent of all plant communities in the South are not in the condition they were in prior to European settlement. Some of these changes have been subtle, but most are readily distinguishable. It is impossible from the perspective of current times to know precisely what has been lost, but we can estimate the general loss sustained by southern native plant communities.

Among the communities to have seen the greatest change in historical times are the regions forests. All of the forests of the South have been touched, directly or indirectly, at one time or another, by the hand of humanity. Sometimes that hand has been gentle, but in most cases it has not.

By some estimates, all of the upland hardwood forests of the Appalachians have been altered. The hardwood forests have suffered from chestnut blight, Dutch elm disease, and butternut canker. Even if the impact of disease is discounted, less than 10 percent of the original native forest area of the region has not been eliminated or altered. Most was cleared prior to the 1930s. Estimates vary from State to State, but, on average, approximately half of all presettlement hardwood forest has been eliminated (Walker and Oswald 1999), and the majority (essentially all) of what remains is compromised by fragmentation, exotic pest and disease organisms, and altered natural processes such as fire and livestock grazing (Mac and others 1998, Noss and others 1995).

Coastal Plains longleaf pine forests, renowned for their high levels of diversity, endemism, and species rarity, have been reduced by more than 98 percent, compared to presettlement conditions. Most have been converted to agriculture or pine plantations, two plant communities notable for their lack of diversity, endemism, and species rarity. Most of the longleaf pine forests were cut by the 1920s, but longleaf pine habitat was still being clearcut and converted into plantations in the 1980s (Noss and others 1995, Stein and others 2000). They were used as a source of timber since aboriginal times, but European settlers were clearcutting vast areas of longleaf pine by mid-18th century. Longleaf that was not cut for lumber was commonly used as a source of naval stores beginning in the 17th century, a practice that continued into the early 20th century (Croker 1987). The remaining large blocks of longleaf exist almost exclusively in public forests (notable privately owned large tracts of longleaf include the Moody tract in southern Georgia and Green Swamp in North Carolina). Many areas of longleaf forests are being managed for the endangered red-cockaded woodpecker. Remaining blocks are, in some places, threatened by exotic plant species, such as Cogon grass (*Imperata cylindrical*), fire suppression, and some forestry (site preparation) practices that disturb the forest understory plants, in lieu of burning, to facilitate the growth of the trees. There is also much concern, but little that can actually be done, about the fragmentation of the original longleaf community (Croker 1987). Only minor fragmentation agents, such as roads, can be managed to increase longleaf habitat continuity, whereas the major fragmentation factors conversion to agricultural and urban land uses are essentially intractable. Many public land management agencies are currently practicing longleaf forest restoration activities, and others are encouraging restoration on private land. These efforts, while very important, vary greatly in their success. While it is relatively simple to successfully grow longleaf pine, the reconstitution of the original plant community is very difficult.

Fewer than 50 percent of the presettlement spruce-fir forests still exist in the Appalachians (Noss and others 1995). Of that quantity, more than 98 percent either have been altered or are under attack by introduced pests. Over 90 percent of the red spruce forests in central Appalachian forests have been lost (Noss and others 1995).

Approximately 90 percent of the forested habitats in Florida have been altered or eliminated, including 60 to 75 percent of the forested uplands of Lake Wales Ridge, an area of exceptionally high species rarity and endemism. Only on the Atlantic and Gulf coastal barrier islands does a majority of the natural forest cover remain. It has survived due to its isolation and unsuitability for agriculture or development (Noss and others 1995, Stein and others 2000).

More than 98 percent of the presettlement old-growth forests in the South have been altered or lost (Stein and others 2000). The vast majority of the remaining old-growth forests in the South are on Federal land in national forests and national parks. Of the original 60 to 90 million acres of Coastal Plain pinelands, only 3 percent survive today as old growth (Croker 1987, Noss and others 1995, Walker and Oswald 1999). Less than 2 percent of the forests in Kentucky have old-growth characteristics (Noss and others 1995). In Tennessee, only about 5 percent of the presettlement old-growth forest on the Cumberland Plateau remains, and no more than 20 percent of the forest of Tennessees Blue Ridge Province can be classified as old growth (Noss and others 1995). Those few tracts of old growth not on public land are mostly in fragments of 100 acres or less, which reduces their value (Stein and others 2000). Most of the forest types classified as old growth today are actually second- or third-growth forests that have or are developing the structural characteristics of old growth.

Open habitats in the South such as glades, barrens, and prairies were common at the time of European settlement, as noted by the earliest travelers to the region. There are, however, no good estimates of how much of the landscape was occupied by these open areas. The current best approximation suggests that as much as 10 percent of the plant communities of the South were historically open habitats (Mac and others 1998). Today, approximately 1 percent of the forested landscape of the South is occupied by openings such as barrens, prairies, and glades. In most cases these areas are very small, and they are not integrated across the landscape (Mac and others 1998, Stein and others 2000) as they once were.

Among open habitat types, prairies seem to have suffered the greatest losses. Settlers saw these relatively flat, treeless, and fertile areas as productive and easy to clear. In Kentucky, less than 200 acres of an original 3 million acres of native prairie remain (Noss and others 1995). In Texas, Louisiana, Florida, Mississippi, and Arkansas, nearly 99 percent of acres originally in prairie types have been lost (Noss and others 1995).

The majority of glades that survive today tend to occur in mountainous regions that were never converted to agriculture, and they typically have very stony soil. There is no information on the total area in glades throughout the region, but estimates are that less than half of the original glade habitat in the region survives intact, and the majority of that which remains is ecologically compromised due to either the presence of exotic species or the lack of fire. In Tennessee, approximately one-half of all the area in cedar glades has been converted (Noss and others 1995). Limestone glades throughout the region have been disturbed at higher rates (Noss and others 1995), probably because they are more commonly located at lower elevations and in areas of gentler topography.

High-elevation grassy balds are mountaintop treeless areas. Although the mountains on which these open areas occur are not high enough to have alpine plant communities, various edaphic and historical circumstances have conspired to keep these areas treeless. Grassy balds tend to support herb-rich communities that require frequent disturbance (Greller 1988). Their ecological origin is still a matter of debate. About 50 percent of the area that was occupied by grassy balds in 1900 remains today (Mac and others 1998).

Almost all of the wet hardwood forests, such as those that occur in bottomlands and hammocks on the tropical Coastal Plain, have declined to approximately 20 percent of their presettlement cover (Mac and others 1998, Noss and others 1995). A slightly larger percentage of the original floodplain forests has survived (Noss and others 1995), but most of it was cleared at some time in the past and has returned to forested cover in the last century. In the last 25 years, accelerated efforts have been made to restore floodplain forest, especially in the Mississippi Valley.

The Southeast comprises only 16 percent of the land area of the lower 48 United States, but it contains 36 percent of all wetlands and 65 percent of forested wetlands. About 78 percent of all wetlands in the Southeast has been altered to some degree (Noss and others 1995).

Unique or isolated wetlands have fared worst overall. Although the Southeastern United States has the highest diversity of carnivorous plants in the World, the habitat in which these plants occur has declined by approximately 97 percent. Reed wetlands, known as canebrakes, have been reduced by more than 98 percent (Mac and others 1998). Mountain bogs, especially those in the Southern Appalachians and Blue Ridge, are home to a great variety of unique native plant species. Although approximately 10 percent of these bogs remain, few are in fully functioning ecological condition (Mac and others 1998).

Pocosins, upland wetlands that occur on the Coastal Plain, have been reduced to about 20 percent of their original area (Mac and others 1998, Noss and others 1995). Similarly, only about 10 percent of the original Atlantic white-cedar forests, which require frequent, low-intensity fires and are typically only seasonally wet, are left (Noss and others 1995).

Table 2.1—Percentage of wetland acres lost in Southeast, 1780s through 1980s

State	Loss
	Percent
Alabama	50
Arkansas	72
Florida	46
Georgia	23
Kentucky	81
Louisiana	46
Mississippi	59
North Carolina	49
Oklahoma	67
South Carolina	27
Tennessee	59
Texas	52
Virginia	42

In the early 1600s, there were approximately 220 million acres of wetlands in the lower 48 States (Mitch and Gosselink 1993). Nationwide, over one-half of wetland acres have been converted to other uses. The degree of wetland loss has been less on the Coastal Plains, thanks in part to restoration and conservation activities that began in the 20th century. Today, only 28 percent of Coastal Plain wetlands have been permanently converted (Noss and others 1995), but a significantly higher proportion have been impacted by human management and exotic plant species.

The degree of loss of wetlands varies widely among States within the South (table 2.1) and is complicated by the large-scale alterations of wetlands and hydrology conducted by humans. Countless acres of wetland have been drained either for agriculture, pasture, or urbanization, and countless other acres were lost during stream channelization, diking, or deforestation (Mac and others 1998, Mitch and Gosselink 1993, Noss and others 1995). The rate of wetland conversion was greatest (Mitch and Gosselink 1993) from the 1950s through the mid-1970s. Since the 1970s the States with the greatest rate of wetland loss nationwide are all in the South: Arkansas, Florida, Mississippi, North Carolina, and South Carolina (Mitch and Gosselink 1993).

The condition of the native plant communities discussed in this chapter is reflective of the condition of the majority of native plant communities in the South. In fact, it is exceptionally rare to find pristine plant communities. Even the most remote places have been affected by invasive exotic plants, introduced disease organisms, changes in community structure and function stemming from altered fire and hydrological regimes, and even changes in the local seed- and pollen-dispersing animals.

Rare Plant Species in the Southern Region

Plant communities, whether rare or common, comprise species that share similar ecological needs and tolerances. The diversity of plant species in the South is rivaled in North America only by the California flora. This diversity is due in part to a broad array of species that are either highly localized in their distribution or are very sparsely distributed over large areas.

Two widely accepted classes/categories of plant species endangerment are protected under the Endangered Species Act of 1973 (ESA); and TNC has commonly used the category of imperiled species (Association for Biodiversity Information 2001).

Within the Assessment area, approximately 115 plant species are listed as either threatened or endangered under the ESA (U.S. Department of the Interior, Fish and Wildlife Service 2001). Of this number, 52 occur in Florida. Those species are clustered in the Appalachicola and Lake Wales Ridge areas. The Southern Appalachians contain the next greatest concentration of threatened and endangered plant species.

Figures 2.1 and 2.2 show the distribution of rare plant taxa in the South by equal-area hexagons and counties, respectively. These maps were derived from data held by State Heritage programs and represent the occurrences of vascular plant species with a TNC rarity rank of G1-G2. These are species considered to be critically imperiled or imperiled (Stein and others 2000) based on the number, size, and condition of populations known to exist. The distribution of rare taxa is used here as a proxy for the distribution of plant diversity. Low-diversity plant communities such as agricultural lands or beaches rarely contain uncommon taxa, whereas there is a Worldwide pattern of uncommon species being associated with highly diverse plant communities. The occurrence data represented in figures 2.1 and 2.2 should not be interpreted as the distribution of plant species on a trajectory toward extinction. Most of the rare plants in the South (or the World for that matter) are species that are naturally rare (Rabinowitz 1981). These data are, in all likelihood, incomplete in that private lands may be under-surveyed for rare plants, and some States have generally better surveys than others. However, figures 2.1 and 2.2 represent the best available data at this time and are more than adequate to elucidate the overall pattern of species diversity and rarity in the South.

These figures display three hotspots of plant diversity in the South: the Southern Appalachian Mountains, the Appalachicola lowlands of the Florida

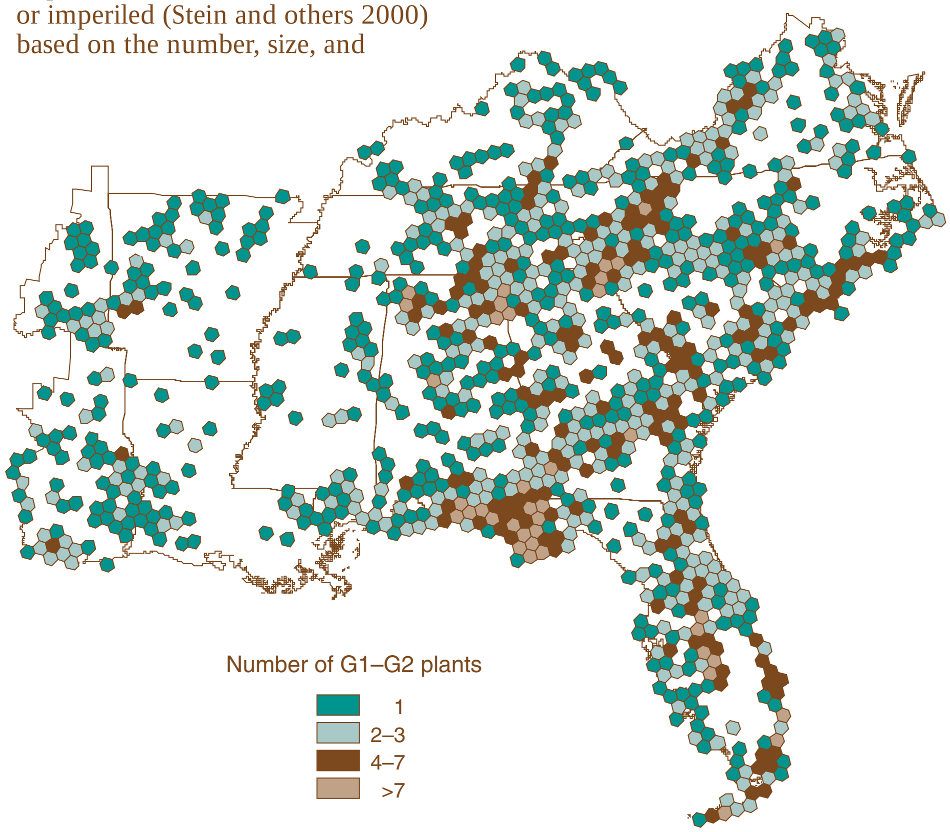


Figure 2.1—Distribution of imperiled vascular plant species in the South based on the number of occurrences in equal-area hexagons.

Panhandle, and the Lake Wales Ridge region of central Florida. The Southern Appalachians are a refuge for a wide range of species in genera with generally more northerly affinities. Many of the rare taxa in the Southern Appalachians are thought to be relicts from periods of glaciation in the distant past. The Lake Wales Ridge hotspot is a portion of Florida that was submerged during times of rising sea levels, such as during the hypsithermal period from 8,700 to 5,000 BP. Many of the rare plants on Lake Wales Ridge are thought to have been more widely distributed in the past. The Apalachicola lowlands plant diversity hotspot is more difficult to explain. Although the area has a striking diversity of habitats such as karst features, a variety of bogs, and wiregrass communities, these factors alone are unlikely to be the cause of the richest endemic flora in the South. Some scientists have suggested that some combination of habitat diversity, generally markedly low levels of soil nutrients, and a long history of frequent fires has made the area a challenge for most plant species and an opportunity for the evolution of specialized taxa.

Other areas with important levels of plant diversity in the South include the Coastal Plain, the Ozark-Ouachita Highlands, and the Cumberland Plateau.

Although most of the rare plant species in the South are species that are naturally rare, forest fragmentation and land conversion have significantly impacted the distribution and abundance of a large number of species. Other factors associated with human density, such as over-harvesting and hydrologic alterations, have diminished many species that were formerly common.

Many of the plant diversity hotspots represented in figures 2.1 and 2.2 occur primarily or largely on public land. This result highlights the importance of public land for the conservation of rare plants. Although not all public land management practices favor rare plants, in many places public land is the only place in which rare plant conservation is politically or economically possible.

Discussion and Conclusions

Plant communities of the South deserve many superlatives. They are exceptionally diverse, being rich in both the number of species and the number of endemic taxa. Forests of the South are also among the most heavily impacted in North America. They are severely fragmented, have experienced greater levels of human habitation for longer than any other forests in North America, and have the greatest number of exotic species. The native plant communities of the South have a history of increasingly intensive use, but recent changes in social attitudes are a source of great hope to those who appreciate the very special qualities of the native southern landscape. There is no chance that the South will ever see the communities that Cabeza de Vaca and De Soto saw, or even the relatively more modified landscapes first described by Bartram and Nuttall. In fact, continuing urbanization and population pressures will almost certainly conspire to keep the majority of the Souths landscape working hard to support its people (table 2.2). However, the remaining public land in the region is increasingly being managed for uses other than commodity production, and native plant community restoration and species protection activities on both public and private land are at an all-time high. Changes will continue into the future, most of them detrimental to the overall health of native plant communities in the South. Increasing human populations and resource demands will further fragment the remaining forests and natural areas. Invasive species will occupy increasingly larger proportions of the southern landscape. Global climate change will also impact the composition and distribution of plant communities in the South. However, increasing awareness of the value of forests and natural areas has slowed the pace of land conversion in the South, and recent efforts by State and Federal Government landowners to improve forest conditions through restoration suggest that, at least in part, some of the inevitable changes coming to southern native plant communities will be improvements. The native plant communities of the South will never be what they were, but if the future brings increasing functionality to the remaining intact ecosystems of the

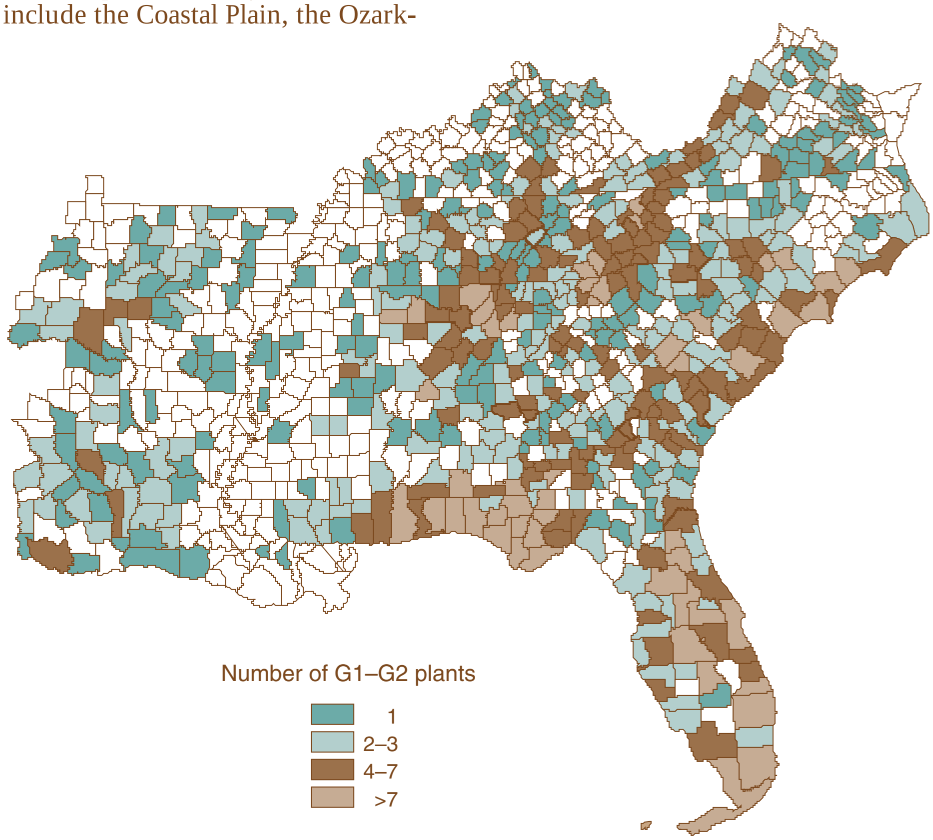


Figure 2.2—Distribution of imperiled vascular plant species in the South based on the number of occurrences in counties.

Table 2.2—Timberland in Southern States by ownership class

State	Hardwoods: All ownerships	Hardwoods: National forests	Hardwoods: Industrial forests	Softwoods: All ownerships	Softwoods: National forests	Softwoods: Industrial forests
	Acres (thousands)					
Alabama	21,931.9	605.4	5,499.4	7,447.1	237.2	2,789.9
Arkansas	18,392.1	2,371.8	4,514.6	5,077.0	831.8	2,450.3
Florida	14,650.7	1,029.5	4,601.5	7,437.8	725.5	2,921.9
Georgia	23,796.1	710.7	4,890.5	10,805.4	192.4	3,154.3
Kentucky	12,347.3	698.9	204.5	682.1	64.2	0
Louisiana	13,783.0	568.5	4,422.5	5,006.7	327.9	2,357.1
Mississippi	18,587.4	1,106.6	3,314.1	5,751.0	505.3	1,579.7
North Carolina	18,710.4	1,082.4	2,420.4	6,261.9	168.0	1,528.2
South Carolina	12,454.9	560.0	2,394.3	5,561.5	311.2	1,492.3
Tennessee	13,965.0	556.8	1,393.0	1,468.9	93.3	336.6
Virginia	12,094.9	1,360.9	714.5	3,352.8	137.2	840.3
Total	180,713.7	10,651.5	34,369.3	58,852.2	3,594.0	19,450.6

Source: Data from Southern Region Forest Inventory and Analysis, http://www.srsfia.usfs.msstate.edu/.

South, then the conservation and restoration efforts of today will have been successful.

Needs for Additional Research

TNCs National Vegetation Classification System is the most important development for the study of natural plant communities in the last decade. This uniform, standardized method for classifying plant communities will provide a reliable means for comparing where we are with where we have been. Alternatively, efforts to model the current and projected distributions of plant communities or forest trees can substantially aid our understanding of the distribution of plant diversity throughout the South. For example, Prasad and Iverson (1999) have developed multiple maps of the current and projected distributions of 80 eastern forest trees based on a variety of sets of projected conditions.

Even though trained botanists have been exploring the Southern United States for over 300 years, the mapping of native plant communities has just begun. A full accounting of the variation and geography of species and their communities is critical. This information is essential to make an accurate assessment of the conservation needs of the region.

The greatest challenges to natural plant communities throughout the nation, but particularly in the South, are conversion to agriculture, the creation of tree plantations, and urbanization. The fourth common source of degradation of natural plant communities is the incursion of exotic invasive plant species. There is a great need to investigate more effective methods of control, whether chemical, biological, or physical. There are many safety concerns associated with chemical and biological control methods, but physical methods usually prove slow and expensive. It is impossible to eliminate exotic species from our region, but we can still take steps to reduce their impact on native plant communities and learn to better manage the impacts.

There is currently a management emphasis on the retention and development of old-growth forests, or forest stands with old-growth characteristics, on public land. However, concerns over the habitat needs of wildlife, especially migratory birds, has recently highlighted the broader need for forests with a range of structural traits. Early successional forest stands in particular support a very different array of native plant communities than do mature forests. There is a significant opportunity for research to contribute to a better understanding of the historical abundance and distribution of open areas in the South.

Finally, a future research priority for native plant communities should be restoration ecology. In the past, restoration has meant the establishment of any kind of vegetative cover on denuded landscape such as eroded farmland or strip mines. In the last decade, there has been a significant trend toward restoration of native communities using native plant material. However, the availability of native material is limited, and there is a growing concern about the source of the plant material used in restoration. We have much to learn about the distribution of genetic diversity in the native species commonly used for restoration, and even more to learn about the potential for use in restoration of the majority of plant species native to the South.

Acknowledgments

Figures 2.1 and 2.2 were developed by the Association for Biodiveristy Information (ABI), Natural Heritage Central Database, Arlington, VA (2001). Throughout the discussion in this chapter, work currently being accomplished by ABI has been attributed to its parent organization, The Nature Conservancy, for the sake of continuity. This chapter would not have been possible without the selfless work of thousands of professional and amateur botanists during the last 300 years. They have sweated and braved insects and briars to document, describe, and extol the flora of the Southeast. This chapter is dedicated to the thousands of young people who have yet to discover their love affair with botany.

Literature Cited

Abrams, M.D. 1992. Fire and the development of oak forests. Biosciences. 42: 346 353.

Anderson, M.; Bourgeron, P.; Bryer, M.T. [and others]. 1998. International classification of ecological communities: terrestrial vegetation of the United States. The national vegetation classification system: list of types. Arlington, VA: The Nature Conservancy. 502 p. Vol. II.

Association for Biodiversity Information. 2001. NatureServe. http://www.natureserve.org/. [Date accessed unknown].

Bailey, R.G. 1994. Ecoregions of the United States. Rev. ed. Washington, DC: U.S. Department of Agriculture, Forest Service. 1: 7,500,000; colored.

Bailey, R.G. 1998. Ecoregion map of North America. Misc. Publ.1548. Washington, DC: U. S. Department of Agriculture, Forest Service. 1: 15,000,000; colored.

Bartram, W. 1791. Travels through North and South Carolina, Georgia, east and west Florida, the Cherokee country, the extensive territories of the Muscogulges or Creek Confederacy, and the country of the Choctaws: containing an account of the soil and natural productions of those regions, together with observations on the manners of the Indians. Philadelphia: James and Johnson. 824 p.

Carrier, L. 1923. The beginnings of agriculture in America. New York: McGraw Hill. [Number of pages unknown].

Christensen, N.L. 1988. Vegetation of the southeastern Coastal Plain. In: Barbour, M.G.; Billings, W.D., eds. North American terrestrial vegetation. New York: Cambridge University Press. [Number of pages unknown].

Cowell, C.M. 1998. Historical change in vegetation and distribution on the Georgia Piedmont. American Midland Naturalist. 140: 78 89.

Croker, T.C., Jr. 1987. Longleaf pine: a history of man and a forest. For. Rep. R8 FR7. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. [Number of pages unknown].

Delcourt, H.R. 1979. Late Quaternary vegetation history of the Eastern Highland Rim and adjacent Cumberland Plateau of Tennessee. Ecological Monographs. 49: 255 280.

Delcourt, H.R. 1987. The impact of prehistoric agriculture and land occupation on natural vegetation. TREE. 2(2): 39 44.

Delcourt, H.R.; Delcourt, P.A. 1997. Pre-Columbian Native American use of fire on Southern Appalachian landscapes. Conservation Biology. 11: 1010 1014.

Delcourt, P.A.; Delcourt, H.R. 1993. Paleoclimates, paleovegetation, and paleofloras during the Late Quaternary. In: Flora of North America. New York: Oxford University Press. [Number of pages unknown]. Vol. 1.

Delcourt, P.A.; Delcourt, H.R. 1998. Paleoecological insights on conservation of biodiversity: a focus on species, ecosystems, and landscapes. Ecological Applications. 8: 921 934.

FLEPPC. 2001. Lists of Floridas invasive species. Florida Exotic Pest Plant Council. http://www.fleppc.org/. [Date accessed: July 2, 2002].

Greller, A.M. 1988. Deciduous forests. In: Barbour, M.G.; Billings, W.D., eds. North American terrestrial vegetation. New York: Cambridge University Press. [Number of pages unknown].

Grossman, D.H.; Faber-Langendoen, D.; Weakley, A.S. [and others]. 1998. International classification of ecological communities: terrestrial vegetation of the United States. The national vegetation classification system: development, status, and applications. Arlington, VA: The Nature Conservancy. [Number of pages unknown]. Vol. 1.

Kuchler, A.W. 1985. Potential natural vegetation. Rev. National atlas of the United States. Reston, VA: U.S. Geological Survey. 1: 7,500,000; colored.

Mac, M.J.; Opler, P.A.; Haecker, C.E.P.; Doran, P.D., eds. 1998. Status and trends of the Nations biological resources. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. [Number of pages unknown]. 2 vol.

Martin, P.S.; Klein, R.G., eds. 1984. Quaternary extinctions. Tucson, AZ: University of Arizona Press. [Number of pages unknown].

Milankovic, M. 1941. Canon of insolation and the ice-age problem. Royal Serbian Acad. Spec. Publ. 132. Belgrade: [Publisher unknown]. [Number of pages unknown].

Mitch, W.J.; Gosselink, J.G. 1993. Wetlands. New York: Van Nostrand Reinhold. [Number of pages unknown].

Noss, R.F.; LaRoe, E.T.; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biol. Rep. 28. Washington, DC: U.S. Department of the Interior, National Biological Service. [Number of pages unknown].

Nuttall, T. 1821. A journal of travels in the Arkansaw Territory during the year 1819. Philadelphia: T.H. Palmer. [Number of pages unknown].

Palmer, E.J. 1926. The ligneous flora of Hot Springs National Park and vicinity. Journal of the Arnold Arboretum. 7: 104 135.

Prasada, A.M.; Iverson, L.R. 1999. A climate change atlas for 80 forest tree species of the Eastern United States [Spatial database]. http://www.fs.fed.us/ne/delaware/atlas/index. Station [Date accessed: July 2, 2002].

Rabinowitz, D. 1981. Seven forms of rarity. In: Synge, H., ed. The biological aspects of rare plant conservation. New York: John Wiley. [Number of pages unknown].

Reveal, J.L.; Pringle, J.S. 1993. Taxonomic botany and floristics. In: Flora of North America. New York: Oxford University Press. [Number of pages unknown]. Vol.1.

Ricketts, T.H.; Dinerstein, E.; Olson, D.M. [and others]. 1999. Terrestrial ecoregions of North America: a conservation assessment. Washington, DC: Island Press. [Number of pages unknown].

Schlarbaum, S.E.; Hebard, F.; Spaine, P.C.; Kamalay, J.C. 1997. Three American tragedies: chestnut blight, butternut canker, and Dutch elm disease. In: Britton, K.O. Exotic pests of eastern forests: Proceedings of a meeting. Nashville, TN: Tennessee Exotic Pest Plant Council: 45 54.

Smith, E.B. 1994. Keys to the flora of Arkansas. Fayetteville, AR: University of Arkansas Press. [Number of pages unknown].

Stein, B.A.; Kutner, L.S.; Adams, J.S., eds. 2000. Precious heritage: the status of biodiversity in the United States. New York: Oxford University Press. [Number of pages unknown].

The Nature Conservancy. 1999. Ecoregional map of the United States. Arlington, VA. [Scale of map unknown]; colored.

University of Illinois. 1997. An introduction to the early cultures of the American bottom. http://www.ncsa.uiuc.edu/Cyberia/RiverWeb/History/Cahokia/. [Date accessed: July 2, 2002].

U.S. Department of the Interior, Fish and Wildlife Service. 2001. Species information: threatened and endangered animals and plants. http://endangered.fws.gov/wildlife.html#Species. [Date accessed: July 2, 2002].

Walker, L.C.; Oswald, B.P. 1999. The southern forest: geography, ecology, and silviculture. Boca Raton, FL: CRC Press. [Number of pages unknown].

Watts, W.A. 1971. Postglacial and interglacial vegetation history of southern Georgia and central Florida. Ecology. 52: 676 690.

Watts, W.A. 1980. The Late Quaternary vegetation history of the Southeastern United States. Annual Review of Ecology and Systematics. 11: 387 409.

Williams, G.W. 2000. The USDA Forest Service the first century. Publ. FS 650. Washington, DC: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Woods, F.W.; Shanks, R.E. 1959. Natural replacement of chestnut by other species in the Great Smoky Mountains National Park. Ecology. 40: 349 361.

Wright, H.E., Jr. 1981. Vegetation east of the Rocky Mountains 18,000 years ago. Quaternary Research. 15: 113 125.

Wunderlin, R.P.; Hansen, B.F. 2000. Flora of Florida: pteridophytes and gymnosperms. Gainesville, FL: University Press of Florida. [Number of pages unknown]. Vol. 1.

Attachment 7

From:	Knapp, Wesley
To:	Kauffman, Gary -FS
Subject:	RE: [External] Re: site boundary question
Date:	Tuesday, January 16, 2018 9:31:15 AM
Attachments:	image002.png image004.png

Can you propose a boundary modification? I agree there is some quality habitat along the road, right where we walked in, but determining the extent of this without a site visit is difficult. Not sure if a site visit is warranted just for this.

Wes

From: Gary Kauffman [mailto:gkauffman@att.net]
Sent: Sunday, January 14, 2018 6:52 AM
To: Knapp, Wesley <Wesley.Knapp@ncdcr.gov>; Gary -FS Kauffman <gkauffman@fs.fed.us>
Subject: [External] Re: site boundary question

OK, now I see. I'm not certain all of that was thinned, particularly right where we entered the stand across from Buck Creek road, however I would agree most of it probably had some activity 35-45 years ago. One reason to extend it to the road is I would hate to see activity from the road for 100-200 feet to the natural area boundary thereby increasing the spread of non-native plants more prevalent on the road. Food for thought.

Thanks for the clarification.

Gary

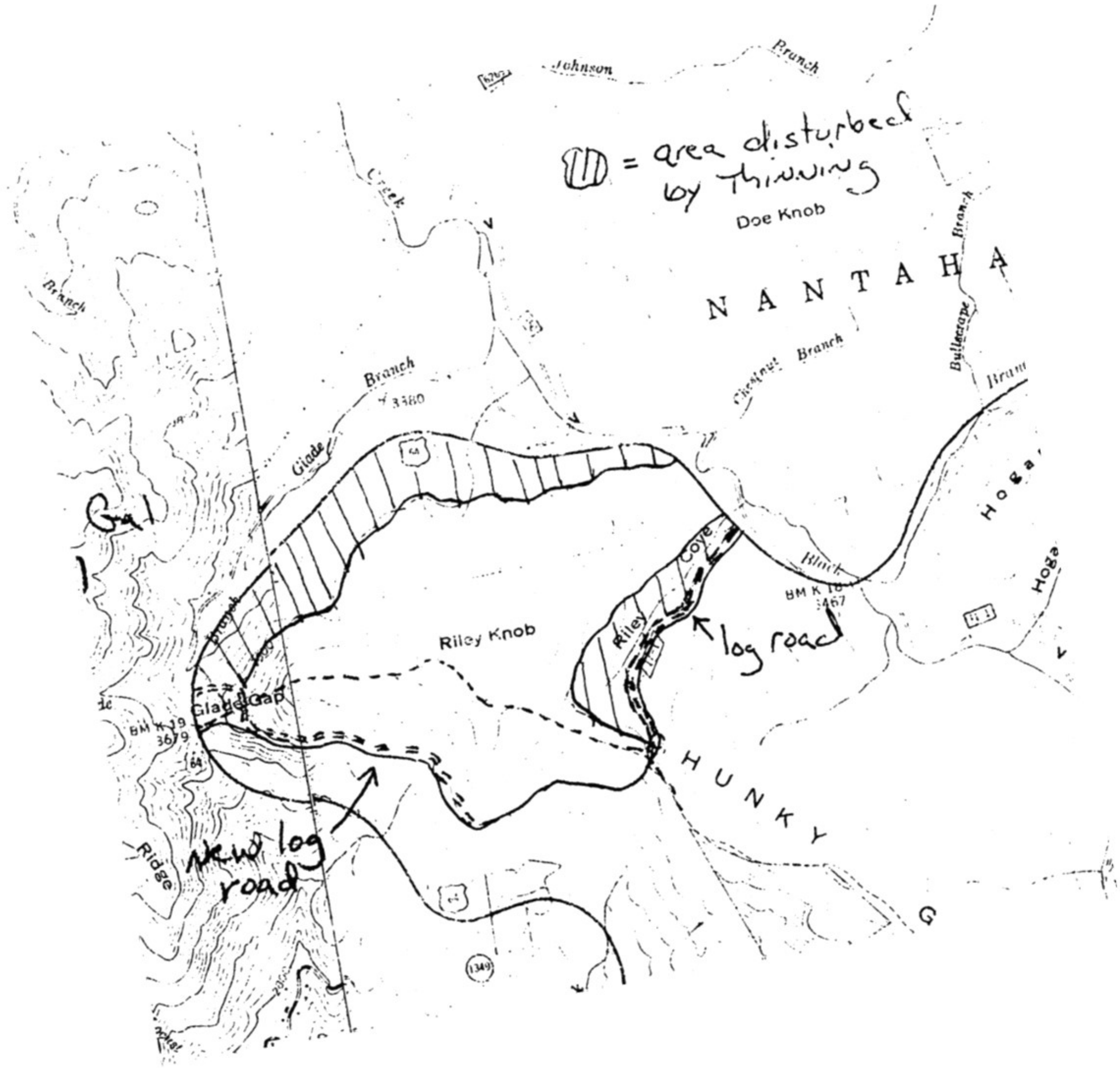
From: "Knapp, Wesley" <Wesley.Knapp@ncdcr.gov>
To: Gary Kauffman <gkauffman@att.net>
Sent: Friday, January 12, 2018 3:39 PM
Subject: FW: site boundary question

Here is what Judy found in the site files. Are we sure we want to expand this to the roadside? Are we sure the roadside had good stuff along it. Now that I think more, lots was thinned and young.

Wes

From: Ratcliffe, Judith
Sent: Friday, January 12, 2018 3:23 PM
To: Knapp, Wesley <Wesley.Knapp@ncdcr.gov>; Warf, Michelle L <Michelle.Warf@ncdcr.gov>; Mason, Suzanne <suzanne.mason@ncdcr.gov>; Buchanan, Misty <misty.buchanan@ncdcr.gov>; Schafale, Michael <michael.schafale@ncdcr.gov>
Subject: RE: site boundary question

In the site file - the 1985-86 Govus reconnaissance files may give you the clue to why it was excluded initially…however if you deem that portion of the natural community along the road is in sufficiently good condition to include in the natural area then you can amend the boundary. Be sure to document your reasons in Biotics and in a note to the file…there are no rules that would preclude a boundary along a roadside or even across a road if there is ecological justification.
1985:



From: Knapp, Wesley
Sent: Friday, January 12, 2018 3:03 PM
To: Warf, Michelle L <Michelle.Warf@ncdcr.gov>; Mason, Suzanne <suzanne.mason@ncdcr.gov>; Buchanan, Misty <misty.buchanan@ncdcr.gov>; Schafale, Michael <michael.schafale@ncdcr.gov>; Ratcliffe, Judith <judith.ratcliffe@ncdcr.gov>
Subject: site boundary question

Suzanne and Michelle,

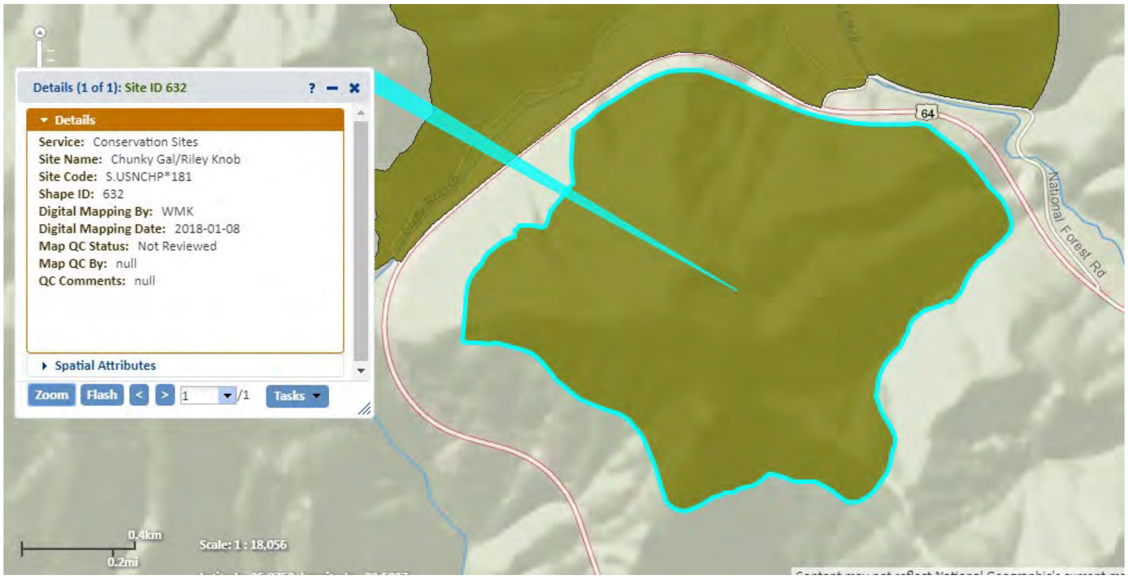
I just got off the phone with Gary Kauffmann (USFS) as he had a question about the Chunky Gal/Riley Knob site boundary. He asked me why the boundary didn't go all the way to the road, and I couldn't answer his question. I assume this could be for a few reasons. I assume these could be:

1. It was intended to go to the road and was drawn along the road initially using a different basemap that has now created a shift in the NA boundary to not appear along the road.
2. We, NHP, doesn't draw sites to roadsides as this will reduce the number of 'hits' from road projects that are going to proceed regardless of a site boundary or,
3. The Biologist who drew it initially left out this habitat on purpose or by mistake. There is no data in Biotics that would support or reject this idea.

If the answer is #1 how do we deal with this? Should the boundary be updated to be continuous with the road as there is now 150+ feet of high quality woods that are outside a site boundary and are potentially targets for land management activities. Gary brought this up because an area of proposed harvest does overlap areas that are outside the drawn NA. I would like to argue that #1 is the cause of this as the boundary does mirror the roadside and the forest along the road should be considered as part of the NA. I pasted a map of the area below. This looks very odd now that we've updated Buck Creek SOB NA to just to the North.

Any thoughts are appreciated thought I don't know if you'll know the answers,

Wes



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Federal Register

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Thursday, December 8, 2016

Presidential Documents

Title 3—

The President

Executive Order 13751 of December 5, 2016

Safeguarding the Nation From the Impacts of Invasive Species

By the authority vested in me as President by the Constitution and to ensure the faithful execution of the laws of the United States of America, including the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, (16 U.S.C. 4701 *et seq.*), the Plant Protection Act (7 U.S.C. 7701 *et seq.*), the Lacey Act, as amended (18 U.S.C. 42, 16 U.S.C. 3371–3378 *et seq.*), the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*), the Noxious Weed Control and Eradication Act of 2004 (7 U.S.C. 7781 *et seq.*), and other pertinent statutes, to prevent the introduction of invasive species and provide for their control, and to minimize the economic, plant, animal, ecological, and human health impacts that invasive species cause, it is hereby ordered as follows:

Section 1. *Policy.* It is the policy of the United States to prevent the introduction, establishment, and spread of invasive species, as well as to eradicate and control populations of invasive species that are established. Invasive species pose threats to prosperity, security, and quality of life. They have negative impacts on the environment and natural resources, agriculture and food production systems, water resources, human, animal, and plant health, infrastructure, the economy, energy, cultural resources, and military readiness. Every year, invasive species cost the United States billions of dollars in economic losses and other damages.

Of substantial growing concern are invasive species that are or may be vectors, reservoirs, and causative agents of disease, which threaten human, animal, and plant health. The introduction, establishment, and spread of invasive species create the potential for serious public health impacts, especially when considered in the context of changing climate conditions. Climate change influences the establishment, spread, and impacts of invasive species.

Executive Order 13112 of February 3, 1999 (Invasive Species), called upon executive departments and agencies to take steps to prevent the introduction and spread of invasive species, and to support efforts to eradicate and control invasive species that are established. Executive Order 13112 also created a coordinating body—the Invasive Species Council, also referred to as the National Invasive Species Council—to oversee implementation of the order, encourage proactive planning and action, develop recommendations for international cooperation, and take other steps to improve the Federal response to invasive species. Past efforts at preventing, eradicating, and controlling invasive species demonstrated that collaboration across Federal, State, local, tribal, and territorial government; stakeholders; and the private sector is critical to minimizing the spread of invasive species and that coordinated action is necessary to protect the assets and security of the United States.

This order amends Executive Order 13112 and directs actions to continue coordinated Federal prevention and control efforts related to invasive species. This order maintains the National Invasive Species Council (Council) and the Invasive Species Advisory Committee; expands the membership of the Council; clarifies the operations of the Council; incorporates considerations of human and environmental health, climate change, technological innovation, and other emerging priorities into Federal efforts to address invasive species; and strengthens coordinated, cost-efficient Federal action.

Sec. 2. *Definitions.* Section 1 of Executive Order 13112 is amended to read as follows:

''**Section 1.** *Definitions.* (a) 'Control' means containing, suppressing, or reducing populations of invasive species.

(b) 'Eradication' means the removal or destruction of an entire population of invasive species.

(c) 'Federal agency' means an executive department or agency, but does not include independent establishments as defined by 5 U.S.C. 104.

(d) 'Introduction' means, as a result of human activity, the intentional or unintentional escape, release, dissemination, or placement of an organism into an ecosystem to which it is not native.

(e) 'Invasive species' means, with regard to a particular ecosystem, a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health.

(f) 'Non-native species' or 'alien species' means, with respect to a particular ecosystem, an organism, including its seeds, eggs, spores, or other biological material capable of propagating that species, that occurs outside of its natural range.

(g) 'Pathway' means the mechanisms and processes by which non-native species are moved, intentionally or unintentionally, into a new ecosystem.

(h) 'Prevention' means the action of stopping invasive species from being introduced or spreading into a new ecosystem.

(i) 'United States' means the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the U.S. Virgin Islands, the Commonwealth of the Northern Mariana Islands, all possessions, and the territorial sea of the United States as defined by Presidential Proclamation 5928 of December 27, 1988.''

Sec. 3. *Federal Agency Duties.* Section 2 of Executive Order 13112 is amended to read as follows:

''**Sec. 2.** *Federal Agency Duties.* (a) Each Federal agency for which that agency's actions may affect the introduction, establishment, or spread of invasive species shall, to the extent practicable and permitted by law,

(1) identify such agency actions;

(2) subject to the availability of appropriations, and within administrative, budgetary, and jurisdictional limits, use relevant agency programs and authorities to:

(i) prevent the introduction, establishment, and spread of invasive species;

(ii) detect and respond rapidly to eradicate or control populations of invasive species in a manner that is cost-effective and minimizes human, animal, plant, and environmental health risks;

(iii) monitor invasive species populations accurately and reliably;

(iv) provide for the restoration of native species, ecosystems, and other assets that have been impacted by invasive species;

(v) conduct research on invasive species and develop and apply technologies to prevent their introduction, and provide for environmentally sound methods of eradication and control of invasive species;

(vi) promote public education and action on invasive species, their pathways, and ways to address them, with an emphasis on prevention, and early detection and rapid response;

(vii) assess and strengthen, as appropriate, policy and regulatory frameworks pertaining to the prevention, eradication, and control of invasive species and address regulatory gaps, inconsistencies, and conflicts;

(viii) coordinate with and complement similar efforts of States, territories, federally recognized American Indian tribes, Alaska Native Corporations, Native Hawaiians, local governments, nongovernmental organizations, and the private sector; and

(ix) in consultation with the Department of State and with other agencies as appropriate, coordinate with foreign governments to prevent the movement and minimize the impacts of invasive species; and

(3) refrain from authorizing, funding, or implementing actions that are likely to cause or promote the introduction, establishment, or spread of invasive species in the United States unless, pursuant to guidelines that it has prescribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions.

(c) Federal agencies shall pursue the duties set forth in this section in coordination, to the extent practicable, with other member agencies of the Council and staff, consistent with the National Invasive Species Council Management Plan, and in cooperation with State, local, tribal, and territorial governments, and stakeholders, as appropriate, and in consultation with the Department of State when Federal agencies are working with international organizations and foreign nations.

(d) Federal agencies that are members of the Council, and Federal interagency bodies working on issues relevant to the prevention, eradication, and control of invasive species, shall provide the Council with annual information on actions taken that implement these duties and identify barriers to advancing priority actions.

(e) To the extent practicable, Federal agencies shall also expand the use of new and existing technologies and practices; develop, share, and utilize similar metrics and standards, methodologies, and databases and, where relevant, platforms for monitoring invasive species; and, facilitate the interoperability of information systems, open data, data analytics, predictive modeling, and data reporting necessary to inform timely, science-based decision making.

Sec. 4. *Emerging Priorities.* Federal agencies that are members of the Council and Federal interagency bodies working on issues relevant to the prevention, eradication, and control of invasive species shall take emerging priorities into consideration, including:

(a) Federal agencies shall consider the potential public health and safety impacts of invasive species, especially those species that are vectors, reservoirs, and causative agents of disease. The Department of Health and Human Services, in coordination and consultation with relevant agencies as appropriate, shall within 1 year of this order, and as requested by the Council thereafter, provide the Office of Science and Technology Policy and the Council a report on public health impacts associated with invasive species. That report shall describe the disease, injury, immunologic, and safety impacts associated with invasive species, including any direct and indirect impacts on low-income, minority, and tribal communities.

(b) Federal agencies shall consider the impacts of climate change when working on issues relevant to the prevention, eradication, and control of invasive species, including in research and monitoring efforts, and integrate invasive species into Federal climate change coordinating frameworks and initiatives.

(c) Federal agencies shall consider opportunities to apply innovative science and technology when addressing the duties identified in section 2 of Executive Order 13112, as amended, including, but not limited to, promoting open data and data analytics; harnessing technological advances in remote sensing technologies, molecular tools, cloud computing, and predictive analytics; and using tools such as challenge prizes, citizen science, and crowdsourcing.

Sec. 5. *National Invasive Species Council.* Section 3 of Executive Order 13112 is amended to read as follows:

''**Sec. 3.** *National Invasive Species Council.* (a) A National Invasive Species Council (Council) is hereby established. The mission of the Council is to provide the vision and leadership to coordinate, sustain, and expand Federal efforts to safeguard the interests of the United States through the prevention, eradication, and control of invasive species, and through the restoration of ecosystems and other assets impacted by invasive species.

(b) The Council's membership shall be composed of the following officials, who may designate a senior-level representative to perform the functions of the member:

(i) Secretary of State;

(ii) Secretary of the Treasury;

(iii) Secretary of Defense;

(iv) Secretary of the Interior;

(v) Secretary of Agriculture;

(vi) Secretary of Commerce;

(vii) Secretary of Health and Human Services;

(viii) Secretary of Transportation;

(ix) Secretary of Homeland Security;

(x) Administrator of the National Aeronautics and Space Administration;

(xi) Administrator of the Environmental Protection Agency;

(xii) Administrator of the United States Agency for International Development;

(xiii) United States Trade Representative;

(xiv) Director or Chair of the following components of the Executive Office of the President: the Office of Science and Technology Policy, the Council on Environmental Quality, and the Office of Management and Budget; and

(xv) Officials from such other departments, agencies, offices, or entities as the agencies set forth above, by consensus, deem appropriate.

(c) The Council shall be co-chaired by the Secretary of the Interior (Secretary), the Secretary of Agriculture, and the Secretary of Commerce, who shall meet quarterly or more frequently if needed, and who may designate a senior-level representative to perform the functions of the Co-Chair. The Council shall meet no less than once each year. The Secretary of the Interior shall, after consultation with the Co-Chairs, appoint an Executive Director of the Council to oversee a staff that supports the duties of the Council. Within 1 year of the date of this order, the Co-Chairs of the Council shall, with consensus of its members, complete a charter, which shall include any administrative policies and processes necessary to ensure the Council can satisfy the functions and responsibilities described in this order.

(d) The Secretary of the Interior shall maintain the current Invasive Species Advisory Committee established under the Federal Advisory Committee Act, 5 U.S.C. App., to provide information and advice for consideration by the Council. The Secretary shall, after consultation with other members of the Council, appoint members of the advisory committee who represent diverse stakeholders and who have expertise to advise the Council.

(e) Administration of the Council. The Department of the Interior shall provide funding and administrative support for the Council and the advisory committee consistent with existing authorities. To the extent permitted by law, including the Economy Act, and within existing appropriations, participating agencies may detail staff to the Department of the Interior to support the Council's efforts.''

Sec. 6. *Duties of the National Invasive Species Council.* Section 4 of Executive Order 13112 is amended to read as follows:

"**Sec. 4.** *Duties of the National Invasive Species Council.* The Council shall provide national leadership regarding invasive species and shall:

(a) with regard to the implementation of this order, work to ensure that the Federal agency and interagency activities concerning invasive species are coordinated, complementary, cost-efficient, and effective;

(b) undertake a National Invasive Species Assessment in coordination with the U.S. Global Change Research Program's periodic national assessment, that evaluates the impact of invasive species on major U.S. assets, including food security, water resources, infrastructure, the environment, human, animal, and plant health, natural resources, cultural identity and resources, and military readiness, from ecological, social, and economic perspectives;

(c) advance national incident response, data collection, and rapid reporting capacities that build on existing frameworks and programs and strengthen early detection of and rapid response to invasive species, including those that are vectors, reservoirs, or causative agents of disease;

(d) publish an assessment by 2020 that identifies the most pressing scientific, technical, and programmatic coordination challenges to the Federal Government's capacity to prevent the introduction of invasive species, and that incorporate recommendations and priority actions to overcome these challenges into the National Invasive Species Council Management Plan, as appropriate;

(e) support and encourage the development of new technologies and practices, and promote the use of existing technologies and practices, to prevent, eradicate, and control invasive species, including those that are vectors, reservoirs, and causative agents of disease;

(f) convene annually to discuss and coordinate interagency priorities and report annually on activities and budget requirements for programs that contribute directly to the implementation of this order; and

(g) publish a National Invasive Species Council Management Plan as set forth in section 5 of this order."

Sec. 7. *National Invasive Species Council Management Plan.* Section 5 of Executive Order 13112 is amended to read as follows:

"**Sec. 5.** *National Invasive Species Council Management Plan.* (a) By December 31, 2019, the Council shall publish a National Invasive Species Council Management Plan (Management Plan), which shall, among other priorities identified by the Council, include actions to further the implementation of the duties of the National Invasive Species Council.

(b) The Management Plan shall recommend strategies to:

(1) provide institutional leadership and priority setting;

(2) achieve effective interagency coordination and cost-efficiency;

(3) raise awareness and motivate action, including through the promotion of appropriate transparency, community-level consultation, and stakeholder outreach concerning the benefits and risks to human, animal, or plant health when controlling or eradicating an invasive species;

(4) remove institutional and policy barriers;

(5) assess and strengthen capacities; and

(6) foster scientific, technical, and programmatic innovation.

(c) The Council shall evaluate the effectiveness of the Management Plan implementation and update the Plan every 3 years. The Council shall provide an annual report of its achievements to the public.

(d) Council members may complement the Management Plan with invasive species policies and plans specific to their respective agency's roles, responsibilities, and authorities."

Sec. 8. *Actions of the Department of State and Department of Defense.* Section 6(d) of Executive Order 13112 is amended to read as follows:

''(d) The duties of section 3(a)(2) and section 3(a)(3) of this order shall not apply to any action of the Department of State if the Secretary of State finds that exemption from such requirements is necessary for foreign policy, readiness, or national security reasons. The duties of section 3(a)(2) and section 3(a)(3) of this order shall not apply to any action of the Department of Defense if the Secretary of Defense finds that exemption from such requirements is necessary for foreign policy, readiness, or national security reasons.''

Sec. 9. *Obligations of the Department of Health and Human Services.* A new section 6(e) of Executive Order 13112 is added to read as follows:

''(e) The requirements of this order do not affect the obligations of the Department of Health and Human Services under the Public Health Service Act or the Federal Food, Drug, and Cosmetic Act.''

Sec. 10. *General Provisions.* (a) Nothing in this order shall be construed to impair or otherwise affect:

(1) the authority granted by law to an executive department or agency, or the head thereof; or

(2) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

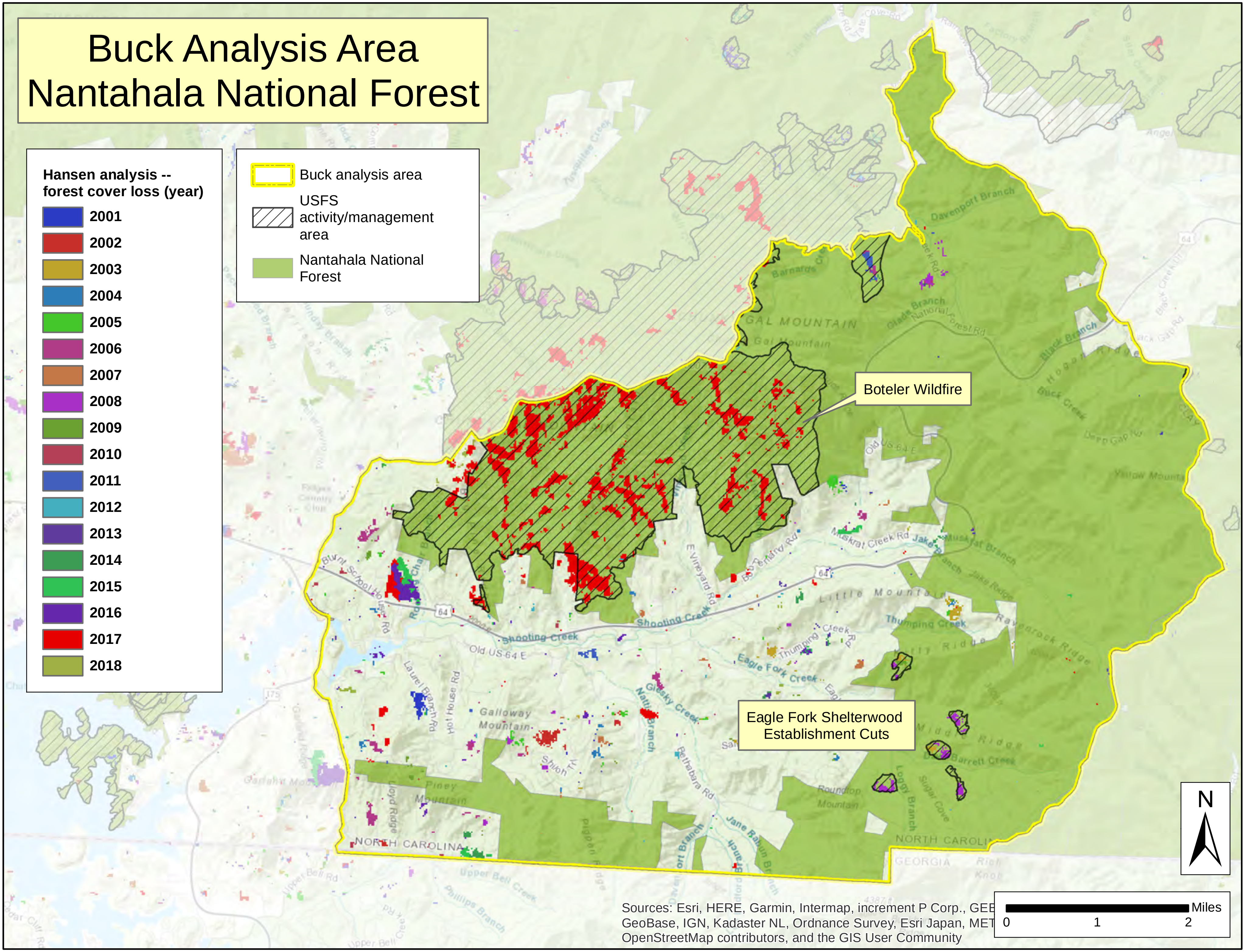
(b) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(c) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

THE WHITE HOUSE,
December 5, 2016.

[FR Doc. 2016–29519
Filed 12–7–16; 8:45 am]
Billing code 3295–F7–P

Attachment 8


Buck Analysis Area
Nantahala National Forest
Hansen analysis -- forest cover loss (year)
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Buck analysis area
USFS activity/management area
Nantahala National Forest
Boteler Wildfire
Eagle Fork Shelterwood Establishment Cuts
GAL MOUNTAIN
Little Mountain
Shooting Creek
Galloway Mountain
Piney Mountain
NORTH CAROLINA
GEORGIA
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEB
GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, MET
OpenStreetMap contributors, and the GIS User Community
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Attachment 9

Best Management Practices For

Golden-winged Warbler Habitats in the Appalachian Region

A Guide for Land Managers and Landowners

Best Management Practices For

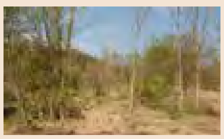
Golden-winged Warbler Habitats in the Appalachian Region

A Guide for Land Managers and Landowners

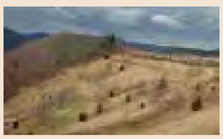
A publication of the Golden-winged Warbler Working Group

This document is one of two regional Best Management Practice (BMP) guides for land managers and landowners, each with several two-page supplements dedicated to the management of specific regional habitat types most important to Golden-winged Warblers. The counterpart to this document is called *Best Management Practices for Golden-winged Warbler Habitats in the Great Lakes Region* and can be downloaded at **www.gwwa.org**.

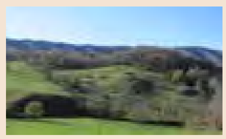
THIS APPALACHIAN BMP GUIDE IS INTENDED TO BE USED WITH THE FOLLOWING HABITAT SUPPLEMENTS:



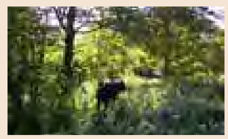
Deciduous Forests



Minelands

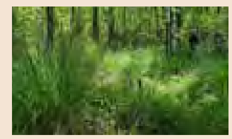


Abandoned Farmlands



Grazed Forest-land/Montane Pastures

Utility Rights-of-Way



Forest and Shrub Wetlands

At landscape and regional scales, forest ecosystems should be managed to generate a shifting mosaic of seral stages that provides habitat for all forest birds. When working at the patch scale, land managers focused on Golden-winged Warbler should strive to create shrubby, young forest with adequate canopy cover that is frequently interspersed with herbaceous openings and includes widely spaced overstory trees for song perches. This basic patch-level configuration often borders more mature forest and is usually set within a landscape matrix of deciduous forest.

Photo credits (from left to right): Jeff Larkin, David Buehler, Lesley Bulluck, Curtis Smalling, Sharon Petzinger, and John Confer.

The regional BMP guides have been produced to compliment and help facilitate the implementation of the *Golden-winged Warbler Status Review and Conservation Plan*. These documents were developed and reviewed under the guidance of the Golden-winged Warbler Working Group, a consortium of more than 140 biologists and managers engaged in research and conservation of this species (**www.gwwa.org**). Funding for the initiative was provided by the National Fish and Wildlife Foundation and U.S. Fish & Wildlife Service, with matching contributions provided by numerous partner organizations including American Bird Conservancy, Appalachian Mountains Joint Venture, Audubon North Carolina, Cornell Lab of Ornithology, Fundacion Proaves-Colombia, Indiana University of Pennsylvania, Ithaca College, Michigan Technological University, Tennessee Wildlife Resources Agency, University of Minnesota, University of Tennessee, West Virginia University, Wisconsin Department of Natural Resources, and Wildlife Management Institute.

Other contributions were provided by Alianza Alas Doradas, Bird Studies Canada, Ecosystem Science Center, Environment Canada, Focus on Energy, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Game Commission, Ruffed Grouse Society, Tall Timbers, The Garden Club of America, U.S. Forest Service, U.S. Geological Survey, West Virginia Cooperative Fish and Wildlife Research Unit, West Virginia Division of Natural Resources, and Wisconsin Society for Ornithology.

This guide was prepared by the Cornell Lab of Ornithology. 2013.

Recommended Citation

Golden-winged Warbler Working Group. 2013. Best Management Practices for Golden-winged Warbler Habitats in the Great Lakes Region. **www.gwwa.org**.

Cover painting of male Golden-winged Warbler by Reyn Ojiri, **www.birds.cornell.edu/artinterns**

Introduction

The purpose of this Best Management Practice (BMP) guide is to provide land managers and landowners with regional, habitat-specific strategies and techniques to begin developing and restoring habitat for Golden-winged Warbler. It includes six separate, habitat supplements dedicated to specific habitat types most important to Golden-winged Warbler in the Appalachian Conservation Region: 1) **Deciduous Forests**, 2) **Minelands**, 3) **Abandoned Farmlands**, 4) **Grazed Forestland/Montane Pastures**, 5) **Utility Rights-of-Way**, and 6) **Forest and Shrub Wetlands**. This document is one of a series distilled from the *Golden-winged Warbler Status Review and Conservation Plan*. Please consult the *Conservation Plan* for full details on Golden-winged Warbler management and population recovery: **www.gwwa.org**.

Golden-winged Warbler in Crisis

Population Decline: During the past 45 years, the Golden-winged Warbler has experienced one of the steepest declines of any North American songbird. The decline in the Appalachian Mountains is especially alarming—a 97.8% population loss from 1966 to 2010 and a 61.7% loss over the last decade (NC -10%, NJ -9%, WV -9%, TN and VA -8%, PA -7%, MD -6%, NY -5% per year) according to the Breeding Bird Survey. The Appalachian population is now largely disjunct from the Great Lakes population (Figure 1). Much of the decline is attributed to habitat loss and land use change, while hybridization with Blue-winged Warbler has exacerbated the declines and added complexity to the development of effective conservation strategies.

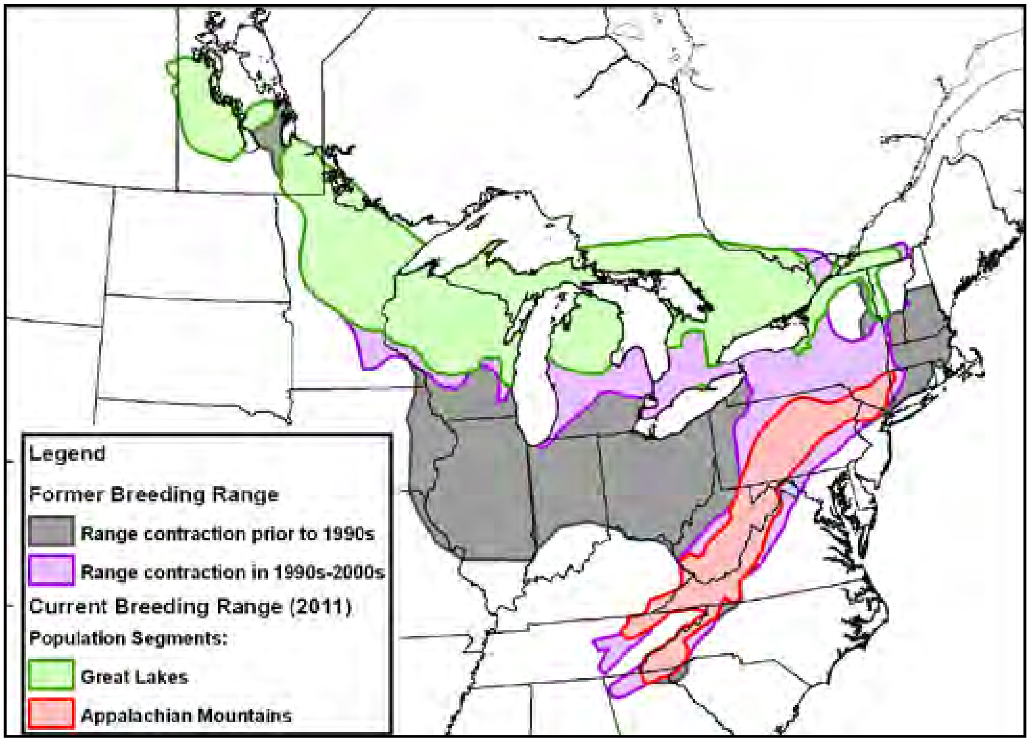


Figure 1. *The Golden-winged Warbler breeding range has two disjunct population segments—Great Lakes and Appalachian Mountains.*

Population/Habitat Goals: The rangewide population goal is to restore the current estimated population of 414,000 breeding individuals to approximately 620,000 birds (similar to population in 1980s). In the Appalachians, the goal is to double the population within 40 years and prevent local extirpations (Table 1).

Table 1. *Golden-winged Warbler population and breeding habitat area estimates and goals. The annual or decadal net gain in breeding habitat needed to attain goals is shown in parentheses. Habitat goals do not account for succession and are likely conservative. Note goals for Great Lakes region are not shown.*

	Population (individuals)/Habitat	Appalachian Conservation Region	Rangewide
Population	Estimated Population (2010)	22,000	414,000
	Population Goal (2020)	27,000	466,000
	Population Goal (2050)	44,000	621,000
Breeding Habitat	Estimated Breeding Habitat (2010)	110,000 ac	2,070,000 ac
	Breeding Habitat Goal (2020)	137,000 ac (+3,000 ac/yr)	2,330,000 ac (+26,000 ac/yr)
	Breeding Habitat Goal (2050)	220,000 ac (+27,000 ac/decade)	3,105,000 ac (+259,000 ac/decade)

Best Management Practices

Where to Work

Focal Areas: Management should be concentrated in the Appalachian Conservation Region, the 18 defined focal areas (Figure 2), or < 5 miles (preferably < 1 mile) from known Golden-winged Warbler populations and < 1 mile from other early successional habitat (ESH) patches. When possible, avoid places where other rare or imperiled resources are higher priority and have conflicting needs, and where Blue-winged Warbler co-occurs and management for Golden-winged Warbler might hasten Blue-winged Warbler invasion, increasing the probability for hybridization. See the *Conservation Plan* for details about individual focal areas.

Scaled Approach to Management: Within appropriate landscape contexts, identify management sites to create, maintain, or restore Golden-winged Warbler habitat (see "Habitat Configuration" sidebar below).

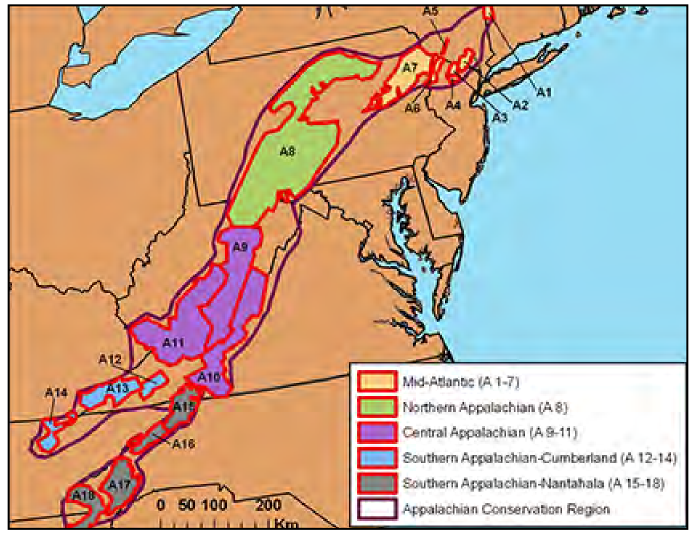


Figure 2. *Subregions and focal areas in the Appalachian Conservation Region.*

Appropriate Landscape Conditions for Management Sites

Macro Landscape Context (within 1.5 miles of a habitat patch)

Elevation:

- Southern and Central Appalachians (GA, KY, NC, TN, VA, WV)—generally above 2,000 ft, varies with site-specific context
- Northern Appalachians (NY, NJ, PA, MD, WV)—generally above 1,300 ft, lower in forested wetlands and heavily forested areas

Forest Cover: > 60% (preferably > 70%)

Forest Type: 80% deciduous; no more than 20% coniferous

Tree Communities: yellow poplar-red oak; sugar maple-beech-yellow birch; aspen-paper birch; mixed oak

Hybridization Risk: avoid valleys and low elevations with areas that have well established populations of Blue-winged Warbler

Micro Landscape Context (within 800 ft of a habitat patch)

Positive Land Cover Associations: forest (60–80% cover), shrub-herbaceous (15–55%), shrub-forest wetlands, and pasture-hay fields (Figure 3)

Negative Land Cover Associations: human development and cropland

Distance Association: when there is a potential for co-occurrence with Blue-winged Warbler, avoid creating habitat adjacent to rivers and streams as these areas are more frequently used by Blue-winged Warbler

HABITAT CONFIGURATION

Decreasing spatial scale

Management site—area where management prescriptions are focused as defined by a management plan.

Patch—area of uniform habitat type or successional stage and defined by a habitat edge.

Habitat edge—distinct boundary between different habitat types or the same habitat but in distinctly different successional stages.

Clump—area of similar vegetation type and height defined by a microedge.

Microedge—readily perceived change in vegetation type or height, such as where grasses change to sedge at the border of a wet area or where a herbaceous opening is bordered by dogwood or *Rubus* shrubs. *Note: due to scale, microedges are not shown.*

Figure 3. *Management site within a forested landscape near a utility right-of-way.*

Suggested Patch Characteristics

Patch Configuration within Management Sites

- Young forest or other ESH with feathered edges leading up to mature deciduous forest boundary
- Patches ≤ 1000 ft from existing breeding habitat should be ≥ 5 acres, while those ≥ 1000 ft should be ≥ 25 acres
- Within large management complexes, 15–20% of area should be maintained in a shifting mosaic of ESH, resulting in a diverse mix of forest ages and types necessary for foraging, post-fledging habitat, and needs of other wildlife

Content within Patches

- Interspersed clumps of shrubs and/or saplings and small herbaceous areas of grasses and forbs (Figure 4)
- Limited canopy cover with widely spaced overstory trees (> 9 inches in diameter) alone or in patches (Figure 5)
- Adjacent mature forest

Configuration of Habitat Components within Patches

- 30–70% shrubs and saplings, 3–13 ft high, unevenly distributed as clumps (see sidebar page 4)
- Shrub and sapling clumps interspersed with small herbaceous openings, primarily composed of native forbs with lesser proportions of grasses and sedges
- Low woody vegetation (< 3 ft), leaf litter, and bare ground can occur in openings but should occupy < 25% of the opening's space
- Infrequent and widely spaced overstory trees as individuals or groups (5–15/acre) resulting in 10–30% canopy cover (20–40 ft^2 basal area) throughout patch (Figure 5), with at least 75% deciduous overstory trees
- A high degree of within-patch heterogeneity is important: average distance to microedge (see sidebar page 4) should be less than 20 ft from any point within patch (Figure 6)

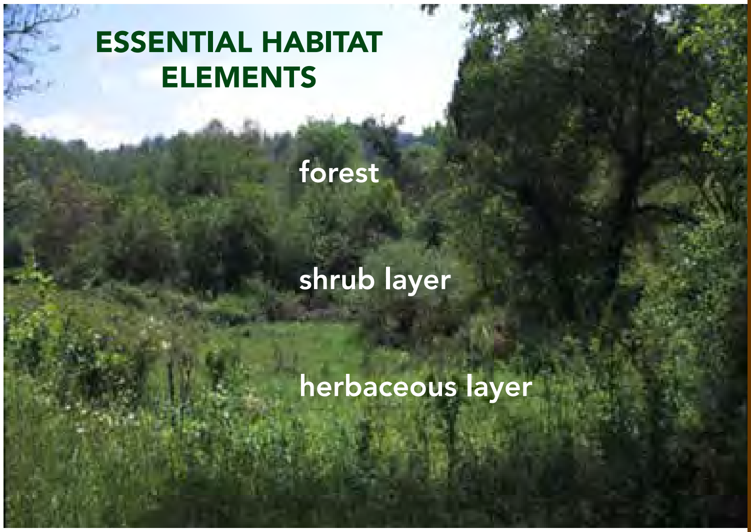


Figure 4. *Structural components of habitat—herbaceous openings interspersed with shurbs and trees bordering more mature forest. Photo by Nathan Klaus.*

Figure 5. *Overstory trees should be infrequent and widely spaced, but are necessary for successful breeding. Photo by Marja Bakermans.*

Figure 6. *High quality habitat with shrubs in clumps interspersed with herbaceous openings (left); poor quality habitat with a contiguous, unbroken shrub layer (right). Photo by Jeff Larkin.*

Management Techniques

A variety of management techniques are available to create, maintain, or restore habitat for Golden-winged Warbler. These techniques can be used to generate the preferred vegetation structure and configuration regardless of habitat type. This can include substantially retarding or advancing succession, or making smaller manipulations to enhance or reduce a given set of conditions (Table 2).

Table 2. *Suggested management techniques to manipulate habitat conditions.*

Symptom	Management Technique	Description of Technique
Excessive canopy cover	Timber Management	Cut to remove canopy trees to achieve 5–15 stems per acre.
	Prescribed Burning	Use fire to kill intolerant trees and reduce canopy cover.
	Restore Natural Disturbances	Restore hydrology on wetland sites to kill non-wetland adapted canopy trees.
Shrubs too evenly distributed	Mechanical Treatment	Mow in irregular patches to create large shrub clumps interspersed with herbaceous openings.
	Prescribed Burning or Grazing	Conduct burns to selectively remove shrubs; graze cattle to reduce shrub density.
	Restore Natural Disturbances	Restore hydrology on wetland sites to kill shrubs and retard re-growth.
Too little herbaceous cover	Timber Management	Harvest canopy trees to create gaps and allow greater sun penetration.
	Mechanical Treatment	Cut or mow in irregular patches; apply herbicide if necessary to retard woody growth; light fall disking.
	Prescribed Burning or Grazing	Use late growing season burns to promote grass/forb growth and frequent (annual) burning to reduce shrub cover.
Too little edge (when residual canopy trees not present)	Timber Management	Create irregular patch margin through timber harvesting.
	Mechanical Treatment	Mow some shrubs and small trees to create feathered edges.
Too few canopy trees	Timber Management	Create feathered edge; retain select saplings and poles of desirable species as future residual trees.
	Plant Desired Species	Plant fast growing native deciduous trees.
High herbaceous cover but low woody cover	Mechanical Treatment	Reduce frequency and/or intensity of mowing.
	Prescribed Burning or Grazing	Reduce frequency and/or intensity of burning/grazing.
	Plant Desired Species	Plant appropriate native shrub and sapling species.

Natural Disturbance Regimes: Promote or restore natural disturbance regimes (fire, beaver activity, and flooding) that create habitat. This is especially relevant in protected areas and wetlands where active management is difficult.

Reclaim and Restore Degraded Sites: Reclaim or restore heavily disturbed sites such as surface mines and gravel pits by planting native grasses with forbs, shrubs, and scattered deciduous trees (plant trees and shrubs in clumps).

Timber Management: Use silviculture treatments such as clearcutting, seed tree harvests, overstory removal with residuals, and shelterwood harvests to provide the proper structural conditions. Retain 10-15 trees/acre, although higher or lower tree density is acceptable under certain conditions (see Deciduous Forests supplement for details).

Mechanical Clearing: Mow and brush-hog in irregular patches to reduce woody growth and promote a patchy woody structure that Golden-winged Warbler prefer (Figure 7).

Prescribed Burning: Use burning to promote or suppress woody vegetation growth by controlling burn intensity and timing (growing season vs. dormant season).

Grazing: Graze pastures and old fields to maintain early-successional conditions by reducing growth of woody vegetation. Graze one animal unit/5–10 acres during the growing season or use higher intensity rotational grazing in the non-breeding season.

Herbicide Application: Apply herbicides that selectively target woody plant growth, especially in combination with other management tools such as fire, grazing, or mowing to retard plant succession and prolong the period of habitat suitability.

See *Conservation Plan* for specifics about each of these management techniques.

Figure 7. *Mechanical clearing or "brush-hogging" can diversify structure, as shown just following management in the left photo and after two growing seasons in the right photo. Photos from left to right: Cathy Johnson; Kyle Aldinger.*

Timing of Management Activities

Whenever possible, habitat management should be conducted during the non-breeding season (mid-July to mid-April), as disturbance during the nesting season can potentially result in "incidental take" of nests, eggs, and young birds.

Associated Species

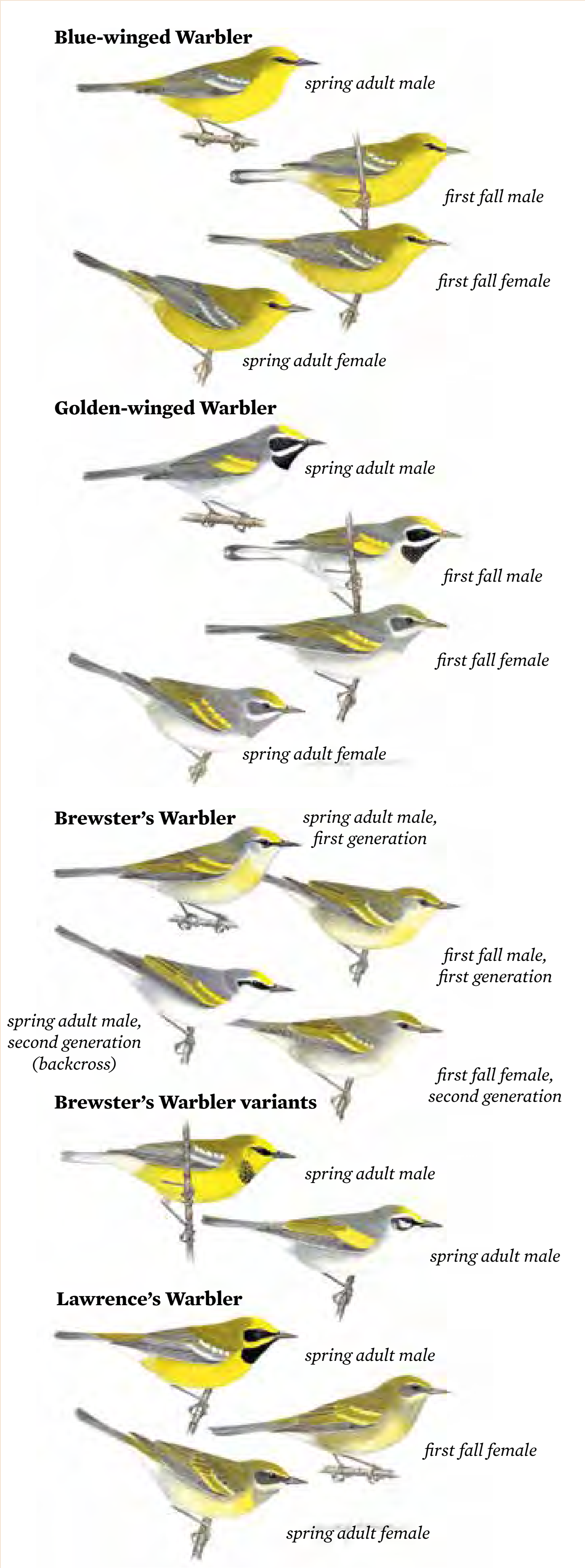
Management for Golden-winged Warbler benefits a host of other wildlife species, including those that rely on ESH and those that will eventually occupy the managed habitat as it succeeds into more mature forest. Many of these associated species have declined since the launch of the USGS North American Breeding Bird Survey in 1966 (see the *Conservation Plan* for a full list of associated species by state). Below is an abbreviated list of species that will benefit from Golden-winged Warbler management:

- American Woodcock
- Blue-winged Warbler
- Prairie Warbler
- Black-billed Cuckoo
- Yellow-billed Cuckoo
- Brown Thrasher
- Field Sparrow
- Eastern Towhee
- Yellow-breasted Chat
- Indigo Bunting

ADDITIONAL RESOURCES

- Golden-winged Warbler Status Review and Conservation Plan, **www.gwwa.org**
- Birds of North America account (requires a subscription or institutional access): **http://bna.birds.cornell.edu/bna/species/020/articles/introduction**
- Golden-winged Warbler Working Group website, **www.gwwa.org**
- Golden-winged Warbler Habitat Best Management Practices for Forestlands in Maryland and Pennsylvania, **www.abcbirds.org/abcprograms/domestic/pdf/GWWA_bmp_FinalSmall.pdf**
- The American Woodcock Management Plan, **www.timberdoodle.org**

When possible, it is important to combine conservation action for Golden-winged Warbler with management for other species, especially when there is potential synergy with partner organizations, such as the Wildlife Management Institute's efforts on behalf of American Woodcock, New England cottontail, and other ESH wildlife species. Clearly there is opportunity to address the needs of a suite of declining species through implementation of these BMPs. Where appropriate, we recommend integrating Golden-winged Warbler management with other wildlife and forest management plans.



Golden-winged Warbler Natural History

Breeding and Wintering Ranges: The breeding range is based on expert knowledge of persistent breeding populations as of 2011. The primary known migratory range is inferred from recent monitoring records; regions with only a few scattered records (e.g., east-central Mexico and Caribbean islands) are excluded. The winter range is based on NatureServe (2011) (Figure 8).

Primary Food: Insects and spiders.

Nesting Habitat: Open woodland; a mosaic of grassy and herbaceous openings, shrubs or saplings, and taller deciduous trees that often borders more mature forest set within a landscape matrix of deciduous forest.

Nest Description: Open cup of grasses, bark, and dead leaves. Leaves may form cap over eggs. Usually on or near ground, often at the base of a small shrub amongst leafy herbaceous growth.

Clutch Size: 3–6 eggs. Single-brooded, with the exception of renesting after early failure of first nests. Eggs are whitish with small streaks of brown near large end.

Threats: Population declines have been attributed to a variety of potential sources including loss of breeding season habitat, interactions with Blue-winged Warbler (both competition and hybridization), Brown-headed Cowbird brood parasitism, and land use changes on the breeding and Neotropical wintering grounds.

Figure 8. *Range map showing breeding and wintering grounds for the Golden-winged Warbler.*

Attachment 10

UNITED STATES OF AMERICA
DEPARTMENT OF AGRICULTURE
UNITED STATES FOREST SERVICE

In re Objection to the Draft Decision Notice,	)	
Finding of No Significant Impact, and	)	
Environmental Assessment for the	)	
Southside Project,	)	
Nantahala Ranger District,	)	
Nantahala National Forest	)	
	)	
	)	Objection No. _______
	)	
Defenders of Wildlife, The Wilderness Society,	)	
MountainTrue,	)	
	)	
Objectors	)	

NOTICE OF OBJECTION AND STATEMENT OF REASONS

Objection Prepared By:

Amelia Burnette
Sam Evans
Julie Reynolds-Engel
Southern Environmental Law Center
48 Patton Ave, Suite 304
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(828) 258-2023

Attorneys for the Objectors

August 27, 2018

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Pursuant to 36 C.F.R. § 218.8(d)(3), The Wilderness Society is designated as the lead objector.

NOTICE OF OBJECTION

Pursuant to 36 C.F.R. § 218, The Wilderness Society, Defenders of Wildlife, and MountainTrue (Conservation Groups) object to the Draft Decision Notice and Finding of No Significant Impact (Decision and FONSI), selecting Alternative B of the Southside Environmental Assessment (EA) in the Nantahala Ranger District of the Nantahala National Forest (the Project). The Decision, FONSI, and underlying EA violate the National Environmental Policy Act (NEPA) and the requirements of 36 C.F.R., Chapter II, Part 220, and the National Forest Management Act (NFMA). The responsible official for this project is Michael Wilkins, Nantahala District Ranger. The public notice was published in the Franklin Press on July 11, 2018. This objection is timely.

The Wilderness Society is a national nonprofit organization working to protect our nation's public lands and is heavily invested in the ongoing forest plan revision for the Nantahala and Pisgah National Forests. Defenders of Wildlife is dedicated to the protection of all native animals and plants in their natural communities. With more than 1.2 million members and activists, Defenders of Wildlife focuses on wildlife and habitat conservation and the safeguarding of biodiversity. MountainTrue is a non-profit organization with the primary goals of protecting, restoring, and preserving public lands and native wildlife through education and public participation in decisions at all levels of government. The Conservation Groups actively participate in the management of the Nantahala National Forest.[1]

The Conservation Groups are familiar with the area of the Southside project and the surrounding national forest. The Conservation Groups' members use and appreciate these lands for their scenic beauty and for remote hiking, hunting, fishing, camping, wildlife viewing, spiritual renewal, and other recreational and educational activities. The Southside project will affect, directly and significantly, the Conservation Groups and their members, including their use of these National Forest system lands.

The Southern Environmental Law Center, legal counsel to the Conservation Groups, is a regional non-profit organization working to conserve natural resources on public lands throughout the Southern Appalachians.

For the reasons that follow, the Conservation Groups request that the Forest Service revisit the project decision and correct the legal errors in its analysis.

[1] The connection between the issues raised in this objection and prior written comments is indicated by footnote throughout the discussion of each issue.

ELIGIBILITY TO OBJECT

The Wilderness Society, Defenders of Wildlife, and Mountain True (Objectors) file this objection to the Southside Project, for which the responsible official is Nantahala District Ranger Michael Wilkins, pursuant to 36 C.F.R. Part 218. Objectors have previously submitted timely specific written comments regarding the Southside Project during designated opportunities for public comment (at Scoping and Draft Environmental Assessment). Each of the issues discussed in this Objection was raised in Objectors' prior comments, and Objectors hereby incorporate those comments by reference.

STATEMENT OF REASONS

The Southside Project analysis area presents a sensitive, ecologically rich landscape, and in that context, a difficult and controversial place for timber harvest. With this Decision, the Forest Service has decided to proceed with the more intensive of alternatives it proposed: logging existing old growth forest, multiple North Carolina natural heritage areas, and two areas that have been inventoried as eligible for wilderness recommendation under the new LRMP, all within an area that is significant for a rare species that depends on habitat with high connectivity.

Proceeding with such intensive activity in this sensitive landscape, with its unique resources, increases the likelihood of significant environmental consequences, and we noted in comments on the EA that many gaps remained in that analysis. As we also explained previously, these gaps owe to the staleness of the current plan and its supporting analysis. Rather than choose a project that avoids unanalyzed cumulative impacts, the Southside Project blunders into the most glaring deficiencies of the current plan—deficiencies that call for a supplemental EIS or, at the very least, a comprehensive EA and well-supported Decision. The necessary environmental analysis is not intended as a check-box exercise necessary to proceed with a decision that has already been made; it is a tool to aid the improvement of a proposal by understanding its impacts at multiple scales and timeframes. The analysis here falls short of that task.

This leaves Objectors and the agency back in the position of clashing over resource management, but this too is symptomatic of a larger challenge: put simply, the current plan is outdated. The current forest plan anticipates rotational-style timber harvest in many areas with sensitive conservation contexts that were not fully known or accounted for when management area boundaries were previously drawn. The Forest Service should know by now that the plan's targets cannot be applied mechanically. For "suitable" management areas that include undeveloped wilderness inventory areas with high ecological integrity and connectivity, intact old growth, and habitat for rare species like the green salamander, the current plan's targets are inconsistent with the agency's obligations and the best available science. Optimistically, this brings into focus how stakeholders might avoid unnecessary project-level disagreements in the future. A revised plan that focuses active management in areas that are most in need of ecological restoration (i.e., not intact old growth, areas with wilderness characteristics, or green salamander habitat) and are least controversial would allow for more efficient implementation of restoration-oriented projects. Accordingly, we have been eager to work with the Forest Service to develop a new plan that focuses active management in areas where it can provide the most benefit with the least harm.

While the plan revision is ongoing, however, these analyses and decisions to harvest in controversial and ecologically significant areas must be addressed at the Project level. The Forest Service has a choice: it can look for opportunities to show its stakeholders that it understands the ecological and social complexities of managing the nation's most important reservoir of biodiversity in its fastest developing region, or it can prove, once again, that it has not earned the public's trust to exercise discretion responsibly. In Southside, the Forest Service has chosen poorly, closing its eyes to the values that make the Nantahala so special, even after they were raised by the public. The Forest Service's EA does not analyze the environmental consequences of the decision to log existing old growth, wilderness characteristics, heritage areas, and green salamander habitat, and leaves the agency blind to the comparative merits of alternatives. As a result, the Forest Service's EA, Decision Notice, and FONSI violate NEPA and NFMA.

I. The EA Ignores Effects of the Action on the Existing Old Growth Forests, Wilderness Inventory Areas, Natural Heritage Natural Areas, and Soil and Water Resources

NEPA requires the Forest Service to take a "hard look" at the environmental impacts of its proposed actions. *Nat'l Audubon Soc'y v. Dep't of the Navy*, 422 F.3d 174, 184 (4th Cir. 2005). This "hard look" insures that (1) the agency carefully will consider the effects of its actions on the environment, and (2) the public and other agencies will be able to analyze and comment meaningfully on the proposal and its impacts. *Id.* at 184; *Klamath-Siskiyou Wildlands Ctr. v. Bureau of Land Mgmt*., 387 F.3d 989, 993 (9th Cir. 2004) (citations omitted).

An Environmental Assessment must address "the environmental impacts of the proposed action and alternatives." 40 C.F.R. § 1508.9(b). The discussion and analysis of the environmental impacts "must provide sufficient information and detail to demonstrate that the agency took the required 'hard look' at the environmental consequences of the project before concluding that those impacts were insignificant." *Sierra Nevada Forest Prot. Campaign v. Weingardt*, 376 F. Supp. 2d 984, 990–991 (E.D. Cal. 2005) (quoting *Save the Yaak Comm. v. Block*, 840 F.2d 714, 717 (9th Cir.1988)). This must include "some quantified or detailed information" supporting the conclusions of the EA. *Klamath-Siskiyou Wildlands Ctr.*, 387 F.3d at 993.

NEPA procedures ensure decisions are "*based on understanding of environmental consequences*, and take actions that protect, restore, and enhance the environment." 40 C.F.R. § 1500.1(c) (emphasis added). An incomplete analysis of environmental effects, or the efficacy of measures to reduce the severity of those effects, "undermine[s] the 'action-forcing' function of NEPA," because "neither the agency nor other interested groups and individuals can properly evaluate the severity of the adverse effects." *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 352 (1989) (citations omitted). NEPA procedures require the necessary environmental information be available to "public officials and citizens *before* decisions are made and *before* actions are taken." 40 C.F.R. § 1500.1(b) (emphasis added). In other words, "NEPA ensures that important effects will not be overlooked or underestimated only to be discovered after *resources have been committed or the die otherwise cast*." *Robertson*, 490 U.S. 332 at 349 (emphasis added).

The Southside EA overlooks the environmental consequences of logging existing old growth and heritage areas identified by the state as conservation priorities, and entirely refuses to engage an analysis of impacts to characteristics of areas being considered for wilderness or other protective designations in the plan revision. Site-specific analysis remains lacking—meaning the extent of effects are not yet determined. Without this, the agency cannot conclude those (unexamined) impacts will be insignificant. As a result, the Southside EA will not support the Decision's FONSI—because the EA dodges assessment of the very impacts that the decision deems inconsequential. The incomplete analysis of effects ultimately leaves the agency and the public uninformed about the environmental consequences of the act. This alone is error, but it also leads to more error still: In the absence of understanding the site-level impacts, the agency cannot evaluate the comparative merits and tradeoffs of the alternatives it considers. Therefore, as discussed in section III, the flawed analysis of the effects of the action, among other legal consequences, undermined the agency's consideration of alternatives.

A. The EA Fails to Analyze Direct and Indirect Impacts of Logging Existing Old Growth Forest in Stand 35-41

In selecting Alternative B, the Forest Service decides to log 26 acres of old-growth forest in stand 35-41, near Brushy Mountain.[2] That this stand is existing old growth is not in dispute: the EA acknowledges as much, finding that stand 35-41 "meets the operational definition for old-growth as defined" in the Region 8 Old Growth Guidance. EA at 60.[3]

Despite this recognition, the agency stops short of analyzing the site-level impacts of converting this old growth forest – a rare and virtually irreplaceable resource – into early successional habitat (ESH), in this location. Disclosure of the forest type alone is insufficient to satisfy NEPA's requirement to analyze project-level impacts of logging existing old growth in the context of this specific area.

Courts recognize that failing to properly account for impacts to old growth runs afoul of NEPA. *See Neighbors of Cuddy Mountain v. U.S. Forest Serv.*, 137 F.3d 1372, 1378 (9th Cir. 1998) (holding as inadequate a cumulative impact analysis of combined effect on depleting existing old growth habitat); *Bair v. Cal. Dep't. of Transp.*, C 10-04360 WHA, 2011 WL 2650896 (N.D. Cal. July 6, 2011) (issuing injunction for road widening through old-growth redwood area where agency issued a FONSI instead of producing an EIS); *see also Alliance for the Wild Rockies v. Wood*, CIV 07-452-EJL, 2008 WL 2152237 (D. Idaho May 21, 2008) (enjoining timber sale where method of calculating old growth was scientifically flawed).

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[2] *See* The Wilderness Society, MountainTrue, Defenders of Wildlife, and SELC EA Comments (Mar. 19, 2018) at 2–6; Scoping Comments (Mar. 20, 2017) at 3–4. These comments will be referred to as "Scoping Comments" and "EA Comments" within this objection.

[3] *See* Guidance for Conserving and Restoring Old-Growth Forest Communities on National Forests in the Southern Region, Report of the Region 8 Old Growth Team (June 1997) (hereafter referred to as Region 8 Old Growth Guidance or Region 8 Guidance), *available at* https://www.fs.fed.us/outernet/r8/planning/R8%20Old%20Growth%20Report.pdf (hereafter referred to as Region 8 Old Growth Guidance or Region 8 Guidance).

In response to comments, the Forest Service offers several rationales for ignoring site-specific impacts to old growth, but none would or could extinguish this NEPA obligation.

1. The EA Fails to Assess Impacts of Logging Existing Old Growth in Stand 35-41

Although the EA acknowledges that stand 35-41 meets the operational definition for existing old growth, the draft EA did not address the rarity, significance, or exceptional values of such existing old growth. Instead of disclosing what about the stand *is* in old growth condition, and what habitat values the stand *is* currently providing, in a location-specific context, the EA's response to comments (1) tries to downplay the old growth, and (2) indicates a willingness to drop the stand but blames NGOs for not supplying another place for the Forest Service to log in the forests it manages. EA at 194. Neither tactic allows the Forest Service to avoid its task of disclosing the environmental consequences of converting a stand of remaining old growth on Brushy Mountain into ESH.

Existing old growth is an exceptionally rare and significant resource in the Southern Appalachians. The Forest Service's own guidance, applicable here, emphasizes the rare occurrence of old growth across Southeastern forests:

> Old-growth communities are rare or largely absent in the southeastern forests of the United States. Existing old-growth communities may represent around 0.5 percent (approximately 676,000 acres) of the total forest acreage (approximately 108,400,000) acres in the Southeast (Davis 1996).

Region 8 Guidance at 1. Forests in old growth condition, according to this guidance, should receive the highest level of consideration and protection: Old growth is "a valuable natural resource worthy of protection, restoration, and management." *Id.*

Scientists and forest researchers similarly agree that the scattered remnants of Eastern old growth forests are an "exceedingly rare part of the natural world." *Eastern Old Growth Forests, Prospects for Recovery and Renewal*, at 3 (1996).[4] Five hundred years ago, this old growth was considered inexhaustible, but today such forest exists on but a tiny fraction of the land: "Isolated pockets of old growth forest are all that remain. As such they are the subject of intense interest to the scientific, academic, and environmental communities." *Id.* Almost all of this remnant of remaining old growth exists on public lands, primarily National Parks and National Forests, heightening the need to conserve whatever old growth remains on our National Forests. *Id.* at 348–49; *see also* 71, 73 ("Because of the history of logging in the East, it is clear that we should preserve all remaining old growth and create more."); 357. Additionally, the forest plan revision analysis shows extremely high levels of "departure" for old growth, demonstrating that the deficits observed by Region 8 also apply at the Forest-wide and mid scales.

[4] Select excerpts from this publication are attached to EA Comments.

Furthermore, the recovery process for lost old growth takes centuries, and it is not clear whether all of the components of old growth, including its unique soil and hydrologic conditions, can ever be restored once the trees are cut: "We do not know whether heavily logged forests will ever regain all the characteristics of the original forests, and the process of recovery will take centuries." *Id.* at 8. Courts have also recognized that loss of old growth forest takes hundreds of years to replace. *Cuddy Mountain*, 137 F.3d at 1382; *Idaho Sporting Congress v. Alexander*, 222 F.3d 562, 569 (9th Cir. 2000).[5]

While "[m]uch is still unknown" about the extent of old growth's ecological importance, old growth is recognized to be biologically critical, providing important reservoirs of biodiversity and exceptional habitat for a diverse range of forest species; it is scientifically unique, providing valuable benchmarks to understand change elsewhere in the forest; and culturally significant, providing spiritual, aesthetic, and existence values. Region 8 Guidance at 12–14. Accordingly, impacts to old growth of the Project's proposed intensity—i.e., outright destruction—implicate many of the factors tending to show that an EIS is required. *See* 42 U.S.C. § 4332(2)(c); 40 C.F.R. § 1508.27(b)(3), (5), (8) (providing that an EIS is more likely to be required when the resource affected is unique, culturally or scientifically significant, or uncertain).

The Region 8 Guidance also has specific provisions for existing old growth management, stating: "For those stands which meet the operational definitions for old growth, the directions in the forest plan will provide management options." Region 8 Guidance at 26. However, the decades-old Nantahala-Pisgah Forest Plan does not address existing old growth, because the Region 8 Guidance was issued after the Forest Plan and Amendment 5. This lack of management options is an issue that the Forest Plan revision currently underway will have to address. In the meantime, the fact that the current Forest Plan does not address existing old growth does not excuse the need to analyze and disclose the impacts of destroying an existing old growth stand; rather, the absence of this analysis at the plan level demonstrates the need for it at the project level. The Forest Service cannot avoid these NEPA obligations by simply failing to investigate and disclose the extent of impacts to old growth and attempting to sweep this issue "under the rug." *See, e.g.*, *Silva v. Lynn*, 482 F.2d 1282, 1285 (1st Cir. 1973). Furthermore, the cumulative impact of logging (or conserving) existing old growth forests is inherently a landscape-scale issue, the cumulative impacts of which have never been analyzed by the Nantahala-Pisgah. This EA neither performs that analysis nor pretends to.

Because the EA does not analyze the direct, site-level impacts of logging old growth, it also does not address indirect effects of logging in and near old growth: namely, impacts related to fragmentation or edge effects that will be caused by logging and by the building of temporary roads and skid trails. *See* EA at 81 (offering only the perfunctory conclusion that "temporary road access to stand 35-41 was evaluated for impacts to wilderness characteristics" and would not "preclude future potential recommendation for wilderness"). Old growth forest communities are sensitive to edge effects, habitat fragmentation, and gradual creep of disturbance from logged areas into the boundaries of neighboring old growth areas. Edge effects from disturbance diminish the habitat value in neighboring interior forest. Many of the species that characterize

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[5] *Overruled on other grounds by Lands Council v. McNair*, 537 F.3d 981, 997 (9th Cir. 2008).

old growth do best in large, unbroken stands. In addition, the Forest Service has recognized that wildlife "[t]ravel corridors are necessary to link areas of suitable habitat for all species" and notes that "[e]xamples of travel corridors are . . . mature forest that link old-growth areas." Supplement to LRMP FEIS at IV-20. In responding to comments about this omission, the Forest Service again simply waves away that analysis, instead discussing the *benefits* of interior edge habitat to certain species. EA at 192. But analysis of the indirect impacts of logging in stand 35-41 and nearby in stand 35-42 on travel corridors for mature forest species, is a separate obligation, and omitting it falls short of the "hard look" standard under NEPA. *Marble Mountain Audubon Soc'y v. Rice*, 914 F.2d 179, 182 (9th Cir. 1990) (finding that failure to analyze fragmentation of wildlife corridors for species preferring mature forest conditions fell short of obligation under NEPA to analyze impact of logging old growth forest). The presence of green salamanders in stand 35-42, a species that requires mature forest cover and forages in down-woody debris and large tree canopies, underscores the importance of engaging this analysis.

Finally, we take strong issue with the rationale in the EA that blames the inclusion of the stand on NGOs because they did not provide alternative locations for logging. On past projects, conservation NGOs have helped the Forest Service find work that can meet ESH objectives without compromising conservation values, but it is not the responsibility of Objectors to do that. Here, Objectors clearly provided an alternative to logging this old growth stand—namely, not logging it. The EA does not provide a basis for comparison of the negative impacts of logging versus not logging this stand. Accordingly, there is no reason whatsoever to assume that the EA would have provided a basis for comparison of the negative impacts of logging this stand versus logging a different stand.

2. The Existence of Patch Designations Under the Forest Plan Does Not Extinguish the Agency's Obligation to Analyze Impacts of Logging Existing Old Growth

Instead of analyzing impacts to old growth, the EA persists in an error the Objectors pointed out in comments (EA Comments at 4-6), by relying upon the extent of the agency's designated old growth patch network under the current plan's framework, and the representation of forest over 100 years of age within this ecozone. Neither rationale is a substitute for the obligation to evaluate impacts of logging this particular existing old growth stand under NEPA. In other words, meeting patch designations pursuant to the existing forest plan does not satisfy the separate obligation to analyze project-level impacts of planned activities. In addition, an age class exceeding 100 years is not the same as a stand in old-growth condition. The Region 8 Guidance explains that old growth is more than just older trees, and it provides rare ecological value not found elsewhere. Elsewhere, where it is convenient to justify the Decision, the District explicitly acknowledges the difference between late-closed forest and existing old growth, declining to recognize older stands identified by some members of the public as "old growth." Yet when it comes to analyzing impacts, the District treats these stands as if they were the same. As a result, the EA is not only deficient; it is also internally inconsistent.

The EA looks to the extent of patch designations and forest over 100 years old across the analysis area, downplaying impacts to stand 35-41 by suggesting that old growth is no more ecologically important than abundant second-growth, even-aged forest over 100 years old. The EA discusses acreage in designated old growth patches within the dry/mesic oak ecozone as "well represented and protected in **existing old-growth designations** within the AA." EA at 60 (emphasis added). The EA concludes, the Forest Service "considered adding stand 35-41 to the existing network of large and small patch designated old growth," but elected not to because it believes its old-growth designations for the dry mesic ecozone are sufficient. *Id.*

The Region's guidance on this topic does not support the assumption that patch designations align with existing old growth. In the Region 8 Old Growth Guidance, "existing old growth" has a specific definition: "individual stands on a national forest currently recognized as meeting the parameters of the old growth operational definition (table 2)." Region 8 Guidance at 115. The EA establishes that stand 35-41 meets these criteria (see above), so it is, by definition, existing old growth.

Old growth patches, on the other hand, are defined separately from existing old growth. Under the forest plan, old growth patches are those areas designated for "future old growth management." LRMP at III-27. Under the Region 8 Guidance, future old growth is comprised of "areas on national forests that have been allocated to old-growth restoration through land management decisions." Region 8 Guidance at 115. The fact that a patch is designated as part of a network to be managed as future old growth does not mean it meets the operational definition for existing old growth. *See, e.g., id.* at 7. Existing old growth requires stand examination to determine if it meets old growth criteria for designation. Most stands within old growth patches have not been examined to determine if they meet old growth criteria, and many that have been examined for small patch designation have actually been found not to be existing old growth. Indeed, as the District is aware because of recent projects like Camp Branch, some designated old growth patches include very young forests that have been recently logged. A few stands within old growth patches are "possible old growth," described as "areas with the highest probability of being existing or future old growth based on the preliminary inventory criteria." *Id.* at 117. Furthermore, the Forest has indicated that some patch designations may be moved or abandoned during plan revision, which highlights the EA's fundamental omission with respect to old growth: designations exist only on paper, but old growth forest exists on the ground, and NEPA is concerned with on-the-ground impacts.

The Region 8 Guidance separately addresses possible old growth, future old growth, and existing old growth. The draft EA, however, conflates these different issues. The Forest Service provides no support (nor could it) to justify a conclusion that the existence of designated future old growth can somehow undo the impacts of logging existing old growth on Brushy Mountain. The same considerations apply to stands "over 100 years of age." EA at 60 (documenting the amount of forest greater than 100 years old in this ecozone within the non-timber-suitable land base). Not only are these stands *not* in old growth condition currently, but they are also scheduled for timber harvest in the future.

Nothing in the EA supports the inference that the existence of these non-old growth stands, many of which will never reach old growth condition, can negate the impact of logging existing old growth in 35-41. Certainly, the inappropriate reference to future (designated) old growth as rationale for the liquidation of existing old growth cannot suffice as adequate NEPA analysis. As a result of these various errors, the Forest Service fails to consider the environmental consequences of eliminating an existing old-growth forest in stand 35-41.

B. The EA Ignores Impacts of Logging in Areas that Are Wilderness Inventory Areas

Stands 29-15 and 29-16 are within the Ellicott Rock WIA, and stand 31-20 is within Terrapin Mountain WIA. These stands are presently being considered for wilderness and other protective management designations in the ongoing plan revision.[6] This Decision allows logging in these areas, based on an EA that declined to analyze the environmental consequences of logging them. Wilderness characteristics or values from these areas include solitude, primitive or backcountry recreation, intact wildlife habitat, water quality, visual integrity and scenic values, unique and outstanding qualities, and the economic values associated with those resources. The current plan, which was revised decades ago under superseded NFMA rules, did not analyze the wilderness characteristics of these areas. Because the significance of these areas was not considered at the plan level, each project must now consider the cumulative impact, over time, to the areas' character and eligibility, from road footprints to follow-up treatments like crop tree selection to the next regeneration harvest.

In comments on the EA, Objectors pointed out that the impacts of vegetation management and associated road and skid trail construction to these areas' unique characteristics and future eligibility for designation have not been considered under NEPA.[7] Instead of undertaking that analysis, the Forest Service disagrees that it is required to analyze those impacts. The Forest Service has pointed out that an area being included in the inventory does not "convey[] or require[] a particular kind of management." EA at 18. While the inclusion in the inventory for plan revision did not change the management designation of these areas under the existing plan, that is not the end of the analysis for purposes of satisfying NEPA. In other words, that does not alleviate the requirement to evaluate the environmental consequences to the wilderness character of these areas from allowing logging and skid trails within them.

Before deciding to proceed with timber harvest within areas that possess the characteristics that qualified them for inventory, the agency must evaluate the impacts of such a decision on those characteristics. *See, e.g.*, *Lands Council v. Martin*, 529 F.3d 1219, 1230 (9th Cir. 2008) (discussing NEPA obligations that extend to the attributes of uninventoried roadless areas); *Sierra Club, Inc. v. Austin*, 82 F. App'x 570, 573 (9th Cir. 2003) (finding error where the Forest Service failed to address the effects of logging in unroaded areas on their characteristics vis-a-vis potential for future wilderness or IRA designation); *Cascadia Wildlands v. Carlton*, 2017 WL 1807607, at *10 (D. Ore. Mar. 20, 2017) (finding deficient the EA's analysis of "timber sale's effects to Wilderness, Potential Wilderness, and other undeveloped areas"); *see also Ore. Nat. Desert Ass'n v. Bureau of Land Mgmt.*, 625 F.3d 1092 (9th Cir. 2010) (concluding that BLM violated NEPA by declining to study wilderness characteristics because "[w]ilderness values are among the resources which the BLM can manage").

Side-stepping that analysis, the Forest Service offers that "management activities would not be an irreversible and irretrievable commitment of resources that would preclude future potential recommendations for wilderness." EA at 18, 196. However, the EA contains no direct

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[6] For stand 31-20, the Forest Service also must consider the cumulative impacts of prescribed burning (Bull Pen) in combination with planned timber harvest on wilderness characteristics, *see* EA Comments at 7.

[7] *See* Scoping Comments at 2; EA Comments at 6–8.

analysis of effects to the characteristics of these areas to support that conclusion. And documents obtained in response to a Freedom of Information Act (FOIA) request indicate that omission is a deliberate choice by the agency.[8]

As to whether management activities in these WIAs would actually preclude future wilderness recommendations, the wilderness evaluation conducted by FS in the plan revision confirms signs of vegetative management do factor into the agency's analysis of wilderness characteristics. Considerations of naturalness include effects of "recent timber harvest, wildlife openings, roads . . . and other past management."[9] Deviations from the natural condition, in the agency's evaluation, included evidence of past management activities, like recent even-aged harvests . . . skid roads, logging decks, [and] cable yarder landings."[10] In evaluating the "naturalness" of the Terrapin Mountain area, the Forest Service noted "[r]ecent timber cuts and maintained wildlife fields represent a departure from naturalness" and "detract from the naturalness" in the western and eastern sides.[11] In the Ellicott Rock West Extension, the Forest Service found "[r]ecent vegetation management activities" apparent in a portion of the area, as relevant to its naturalness.[12] Against this backdrop, and without site-specific analysis, it is simply not credible to suggest that additional timber harvest and signs of management that detract from "naturalness" would not factor into future potential recommendations, premised in part on naturalness. The same applies to management activities proposed in compartment 35, adjacent to Terrapin Mountain.

The agency should not take action in this project that would prejudice or limit the consideration of alternatives for these areas in the future. *See* 40 C.F.R. § 1506.1. Making a decision to enter into a timber sale contract that would create signs of vegetation management and road construction within WIAs that are being simultaneously considered for more protective management in the plan revision, for example, may convey agency bias in consideration of alternatives for these areas, or represent a decision in principle about their future management because of the functional impact (which as discussed later, requires an EIS). *See Native Ecosystems Council v. U.S. Forest Serv. ex rel.*, 866 F. Supp. 2d 1209, 1220, 1229–30; *cf. Metcalf v. Daley*, 214 F.3d 1135, 1144 (9th Cir. 2000) (agency entering contract prior to EA indicated "subtle bias" in selection of alternatives). The future direction of these areas is subject to a detailed environmental review during plan revision, with robust public involvement and science-based analysis of alternatives. Logging and associated impacts in these areas now could degrade values that qualified them for the inventory and protective management in the first place.

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[8] *See, e.g.* attached, Email from H. Luczak to B. Houck (Mar. 15, 2018) (acknowledging "[t]here is no direct analysis of impacts of the treatments on the inventory areas in the body of the EA," and referring instead to general discussions in the EA).

[9] *See* attached, Evaluation of Areas that may be Suitable for Inclusion in the National Wilderness Preservation System, Nantahala and Pisgah National Forests (June 2017) at 7.

[10] *See id.* at 269.

[11] *See id.* at 182–83.

[12] *See id.* at 149.

In other words, inclusion in the Chapter 70 process is not a designation that confers protection, but it is absolutely a good reason to defer decisions to develop those areas until after a landscape-level look at their unique characteristics and their ability to meet ecological and social needs that are outside the scope of the project. More to the point, regardless of whether the Forest Service agrees that it should defer such decisions, it cannot proceed to degrade these areas without transparently disclosing the impacts to the public. But that would require a level of accountability that the Forest is apparently not prepared to accept—hence the vacuous conclusion that the project would have no impact. Despite the Forest Service's reticence, these kinds of impacts are nonetheless matters of significant public interest, at a time of heightened interest generally in the plan revision. Even if the Forest Service is unwilling to disclose these impacts to the public, Objectors believe it is important that this information is made available and will be transparent about that.

The Forest Service's response to comments suggests that the expected timing of project implementation could remedy whatever problem might be created by deciding to log in areas being considered for other designations. The Forest Service *does not* agree to delay a decision on the project until future management of these areas is properly decided with detailed environmental review and stakeholder participation; rather, *if* a wilderness designation beats project implementation (anticipated 2020), then "these actions would not occur." EA at 196, 18. These statements, however, miss the requirements of NEPA. The Forest Service cannot decide to impact wilderness characteristics in a WIA and put off analysis of those impacts because the area might be protected if the plan revision concludes quickly enough. It must either analyze those impacts commensurate with a decision, or remove stands within the WIAs from the project. The EA cannot rely on speculation about what may happen in the plan revision or when the plan revision may be finalized in the future to avoid consideration of impacts to an area it puts on the table for harvest now.

Because of the potential significance of disturbance activities to WIAs, an EIS would be required. Attributes that qualify an area as potential wilderness "possess independent environmental significance." *Lands Council*, 529 F.3d at 1230 (EIS that provided "a three-page analysis on 'roadless character'" was "cursory" and therefore insufficient); *Cascadia Wildlands*, 2017 WL 1807607, at *10 (timber sale's effects to Wilderness, Potential Wilderness, and other undeveloped areas necessitated an EIS). In addition, the potential for designation as wilderness areas is an independent factor of significance. *Smith v. U.S. Forest Serv.*, 33 F.3d 1072, 1078–79 (9th Cir. 1994). Impacts that would make an area ineligible for inventory in the future are likely to be "significant," requiring full consideration in an EIS. *See* 36 C.F.R. § 220.5(a)(2) ("Proposals that would substantially alter the undeveloped character of an inventoried roadless area or a potential wilderness area" will ordinarily require an EIS.).

C. The EA's Analysis Does Not Acknowledge Direct Effects of Logging in NHNAs

The Southside project includes logging in stands in or adjacent to several Natural Heritage Natural Areas (NHNAs), including the Whitewater River Falls and Gorge NHNA (stands 41-44 and 41-53), Blackrock Mountain/Granite City NHNA (stand 31-18), and Slick Rock NHNA (stand 29-16). In responding to comments that impacts to these NHNAs were unanalyzed in the Draft EA, the agency states that several areas slated for logging have been removed from NHNA designation.[13] Stand 41-44 was excluded from the Whitewater River Falls and Gorge NHNA boundary after review by the North Carolina Natural Heritage Program, as a result of "more recent group selections harvests which do not meet natural area criteria." EA at 54, 199. The boundary of that same NHNA was modified further "in other areas to exclude young and mid-seral habitat." EA at 54. The boundary of the Blackrock Mountain/Granite City NHNA was redrawn to exclude stand 31-18 after a review of the site, because that area included "younger forest and previously disturbed forested areas with roads." EA at 53–54, 200.

For those stands that still fall inside of these modified NHNA boundaries, the EA states that there will be no impacts from timber harvest. Stand 41-53 in the Whitewater River Falls and Gorge NHNA would be subject to two-aged treatment. The EA states that the treatment would take place outside of the 303-acre portion of this NHNA that is protected under the forest plan and that the Natural Heritage Program stated white pine could be removed, but the EA sidesteps actually addressing the impacts of logging to the NHNA. EA at 54. Instead, the EA writes off any concern, stating that "[t]he activities proposed in the Southside project would not negatively impact the core values of the Whitewater River Falls and Gorge NHNA, which are listed as waterfalls, spray cliffs, grottos, cliffs, dry rocky outcrops, and rare plants in the Whitewater River gorge in the Transylvania County Natural Area Inventory." EA at 54. But specific geographical features are not the only "core values" of this NHNA. It was designated because it represents unique ecological values. If portions outside of the "waterfalls, spray cliffs, grottos, cliffs, dry rocky outcrops, and rare plants" were not considered significant, they would not have been included in the NHNA designation in the first place.

One of the primary problems in the EA is the internally inconsistent reasoning employed to write off impacts in these stands. The EA specifically admits that several portions of NHNAs were removed from that designation as a result of timber cutting. It then says in the very same section that tree harvesting in other NHNA areas will have no impacts on the NHNA. But allowing tree harvesting is exactly what caused the Natural Heritage Program to redraw the boundaries of several NHNAs for this project. The Forest Service cannot rely on the fact that past timber harvesting means certain areas are no longer NHNAs and then say there will be no impacts to current NHNAs from timber harvesting. That kind of reasoning is plainly arbitrary and capricious. The problem with this reasoning was pointed out in previous comments, EA Comments at 8, but was not addressed in the EA.

[13] *See* Scoping Comments at 2–3; EA Comments at 8–9.

D. <u>The EA Does Not Disclose or Analyze Risks of Soil Erosion, Sedimentation, or Impacts to ORW Streams Based Upon Site-Specific Information</u>

The Decision is based on a finding of no significant impact to soil and water resources from project activities. This conclusion is not based upon a site-specific analysis of risk from erosive soils, steep slopes, or logging methods and related ground disturbances from skid trails and log landings in particular stands. The EA does not disclose the soil erosion factor or slope in each stand. Nor does the EA disclose the method of logging to be used in each stand, so it is unclear where soil disturbance will be more intense for ground-based logging. Because the EA declines to limit the use of ground-based logging,[14] the EA must consider the impacts of ground-based logging everywhere it is allowed. Likewise, the EA omits a site-specific analysis of how logging activities in erosion-prone soils might impact nearby streams.

Although not disclosed or analyzed in the EA, soil data available from the USDA NRCS and slope data available from multiple sources to Objectors and the Forest Service indicates that, for example, the soils in stands 35-41 (old growth stand), 35-42 (green salamander present), and 29-16 (WIA) are rated "severe" for erosion risk. In stands where logging will occur for the project, over one-third of slopes exceed 35 percent, and over one-fourth exceed 40 percent. Most of stand 35-42, for example, has slopes exceeding 35 percent, in severely erosive soils. *See* attached, Soil and Slope Charts for Southside Stands.

The presence of steep slopes and high quality streams in areas proposed for ground-based logging are project-specific factors that trigger taking a hard look at likely erosion risk from exposed road cuts, skid trails, bank cuts for log landings, and other soil disturbing activities. Although the EA is devoid of an analysis of site-specific factors influencing soil erosion and sedimentation risks, the EA assumes BMPs will perform at near perfect rates (97 percent) when implementation occurs, despite using undisclosed logging methods, in unassessed risk conditions, with unknown operators. *See e.g.*, EA at 65 (water resources); EA at 29–30 (coldwater stream impacts).

The EA assumes this, not from site-specific analysis, but by relying on monitoring reports compiled by the Forest Service in 2013 and 2018. The implementation rates derived from these reports are not based upon comprehensive monitoring from all timber sales in the Pisgah or Nantahala National Forests, but rather, some limited subset "selected" for review from across North Carolina. The 2018 report, for example includes many sales from forests with conditions that are not relevant to analyzing BMP efficacy at Southside, like Croatan National Forest and Uwharrie National Forest, in terrain where, generally, BMP implementation is less challenging. For those timber harvests that are included from the Pisgah and Nantahala, it is unclear on what basis the Forest Service selected some for inclusion, and excluded others. The 2018 report, for example, *includes* the Scott Mountain and Mince Cove Timber sales on the Pisgah National Forest, but *excludes* the Panther Branch Sale, where BMPs were not effective at controlling sediment.

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[14] The EA relies on a general statement that it will use "cable logging systems in areas of steep terrain," but does not explain where on a site-specific basis it believes steep terrain requires cable logging. EA at 10.

In fact, Objectors argued that ordinary forest design criteria and BMPs were unlikely to be successful at keeping sediment out of Courthouse Creek and its tributaries in the project that led to the Panther Branch Sale. By July 2017, with logging operations well underway, it was clear that storm events and road cuts indeed proved too intense for the usual BMPs; sediment was not contained on-site as predicted and instead ran off into trout streams. *See* attached, Panther Branch Sale map and photos from 2017. DWR reported "~200 feet of a headwater stream/seep was impacted with sediment measured to be 2-3 inches in depth." *See* attached, DWR inspection report, July 27, 2017. The Panther Branch sale confirms that temporary roads, skid roads, and skid trails can, with ordinary BMPs, prove to be persistent sources of sediment runoff, in areas with highly erosive soils and high rainfall. Other sales throughout Region 8 have demonstrated the same (*see* Hogback in Cherokee National Forest[15]).

The District cannot rely on a generic BMP report, without more, to dismiss Objectors' concerns about similarities to actual, significant, and unlawful BMP failures that occurred at Panther Branch, close by to the Southside Project area. At a minimum, the District must explain why this sale has more in common with remote, dissimilar projects than it does with the recent and glaring example where BMPs and plan standards were inadequate. The EA here makes no effort to explain how the conditions at Southside are anything like the handful of timber harvests *included* in the BMP report, or conversely, why they are unlike the sales *excluded*, like those with lower BMP effectiveness rates. In the absence of specific analysis, reliance on BMP effectiveness assumptions derived from sales throughout North Carolina is just speculation.

In addition to the BMP survey reports, the EA relies on "watershed research" to downplay impacts to water resources. However, the sole article the EA cites also found significant impacts on sedimentation following logging at the Coweeta Hydrologic Laboratory in the Nantahala Mountain Range. A "major effect of management was pulsed sediment inputs from newly constructed roads." Although BMPs "were used in harvesting and road, location, and design," "cumulative increases in sediment yield were observed downstream over the next 15 years," and the rate of sediment yield over the 5-15-year period after disturbance remained "nearly 50% above pre-treatment levels" in a ponding basin in a second-order stream. W.T. Swank et al., Forest Ecology and Management 143 (2001) at 163, 175, 176. The study attributed the higher-than-projected sediment pulses to two storm events that occurred in the month following road construction.[16] It is unclear how this watershed research supports the Forest Service's conclusion that there will be "little" short-lived sedimentation at Southside. At any rate, as explained below, an undefined threshold for "little" sediment is not the substantive standard required by state law or the Forest Plan. Instead, consistent with state law, the Plan forbids the delivery of "visible sediment" to streams. The current analysis cannot and does not attempt to justify a conclusion that this standard will be met.

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[15] *See* attached, Complaint and Forest Service Notice withdrawing the Dinkey project. The attached Complaint describes the Forest Service's failure to adequately consider soil risk in light of recent project failures on the Cherokee National Forest, which, after further consideration, necessitated the attached Notice of Withdrawal.

[16] The study hypothesized that two major storm events contributed to sediment pulses that pushed sediment yield towards the upper limits of what might be expected, but the study also noted that impacts on resources could be substantially greater in projects where there is greater soil disturbance. W.T. Swank et al., Forest Ecology and Management 143 (2001) at 176.

The Forest Service must move beyond base assumptions about BMP efficacy, and evaluate the likely performance of these ordinary measures against site conditions in the Southside project area, instead of relying on the same faulty assumptions that led to un-analyzed impacts in the Panther Branch sale. An agency may not escape the obligation to analyze site-specific environmental consequences of the action by relying on general mitigation measures, without the requisite analysis determining the efficacy of those measures on site-level impacts. *See Colorado Envt'l. Coal. v. Dombeck*, 185 F.3d 1162, 1173 (10th Cir. 1999) ("merely list[ing] possible mitigation measures" is insufficient); *Cuddy Mountain*, 137 F.3d at 1381 (disapproving an EIS that lacked such an assessment); *see also Ohio Valley Envtl. Coal. v. Hurst,* 604 F. Supp. 2d 860, 889 (S.D.W. Va. 2009) (a "perfunctory description" or "mere listing" of mitigation measures without supporting analysis insufficient to support a FONSI).

Such an analysis must consider that streams in the project area, like Scotsman Creek and Bryson Branch near logging proposed in stand 35-41, are designated "outstanding resource waters" and "trout waters" and are subject to more protective standards, including a tighter turbidity standard. The Outstanding Resource Water (ORWs) designation is reserved for "unique and special" waters of the state that are of "ecological significance" and "exceptional water quality." 15A NCAC 02B .0225. Inherent in this supplemental designation is the recognition "that the characteristics which make these waters unique and special may not be protected by the assigned narrative and numerical water quality standards." *Id.* The outstanding resource values of an ORW must be protected, without qualification, and the Forest Service must comply with this requirement in its own decisions. 15 A NCAC 2B .0201. The presence of ORW streams underscores the special characteristics existing in the Southside Project area already, and raises the stakes of making sure the NEPA analysis for this project assesses the full range of impacts on water quality.

The Forest Service's Decision also approves stabilization work within Scotsman Creek based upon the EA's observation of "severe stream bank erosion" that it indicates is "contributing sediment to Scotsman Creek." EA at 12. While we noted the *potential* benefits of restoration-focused work, Objectors also cautioned that the EA does not anticipate how project activities proposed in the watershed on erosion-prone soils might exacerbate sedimentation in Scotsman Creek.[17] The Decision and EA leave this concern unaddressed, allowing both timber harvest activities and the proposed in-stream stabilization work to proceed, but without examining what is contributing to stream bank erosion to begin with, or whether the Forest Service's activities, which will cause some in-stream sediment (EA at 32), might exacerbate that unidentified cause. For example, project implementation could worsen erosion and sedimentation by exposing particularly erosion prone soils, even for short periods when storm events occur before road or skid trail stabilization is required. *See, e.g.,* Decision at 3 (not requiring waterbars and seeding until after logging: "Waterbar and seed skid trails, landings, and roads with an appropriate seed mixture *following completion of logging activities*") (emphasis added).

[17] EA Comments at 10-11.

In the absence of a broader analysis of the cause of stream bank erosion in Scotsman Creek (besides identifying high, steep banks),[18] and with no attempt to reconcile project activities as potential future contributors to sediment in Scotsman Creek, it is unclear based on the limited information in the EA that the proposed stream bank stabilization activities will be successful. If a factor increasing sediment risk in the project area is erosion-prone soils, for example, the EA and Decision have failed to anticipate it, and Scotsman Creek restoration will not address it. Temporary impacts might even worsen it. The EA does not account for the increased water yield that may result from construction of 0.67 miles of temporary road or reduction of basal area upgradient. Without that information, the Forest Service cannot accurately predict increased stream discharge or velocity, hence the amount of erosion and whether erosion controls installed to stabilize the stream are adequate. In the absence of information identifying the cause of localized stream bank erosion, the EA proposes efforts that could, in practice, worsen conditions in Scotsman Creek. For example, the EA includes plans to install rootwads "at an elevation of ½ the stream's bankfull height in the eroding bank." But rootwads can increase scour upstream and downstream and are prone to failure.[19] Relying on bankfull stage to develop stream restoration can neglect other flows that can be erosive, especially in flashy streams (including streams made more flashy by upstream logging) or areas where heavy precipitation events can frequently occur (like the project area).[20] Objectors further note it is unclear what permitting strategy the Forest Service intends to rely on under the Clean Water Act Section 404. For ORWs, the Army Corps must determine "that the impacts to the critical resource waters will be no more than minimal," even if the Forest Service believes it can rely on a nationwide permit.[21]

Because of the paucity of factors in the EA about what is driving erosion in Scotsman Creek, and the previously discussed lack of analysis of project activities that might contribute to those factors, the project, as currently conceived, appears to be taking unsupported risks in an ORW, and one that is identified as currently providing habitat for wild brook trout. *See* EA at 20.

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[18] *See* attached, Mathias Kondolf & Kristen Podolak, Space and Time Scales in Human-Landscape Systems, Environmental Management (2014) 53:76–87 (2014) at 80 ("However, the ecological degradation motivating the restoration efforts has usually …occurred across large areas of the landscape….") (internal citations omitted); *see also* attached, Cockerill, Kristan & William P. Anderson, Jr., 2014. Creating False Images: Stream Restoration in an Urban Setting, Journal of the American Water Resources Association (JAWRA) 50(2): 468-482. DOI: 10.1111/jawr.12131 ("Studies have demonstrated that restoration projects are often site-specific, small-scale, and opportunistic. . . rather than implemented as part of a broader effort to address watershed scale land and water use impacts.")

[19] *See* attached, Jerry R. Miller & R. Craig Kochel, Use and performance of in-stream structures for river restoration: a case study from North Carolina, Environ Earth Sci (2013) 68:1563–1574 ("Rootwads, which were typically installed at meander bends (75 % of evaluated rootwads), also performed poorly where large changes in channel capacity occurred, a finding that is also consistent with that of Brown (2000). Individual rootwads commonly exhibited scour holes upstream, above, or downstream of the features. In many cases the scour holes appear to result from an increase in vortices along their margins," at 1572).

[20] *See* attached, Ellen Wohl, Rivers in the Landscape: Science and Management (2014) at 126-127; attached, Martin W. Doyle et al., Channel-Forming Discharge Selection in River Restoration Design J. Hydraul. Eng. (2007), 133(7): 831-837.

[21] *See* Corps Nationwide Permit 27, condition 22, http://www.saw.usace.army.mil/Portals/59/docs/regulatory/regdocs/NWP2012/NWP27_3-23.pdf.

Finally, the necessity to fully analyze and disclose the risks of the project is not only a NEPA requirement, but essential to developing an alternative that complies with the plan standards. The Forest Plan directs the Forest Service to "[p]revent visible sediment from reaching perennial and intermittent stream channels and perennial water bodies in accordance with NC Forest Practice Guidelines Related to Water Quality."[22] LRMP Amend. 5, III-40. The Forest Plan repeats the requirement to "prevent visible sediment" under forest direction aimed at protecting water quality and minimizing soil damage (III-41 and III-42). Non-compliance would not only violate the Forest Plan, but would violate state water quality law, with which the Forest Service must comply under the Clean Water Act. 33 U.S.C. § 1323.

II. The Analysis of Green Salamanders Ignores Best Available Science, Leaving Impacts to Habitat Unanalyzed

A. Field Surveys of Green Salamanders Were Not Based on Best Available Science

The analysis of impacts to the green salamander in the EA is cursory, inaccurate, and inadequate to consider impacts or explain how they are being avoided and mitigated. In response to comments that the draft EA failed to consider impacts to green salamanders,[23] the EA states that "the research, consultation, and coordination that had been done with respect to the green salamander" was not disclosed in the draft EA "because the stands near known green salamander populations were withdrawn from proposed management activities." EA at 197. Noting that the green salamander was "raised from forest concern status to regionally sensitive status"[24] after the publication of the draft EA, the Biological Evaluation now offers a "disclosure of potential direct, indirect, and cumulative effects." EA at 197. However, this "disclosure" is based on inadequate surveys and mitigation techniques that do not demonstrate the real extent of potential impacts to the species.

To make the determinations in the Biological Evaluation, the EA states that the Forest Service "consulted with and conducted field surveys with herpetologists with the NCWRC and also conducted independent field surveys," as well as arranging "with herpetologists from Appalachian State University and Ohio State University to conduct independent surveys of the

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[22] Forest Practices Guidelines Related to Water Quality are a set of performance standards for forest harvesting practices intended to protect aquatic resources.

[23] *See* EA Comments at 13–14.

[24] "Forest concern" and "regionally sensitive" status refer to designations under the 1982 Planning Rule for at-risk species on the forest that are not formally listed under the Endangered Species Act. The Nantahala NF LRMP is currently being revised under the 2012 Planning Rule, which requires forests to identify "species of conservation concern," or "species, other than federally recognized threatened, endangered, proposed, or candidate species, . . . known to occur in the plan area and for which the regional forester has determined that the best available scientific information indicates substantial concern about the species' capability to persist over the long-term in the plan area." 36 C.F.R. § 219.9(c) (emphasis added). The green salamander was designated as a species of conservation concern for the Nantahala-Pisgah NFs in 2015, as part of the plan revision process, presumably after consideration by the Forest Service of "the best available scientific information." *See* attached, Species of Conservation Concern (SCC), Nantahala-Pisgah Forest Plan. The 2012 Planning Rule "underscores maintaining and restoring ecological integrity and ecosystem diversity, and providing for sustainability as the primary elements for effective and efficient species conservation." Attached, U.S. Forest Service, Applying the 2012 Planning Rule to Conserve Species: A Practitioner's Reference, at 6 (June 2016).

area for green salamanders." EA at 197. The EA includes almost no information about these surveys. In response to scoping comments, the draft EA stated that "[s]tands 29-11, 29-16, and 41-44 were surveyed for green salamanders." *See* Draft EA at 20, EA at 20. The updated Biological Evaluation in the decisional EA states only that "[i]n November 2017, wildlife staff from both the U.S. Forest Service and North Carolina Wildlife Resources Commission conducted site visits to proposed units and nearby known green salamander sites to document presence/absence of the species or its habitat and to determine if proposed activities near known salamander populations would impact sites adjacent to exiting populations." EA at 120. It states that "the element occurrence record which indicated that green salamanders are located in stand 41-39 was misidentified" and a new occurrence for green salamander was located "at the edge of stand 35-42." EA at 187. The list of stands surveyed as provided in the Draft EA did not include either of these stands, though they were supposedly also surveyed in November 2017. These statements are the only discussion of what places within the project area were surveyed, though they do not provide sufficient information about locations or survey protocols to understand the Forest Service's methodology or procedures.

In documents obtained through a FOIA request, few more details about the surveys were apparent. Three total surveys were performed, two in July 2017 and one in November 2017, with two including experienced herpetologists. *See* attached, June 28, 2018 Email Summarizing Survey Results. There is further mention of a survey performed by "Dr. Mike Osbourn with Appalachian State University . . . during early August 2017." *Id.* These surveys appear to have focused on "rock outcroppings," and three of the four surveys, including the one performed by an independent herpetologist, took place in the summer months despite the Service having learned in this process that "adult males, adult non-egg laying females, and juvenile G[reen] Salamanders do not typically occupy the specialized rock crevices they like during the summer months." Attached, Sept. 11, 2017 Email with Chattooga Conservancy.

An agency is required under NEPA to "ensur[e] the accuracy and scientific integrity of its analysis." *Oregon Nat. Desert Ass'n v. Jewell*, 840 F.3d 562, 570 (9th Cir. 2016) (citing 40 C.F.R. §§ 1500.1(b), 1502.24). Here, the conclusions in the EA are based on outdated information about green salamander habitat and behavior. As pointed out in our EA comments, the only source cited in the EA is from 2005, despite the availability of more recent scientific information. EA Comments at 13. For example, the FWS gave the green salamander a positive 90-day finding in 2015, and cited to a number of scientific studies in support of its determination.[25] While the Forest Service provided almost no detail about its survey protocol, what was provided demonstrates that the surveys were inadequate to adequately assess the presence of green salamanders in or near the project area. The majority of the surveys took place

[25] *See, e.g.*, attached, Center for Biological Diversity, Petition to List 53 Amphibians and Reptiles in the United States as Threatened or Endangered Species Under the Endangered Species Act (July 2012), at 13 ("The green salamander, one of the petitioned salamanders, is a species threatened by mountaintop removal coal mining, as are many high elevation endemics (Gatwicke 2008, Wood 2009)."); *id.* at 36 ("Sedimentation is a threat to several of the petitioned species, including the . . . green salamander . . . . Numerous studies have documented reductions of amphibian densities or populations of their invertebrate prey in streams experiencing sediment loading (Morse et al. 1997, Richter 1997, Welsh and Ollivier 1998, Semlitsch 2000).); *id.* at 39 (citing "(Rovito et al. 2009, Early and Sax 2011)" regarding impact of climate change on the green salamander); *id.* at 413–24 (citing dozens of studies while discussing green salamander conservation).

in the summer months, when the Forest Service was aware that all green salamanders except brooding females would be foraging in trees. Only the November survey took place at an appropriate time of year to assess the presence of all stages of green salamander. That single data point is insufficient. Minimally adequate surveys would include multiple surveys covering various times of year, environmental conditions, and times of day to survey an individual outcrop. *See* attached, JJ Apodaca Comments.

There is no discussion at all in the EA of survey techniques or methods. The EA provides extremely little information that would permit the public to weigh in on the adequacy of the determination of impacts for a regionally sensitive species. This wholly fails to live up to the Forest Service's obligation under NEPA to "insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken." 40 C.F.R. § 1500.1(b). "Accurate scientific analysis . . . and public scrutiny are essential to implementing NEPA." *Id.* These essential elements are lacking in the EA's discussion of green salamanders. To fulfill its obligation to publicly disclose the basis for its decisions, an "agency must provide to the public 'the underlying environmental data' from which [it] develops its opinions." *WildEarth Guardians v. Montana Snowmobile Ass'n*, 790 F.3d 920, 925 (9th Cir. 2015). The EA provides no data that could be used by the public to determine how the Forest Service surveyed for green salamanders and whether its protocols were based on updated scientific information. This is a complete failure to "guarantee[] that the relevant information . . . be made available to the larger audience that may also play a role in both the decisionmaking process and the implementation of that decision." *Robertson*, 490 U.S. at 349.

Alternatively, if performing a comprehensive survey is difficult for the green salamander given its behavior, the Forest Service should consider a habitat proxy. If habitat is adequately inventoried and protected, exhaustive surveys for presence/absence of individuals would be unnecessary. If used correctly and explained in the EA, this method could also satisfy the Service's NEPA obligation to consider impacts to the species.

While the Forest Service included the green salamander in its EA, which is required, the failure to utilize more current scientific information to design adequate survey protocols means that the EA's assessment of impacts to this designated regionally sensitive species and its habitat were wholly inadequate under NEPA to understand the current distribution of the species and habitat in the project area. *See Defenders of Wildlife v. N.C. Dep't of Transp.*, 762 F.3d 374, 396 (4th Cir. 2014) (agency must examine "relevant data" and articulate a "satisfactory explanation").

B. The EA Does Not Consider Impacts to Green Salamanders at the Time of Implementation

The limited surveys that were performed searching for green salamanders were all completed in 2017. However, timber sales are not expected to be implemented in the project area until 2020–2024. *See, e.g.,* EA at 41. The EA does not commit to any plans to re-survey for salamanders before the sales are implemented. This assumes, without support, that the green salamander found in stand 35-42 and all other green salamanders will stay in exactly the same place they were (or were not) found in underwhelming surveys in 2017. This policy entirely fails to ensure green salamander protection at the time of implementation. In addition to developing original surveys based upon best available science, for purposes of an EA, additional surveys should be performed much closer in time to implementation of the project in order to ensure accurate data on green salamanders is being utilized and impacts to the species are minimized. Because it does not consider impacts at the time of implementation, the EA fails to adequately analyze impacts to green salamanders.

C. The EA Does Not Consider Cumulative Fragmentation Effects on Salamanders

The EA states that the one site determined during field surveys to have a green salamander will "be buffered to avoid negative impacts to the small, isolated rock outcropping." EA at 121. But while buffering may protect one "small, isolated" rock, the EA provides no basis to support the idea that buffering around one rock is actually protective of the species. EA at 120. Green salamanders are arboreal, spending a large part of their lives in trees that are equally necessary for the species. *See* attached, FWS 2016 Green Salamander Fact Sheet; JJ Apodaca Comments. The extent to which they disperse while in the trees is unknown, but may be wider than previously believed.

Any assumption that green salamanders do not need or rely on connectivity between suitable habitat zones is also unfounded. The EA provides no information supporting the policy that creation of an isolated pocket of trees around a single, green salamander-inhabited rock is protective of the species and would therefore not be "likely to lead toward federal listing or a decrease in viability across the forest for the green salamander," as claimed. EA at 121. Even if buffering a specific, known green salamander location protects that one individual salamander, the effects of habitat fragmentation on the species as a whole are left out of consideration in the EA.

The EA essentially reasons that creating islands of "individual rock outcropping[s]" surrounded by a circle of trees will not "lead toward federal listing or a decrease in viability across the forest for the green salamander," no matter that connectivity between appropriate habitat could be destroyed. Employing such reasoning over time would allow the creation a patchwork landscape of "small, isolated" clusters of trees while allowing the Forest Service to dodge its responsibility to consider the cumulative effects of such a policy on the future of a species that depends on un-fragmented habitat.

As a result of these various errors, the EA fails to adequately consider impacts to green salamanders and fails to provide adequate information for public input on the issue.

III. The Forest Service's Analysis of Alternatives Is Predicated on a Deficient Consideration of Effects and Omits Evaluation of the Merits of Avoiding or Minimizing Effects on Ecologically Significant Resources.

NEPA "place[s] upon a federal agency the obligation to consider every significant aspect of the environmental impact of a proposed action [and] ensure[s] that the agency will inform the public that it has indeed considered environmental concerns in its decision making process." *Baltimore Gas & Elec., Co. v. Nat. Res. Def. Council, Inc.*, 462 U.S. 87, 97 (1983). To fulfill this mandate, NEPA requires federal agencies to consider alternative courses of action. Adequate consideration of alternatives is the "heart" of the NEPA process because it defines the issues and provides a clear basis for choices by the decision maker and the public. 40 C.F.R. § 1502.14.

Through environmental review agencies must, "to the fullest extent possible," identify and assess "reasonable alternatives" that would "avoid or minimize adverse effects" of its proposed actions. 40 C.F.R. § 1500.2(e).[26] This requirement applies to both EAs and EISs. 42 U.S.C. § 4332(2)(E). Consideration of alternatives is meant to "foster both informed decision-making and informed public participation." *Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin*., 538 F.3d 1172, 1194 (9th Cir. 2008) (citations omitted).

The Southside EA identified two action alternatives (Alternative B and Alternative C) and a no action alternative (Alternative A). The two action alternatives were similar in types of activities; the main difference is that Alternative C reduces the scale of two-age harvest by one-third, including timber harvest in sensitive areas: stand 35-41 (existing old growth) and stand 35-42 (green salamander), both near the Terrapin Mountain WIA, as well as stand 29-16 in the Ellicott Wilderness Extension. *See* EA Section 2.4.1 (comparison of alternatives). According to the EA, most of the planned logging is within Management Areas 4D and 4A, including compartments 29 (4A & 4D) and 35 (4A). EA at 5-6. These areas have no "minimum" ESH requirements (LRMP III-31), meaning either alternative would meet plan objectives for ESH.

Consequently, the EA was structured in a way that should have allowed for reasoned comparison of the alternatives in light of the potentially significant issues identified by the public. Yet, the Decision does not disclose or consider the negative impacts of Alternative B, which necessitated the development of Alternative C. The Decision selects Alternative B based on the metric of volume of ESH created: "Alternative C would have produced less ESH than Alternative B, resulting in fewer wildlife benefits." Decision at 6.

The tradeoffs of implementing Alternative B, as opposed to Alternative C, in terms of environmental consequences, remain unexamined.[27] To do so, the Forest Service's EA would have to analyze the environmental effects of each alternative – which has not occurred – and then evaluate the comparative merits of each alternative. Instead of differentiating between the impacts, the EA again and again lumps together the environmental consequences of both Alternatives B and C. For water resources, the EA finds for both alternatives "minor, short duration effects to water quality," leaving unanswered the risk added in Alternative B, for example, of constructing temporary road to enable logging old growth upgradient of an ORW, Scotsman Creek. *See e.g.,* EA at 65. For soil resources, the EA likewise assumes (but does not examine site conditions to determine) the effects will be the same under Alternatives B and C – ignoring that Alternative C reduces temporary road construction by 65 percent. Likewise, the scenery analysis finds "minor effects to the visual resources from these proposed actions," in discussing both action alternatives, even though Alternative C eliminates stands that are expected to have visual impacts from Slick Rock, Ravenel Park Overlook, and Whiteside Mountain.

Because the EA is also premised upon an insufficient analysis of the ecological value of old growth, areas comprising WIAs, and NHNAs, the comparison of alternatives provides no

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[26] 40 C.F.R. § 1500.2(e): "Federal agencies *shall*, to the fullest extent possible: [u]se the NEPA process to identify and assess the reasonable alternatives to proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment." (emphasis added).

[27] *See* EA Comments at 11–12.

discussion about the ways in which the scaled-back Alternative C would better protect old growth, WIA character and eligibility, and NHNA values. Because of these errors, the EA leaves the agency ill-equipped to determine the tradeoffs between alternatives.

Objectors raised the error in the draft EA's approach to alternatives in comments, but instead of pursuing an analysis that examines the environmental consequences and tradeoffs of each alternative, the agency criticizes Objectors for not bringing an alternative logging proposal to the agency that allows it to create this same volume of ESH in this location. *See* EA Sec. 5.2. Of course, the Forest Service's obligation to comply with NEPA requirements is independent of whether stakeholders locate a new, viable alternative in the Forest Service's selected project area. And the Forest Service must allow that the sensitive landscape of this particular project might be a difficult place for the scale and intensity of this type of project without significant environmental consequences, and hence, significant environmental study.

That consideration is exactly what the EA leaves unanalyzed. For example, eliminating logging and temporary roads on Brushy Mountain, an area with erosive soils, steep slopes, and sensitive streams, and reducing the overlap of proposed treatments with WIAs would certainly yield environmental benefits that must be considered as part of the tradeoffs between alternatives. Such a plan would protect these areas for the values they are currently serving, like the biological significance of old growth forest types, habitat connectivity in an area fragmented with private lands, and backcountry experiences. It would also eliminate risks of adversely impacting streams and soils in these areas, and reduce the scale of the project, which in turn would reduce the footprint and erosion risks from temporary road construction and skid trails.

NEPA requires a comparison of the full measure of impacts under each alternative. *See Baltimore Gas & Elec.*, 462 U.S. at 97 (requiring consideration of "every significant aspect of the environmental impact of a proposed action"). To meet these obligations, the Forest Service should have fully analyzed the impacts of logging in sensitive ecological areas and fully examined alternatives that would avoid impacts to these areas. Indeed, in comments on the draft EA, Objectors recommended evaluation of a modified Alternative C that redesigned the project to eliminate all stands within the WIAs (including 29-15), in order to "avoid or minimize adverse effects of these actions upon the quality of the human environment." 40 C.F.R. § 1500.2(e). As with Alternative C, the comparative merit of a modified Alternative C remains unexamined. Failure to consider a "viable but unexamined alternative" also renders an EA inadequate. *Alaska Wilderness Recreation and Tourism Ass'n v. Morrison*, 67 F.3d 723, 729 (9th Cir. 1995) (internal quotations omitted); *accord Dubois v. U.S. Dep't of Agric.*, 102 F.3d 1273, 1289 (1st Cir. 1996).

The agency erred in selecting Alternative B, based solely on the metric it preferred to evaluate (ESH volume), instead of evaluating the environmental consequences of each alternative to allow an informed comparison. This was arbitrary and capricious. Consider, for example, if the selected metric had been ability to conserve old growth, or green salamander habitat, or to protect soil resources—the choice would have been very different. This highlights why the Forest Service cannot cherry pick one goal from among its many obligations, ignore negative impacts, and impose unscientific and inappropriate management on a landscape that is much more complex than a rotational mosaic of age classes. As a result, the Forest Service failed to "emphasize real environmental issues and alternatives," 40 C.F.R. § 1500.2(b), and failed to assess reasonable alternatives that would "avoid or minimize adverse effects." 40 C.F.R. § 1500.2(e). The EA, Decision, and FONSI must be withdrawn so the EA can be revised to appropriately consider tradeoffs of alternatives.

IV. An Environmental Impact Statement (EIS) Is Required Because the EA Did Not Adequately Support the Finding of No Significant Impact (FONSI) and the Project May Have a Significant Effect on the Environment.

Because impacts of this Project on old growth, WIAs, NHNAs, and sensitive species could be significant, we maintain that a FONSI is inappropriate for the Southside Project and an EIS is required.[28] *See* 42 U.S.C. § 4332(2)(c) (all agencies shall include environmental impact statement on proposals for "major Federal actions significantly affecting the quality of the human environment"); 40 C.F.R. § 1508.3 ("'Affecting' means will or *may have* an effect on.") (emphasis added). In this case, environmental impacts to old growth, WIAs, sensitive species, and water quality, which should have been (but were not) assessed, indicate that this Project may have a significant impact.

Courts have held that "an EIS *must* be prepared if substantial questions are raised as to whether a project . . . *may* cause significant degradation of some human environmental factor." *Idaho Sporting Congress*, 137 F.3d at 1149 (internal citation omitted) (emphasis in original). Objectors "'need not show that significant effects *will in fact occur*,' raising 'substantial questions whether a project may have a significant effect' is sufficient." *Id.* at 1150 (internal citation omitted) (emphasis in original). A decision not to prepare an EIS is unreasonable "[i]f substantial questions are raised regarding whether the proposed action may have a significant effect upon the human environment," or if the agency fails to "supply a convincing statement of reasons why potential effects are insignificant." *Save the Yaak Committee*, 840 F.2d at 71 (internal citations omitted).

The Southside Project may have significant impacts on the environment because it is likely to adversely affect many of the significant resources set forth in the NEPA regulations, as well as national forest resources established as important (such as old-growth forests and species of conservation concern). The Council on Environmental Quality regulations clarify that weighing the significance of an impact requires evaluation of both context and intensity. 40 C.F.R. § 1508.27. Several of the factors enumerated in that regulation for evaluating intensity underscore the significance of logging in old growth forest and WIAs, as well as failing to protect water quality and species of conservation concern:

> (3) Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
>
> (4) The degree to which the effects on the quality of the human environment are likely to be highly controversial.

[28] *See* Scoping Comments at 2; EA Comments at 2, 12–13.

> (5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
>
> (6) The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
>
> (8) The degree to which the action may cause the loss or destruction of significant scientific, cultural, or historical resources.

Id. The environmental concerns laid out in detail above—including destruction of unique and ecologically important old-growth forest, WIAs, high quality waters, and species of conservation concern, ahead of a plan revision—are controversial and could set a dangerous precedent. The significance of the impacts to these resources underscore the need for an EIS to assess those impacts in this project.

Logging existing old growth forest undermines a unique characteristic of the national forests. Old growth forests are virtually irreplaceable and serve as reference ecosystems. Logging of old growth is also highly controversial. A federal action is controversial and requires an EIS if "substantial questions are raised as to whether a project . . . may cause significant degradation of some human environmental factor," or when there is "a substantial dispute [about] the size, nature, or effect" of the action. *Blue Mountains Biodiversity Project v. Blackwood*, 161 F.3d 1208, 1212 (9th Cir. 1998) (alteration in original). Recent proposals to log old growth in the national forests of North Carolina have drawn close attention and criticism from the public. There is strong scientific support for the view that trading rare old growth communities for early successional habitat creation, which could and will occur elsewhere in the Project area, is counterproductive. In addition, logging existing old growth would destroy significant scientific, cultural, and historical resources. The Region 8 Old Growth Guidance specifically describes the scientific, cultural, and historical value of old growth, among other values.

Logging in potential wilderness areas before they are fully considered for designation under the new plan is similarly controversial. The Forest Service solicited input from stakeholders in creating the list of WIAs ahead of plan revision. Those stakeholders have already expressed strong interest in protecting the ecological integrity of those WIAs, and an advance permit to log in those areas that could have any impact on the ultimate decision to designate them as wilderness is a highly controversial decision. Allowing logging in these areas could also essentially be a "decision in principle" about the "future consideration" of whether these WIAs are listed as wilderness in the plan revision. *See, e.g., Native Ecosystems Council v. U.S. Forest Service ex rel. Davey*, 866 F. Supp. 2d 1209, 1229–30 (D. Id. 2012) (adoption of a lynx habitat map into a tree thinning EA represented a decision in principle about "future use of the land" under 40 C.F.R. § 1508.27(b)(6)).

Permitting the removal of potential habitat for green salamanders, following field surveys utilizing inadequate protocols based on outdated science, may establish precedent for how impacts to species of conservation concern are treated in the future. The EA provides scant details about the surveys that were performed, and no scientific basis to support the assertion that a 100-meter timber harvesting buffer around one rock in the project area means there will be no impacts on green salamanders from timber harvesting elsewhere in the stand or in nearby stands. Determining impacts to a species of conservation concern without consideration of current science sets a poor precedent for how these species will be treated in other forest projects in the future. The 2012 Planning Rule applicable to the current plan revision emphasizes "maintaining and restoring ecological integrity and ecosystem diversity, and providing for sustainability as the primary elements for effective and efficient species conservation."[29] This Forest is the cradle of salamander biodiversity in the U.S. The District cannot dismiss impacts to such a significant scientific resource based on inadequate scientific analysis.

The EA leaves "substantial questions" about the project's effects on old-growth, WIAs, slope stability, sedimentation, water quality, and the green salamander, necessitating an EIS. *See Blue Mountains Biodiversity Project*, 161 F.3d at 1213–14 (stating an EIS is required to address multiple inadequacies in an EA, including cursory and inconsistent analysis of sedimentation issues, which raised substantial questions about the project's effects on the environment); *see also Found. for N. Am. Wild Sheep v. U.S. Dep't of Agric.*, 681 F.2d 1172, 1178 (9th Cir. 1982) (holding that failure to address "certain crucial factors, consideration of which [is] essential to a truly informed decision whether or not to prepare an EIS," renders an agency's EA arbitrary in violation of NEPA).

A common theme runs through the errors in the Southside EA. The EA consistently fails to analyze impacts or claims there will be no impacts because the effects of this project will be small—only a small percentage of old growth in the project area will be cut down; only timber in parts of NHNAs that are not Special Interest Areas will be harvested; impacts to green salamanders will not be significant because of a buffer. But this reasoning cannot be employed over and over again to ignore the cumulative effects of these management actions on unique ecosystems, sensitive species, and the forest as a whole. *See* 40 C.F.R. § 1508.27(7). A cumulative impact is defined under NEPA as an "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions" and "can result from individually minor but collectively significant actions taking place over a period of time." 40 C.F.R. § 1508.7. Consideration of cumulative impacts is especially important when using an EA to support a FONSI. *See, e.g., Kern v. U.S. Bureau of Land Management*, 284 F.3d 1062, 1075–79 (9th Cir. 2002).

It is reasonably foreseeable that other timber sales will take place in the Nantahala National Forest, in general, and near this project area, specifically. If those projects take the path of this one, they would justify logging in old growth, WIAs, NHNAs, and green salamander habitat, by arguing the stands are small relative to available habitat across the Forest. Even if the Forest Service wants to repeatedly offer this argument, it must analyze the cumulative impacts of whittling away at these unique resources, one project at a time. Taken in combination with other timber sales close to this project, those impacts are cumulatively much larger. If the District

[29] Attached, U.S. Forest Service, Applying the 2012 Planning Rule to conserve species: a practitioner's reference, at 6, *available at* https://www.fs.fed.us/rm/pubs_journals/2016/rmrs_2016_hayward_g001.pdf.

hopes to avoid the burden of this cumulative impacts analysis, which would certainly require an EIS, then it must avoid locations for harvest that would implicate these concerns.

The EA, Decision Notice, and FONSI for Southside must be withdrawn both because they fail to disclose and analyze impacts to forest resources including old growth, WIAs, and green salamanders and because logging under this plan is likely to create impacts significantly affecting the human environment that require evaluation through an EIS.

V. Conclusion

We sincerely hope that a revised forest plan will decrease the project-level burden of analyzing these impacts by fully addressing them at the landscape level, but in the absence of such a plan, the Forest Service must undertake an analysis that meets the basic objective of informing it and the public of the environmental consequences of its Decision. That has not happened for the Southside Project. We are eager to continue to working with the Planning staff and other stakeholders to find solutions that focus management activities where they will not undermine progress toward restoring ecological integrity. We hope that this objection process will present an opportunity to discuss the protection of these rare and intact habitats at the project level.

REQUEST FOR RELIEF

For the reasons stated, the Forest Service's EA, Decision Notice, and FONSI violate NEPA and the NFMA. Accordingly, the Forest Service should withdraw this project. If the Forest Service nonetheless intends to proceed with this project, it must prepare an EIS to satisfy its NEPA obligations.

Date: August 27, 2018 Signed for Objectors

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Attachment 11

ELSEVIER

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Forest Ecology and Management

Spatial distribution of biomass in forests of the eastern USA

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Abstract

We produced a map of the biomass density and pools, at the county scale of resolution, of all forests of the eastern US using new approaches for converting inventoried wood volume to estimates of above and belowground biomass. Maps provide a visual representation of the pattern of forest biomass densities and pools over space that are useful for forest managers and decision makers, and as databases for verification of vegetation models. We estimated biomass density and pools at the county level from the USDA Forest Service, Forest Inventory and Analysis database on growing stock volume by forest type and stand size-class, and mapped the results in a geographic information system. We converted stand volume to aboveground biomass with regression equations for biomass expansion factors (BEF; ratio of aboveground biomass density of all living trees to merchantable volume) versus stand volume. Belowground biomass was estimated as a function of aboveground biomass with regression equations. Total biomass density for hardwood forests ranged from 36 to 344 Mg ha^{-1}, with an area-weighted mean of 159 Mg ha^{-1}. About 50% of all counties had hardwood forests with biomass densities between 125 and 175 Mg ha^{-1}. For softwood forests, biomass density ranged from 2 to 346 Mg ha^{-1}, with an area-weighted mean of 110 Mg ha^{-1}. Biomass densities were generally lower for softwoods than for hardwoods; ca. 40% of all counties had softwood forests with biomass densities between 75 and 125 Mg ha^{-1}. Highest amounts of forest biomass were located in the Northern Lake states, mountain areas of the Mid-Atlantic states, and parts of New England, and lowest amounts in the Midwest states. The total biomass for all eastern forests for the late 1980s was estimated at 20.5 Pg, 80% of which was in hardwood forests. 1999 Published by Elsevier Science B.V.

Keywords: Aboveground biomass; Belowground biomass; Biomass distribution; Carbon cycle; Disturbance; Hardwood forests; Softwood forests; USA

1. Introduction

Forests play an important role in regional and global carbon (C) cycles because they store large quantities of C in vegetation and soil, exchange C with the atmosphere through photosynthesis and respiration, are sources of atmospheric C when they are disturbed by human or natural causes, become atmospheric C sinks during regrowth after disturbance, and can be managed to sequester or conserve significant quantities of C on the land (Brown et al., 1996). Because of their importance in the global C cycle, there is an increasing need to improve the accuracy of estimates

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of the amount of C (or biomass of which ca. 50% is C; Brown and Lugo, 1982; Birdsey, 1992) forests contain. The outcome of the 1997 Kyoto meeting on climate change affirms the importance of forests for meeting greenhouse gas emissions targets during commitment periods for signatory countries of the UN Framework Convention on Climate Change. Emissions and removals of greenhouse gases, including carbon dioxide, from land-use change and forestry are included in these targets. Forest biomass represents the potential amount of C that can be added to the atmosphere or conserved or sequestered on the land when forests are managed for meeting emission targets (Brown et al., 1996).

The quantity of biomass in a forest is the result of the difference between production through photosynthesis and consumption through respiration, mortality, harvest, and herbivory. Forest biomass changes as a result of succession; direct human activities such as silviculture, harvesting, and clearing for conversion to non-forest use; natural disturbances caused by wildfire or pest outbreaks; and changes in climate and atmospheric pollutants. Thus, biomass is a useful measure for assessing changes in forest structure and a useful measure for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions.

Forest biomass also provides valuable information for many global issues, however estimating this quantity at suitable scales is not without its problems. The use of remote sensing techniques has been investigated, but as yet this approach has met with little success for multi-age, multi-species forests, and only with limited success in forests with few species and age classes representing a broad range of biomass distributions (Wu and Strahler, 1994; Hall et al., 1995). We believe that, at present, the best approach for estimating forest biomass on a national or regional scale is to use existing data from national forest inventories. This is an appropriate method for broad scale studies because inventory data are generally collected at regional scales from the population of interest and are designed to be statistically valid. Such data are collected on the ground on a regular basis in many countries, particularly industrialized countries. The most common reporting unit is forest wood volume ($m^3 ha^{-1}$) that is derived from field measurements and summarized by forest types, administrative unit (e.g., county), and/or stand age or size class. Inventories of forest wood volume, however, do not characterize all forest biomass; they report only the commercially valuable wood and exclude non-merchantable species and other important components such as branches, twigs, bark, stumps, foliage, roots, and seedlings and saplings. Methods and factors have been developed for converting inventoried forest volume to total biomass for a range of forest types (e.g., Brown, 1997; Cairns et al., 1997; Schroeder et al., 1997; Brown and Schroeder, in press). Forest volume inventories have provided the basis for several national-level C budgets (e.g., Birdsey, 1992; Krankina et al., 1996; Kurz and Apps, 1993).

The forests of the eastern USA have been subject to human disturbance for longer than any other forests on the continent, and virtually all of the forest landscape that we see today has been altered by humans to some degree at some time in the past (Perlin, 1991). While some disturbances were likely caused by the indigenous human population, widespread human disturbance began with the arrival of European colonists. They cleared forests for farming, and logged them for lumber and building materials, railroad expansion, and fuelwood (Perlin, 1991). In this century, large areas of land have reverted to forests as marginal farmlands were abandoned and forests naturally regenerated or were converted to plantations (Williams, 1988; Turner, 1990). The timing of these activities varied by state, with the eastern most states being disturbed earlier than more western ones of the region. Today, most forests in the eastern US are managed for the variety of goods and services that humans value. The biomass of the eastern forests is thus likely to vary widely across the region because of differences in past and present use and management of the land.

The US has an extensive forest inventory database, and data for eastern forests are readily available on the World-Wide Web at various levels of detail. We have previously developed methods for converting US inventory volume data to above and belowground biomass (Cairns et al., 1997; Schroeder et al., 1997; Brown and Schroeder, in press). The main goal of this paper is to use these previously developed methods and apply them to the eastern US forest inventory database to produce spatially explicit estimates of the biomass density (above plus belowground biomass per unit area) and pools of eastern forests (hardwoods and softwood; encompassing 33 states) at the county scale of resolution. Maps not only provide a vivid visual representation of the pattern of forest biomass densities and pools over space that are useful for forest managers and decision makers, but they also serve as databases for verification of vegetation models (e.g., BIOME—Prentice et al., 1992; CENTURY—Parton et al., 1988; MAPSS—Neilson et al., 1992).

2. Methods

Our overall approach was (1) to use the USFS Forest Inventory and Analysis (FIA) database retrieval system to download data on growing stock volume and area by forest type and stand size-class for each of the 2009 counties of the 33 eastern states. (2) We converted these volume data to estimates of aboveground biomass density using previously developed methods (Schroeder et al., 1997; Brown and Schroeder, in press). (3) Belowground biomass densities were estimated from a regression equation relating belowground biomass (coarse and fine roots) to aboveground biomass (Cairns et al., 1997). (4) Biomass pools were the product of biomass density and area, summed by stand-size class. Area-weighted biomass densities were calculated for each county. (5) Biomass pools were mapped in a geographic information system (GIS) by county. For biomass density, we made a forest distribution map by reclassifying a map of US forests based on satellite data (advanced very high resolution radiometer – AVHRR, 1 km resolution; Powell et al., 1993) into two classes: hardwood and softwood forests. This two-class map was then used with the forest biomass density data to clip maps of biomass density at a resolution of 4 km $\times$ 4 km to show biomass density at its mapped location.

2.1. Forest inventory data

Data were extracted from the USDA Forest Service FIA unit database for all states from FIA's website: *http://www.srsfia.usfs.msstate.edu/scripts/ew.htm*. We acquired data on area of all timberland and total growing stock volume by forest type (e.g., oak–hickory, maple–beech–birch, spruce–fir, loblolly–shortleaf pine) and stand size-class (seedling/sapling, poletimber, and sawtimber) for each county in the eastern US. Timberland is defined by the Forest Service as land producing or capable of producing in 'excess of 20 cubic feet per acre per year (or ca. 1.4 m^3 ha^{-1} $year^{-1}$) of industrial roundwood products'. With respect to the eastern US, this definition accounts for 94% of all forest land (or 145×10^6 ha out of a total of 154×10^6 ha; Powell et al., 1993). Of the forest lands not included, ca. 3% are wilderness areas, parks, and other lands withdrawn from use for timber by statute or administrative regulation (mostly in the states of New York, Pennsylvania, and Minnesota) and 3% in other forest lands of low primary production such as post oak and blackjack oak forests in Texas and Oklahoma (Powell et al., 1993). Growing stock volume is defined as under-bark volume of main stem to a 10 cm top for trees 12.7 cm diameter and larger, excluding unmerchantable (cull) trees. Details of plot design, field data collection, subsequent manipulation, and the FIA database itself are available at the website or by referring to Hansen et al. (1992).

The database contains information from inventories of forest resources conducted on a cycle of $\approx$10 years. The year of the most recent inventory varied by state, from as far back as 1985 to as recent as 1996 (Table 1). However, about two-thirds of the eastern states had their most recent inventory in the 1990s.

2.2. Estimation of biomass

We estimated the total above and belowground (oven dry mass) of all living trees with a minimum breast-height diameter of 2.54 cm. After downloading the data from the web site, we first summed the growing stock volume and area by three categories of forests—hardwoods, pines, and spruce–fir—for each stand size-class and county. We then divided the total growing stock volume by the corresponding area to generate estimates of growing stock volume per unit area (GSVD; m^3 ha^{-1}). This resulted in a possible nine values of GSVD per county.

To convert GSVD to aboveground biomass, we used functions that related biomass expansion factors (BEF) to GSVD for hardwood, pine, and spruce–fir forest types (Schroeder et al., 1997; Brown and Schroeder, in press). The BEF (Mg m^{-3}) is defined as the ratio of aboveground biomass density of all living trees of DBH $\geq$2.54 cm to GSVD for all trees of

Table 1
Dates of current inventory (from data on the USDA Forest Service FIA unit's website)

State	Current inventory
Alabama	1990
Arkansas	1995
Connecticut	1985
Delaware	1986
Florida	1995
Georgia	1989
Illinois	1985
Indiana	1986
Iowa	1990
Kentucky	1988
Louisiana	1991
Maine	1995
Maryland	1986
Massachusetts	1985
Michigan	1993
Minnesota	1990
Mississippi	1994
Missouri	1989
New Hampshire	1983
New Jersey	1987
New York	1993
North Carolina	1990
Ohio	1991
Oklahoma	1993
Pennsylvania	1989
Rhode Island	1985
South Carolina	1993
Tennessee	1989
Texas	1992
Vermont	1989
Virginia	1992
West Virginia	1989
Wisconsin	1996

DBH $\geq$12.7 cm. Our previous work (Schroeder et al., 1997; Brown and Schroeder, in press) presented a general approach to convert GSVD to total aboveground biomass of all living trees for hardwood and softwood forests. Our approach accounted for non-commercial tree species, non-merchantable commercial tree species (e.g., cull trees), non-commercial tree components (branches, twigs, and leaves), and all trees of diameter $\geq$2.5 and <12.5 cm, and estimated aboveground biomass density of the tree component (AGBD, Mg ha^{-1}) directly from growing stock volume density (m^3 ha^{-1}).

In our previous work (Schroeder et al., 1997; Brown and Schroeder, in press), we developed BEFs that were based on: oak–hickory and maple–beech–birch forests for hardwoods, and spruce–fir and loblolly/shortleaf pine forests for softwoods. We aggregated the database into these three broad forest categories because it was not practical to attempt to formulate BEFs for every forest type in the eastern US. The relationship between BEF and GSVD for hardwoods was based on the oak–hickory and maple–beech–birch forests that account for ca. 50% of all eastern hardwood forests. As there was no significant difference in the relationships between BEF and GSVD for these two forest types, the data were pooled and a single regression equation was developed (Schroeder et al., 1997). We assumed that this regression equation was applicable for all hardwood forests reported in the FIA databases. Statistically significant regression equations between BEFs and GSVD were obtained for aggregated hardwoods and spruce–fir forests. The equations are:

Hardwoods:

$$\mathrm{BEF} = \exp\{1.91 - 0.34 \times \mathrm{Ln}(\mathrm{GSVD})\};$$
$$r^2 = 0.85,\ n = 208,\ \mathrm{SE} = 0.109 \tag{1}$$

for GSVD >200 m^3/ha, BEF = 1.0.

Spruce–fir:

$$\mathrm{BEF} = \exp\{1.77 - 0.34 \times \mathrm{Ln}(\mathrm{GSVD})\};$$
$$r^2 = 0.88,\ n = 49,\ \mathrm{SE} = 0.095 \tag{2}$$

for GSV >160 m^3/ha, BEF = 1.0.

Biomass expansion factors decrease with increasing GSVD for both forest categories, a pattern consistent with theoretical expectations (Schroeder et al., 1997). At high GSV, the slopes approach zero, beyond which point the BEFs approach a constant.

No significant relationship between BEF and GSVD was obtained for pine forests. Because of the general similarity of pine forests in the eastern US, and their common structural characteristics and branching patterns, we assumed that they would have similar BEFs. The only other comparable analysis of pine data that we are aware of (Brown, 1997) also found no relationship between GSVD and BEF, which further demonstrates the similarity of pine forests. Thus, we used the following median BEFs for the indicated range in GSVD:

$$\mathrm{GSVD} < 10\,\mathrm{m}^3\,\mathrm{ha}^{-1};$$
$$\mathrm{BEF} = 1.68\,\mathrm{Mg\,m}^{-3}(n = 72,\ \mathrm{SE} = 0.13)$$

$$\mathrm{GSVD} = 10\text{–}100\,\mathrm{m^3\,ha^{-1}};$$
$$\mathrm{BEF} = 0.95(n = 86,\ \mathrm{SE} = 0.02) \qquad (3)$$
$$\mathrm{GSVD} > 100\,\mathrm{m^3\,ha^{-1}};$$
$$\mathrm{BEF} = 0.81(n = 16,\ \mathrm{SE} = 0.03)$$

For each forest category and stand size-class, we calculated aboveground biomass density as the product of GSVD and BEF. We used Eqs. (1)–(3) to convert volume estimates to aboveground biomass for the hardwood, pine, and spruce–fir forest categories.

We estimated belowground biomass density (BGBD = fine and coarse roots) for each forest category and stand size class from AGBD by using the following regression equation for temperate forests (from Cairns et al., 1997):

$$\mathrm{BGBD} = \exp\{-1.059+0.884\times \mathrm{Ln(AGBD)}+0.284\};$$
$$r^2 = 0.84,\ n = 151$$

Estimates of belowground biomass density were then added to the aboveground estimates to produce a total biomass density estimate. An area-weighted average total biomass density was then calculated for hardwood and softwood (pine plus spruce–fir) forests for each county. Biomass pools were estimated as the sum of the products of total biomass density, by forest category and stand size-class, and the corresponding area for each county. We combined the data for hardwoods and softwoods for each county to generate an estimate of total forest biomass.

2.3. Mapping biomass

We produced and displayed all maps using version 7.0 of the ARC/INFO GIS software (ESRI, 380 New York St., Redlands, CA 92373). We used the Albers conic equal-area projection with standard parallels at 29° 30′ and 45° 30′, the central meridian at −96° and the latitude of origin at 23°.

We first made a forest distribution map by reclassifying a map of the forests of the US (Powell et al., 1993), based on 1 km AVHRR satellite data, into two classes: hardwood and softwood forests. This two-class map was then used as a template with the forest biomass density data to generate maps at a resolution of 4 km × 4 km to convey the biomass density at its mapped location. This resulted in hardwood forests being mapped in all counties except a few with an extremely small area of forest. The results were not as complete for softwood forests; many counties had data for softwood biomass but no area according to the forest cover map. This was due to interpretation differences between field-based forest inventory and a relatively coarse satellite-based map. We added a 4 km × 4 km pixel in the center of any county that had softwood biomass data but no mapped softwood forest. This was for display purposes only and did not affect the maps of total biomass. Maps of total biomass per county were not clipped by the two-class map because the area of forest by county was already included in the calculation.

2.4. Error estimation

The FIA program uses a statistically based sampling scheme designed to provide growing stock volume estimates with a sampling error of 5% for $28.3 \times 10^6\,\mathrm{m^3}$ (billion cubic feet), and forest area estimates with a sampling error of 3% for 0.4×10^6 ha (million acres) (Noel Cost, USDA Forest Service, 1998, personal communication). Larger forest areas and volumes have smaller relative standard errors, and vice versa. The sources of error in volume or biomass estimation are measurement error, sampling error, and regression error; the sampling error has been shown to be the largest component of the total error (Phillips et al., 1998). Analysis of the data at the county level, as done in this paper, would result in a larger total error, mostly due to the increase in sampling error at this smaller scale. For example, the sampling errors for volume at the state level for Virginia and North Carolina increased by about a two to three-fold factor or more at the county level (Brown, 1993; Thompson and Johnson, 1994). How the various sources of error compound into total error for biomass at the county level is not known, and indicates an area deserving more attention.

3. Results and discussion

3.1. Distribution of biomass densities

Hardwood forests with the highest biomass densities (>200 Mg $\mathrm{ha^{-1}}$) are mostly located in the

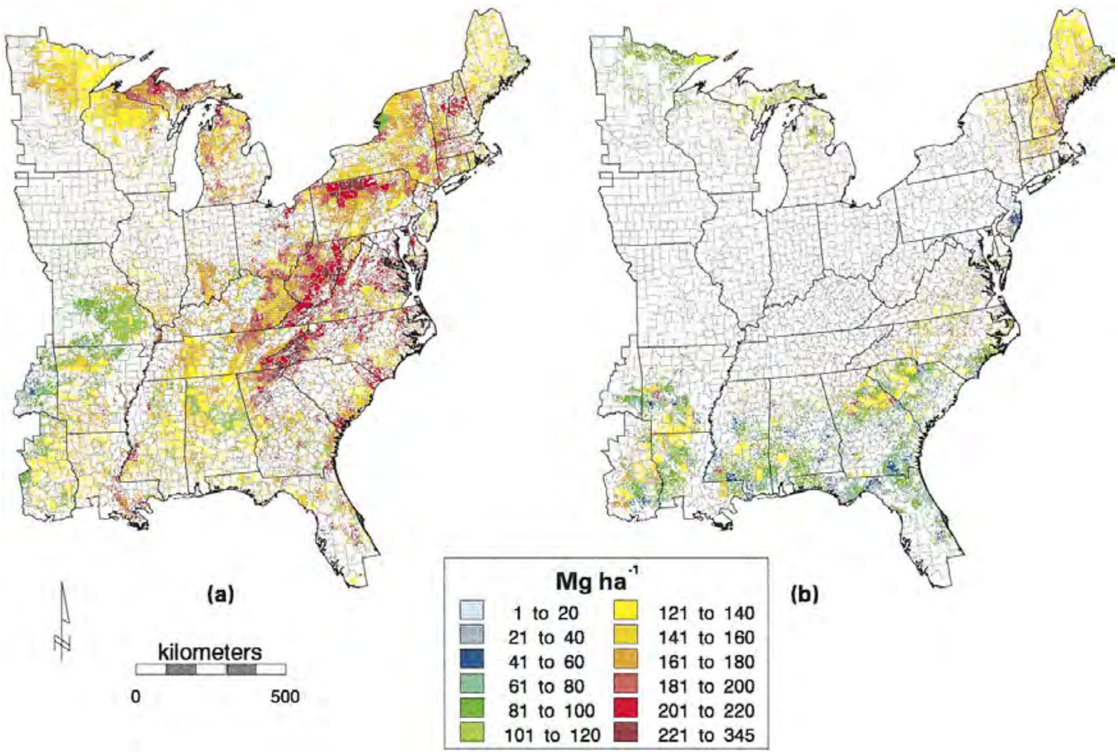

Fig. 1. Map of biomass density (above and belowground biomass, Mg ha^{-1}) for (a) hardwood and (b) softwood forests of the eastern US.

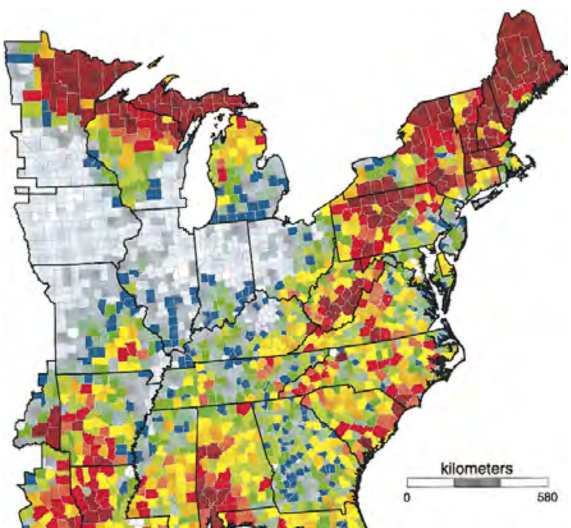

Fig. 4. Map of total biomass (hardwood plus softwood) for forests of the eastern US.

Appalachian Mountains, stretching from northern Georgia to as far north as the New England states; the coastal plain of North Carolina and Virginia; and in the upper peninsula of Michigan (Fig. 1(a)). Scattered counties in Illinois, Indiana, and Wisconsin also contain forests with biomass densities above 200 Mg ha^{-1}. Hardwood forests with some of the lowest biomass densities (<100 Mg ha^{-1}) are located in Iowa, Missouri, Oklahoma, and Texas.

States in the northeast have softwood forests with some of the highest biomass densities, while the southern states have forests with a wide range of biomass densities (Fig. 1(b)). The wide range of biomass densities in southern states most likely reflects the influence of more intensive management of pine plantations and natural forests (Birdsey, 1992), producing a mosaic of different age classes and thus biomass.

Biomass densities for hardwood forests, at the county scale of resolution, ranged from 36 to 344 Mg ha^{-1}, with an area-weighted mean of 159 Mg ha^{-1}. And, for softwood forests, biomass densities ranged from 2 to 346 Mg ha^{-1}, with a weighted mean of 110 Mg ha^{-1}. About 50% of all counties had hardwood forests with biomass densities between 125 and 175 Mg ha^{-1} (Fig. 2). Biomass densities were generally lower for softwoods than for hardwoods; ca. 40% of all counties had softwood forests with biomass densities between 75 and 125 Mg ha^{-1}.

The present biomass density of eastern forests reflects their stage of recovery from the historical pattern of human use (Brown et al., 1997), the ongoing management for timber, and the variation in environmental factors that affect rates of biomass accumulation. For example, forests with some of the highest biomass density are most likely those that are older because they were either subject to less human disturbance or the lands were abandoned from agricultural use sooner and have had a longer time to regrow (e.g., Maine, upper peninsula of Michigan, Appalachian Mountains) (Perlin, 1991 Whitney, 1994). Rather than age or harvesting, environmental factors such as drier climate and shorter growing season are likely the main causes for the lower biomass density forests in counties at the western edge of the region (e.g. Iowa, Oklahoma, and Texas).

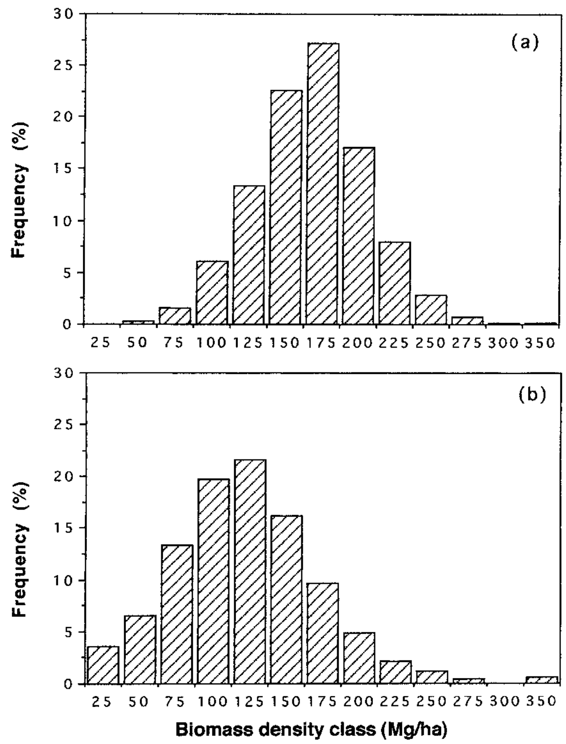

Fig. 2. Frequency distribution of biomass density classes for (a) hardwood and (b) softwood forests in the eastern US. The values plotted on the horizontal axis are the upper limit of the biomass density class.

3.2. Distribution of biomass pools

Pools of total forest biomass by county (Tg = 10^{12} g) range over two orders of magnitude in the eastern US (Figs. 3 and 4). Because most of the counties in this region are somewhat similar in size (except those in Minnesota and Maine which tend to be larger than average and those in Georgia which tend to be smaller), this range in pools reflects comparative amounts of forest biomass. More than 60% of the counties have biomass pools of $\leq$10 Tg, and only about 6% have biomass pools >25 Tg (Fig. 3). Counties with the smallest pool of forest biomass ($\leq$2.0 Tg) are those mostly located in midwestern states as might be expected, with additional low biomass counties scattered along the Mississippi valley and parts of Florida. Counties in New England, Maine, and the upper peninsula of Michigan have some of the highest

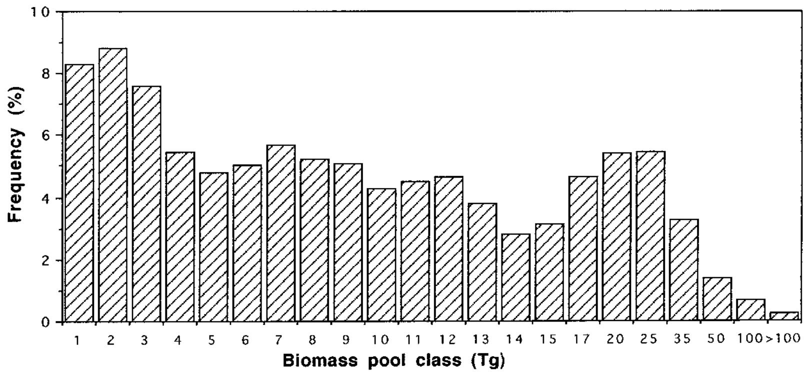

Fig. 3. Frequency distribution of total biomass pools for hardwood and softwood forests combined for all counties in the eastern US. Values plotted on the horizontal axis are the upper limit of the biomass pool class. Note that the scale is non-linear after the 15 Tg class.

biomass pools because they have forests with high biomass densities and large forest areas. The large pools in counties of northeastern Minnesota and northern Maine are mostly due to their large size as well as high forest cover; their biomass densities are in the mid-range.

The total biomass pool for all eastern forests is 20 500 Tg, 80% of which is in hardwood forests (Table 2). North Carolina and Georgia have the highest biomass pools (>1200 Tg), and ca. 65–75% of this is in hardwood forests. These two states plus an additional four (Alabama, Michigan, Pennsylvania, and Virginia), containing more than 1000 Tg of biomass each, account for more than a third of the total biomass in the eastern states. Delaware, Iowa, New Jersey, and Rhode Island each contain ca. 100 Tg or less of biomass. About 27% of the states had 25% or more of their biomass pool in softwood forests. Two states only (Louisiana and Maine) had more than 40% of their biomass in softwood forests.

The total biomass pool that we obtained is ca. 1.25 times higher than the 16 200 Tg reported by Birdsey (Birdsey, 1992; tree component only) for the same area. This difference in pool estimates could partly be due to the higher level of resolution that we used, and partly due to the various factors and approaches that the respective studies used in estimating tree components other than growing stock volume. However, with all the potential sources of uncertainty in the analysis, the difference may not be significant.

3.3. Potential for increased biomass-carbon storage

Although the total biomass density of eastern hardwood forests span a wide range, their average biomass density is less than half of what it could be because they lack numerous large diameter trees as is typical for old-growth forests (Brown et al., 1997). This lack of large diameter trees is because the forests are still either aggrading or are managed for commercial timber production. Eastern forests have the potential to accumulate significant quantities of additional biomass in living trees (at least an additional 20 000 Tg) if left unharvested, and thus storing atmospheric C into the future. As many of the forests in the eastern US are <100 year old, they would require a few hundred years more to attain the structure of old-growth forests (Brown et al., 1997). The biological possibility of storing additional C does not mean that this possibility will be realized because of the many competing uses and objectives for forest lands. Promoting C storage in existing forests by reducing harvesting or lengthening rotations are options to increase C sequestration, but ones that must be weighed against the benefits of conventional forest management, potential risks of catastrophic wildfires, and the costs of C emissions from the manufacture of materials to replace wood products. An alternative is to increase the area of forest lands by afforesting marginal farmland, a trend that is occurring in many parts of the eastern US under federal incentive programs such as the Conservation Reserve Program and the Wetlands Reserve Program.

Table 2
Total forest biomass pool and fraction of pool in hardwood forests by state

State	Biomass pool (Tg)	Fraction
Alabama	1054	0.75
Arkansas	876	0.79
Connecticut	128	0.91
Delaware	27	0.86
Florida	635	0.68
Georgia	1211	0.65
Illinois	249	0.99
Indiana	261	0.98
Iowa	95	1.00
Kentucky	787	0.97
Louisiana	751	0.59
Maine	970	0.58
Maryland	190	0.90
Massachusetts	199	0.74
Michigan	1210	0.81
Minnesota	771	0.76
Mississippi	915	0.77
Missouri	543	0.98
New Hampshire	336	0.66
New Jersey	107	0.87
New York	982	0.84
North Carolina	1284	0.74
Ohio	466	0.98
Oklahoma	168	0.78
Pennsylvania	1133	0.95
Rhode Island	21	0.94
South Carolina	668	0.67
Tennessee	806	0.93
Texas	565	0.65
Vermont	286	0.76
Virginia	1088	0.85
West Virginia	917	0.98
Wisconsin	791	0.86
Total	20 500	0.80

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References

Birdsey, R.A., 1992. Carbon storage and accumulation in United States forest ecosystems. United States Department of Agriculture Forest Service GTR WO-59.

Brown, M.J., 1993. North Carolina's forests, 1990. Forest Service Resource Bulletin SE-142.

Brown, S., 1997. Estimating biomass and biomass change in tropical forests: a primer. FAO Forestry Paper 134, Food and Agriculture Organization, Rome, Italy.

Brown, S., Lugo, A.E., 1982. Storage and production of organic matter in tropical forests and their role in the global carbon cycle. Biotropica 14, 161–187.

Brown, S., Sathaye, J., Cannell, M., Kauppi, P., 1996. Mitigation of carbon emission to the atmosphere by forest management. Commonwealth Forestry Review 75(1), 80–91.

Brown, S., Schroeder, P.E., in press. Spatial distribution of aboveground production and mortality of woody biomass for eastern US forests. Ecological Applications, in press.

Brown, S., Schroeder, P., Birdsey, R., 1997. Aboveground biomass distribution of US eastern hardwood forests and the use of large trees as an indicator of forest development. Forest Ecology and Management 96, 37–47.

Cairns, M.A., Brown, S., Helmer, E.H., Baumgardner, G.A., 1997. Root biomass allocation in the world's upland forests. Oecologia 111, 1–11.

Hall, F.G., Shimabukuro, Y.E., Huemmrich, K.F., 1995. Remote sensing of forest biophysical structure using mixture decomposition and geometric reflectance models. Ecological Applications 5, 993–1013.

Hansen, M.H., Frieswyk, T., Glover, J.F., Kelly, J.F., 1992. The eastwide forest inventory database: users manual. USDA Forest Service General Technical Report NC-151.

Krankina, O.N., Harmon, M.E., Winjum, J.K., 1996. Carbon storage and sequestration in the Russian forest sector. Ambio 25, 284–288.

Kurz, W.A., Apps, M.J., 1993. Contribution of northern forests to the global carbon cycle: Canada as a case study. Water, Air, and Soil Pollution 70, 163–176.

Neilson, R.P., King, G.A., Koerper, G., 1992. Towards a rule-based biome model. Landscape Ecology 7, 27–43.

Parton, W.J., Stewart, J.W.B., Cole, C.V., 1988. Dynamics of C, N, P and S in grassland soils: a model. Biogeochemistry 5, 109–131.

Perlin, J., 1991. A forest journey: The role of wood in the development of civilization. Harvard University Press, Cambridge, MA, 445 pp.

Phillips, D., Schroeder, P., Brown, S., Birdsey, R., 1998. Land cover dynamics and greenhouse gas emissions: error analysis of large-scale forest carbon budgets. GCTE-LUCC Open Science Conference on Global Change: The Earth's Changing Land, Abstracts. Institute Cartografic de Catalunya, Barcelona, Spain, p. 97.

Powell, D.S., Faulkner, J.L., Darr, D.R., Zhu, Z., MacCleery, D.W., 1993. Forest resources of the United States, 1992. USDA Forest Service GTR RM-234. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Prentice, I.C., Cramer, W., Harrison, S.P., Leemans, R., Monserud, R.A., Solomon, A.M., 1992. A global biome model based on plant physiology and dominance, soil properties and climate. Journal of Biogeography 19, 117–134.

Schroeder, P., Brown, S., Mo, J., Birdsey, R., Cieszewski, C., 1997. Biomass estimation for temperate broadleaf forests of the US using forest inventory data. Forest Science 43, 424–434.

Thompson, M.T., Johnson, T.G., 1994. Virginia's forests, 1992. United States Department of Agriculture Forest Service Resource Bulletin SE-151.

Turner, M., 1990. Landscape changes in nine rural counties in Georgia. Photogrammetric Engineering and Remote Sensing. 56(3), 379–386.

Whitney, G.G., 1994. From coastal wilderness to fruited plain. Cambridge University Press, Cambridge, UK.

Williams, M., 1988. The death and rebirth of the American forest: clearing and reversion in the United States, 1900–1980. In: Richards, J.F., Tucker, R.P. (Eds.), World deforestation in the twentieth century. Duke Press Policy Studies, Duke University Press, Durham, NC.

Wu, Y., Strahler, A.H., 1994. Remote estimation of crown size, stand density, and biomass on the Oregon transect. Ecological Applications 4, 299–312.

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Insular Ecosystems of the Southeastern United States: A Regional Synthesis to Support Biodiversity Conservation in a Changing Climate

Professional Paper 1828

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs, left column, top to bottom:

Photographs are by Alan M. Cressler, U.S. Geological Survey, unless noted otherwise.

Ambystoma maculatum (spotted salamander) in a Carolina bay on the eastern shore of Maryland. Photograph by Joel Snodgrass, Virginia Polytechnic Institute and State University.

Geum radiatum, Roan Mountain, Pisgah National Forest, Mitchell County, North Carolina.

Dalea gattingeri, Chickamauga and Chattanooga National Military Park, Catoosa County, Georgia.

Round Bald, Pisgah and Cherokee National Forests, Mitchell County, North Carolina, and Carter County, Tennessee.

Cover photographs, right column, top to bottom:

Habitat monitoring at Leatherwood Ford cobble bar, Big South Fork Cumberland River, Big South Fork National River and Recreation Area, Tennessee. Photograph by Nora Murdock, National Park Service.

Soil island, Davidson-Arabia Mountain Nature Preserve, Dekalb County, Georgia. Photograph by Alan M. Cressler, U.S. Geological Survey.

Antioch Bay, Hoke County, North Carolina. Photograph by Lisa Kelly, University of North Carolina at Pembroke.

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Contents

Figures [All are photographs unless noted otherwise]

Tables

Conversion Factors

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Flow rate	
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Horizontal coordinate information is referenced to the World Geodetic System of 1984 (WGS 84).

Abbreviations

ITESC International Terrestrial Ecological Systems Classification

USNVC U.S. National Vegetation Classification

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[13]Tennessee Department of Environment and Conservation.

Insular Ecosystems of the Southeastern United States: A Regional Synthesis to Support Biodiversity Conservation in a Changing Climate

By Jennifer M. Cartwright and William J. Wolfe

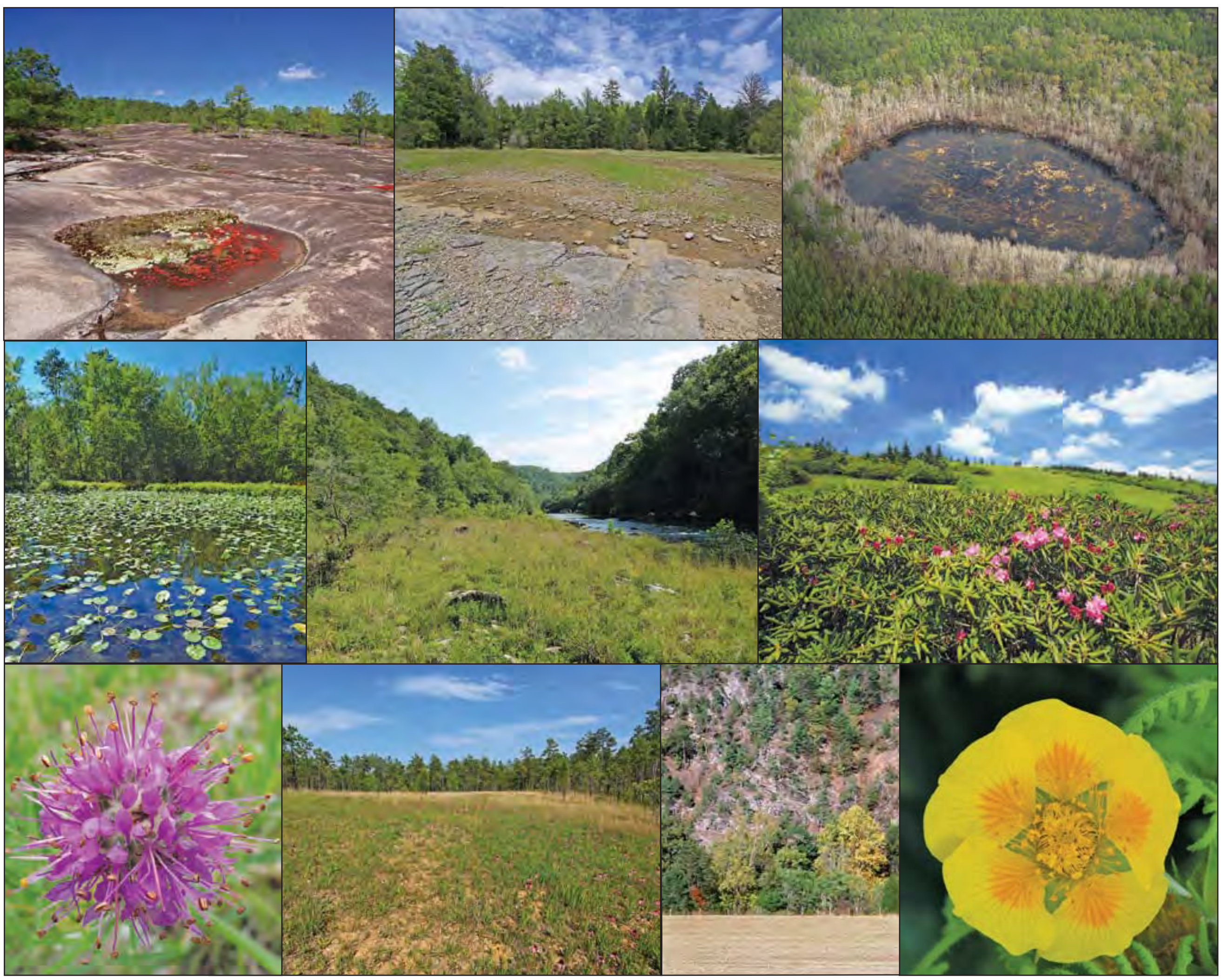
Abstract

In the southeastern United States, insular ecosystems—such as rock outcrops, depression wetlands, high-elevation balds, flood-scoured riparian corridors, and insular prairies and barrens—occupy a small fraction of land area but constitute an important source of regional and global biodiversity, including concentrations of rare and endemic plant taxa. Maintenance of this biodiversity depends upon regimes of abiotic stress and disturbance, incorporating factors such as soil surface temperature, widely fluctuating hydrologic conditions, fires, flood scouring, and episodic droughts that may be subject to alteration by climate change. Over several decades, numerous localized, site-level investigations have yielded important information about the floristics, physical environments, and ecological dynamics of these insular ecosystems; however, the literature from these investigations has generally remained fragmented. This report consists of literature syntheses for eight categories of insular ecosystems of the southeastern United States, concerning (1) physical geography, (2) ecological determinants of community structures including vegetation dynamics and regimes of abiotic stress and disturbance, (3) contributions to regional and global biodiversity, (4) historical and current anthropogenic threats and conservation approaches, and (5) key knowledge gaps relevant to conservation, particularly in terms of climate-change effects on biodiversity. This regional synthesis was undertaken to discern patterns across ecosystems, identify knowledge gaps, and lay the groundwork for future analyses of climate-change vulnerability. Findings from this synthesis indicate that, despite their importance to regional and global biodiversity, insular ecosystems of the southeastern United States have been subjected to a variety of direct and indirect human alterations. In many cases, important questions remain concerning key determinants of ecosystem function. In particular, few empirical investigations in these ecosystems have focused on possible climate-change effects, despite the well-documented ecological effects of climate change at a global level. Long-term management of these ecosystems could benefit from increased scientific effort to characterize and quantify the linkages between changing environmental conditions and the ecological processes that sustain biodiversity.

Chapter A. Introduction

The southeastern United States is rich in biodiversity (Noss, 2013) and contains multiple "hotspots" of rarity-weighted **richness** (bold terms can be found in glossary) for globally rare **taxa** (Stein and others, 2000; NatureServe, 2013). In part, this is because of concentrations of rare and **endemic** plant taxa (Marcinko, 2007), which are clustered into several "centers of endemism" including the southern Appalachian Mountains, the Nashville (Central) Basin of Tennessee and Alabama, and the Mid-Atlantic Coastal Plain (see maps in Estill and Cruzan, 2001; Sorrie and Weakley, 2001).

Across the southeastern United States, rare-species biodiversity is commonly associated with clusters of "habitat islands" (Collins and others, 2001; Edwards and Weakley, 2001) that form regional "archipelagos" (Loehle, 2006). Although these **insular ecosystems** are critically important to the natural heritage of the southeastern United States (Stein and others, 2000; Noss, 2013), they have also been vulnerable to damage and destruction from many types of human activities (Noss and others, 1995). In some cases, insular ecosystems have been the subjects of extensive botanical inventories and localized ecological investigations; however, regional and conceptual syntheses are less common. Effective conservation and management of these ecosystems—especially in the face of climate-change—will likely require improved understanding of the key drivers of ecosystem dynamics, their biotic and abiotic interactions, and their sensitivities to human alteration.



Background

Recognition of the ecological importance of islands dates back to the work of Darwin in the Galapagos Archipelago and that of Wallace in the Malay Archipelago (Simberloff, 1974). MacArthur and Wilson (1963, 1967) pioneered the study of island biogeography, and soon afterward the conceptual models and analytic approaches derived from studies of oceanic islands were adapted to metaphorical islands such as mountain tops (Brown, 1971; White and others, 1984) and lakes (Keddy, 1976; Browne, 1981). The ecological definition of "island" was expanded to include any "patch of suitable habitat surrounded by unfavorable environment that limits the **dispersal** of individuals" (Brown, 1978).

More recently, general patterns have been discerned linking biodiversity-rich insular ecosystems to localized aberrations in geologic, topographic, **edaphic**, or geomorphic conditions (Collins and others, 2001), termed "landscape anomalies" by Kelso and others (2001). Spatial heterogeneity in these conditions creates geodiversity (Gray, 2013), a landscape quality that may be important to conserving biodiversity as climatic conditions change (Anderson and Ferree, 2010; Beier and Brost, 2010; Schloss and others, 2011; Groves and others, 2012). Indeed, geodiversity conservation has been increasingly recognized for its importance in planning for climate-change mitigation of biodiversity losses (Anderson and others, 2015; Comer and others, 2015). Thus, scientifically based conservation of insular ecosystems may prove important not only to protecting current biodiversity but also to improving regional resiliency to climate change.

Purpose and Scope

This report presents a state-of-the-science review of the literature on selected ecosystems of the southeastern United States that meet five key criteria for ecological insularity:

1. Geographic discreteness, meaning spatial isolation from other occurrences of the same ecosystem type,
2. Distinctive geographic **distributions** reflecting highly specific geologic, edaphic, geomorphic, and (or) topographic controls,
3. Biogeographic endemism[1] and (or) **disjunction** for vascular plant taxa,
4. Abiotic conditions and (or) **disturbance** regimes that produce stressful conditions for plant growth, and
5. Sharply defined boundaries with steep environmental and ecological gradients to the surrounding landscape.

Rather than attempt an exhaustive review of all ecosystems meeting this definition within the southeastern United States[2], this report focuses on eight categories of insular ecosystems for which sufficient scientific literature exists to enable a synthesis across site-level investigations:

1. Granite outcrops of the Piedmont region,
2. Limestone cedar glades,
3. Xeric limestone prairies,
4. Mid-Appalachian shale barrens,
5. High-elevation outcrops and balds of the southern Appalachians,
6. Carolina bays,
7. Karst-depression wetlands, and
8. Riverscour ecosystems.

The geographic focus of this selection was the area east of the Mississippi River and south of the Ohio and Potomac Rivers, although some insular ecosystems have occurrences beyond these boundaries. Peninsular Florida was excluded from this review because this region contains many insular ecosystems and arguably deserves its own regional synthesis.

Approach

The approach to assessing the state-of-the-science for the selected insular ecosystems took the form of literature syntheses addressing the physical geography, abiotic conditions, biodiversity contributions, plant community types, vegetation dynamics, and documented anthropogenic threats to each ecosystem. The body of this report is organized in eight chapters (B through I), each focused on one of the selected insular ecosystems. These eight chapters:

1. Summarize basic information concerning geographic distribution[3], geologic and topographic context, and physical environmental characteristics,

[1]Anderson (1994) differentiated "habitat endemism" (confined to a particular habitat that may be geographically widespread) from "geographic endemism" (geographically limited to an area or region). The insular ecosystems reviewed here typically support plant taxa that are narrowly endemic based on habitat and display varying degrees of geographic endemism, depending on the species and geographic scale considered.

[2]Additional ecosystems in the southeastern United States meeting this definition are listed in table J–1.

[3]A map is presented for each insular ecosystem, showing the general geographic distribution of ecosystem occurrence or, where appropriate, selected sites where previous investigations have been performed. Exhaustive depiction of all ecosystem occurrences was outside the scope of this study and would likely be impracticable for most ecosystems due to incompleteness of regional surveys. Similarly, showing map locations of all place names mentioned in the text would have been prohibitively complex at the map scales used in this report; therefore, the maps included here are for general illustrative purposes only.

2. Provide a synthesis of known ecological drivers and determinants of **community** structures, including factors regulating spatial distributions of taxa and **successional** dynamics,
3. Discuss prominent contributions to regional and global biodiversity, especially in terms of endemic plant taxa, disjunct plant **populations**, and provision of faunal habitat,
4. Describe historical and current threats to ecosystems as well as established conservation approaches to mitigate these threats, and
5. Identify key areas where further research is needed to help inform management and conservation of these ecosystems, particularly in terms of climate-change effects on biodiversity.

Particular focus was given to the distinctive regimes of abiotic stress factors (for example, thin soils, widely fluctuating hydrology, low soil pH, or seasonally high soil surface temperatures) and disturbance events (for example, fires, droughts, and episodic scouring from high-energy floods) that characterize each ecosystem. Illustrative examples are included of how these abiotic stresses and disturbance regimes are reflected in specialized adaptations promoting stress tolerance in the plant taxa that are endemic to, or characteristic of, each ecosystem. Where applicable, the report discusses the mechanisms by which stress and disturbance regimes help shape successional dynamics and spatial vegetation patterns, for example by regulating rates of **woody encroachment** into herbaceous communities or by producing species turnover along abiotic gradients. For each ecosystem, existing conservation practices are described along with human activities and resulting processes that have been documented in the literature as prominent threats to ecosystem integrity.

Additionally, this report identifies key knowledge gaps concerning fundamental ecological questions for each ecosystem. Documentation of basic ecological characteristics is uneven across ecosystems in the published literature. Some of these systems, such as limestone cedar glades (Quarterman, 1950; Quarterman and others, 1993; Baskin and others, 2007), Appalachian shale barrens (Platt, 1951; Keener, 1983; Norris and Sullivan, 2002), and Carolina bays (Ross, 1987; Sharitz, 2003) have received attention for decades from botanists and geographers and are the subjects of relatively recent regional reviews. Others, such as karst-depression wetlands (Wolfe, 1996; Buhlmann and others, 1999) and riverscour ecosystems (Murdock and others, 2007; Wolfe and others, 2007) are known primarily from individual site-level studies across a number of discrete occurrences in several physiographic provinces, the findings of which have not previously been synthesized at a regional level. To expand the knowledge base from which to derive general patterns and pose new questions, this approach included reviews not only of easily accessible publications such as peer-reviewed journal articles but also of government reports, academic theses, and Internet-inaccessible publications. In cases where inconsistencies in terminology and nomenclature have created confusion or ambiguity in the ecological literature, this report attempts to articulate these inconsistencies and clarify the definition of terms. In cases where disagreements have existed among researchers concerning important ecological questions, the conflicting viewpoints are presented, with particular emphasis on those supported by findings from rigorous empirical research. Scientific names of taxa are in accordance with those used by NatureServe (2015) unless otherwise noted.[4] Names of ecological systems and plant associations generally follow the International Terrestrial Ecological Systems Classification (ITESC) and the U.S. National Vegetation Classification (USNVC), unless otherwise attributed (Jennings and others, 2009; Franklin and others, 2012). Conservation status rankings for associations and individual taxa are in accordance with NatureServe (2015) and are explained in the glossary.

This regional synthesis for insular ecosystems of the southeastern United States addresses one of the six U.S. Geological Survey, 2007 science strategy goals, “Understanding ecosystems and predicting ecosystem change” (U.S. Geological Survey, 2007). Particular attention was given to the ecological factors and forces that may prove sensitive to climate change. Effective management of these ecosystems in the face of increasing regional temperatures and changing precipitation patterns requires improved understanding in a number of areas, including the abiotic regulation of community structure, drivers of and constraints on succession, species-level physiological tolerance thresholds, and interspecific relationships. In general, these interactions and processes are inadequately understood for purposes of climate-change vulnerability assessment in the reviewed ecosystems. As such, an attempt was made to frame relevant questions for future research and, where warranted based on sufficient scientific documentation of climate-regulated ecosystem dynamics, to propose plausible and testable hypotheses concerning possible ecological effects of climate change. Because climate-change projections vary between different regionally downscaled climate models for the southeastern United States (Chen and others, 2003; Mearns and others, 2003; Mitchell and others, 2014), these hypotheses involved consideration of general and qualitative climatic changes rather than quantitative projections. Variability between models notwithstanding, climate change in the southeastern United States is likely to involve spatially and temporally variable temperature increases combined with changes in the timing, frequency, and magnitude of precipitation, possibly including increased storm intensity and increased drought severity (Karl and Knight, 1998; Chen and others, 2003; Mearns and others, 2003; Anchukaitis and others, 2006; Ibáñez and others, 2006; Mitchell and others, 2014). Thus, these types of changes were

[4]Recently renamed or reclassified taxa names may not appear in the updated form in NatureServe (2015). Naming revisions, reclassifications, synonyms, and basionyms are available in the International Plant Names Index (2015), the Integrated Taxonomic Information System (2015), and Natural Resources Conservation Service (2015).

given primary consideration in this report for the formulation of climate-change hypotheses for insular ecosystems of the southeastern United States. Given the paucity of previous scientific investigations addressing climate-change effects in these ecosystems, the hypotheses presented here are necessarily speculative and should be viewed not as predictions but rather as starting points for future empirical work. Although answers are rare and questions are abundant concerning climate-change ecology in insular ecosystems, regional and conceptual syntheses constitute an important first step toward the formulation of scientifically grounded approaches to the conservation and management of these biodiverse ecosystems in the decades to come.

References

Anchukaitis, K.J., Evans, M.N., Kaplan, A., Vaganov, E., Hughes, M.K., Grissino-Mayer, H.D., and Cane, M., 2006, Forward modeling of regional scale tree-ring patterns in the southeastern United States and the recent influence of summer drought: Geophysical Research Letters, v. 33, no. 4, p. L04705.

Anderson, S., 1994, Area and endemism: The Quarterly Review of Biology, v. 69, no. 4, p. 451–471.

Anderson, M., Comer, P., Beier, P., Lawler, J., Schloss, C., Buttrick, S., Albano, C., and Faith, D., 2015, Case studies of conservation plans that incorporate geodiversity: Conservation Biology, v. 29, no. 3, p. 680–691.

Anderson, M., and Ferree, C., 2010, Conserving the stage—Climate change and the geophysical underpinnings of species diversity: PLOS ONE, v. 5, no. 7, p. e11554.

Baskin, J., Baskin, C., and Quarterman, E., 2007, Flow diagrams for plant succession in the Middle Tennessee cedar glades: Journal of the Botanical Research Institute of Texas, v. 1, no. 2, p. 1131–1140.

Beier, P., and Brost, B., 2010, Use of land facets to plan for climate change—Conserving the arenas, not the actors: Conservation Biology, v. 24, no. 3, p. 701–710.

Brown, J., 1971, Mammals on mountaintops—Nonequilibrium insular biogeography: The American Naturalist, v. 105, no. 945, p. 467–478.

Brown, J., 1978, The theory of insular biogeography and the distribution of boreal birds and mammals: Great Basin Naturalist Memoirs, p. 209–227.

Browne, R., 1981, Lakes as islands—Biogeographic distribution, turnover rates, and species composition in the lakes of central New York: Journal of Biogeography, v. 8, no. 1, p. 75–83.

Buhlmann, K., Mitchell, J., and Smith, L., 1999, Descriptive ecology of the Shenandoah Valley sinkhole pond system in Virginia: Banisteria, v. 13, p. 23–51.

Chen, M., Pollard, D., and Barron, E., 2003, Comparison of future climate change over North America simulated by two regional models: Journal of Geophysical Research, v. 108, no. D12, p. ACL 3–1—ACL 3–19.

Collins, B., White, P., and Imm, D., 2001, Introduction to ecology and management of rare plants of the southeast: Natural Areas Journal, v. 21, no. 1, p. 4–11.

Comer, P., Pressey, R., Hunter, M., Schloss, C., Buttrick, S., Heller, N., Tirpak, J., Faith, D., Cross, M., and Shaffer, M., 2015, Incorporating geodiversity into conservation decisions: Conservation Biology, v. 29, no. 3, p. 692–701.

Edwards, A., and Weakley, A., 2001, Population biology and management of rare plants in depression wetlands of the southeastern Coastal Plain, USA: Natural Areas Journal, v. 21, no. 1, p. 12–35.

Estill, J., and Cruzan, M., 2001, Phytogeography of rare plant species endemic to the southeastern United States: Castanea, v. 66, no. 1, p. 3–23.

Franklin, S., Faber-Langendoen, D., Jennings, M., Keeler-Wolf, T., Loucks, O., Peet, R., Roberts, D., and McKerrow, A., 2012, Building the United States National Vegetation Classification: Annali di Botanica, v. 2, p. 1–9.

Gray, M., 2013, Geodiversity—Valuing and conserving abiotic nature: Chichester, Wiley-Blackwell.

Groves, C., Game, E., Anderson, M., Cross, M., Enquist, C., Ferdaña, Z., Girvetz, E., Gondor, A., Hall, K., Higgins, J., Marshall, R., Popper, K., Schill, S., and Shafer, S., 2012, Incorporating climate change into systematic conservation planning: Biodiversity and Conservation, v. 21, no. 7, p. 1651–1671.

Ibáñez, I., Clark, J., Dietze, M., Feeley, K., Hersh, M., LaDeau, S., McBride, A., Welch, N., and Wolosin, M., 2006, Predicting biodiversity change—Outside the climate envelope, beyond the species-area curve: Ecology, v. 87, no. 8, p. 1896–1906.

International Plant Names Index, 2015, The international plant names index, accessed October 5, 2015, at http://www.ipni.org.

Integrated Taxonomic Information System, 2015, The Integrated Taxonomic Information System, accessed October 5, 2015, at http://www.itis.gov.

Jennings, M., Faber-Langendoen, D., Loucks, O., Peet, R., and Roberts, D., 2009, Standards for associations and alliances of the U.S. National Vegetation Classification: Ecological Monographs, v. 79, no. 2, p. 173–199.

Karl, T.R., and Knight, R.W., 1998, Secular trends of precipitation amount, frequency, and intensity in the United States: Bulletin of the American Meteorological Society, v. 79, no. 2, p. 231–241.

Keddy, P., 1976, Lakes as islands—The distributional ecology of two aquatic plants, *Lemna minor* L. and *L. trisulca* L.: Ecology, v. 57, no. 2, p. 353–359.

Keener, C., 1983, Distribution and biohistory of the endemic flora of the mid-Appalachian shale barrens: The Botanical Review, v. 49, no. 1, p. 65–115.

Kelso, S., Hall, C., and Maentz, G., 2001, The role of landscape anomalies in regional plant conservation, *in* Southwestern Rare and Endangered Plants: Proceedings of the Third Conference: Flagstaff, Ariz., p. 13–19.

Loehle, C., 2006, Endemic plant distributions in Eastern North America—Implications for conservation: Journal of Forestry, v. 104, no. 8, p. 415–418.

MacArthur, R., and Wilson, E., 1963, An equilibrium theory of insular zoogeography: Evolution, v. 17, no. 4, p. 373–387.

MacArthur, R., and Wilson, E., 1967, The theory of island biogeography: Princeton, N.J., Princeton University Press.

Marcinko, S., 2007, Pattern and process in rare plant conservation—An assessment of the southeastern U.S.: Chapel Hill, N.C., University of North Carolina, Masters Thesis.

Mearns, L.O., Giorgi, F., Mcdaniel, L., and Shields, C., 2003, Climate scenarios for the southeastern U.S. based on GCM and regional model simulations: Climate, v. 60, p. 7–35.

Mitchell, R.J., Liu, Y., O'Brien, J.J., Elliott, K.J., Starr, G., Miniat, C.F., and Hiers, J.K., 2014, Future climate and fire interactions in the southeastern region of the United States: Forest Ecology and Management, v. 327, p. 316–326.

Murdock, N., Hughes, J., and Emmott, R., 2007, Understanding hydrologic links between "river prairies" and other threatened riparian resources of the Cumberland Plateau, *in* Selleck, J. ed., Natural resource year in review—2006, publication D-1859: Denver, Colo., National Park Service, Natural Resource Program Center, p. 45–46.

Natural Resources Conservation Service, 2015, The USDA plants database: Greensboro, N.C., U.S. Department of Agriculture, Natural Resources Conservation Service, National Plant Data Team, accessed September 25, 2015, at http://plants.usda.gov.

NatureServe, 2013, NatureServe rarity-weighted richness model of critically imperiled and imperiled species in the United States (updated in 2013), accessed November 15, 2015, at http://www.natureserve.org/conservation-tools/natureserve-hotspots-map.

NatureServe, 2015, NatureServe Explorer—An online encyclopedia of life [web application], ver. 7.1, accessed October 7, 2015, at http://www.natureserve.org/explorer.

Norris, S., and Sullivan, R., 2002, Conservation assessment for the mid-Appalachian shale barrens: Elkins, W.Va., West Virginia Division of Natural Resources.

Noss, R., 2013, Forgotten grasslands of the south: Washington, D.C., Island Press.

Noss, R., LaRoe, E., and Scott, J., 1995, Endangered ecosystems of the United States—A preliminary assessment of loss and degradation: Washington, D.C., U.S. Department of the Interior.

Platt, R., 1951, An ecological study of the mid-Appalachian shale barrens and of the plants endemic to them: Ecological Monographs, v. 21, no. 4, p. 269–300.

Quarterman, E., 1950, Major plant communities of Tennessee cedar glades: Ecology, v. 31, no. 2, p. 234–254.

Quarterman, E., Burbanck, M., and Shure, D., 1993, Rock outcrop communities—Limestone, sandstone, and granite, *in* Martin, W., Boyce, S., and Echternacht, A. eds., Biodiversity of the southeastern United States—Upland terrestrial communities: New York, John Wiley and Sons, Inc., p. 35–86.

Ross, T., 1987, A comprehensive bibliography of the Carolina bays literature: The Journal of the Elisha Mitchell Scientific Society, v. 103, no. 1, p. 28–42.

Schloss, C., Lawler, J., Larson, E., Papendick, H., Case, M., Evans, D., DeLap, J., Langdon, J., Hall, S., and McRae, B., 2011, Systematic conservation planning in the face of climate change—Bet-hedging on the Columbia Plateau: PLOS ONE, v. 6, no. 12, p. e28788.

Sharitz, R., 2003, Carolina bay wetlands—Unique habitats of the southeastern United States: Wetlands, v. 23, no. 3, p. 550–562.

Simberloff, D., 1974, Equilibrium theory of island biogeography: Annual Review of Ecology and Systematics, v. 5, p. 161–182.

Sorrie, B., and Weakley, A., 2001, Coastal Plain vascular plant endemics—Phytogeographic patterns: Castanea, v. 66, no. 1, p. 50–82.

Stein, B., Kutner, L., and Adams, J., eds., 2000, Precious heritage—The status of biodiversity in the United States: New York, N.Y., Oxford University Press.

U.S. Geological Survey, 2007, Facing tomorrow's challenges—U.S. Geological Survey Science in the decade 2007–2017: U.S. Geological Survey Circular 1309, 67 p.

White, P., Miller, R., and Ramseur, G., 1984, The species-area relationship of the southern Appalachian high peaks—Vascular plant richness and rare plant distributions: Castanea, v. 49, no. 2, p. 47–61.

Wolfe, W.J., 1996, Hydrology and tree-distribution patterns of karst wetlands at Arnold Engineering Development Center, Tennessee: U.S. Geological Survey Water-Resouces Investigations Report 96–4277, 46 p.

Wolfe, W.J., Fitch, K.C., and Ladd, D.E., 2007, Alluvial bars of the Obed Wild and Scenic River, Tennessee: U.S. Geological Survey Scientific Investigations Map 2007–2972, 1 sheet.

National Roadmap for Responding to Climate Change

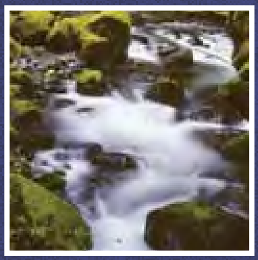
United States
Department of
Agriculture

Forest Service

FS-957b
February 2011

Nature is enormously complex.

Climate change magnifies those complexities and introduces additional uncertainties.




Contents

National Roadmap for Responding to Climate Change

The mission of the Forest Service, U.S. Department of Agriculture (USDA), is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. Americans rely on their forests and grasslands for a wide range of benefits—for provisioning services such as water, wood, and wild foods; for regulating services such as erosion, flood, and climate control; and for cultural services such as outdoor recreation, spiritual renewal, and aesthetic enjoyment. These services are connected and sustained through the integrity of the ecosystems on these lands.

Climate change places those ecosystems at risk. Most of the urgent forest and grassland management challenges of the past 20 years, such as wildfires, changing water regimes, and expanding forest insect infestations, have been driven, in part, by a changing climate. Future impacts are projected to be even more severe. Managing America's forests and grasslands to adapt to changing climates will help ensure that they continue to produce the benefits that Americans need, while helping to mitigate the effects of a changing climate and to compensate for fossil fuel emissions through carbon storage in healthy forests.

The Forest Service has a long history of managing the national forests and grasslands to enhance ecosystem health, sustainability, and resilience. Working with the States, the Forest Service assists private landowners who wish to sustainably manage their woodlands and, increasingly, participate in markets and programs to gain credit for climate change mitigation activities. To these ends, the agency's management strategies and actions have evolved to address a changing climate. Agency scientists are participants in national and international assessments of climate change effects on forests and grasslands, and they have summarized a range of management strategies to respond to climate change. Many of the agency's actions to sustain and restore healthy, flourishing ecosystems are responses to changing climatic conditions.

The sustainability of the Nation's forests and grasslands, however, requires these programs and field units to work together even more closely in an integrated national response.

In June 2010, USDA released the *2010-2015 Strategic Plan* that guides its agencies towards achieving several goals including Strategic Goal 2—Ensure our national forests and private working lands are conserved, restored, and made more resilient to climate change, while enhancing our water resources. This goal has several objectives. Objective 2.2 is to lead efforts to mitigate and adapt to climate change. The performance measures under this objective seek to reduce greenhouse gas emissions by the U.S. agricultural sector, increase the amount of carbon sequestered on U.S. lands, and bring all national forests into compliance with a climate change adaptation and mitigation strategy. The Forest Service response to this goal includes this National Roadmap for Responding to Climate Change and a Performance Scorecard.

In October 2008, the Forest Service introduced a "Strategic Framework for Responding to Climate Change." As field units began to implement the framework, the need emerged for a national roadmap to help the agency move from what it is already doing in response to climate change, through a range of additional short-term initiatives, to longer term investments in the future of America's forests and grasslands. The roadmap set forth here builds on the strategic framework. Based on regional guidance, individual units can put this roadmap to use, using a performance scorecard to track local implementation. The Forest Service will hold itself accountable for progress under this roadmap in four major dimensions: agency or organizational capacity; partnerships and conservation education; adaptation; and mitigation **(figure 1).**

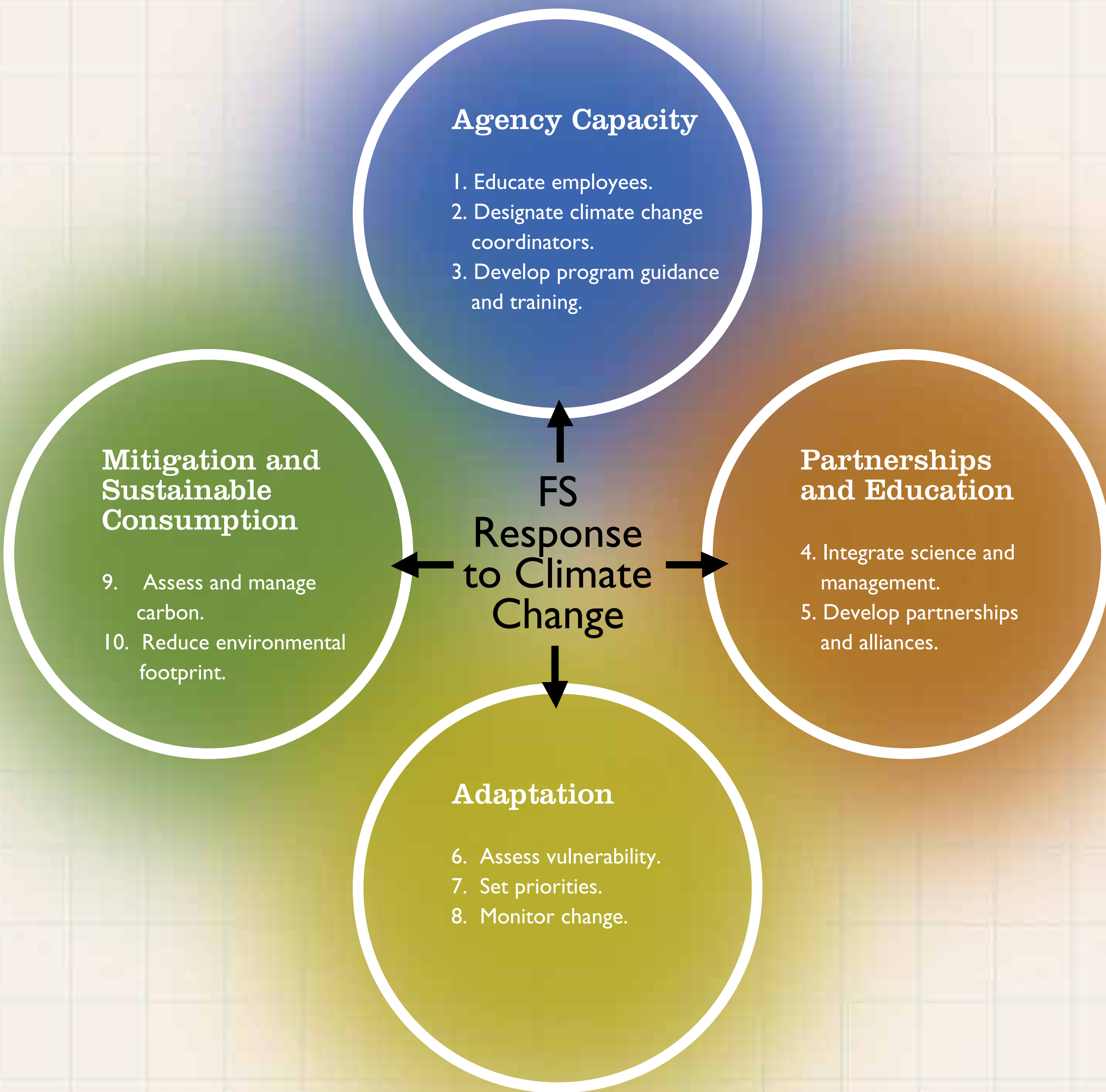


Figure 1. *The Forest Service Performance Scorecard for accountability in responding to climate change considers 10 elements in 4 dimensions.*

Modes of Action

The Forest Service will respond to climate change in three interconnected ways ***(figure 2)***:

- *Assess* current risks, vulnerabilities, policies, and gaps in knowledge.
- *Engage* employees and stakeholders to seek solutions.
- *Manage* for resilience, in ecosystems as well as in human communities, through adaptation, mitigation, and sustainable consumption strategies.

All three modes of action are dynamic and mutually reinforcing. They are interconnected through monitoring and evaluation, forming a continual feedback loop to allow opportunities for adjustment in direction or tactics.

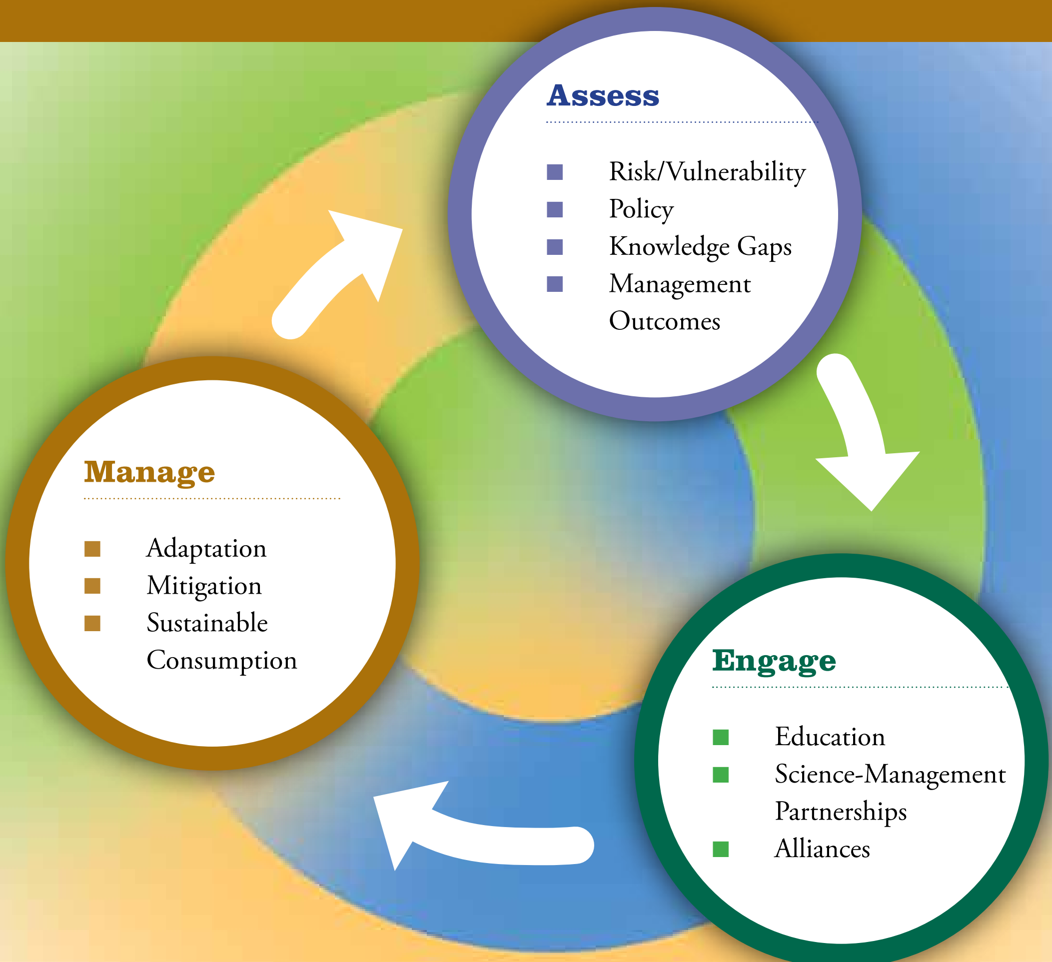


Figure 2. *The Forest Service will use three types of actions—assessing risks, vulnerabilities, policies, and knowledge gaps; engaging employees and external partners; and managing for adaptation and mitigation—in a continuous cycle of adaptive management informed by monitoring and evaluation.*

Assess

Nature is enormously complex. Climate change magnifies those complexities and introduces additional uncertainties. Not only is climate change having different impacts in different places; the likelihoods of those impacts will vary greatly. There will never be enough financial or other resources to address all of these risks. The first step in addressing climate change is to carefully assess the associated risks and vulnerabilities for natural and human communities alike. A primary role for scientists in addressing climate change will be to identify the associated knowledge gaps and fill them. As knowledge increases and uncertainty recedes, policies can be formulated and refined to better address climate change. Through careful monitoring, climate change and its impacts can be tracked, and the effectiveness of policies and the benefits of management actions can be evaluated.

Risks and Vulnerabilities

Climate change impacts will vary. Some ecosystems might experience only minor changes, whereas others might cease to exist, supplanted by new ecosystems. Impacts on water will also vary; desired ecosystem functions might diminish in some watersheds. Ecosystem vulnerability to climate change will depend on a suite of interacting factors, including the following:

- Climate change impacts on air and water quality.
- Plant community succession dynamics.
- The frequency and intensity of extreme events.
- Landscape patterns in relation to species dispersal.
- The magnitude of temperature and precipitation changes.
- Contextual features, such as topography and physical substrates.
- The ability of systems to adapt.
- Changes in disturbance regimes comprised of insects, pathogens, and wildland fire and their effects on key ecosystem processes.

Species vulnerability is also dependent on these factors, as well as on the sensitivity of individual species to change and the effectiveness of management actions in facilitating adaptation.

Infrastructure and human communities might also be vulnerable. Bridges, culverts, and campgrounds will be increasingly vulnerable to floods caused by rain-on-snow

The Forest Service Response to Climate Change: Why It Matters

Americans depend on forests and grasslands in many ways. Climate change will affect the ability of these lands to continue delivering a broad range of benefits, including clean air and water, habitat for wildlife, opportunities for outdoor recreation, and more.

- Climate change could exacerbate global conflicts over natural resources, inducing mass migrations in coming decades. Stewardship of America's forests and grasslands will become more critical than ever.
- Carbon dioxide uptake by forests in the contiguous United States offsets 11 percent of total carbon dioxide emissions. Forests and other ecosystems are carbon sinks, as they absorb CO2, thereby removing it from the atmosphere. Forest management activities will play a critical role in ensuring that forests remain a net carbon sink.
- Forests are an important source of employment and rural development. More than 2.5 million Americans have forest-related jobs, including in forest management, outdoor recreation, and the forest products industry.
- The Forest Service manages more than 35 million acres of designated wilderness areas, providing critical habitat and ecological connectivity.
- Nearly one-fifth of the Nation's water originates on the National Forest System.
- Virtually all lands that the Forest Service manages are open for public recreation. Americans spend up to 7.5 billion activity days per year enjoying their national forests and grasslands. With 80 percent of the U.S. population residing in urban areas, public opportunities to connect with the land are more important than ever.

Forests and Watershed Stewardship

A primary purpose for reserving Federal forest land at the turn of the 20th century was to protect watersheds. Today, roughly one out of five Americans depends on a national forest for drinking water. The quantity and quality of America's water, however, are affected by a changing climate. Rising air temperatures mean less snow, along with faster and earlier snowmelts. Greater variability in the volume and timing of precipitation means more floods and droughts. Warmer water in lakes and streams alters critical fish habitat, while increased evapotranspiration leads to drier vegetation and more fire, insects, and pathogens.

In an era of climate change, forests will play an increasingly vital role in protecting the Nation's watersheds. Forests reduce erosion, recharge aquifers, regulate stream flows, moderate water temperatures, and protect water quality. Wild and scenic rivers on the national forests, with relatively little direct human impact, provide ecosystem connectivity along elevational gradients and serve as baseline watersheds for scientific study. As the climate changes, the importance of America's forests is bound to grow as a source of clean and abundant water. A successful response to climate change will entail sound stewardship of America's watersheds.

events in warmer winters. Some groups of communities, such as American Indians, might be especially vulnerable because of location or cultural and economic circumstances. Some 70,000 communities in the wildland-urban interface might be at additional risk from wildland fires.

To address the risks and vulnerabilities associated with climate change, land managers will need science-based assessments of the relative vulnerability of key ecosystem components and their ability to adapt to increased stress. These assessments will help managers set priorities in maintaining healthy, resilient ecosystems and protecting communities and infrastructure. Basing their decisions on such assessments, land managers can avoid fragmented, piecemeal approaches and make cost-effective investments.

Vulnerability assessments will need to span the range of ecosystem elements and values at risk. Designated wilderness areas and wild and scenic rivers will need to be studied to help determine the potential impacts of climate change on these unique resources and determine their important role in adaptation and mitigation. Vulnerability assessments are needed for communities, their institutions, and their capacity to adapt to disturbances associated with climate change. Vulnerability assessments are the basis for defining the social, economic, and ecological costs of inaction as a reference point against which to compare proactive adaptation measures.

Understanding climate change effects and the systems involved requires integration across agencies, disciplines, and programs. Numerous efforts to assess the vulnerability of species, ecosystems, and communities are already underway, and additional efforts are planned. Various methods have been applied and new methods are in development to provide a reliable suite of tools for assessing various aspects of vulnerability. Existing vulnerability assessments will need to be synthesized and interpreted, using the results to guide more targeted appraisals for forest and grassland ecosystems. Useful assessments will require strong partnerships among science, management, and communities.

Knowledge Gaps

Scientists know a great deal about climate change, but not yet enough to help land managers fully facilitate successful adaptation. Climate change models predict temperature increases reasonably well; with the magnitude varying by model and emissions scenario, but uncertainty still surrounds future precipitation patterns for different parts of the United States. The frequency of extreme weather events, such as floods and droughts, will likely increase, but the local and regional impacts remain far from clear.

Advances in climate change knowledge, both scientific and experiential, can temper the risks and vulnerabilities associated with climate change and its impacts. Fortunately, the Forest Service is well positioned to make those advances. The agency has a century of experience in conducting, synthesizing, and applying forest and grassland research and in examining the social and environmental processes that maintain healthy, resilient ecosystems. Since the 1980s, the agency has studied the actual and potential impacts of climate change and ecosystem response.

Efforts are under way to improve projections at spatial and temporal scales relevant to land managers and policymakers. In its ongoing research, the Forest Service is trying to better understand the effects of changing temperature and precipitation regimes on the major forest and grassland stress agents such as fire, insects and disease, and invasive species, and the resultant vulnerability of plants and animals. More research is needed on the capacity of individual species to adapt or migrate, their likelihoods of extinction, and their possible roles in emerging ecosystems.

The Forest Service's *Global Change Research Strategy for 2009–19 (http://www.fs.fed.us/climatechange/documents/global-change-strategy.pdf)* will build a progressively stronger foundation for assessing climate change and its impacts. The research will continue to improve the scientific basis for a unified approach to managing ecosystems based on a better understanding of the uncertainties created by climate change. The strategy calls for research to help accomplish the following:

- Enhance ecosystem sustainability (adaptation).
- Increase carbon sequestration and reduce emissions (mitigation).
- Provide better decision support.
- Address shared research needs (infrastructure, scientific collaboration, and science delivery).

To these ends, Forest Service Research and Development is building on existing expertise in areas such as landscape ecology, watershed hydrology, vegetation modeling, nutrient cycling, wildlife ecology, and ecosystem management. Long-term data from Forest Inventory and Analysis (FIA) plots across the Nation and from the Forest Service's network of experimental forests and ranges and its research natural areas will provide both a baseline on ecosystem composition and structure and a valuable network of sites for monitoring the future effects of climate change.

Policy

Forest Service policies, developed over many years, were mostly devised before the agency took climate change into account in its programs for public land management and private landowner assistance. Such policies might not provide the most effective means for guiding actions to address climate change across broad landscapes, jurisdictions, and resource areas. The Forest Service will identify shortcomings in its policies, procedures, and program guidance, reformulating them where necessary to align resources with an effective climate change response and to more effectively collaborate with other Federal agencies, States, tribes, and other stakeholders for landscape-scale conservation.

Monitoring

Monitoring will be key to the program's success. Monitoring paves the way for assessments to be updated and validated, revealing critical new issues. A unified, multiscale monitoring system capable of detecting and evaluating national, regional, and local trends will enable land managers to develop and adjust adaptation and mitigation strategies to improve their effectiveness across landscapes and landownerships. Improved information delivery systems will provide reliable, timely, and transparent information to inform planning, decisionmaking, and project implementation at all levels.

The Forest Service and other organizations have monitoring programs, but they are not well integrated. Climate-informed planning and monitoring of forests and grasslands will focus on shared landscapes and broad spatial contexts across ecological regions. A comprehensive interagency approach is needed to connect various monitoring efforts and to fill information gaps. Other organizations have monitoring systems, data, and expertise that the Forest Service needs; other organizations can benefit from Forest Service data, including periodic updates on the overall condition of America's forests.

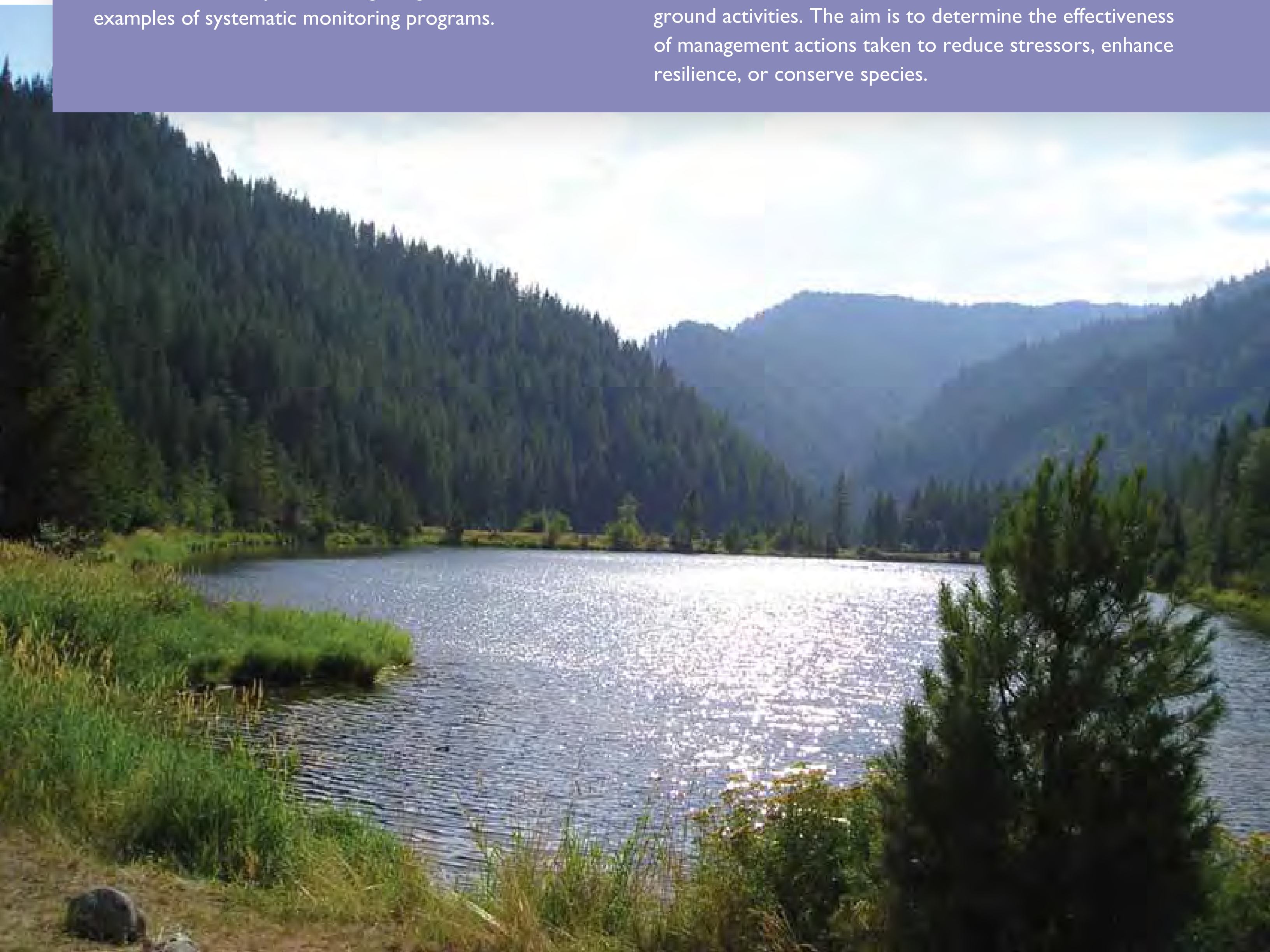
Mechanisms and methods for effectively monitoring climate change impacts and program effectiveness are developing. In the short term, the Forest Service will undertake three interrelated forms of monitoring: systematic monitoring, targeted monitoring, and effectiveness monitoring (see the sidebar Monitoring Strategies). The Forest Service will also monitor changing trends in human behavior, using U.S. census data, the USDA Natural Resources Conservation Service's Natural Resource Inventory, and other large-scale land use surveys. The agency will constantly reevaluate its monitoring mechanisms, integrating tools such as the FIA landowner survey and the Resources Planning Act (RPA) assessments, adjusting them to the pace and nature of climate-induced changes.

Monitoring Strategies

Systematic monitoring establishes monitoring locations across large areas, with monitoring stations often located in an established grid of various resolutions. An example of systematic monitoring is the Forest Inventory and Analysis (FIA) program, which uses a systematic plot-based system that has extensive coverage and uses standard measures within U.S. forest lands. FIA uses a broad suite of indicators to assess status and trends in forest resource conditions and health over time. The U.S. Geological Survey (USGS) National Stream Gauging Network, the USGS National Atmospheric Deposition Program's National Trends Network, the Natural Resources Conservation Service's Natural Resource Inventory, and the Environmental Protection Agency's Ambient Air Quality Monitoring Program are additional examples of systematic monitoring programs.

Targeted monitoring assesses particular areas based on specific objectives, using measurements or indicators related to those objectives. It obtains quantitative or qualitative population density and trend estimates in areas where a given species or community has been identified as potentially vulnerable. Targeted monitoring enables early detection of adverse climate change effects and facilitates rapid responses for adaptation or restoration needs. Examples include monitoring of weather-related changes in watershed hydrology and outbreaks of insects and diseases or invasive species in areas that have been identified as vulnerable to infestation due to climate change.

Effectiveness monitoring is focused on evaluating resilience and adaptation outcomes that result from on-the-ground activities. The aim is to determine the effectiveness of management actions taken to reduce stressors, enhance resilience, or conserve species.



Assessment Actions

The Forest Service is already studying climate change, assessing risks and vulnerabilities, identifying knowledge gaps and monitoring needs, and formulating new policy designed to facilitate an effective response. The agency will continue such activities while undertaking a series of additional immediate and longer term assessment initiatives to help meet the challenge of climate change.

Ongoing Activities

- **Providing basic and applied science** to help managers respond to climate change. The Forest Service's Climate Change Resource Center (CCRC) Web site (*http://www.fs.fed.us/ccrc/*) is continuously updated with new tools and information for managers. Efforts include the following:
  - Upgrading carbon inventory and accounting tools, such as the Carbon OnLine Estimator (COLE) and I-Tree (for urban forest assessments) (*http://nrs.fs.fed.us/carbon/tools/*).
  - Evaluating potential future climate change impacts on ecosystems, thereby identifying vulnerabilities and helping to prioritize management actions.
  - Using RPA assessments (*http://www.fs.fed.us/research/rpa/*) to evaluate the effects of climate change, both current and projected, on America's natural resources.
- **Conducting workshops** that bring scientists and managers together at local, regional, and national levels to facilitate learning and develop adaptation strategies.
- **Utilizing national monitoring networks**, such as the FIA program (for forest cover and conditions); Integrated Monitoring of Protected Visual Environments, the Clean Air Status and Trends Network, and the U.S. Environmental Protection Agency's National Atmospheric Deposition Network (for air quality); and the U.S. Geological Survey's (USGS) National Water-Quality Assessment Program (for water quality). Other networks are associated with disturbances, such as insects and pathogens (Forest Health Monitoring), fires (Monitoring Trends in Burn Severity), and weather (remote automated weather stations).

Climate Change Resource Center

The Climate Change Resource Center (CCRC) is a Forest Service reference Web site for resource managers and decisionmakers who need information and tools to address climate change in planning and project implementation. The CCRC addresses the manager's question, "What can I do about climate change?" by providing information about basic climate sciences and compiling knowledge resources and support for adaptation and mitigation strategies. The site offers educational information, including basic science modules that explain climate and climate impacts, decision-support models, maps, simulations, case studies, and toolkits. Visit *http://www.fs.fed.us/ccrc/*.

Immediate Initiatives

- **Furnish more predictive information on climate change and variability**, both immediate and longer term, building on current research capacity and partnerships with the National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, USGS, and other scientific agencies.
  - Develop, interpret, and deliver spatially explicit scientific information on recent shifts in temperature and moisture regimes, including incidence and frequency of extreme events.
  - Provide readily interpretable forecasts at regional and subregional scales.
- **Develop vulnerability assessments**, working through research and management partnerships and collaboratively with partners.
  - Assess the vulnerability of species, ecosystems, communities, and infrastructure and identify potential adaptation strategies.
  - Assess the impacts of climate change and associated policies on tribes, rural communities, and other resource-dependent communities.
  - Collaborate with the U.S. Fish and Wildlife Service and National Marine Fisheries Service to assess the vulnerability of threatened and endangered species and to develop potential adaptation measures.
- **Tailor monitoring** to facilitate adaptive responses.
  - Expand observation networks, intensify sampling in some cases, and integrate monitoring systems across jurisdictions (see, for example, the national climate tower network on the experimental forests and ranges).
  - Monitor the status and trends of key ecosystem characteristics, focusing on threats and stressors that may affect the diversity of plant and animal communities and ecological sustainability. Link the results to adaptation and genetic conservation efforts.
- **Align Forest Service policy and direction** with the Forest Service's strategic response to climate change.
  - Review manuals and other policy documents to assess their support for the agency's strategic climate change direction. Evaluate current policy direction for its ability to provide the flexibility and integration needed to deal with climate change.
  - Develop proposals for addressing critical policy gaps.

Longer Term Initiatives

- **Expand capacity for assessing the social impacts and drivers** of climate change.
  - Increase support for research on how society will be affected by the impacts of climate change on natural resources.
  - Initiate partnerships to interpret and forecast changes in human behavior and land use patterns at multiple scales over time.
- **Implement a genetic resources conservation strategy**. Improve the Forest Service's genetic resources program to conserve at-risk species and facilitate transitions to more resilient ecosystems (see the sidebar Gene Resource Management).
- **Fortify internal climate change partnerships**. Building on existing research and management partnerships, formalize joint positions across Forest Service deputy areas focusing on improving climate change science delivery.

Forest Carbon Stocks

Since the early 1990s, the Forest Inventory and Analysis (FIA) program has provided official estimates of forest carbon stocks and flows for the United States. The estimates are used in international negotiations and domestic assessments. A three-phase approach is used to estimate changes in forest resources, including forest carbon stocks (see *http://www.fia.fs.fed.us* for more details):

- Phase 1: Remote sensing.
- Phase 2: Ground measurements of tree and plot attributes.
- Phase 3: Additional measurements for bioindicators of forest health and diversity.

Statistical estimates of forest area, species, and stand density are converted to ecosystem carbon estimates with known precision. This information has been incorporated into tools for estimating carbon stocks.

The Forest Carbon Calculator Tool estimates carbon sequestration in forests at the State level. State values are summed and used as the official U.S. forest carbon stocks reported to the United Nations Framework Convention on Climate Change.

The Carbon OnLine Estimator (COLE) is a Web-based tool that generates carbon estimates based on FIA data for any part of the Continental United States, down to the county level. In 2004, COLE was named the official 1605b Web-tool by the U.S. Departments of Agriculture and Energy. A new version (COLE-EZ), designed for reporting estimates in the format for reporting to the Department of Energy for its national carbon registry, has been released.

The Forest Service has also developed additional tools to estimate carbon in forests and urban settings at various scales. These tools can be found at *http://nrs.fs.fed.us/carbon/tools/*.

Gene Resource Management

Successful restoration activities use species and populations that are adapted to current and likely future conditions to successfully reestablish resilient ecosystems after disturbances. Genetically appropriate material is called for in the Forest Service's native plant materials policy (FSM 2070), but most species used in restoration lack suitable seed and propagation sources. In responding to climate change, the Forest Service will develop strategies and seed sources adapted to both current and likely future conditions. The agency will use more genetically diverse populations and breed for appropriate abiotic and biotic resistances.

Gene conservation practices will be critical in preserving populations and species at risk of extinction. Strategies will use both *in situ* (onsite) and *ex situ* (offsite) conservation practices. Maintaining species and their ecotypes *in situ* provides the Forest Service with a continuing source of restoration plant material that is adapted to a known set of conditions. *Ex situ* practices are becoming more important as factors such as climate change, increased insect and disease pressure, and invasive species reduce areas of suitable habitat.

Basic strategies for using seed as a gene conservation method have been developed (see *Forest Service General Framework for Genetic Conservation of U.S. Forest Tree Species*), and agreements are in place to use the USDA Agricultural Research Service's National Genetic Resources Program. Efforts are under way to preserve the seed of a handful of tree species, including high-elevation pines in the West and hemlocks and ashes in the East. Other efforts involve establishing conservation plantings (e.g., arboreta, botanic gardens, and specific conservation plantings in the field) in environments that do not experience the pathogen pressure threatening a species. Present efforts involve establishing oaks (at risk from sudden oak death) and hemlock (at risk from hemlock woolly adelgid) in other countries. These efforts are especially important for species whose seed cannot be stored long term (such as acorns).

Engage

A successful response to climate change will require working across organizational boundaries to discover common goals, avoid duplication, and build on complementary assets. The Forest Service will maintain its strong current partnerships; develop additional partnerships; and enhance awareness and understanding through effective education and outreach, engaging a wider range of stakeholders in learning about forests, grasslands, and climate change.

Forest Service Climate Change Education Resources

The Forest Service's Conservation Education Program coordinates the development and delivery of high-quality, science-based conservation education programs and materials nationwide. These efforts promote the connection of youth to nature, the development of environmental literacy, and the understanding of climate change and ways each of us can help to mitigate its effects.

Conservation Education's goal is to help prepare students for real-world 21st century challenges.

We will be passing on complicated environmental problems to future generations. We must give the next generation a solid understanding of these problems and the basic tools to overcome them and make informed choices in their own lives.

The Forest Service's Conservation Education Program helps people of all ages understand and appreciate our country's natural resources and how to conserve those resources for future generations. Last year, more than 4 million people, including children and their educators, were reached through a diversity of Forest Service educational and experiential programs.

Research and Management Partnerships

The Forest Service will improve its processes for defining and addressing important management problems and knowledge needs. An effective response to climate change starts with well-framed management questions that science can accurately address. Well-developed partnerships between managers and researchers will identify information needs and specify how information is to be delivered; managers will describe information needs, both current and possible future needs, and the modes of delivery with the highest probability of success. The problem-framing process itself will strengthen partnerships between managers and researchers.

The Forest Service will establish dedicated contacts at the national, regional, research station, and area levels to transfer information related to climate change and nurture research and management partnerships. The contacts will provide the latest technology to policymakers and managers and consult with managers to determine needs. Existing technology and development service centers and threat assessment centers will emphasize climate change technology transfer. Forest Service regions and stations will formalize joint approaches to organize evolving science and assessment findings for cost-effective adoption by field units.

All-Lands Approach

Landscapes are composed of mosaics of plant and animal communities and of landownership and human communities. In the Eastern and Western United States alike, critical issues such as forest health, invasive species, fire and fuels, water quantity and quality, and wildlife habitat connectivity are exacerbated by climate change. Such issues neither begin nor end at national forest boundaries. The Forest Service will work with its neighbors to devise and implement solutions that operate across jurisdictions at a landscape scale.

Accordingly, the Forest Service has embraced an all-lands approach to conservation through cross-boundary partnerships (see the sidebar A Shared Vision for America's Forests). Landscape-scale conservation is a logical extension of the collaborative approaches that have evolved over the past 100 years in wildland fire management and cooperative pest management, with State and Federal partners jointly setting policy and sharing resources to address cross-jurisdictional challenges. The Forest Service will use its full range of authorities to provide climate change adaptation services to citizens. All parts of the Forest Service are working to integrate research, management, and landowner assistance programs to address issues in high-priority landscapes across the country.

To this end, the Forest Service will expand collaboration beyond traditional partnerships, increasing cooperation and coordination with industry, environmental, outdoor recreation, and fish and wildlife stakeholders. The Collaborative Forest Landscape Restoration Program (*http://www.fs.fed.us/restoration/CFLR/index.shtml*) provides additional impetus to work across ownerships to build resilient forested landscapes.

Education

The Forest Service has a long tradition of fostering environmental awareness and understanding through multiple programs and disciplines. The agency will incorporate climate change science into programs to create awareness, build knowledge, and develop skills that lead to action. Three audiences will be targeted:

- *Youth:* Through a variety of programs, the Forest Service will engage youth in responding to climate change. Youth will be most affected by climate change and can do the most about it. In the decades to come, whole careers will be built around climate change and its effects.
- *The general public:* The Forest Service will provide all Americans with information that prepares them to participate in climate-related decisionmaking and actions affecting the Nation's forests and grasslands.
- *Employees:* A successful climate change response requires employees who are aware of potential climate change impacts and options for adaptation and mitigation. The Forest Service will educate employees accordingly.

Providing education on climate change adaptation will require substantial investment and planning. The Forest Service will employ a full range of communication methods, including printed materials, seminars and workshops, and interactive, on-demand electronic resources. Workshops held by individual units will engage employees and partners in developing context-specific climate change adaptation and mitigation strategies. It will be particularly important to maintain technology transfer positions that are dedicated to climate change.

Engagement Actions

Actions are already under way to engage partners and build public support for a strong climate change response. The Forest Service will continue ongoing activities while undertaking a series of additional immediate and longer term initiatives.

Ongoing Activities

- **Building public awareness** of climate change by doing the following:
  - Tailoring training and education to audience needs.
  - Providing professional development training for Kindergarten–12 educators through symposia, workshops, and webinars.
  - Presenting climate change as a global issue, emphasizing what the Forest Service does locally in research and management.

- **Building management capacity** for addressing climate change by doing the following:
  - Working with partners to develop education and information resources for land managers and natural resource practitioners.
  - Establishing climate change technology transfer contacts at the regional, station, and area levels.

Immediate Initiatives

- **Use collaborative approaches** to support multiparty climate change responses.
  - Establish a collaborative agreement on landscape-scale conservation between the U.S. Departments of Agriculture and the Interior.
  - Agree on a consistent Federal framework for responding to climate change.
  - Work with leaders from other Federal agencies, States, tribal, and local governments to develop national policies on climate change.
  - Develop landscape-scale assessments, adaptation plans, and management strategies.

- **Build public support** for a strong, well-coordinated climate change response.
  - Translate climate change science into messages tailored to youth, the public, and employees, partly through existing educational tools (such as *Natural Inquirer (http://www.naturalinquirer.org/)*, the CCRC *(http://www.fs.fed.us/ccrc/)*, and employee seminars or workshops).
  - Develop consistent climate change communication strategies to: (1) increase awareness of fundamental principles regarding climate change, (2) clarify the role of forests and grasslands and of the Forest Service in responding to climate change, and (3) use place-based messages to motivate action.

Longer Term Initiatives

- **Build interagency coordination** by developing the following:
  - A climate change infrastructure (such as councils and boards) for interagency coordination on climate change and land management issues.
  - A complementary interagency research and decision-support consortium and network to coordinate science delivery.
- **Engage youth in climate change response.** Work with partners to sponsor high school students as "climate ambassadors" who will educate other students and organize community learning projects.
- **Support community and regional collaboration.** Convene forums for dialogue among business and other nongovernmental stakeholders in the Nation's forests and grasslands, building support for actions at local, State, and Federal levels.

Climate Change Impacts: Rare Red Oaks in the Southeast

Some plant species, such as oaks, do not have seed that can be stored in long-term seed storage facilities. The Forest Service is in a partnership with Botanic Gardens Conservation International to conserve three rare southeastern trees in the red oak group: maple-leaf oak *(Quercus acerifolia),* Arkansas oak *(Q. arkansana)*, and Georgia oak *(Q. georgiana).* If sudden oak death, caused by the pathogen *Phytophthora ramorum,* becomes established in the Southeast, these three oaks will be at great risk of extinction. Tissue culture will be used and living collection will be established at an Australian arboretum; Australia has been chosen because *P. ramorum* is not known to occur there.

Environmental Justice

Many Federal agencies are engaged in activities to assess the potential and actual impacts of climate change on human and natural communities; develop strategies to mitigate these impacts where possible; and develop adaptation strategies that will reduce the vulnerability of human and natural communities to expected climate change effects. The Forest Service is working with partners to ensure consideration of the effects of climate change on low-income, minority, and indigenous populations. The Forest Service offers guidance and direction on priorities and gaps that leverage limited resources, prevent unnecessary duplication, and encourage the development and consistent implementation of policies and programs that appropriately engage diverse populations in climate change. In partnership with the Joint Center for Political and Economic Studies, Forest Service Research and Development is creating a benchmark report and compendium of information and resources for policymakers, researchers, and others that documents current and historic challenges, consequences, and actions that address the concerns of communities of color with regard to climate change issues.

Manage

Ultimately, the Forest Service's management response on the ground will be threefold: adaptation, mitigation, and sustainable consumption. The agency is responding to climate change through adaptive restoration—by restoring the functions and processes characteristic of healthy, resilient ecosystems, whether or not those systems are within the historical range of variation. Through restoration, the Forest Service is conditioning and repairing the key functions of ecosystems across landscapes so that they can withstand the stresses and uncertainties associated with climate change. In land management activities, adaptation and mitigation goals are inextricably linked. Forested landscapes capable of adapting to changing conditions will be more likely to sequester and store carbon sustainably, while furnishing woody materials to help offset fossil fuel use.

Climate Change Adaptation

The Intergovernmental Panel on Climate Change (IPCC) defines *adaptation* as an initiative to reduce the vulnerability of natural or human systems to expected climate change effects. Adaptation strategies include the following:

1. Building *resistance* to climate-related stressors such as drought, wildfire, insects, and disease.
2. Increasing ecosystem *resilience* by minimizing the severity of climate change impacts, reducing the vulnerability and/or increasing the adaptive capacity of ecosystem elements.
3. Facilitating large-scale ecological *transitions* in response to changing environmental conditions.

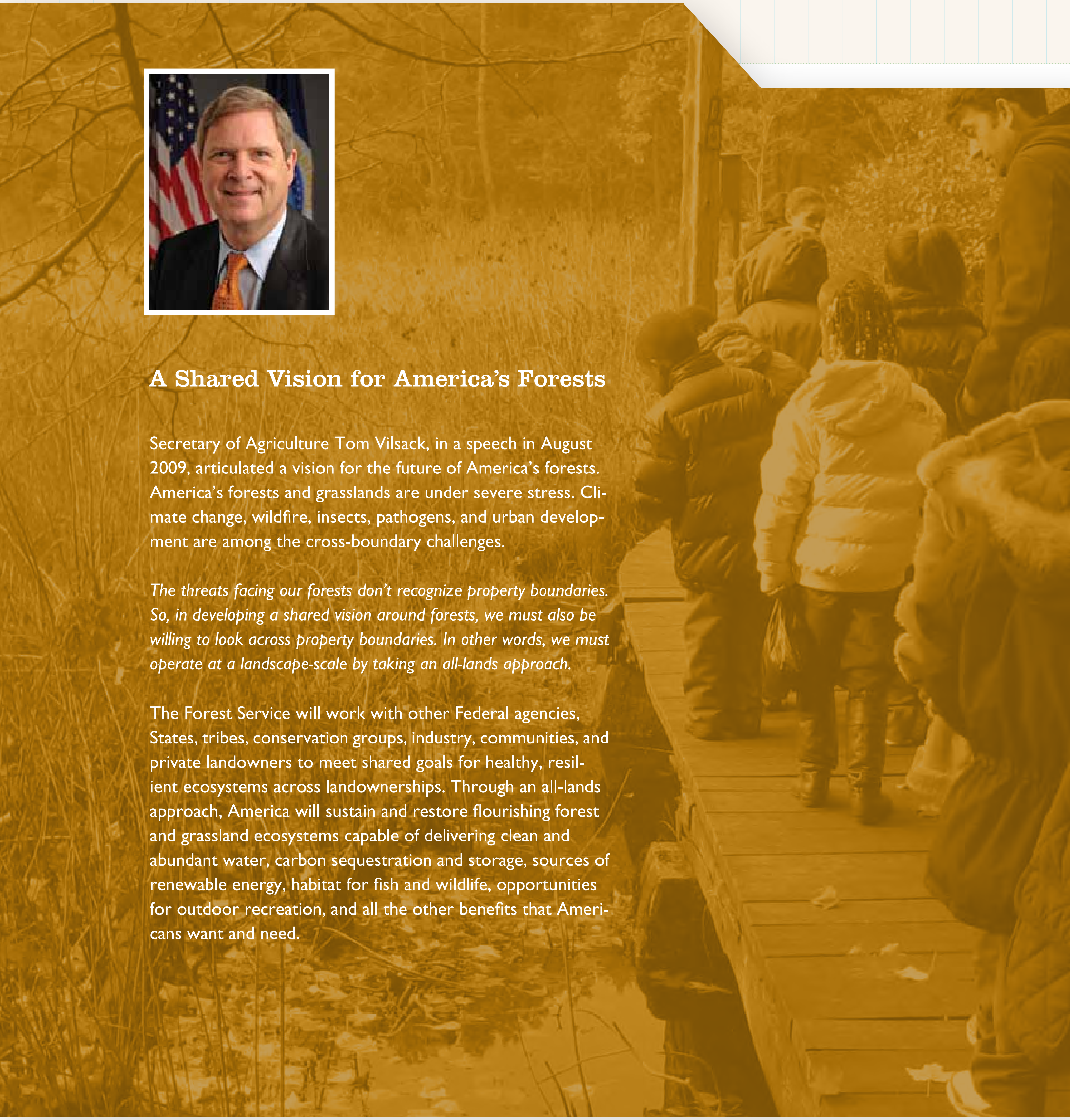
Resistance strategies are appropriate for short-term protection of high-value resources, such as a human community or an endangered species; they tend to be costly and site specific. Resilience strategies are longer term and broader in scale, designed to help ecosystems attain a healthy condition, often within the historic pattern of stressors. Transitions are the longest term approach, responding to changes in environmental conditions and a concomitant need for ecosystems to adapt by moving or changing, often taking a trajectory beyond the historical conditions. Resistance, resilience, and transitions are tiered to increasing levels of environmental change; one task for science is to find ways of assessing change and choosing the most appropriate blend of management tools based on the relative risks, vulnerabilities, and likelihood of success.

Climate Change Mitigation

The IPCC (*http://www.ipcc.ch/*) defines *mitigation* as an intervention to reduce the emissions or enhance the storage of greenhouse gases. Mitigation is predicated on adaptation: the long-term capacity of ecosystems to capture and store carbon depends in large part on their ability to adapt to a rapidly changing climate. Mitigation strategies include the following:

1. Promoting the uptake of atmospheric carbon by forests and the storage of carbon in soils, vegetation, long-lived wood products, and recycled wood materials.
2. Indirectly reducing greenhouse gas emissions (for example, through the use of carbon-neutral bioenergy to offset fossil fuel emissions and substituting wood for more fossil fuel-intensive building products).
3. Diminishing greenhouse gas emissions (for example, through the cooling effects of urban forests, which reduce the need for fossil fuels to run air conditioners) or through more prudent consumption in facilities, fleet, and other operations.

The United States has historically addressed climate change simply by conserving forests. The national forests and Forest Service were established, in part, to help stem the Nation's dramatic forest losses in the 19th century. Within a single generation, net forest loss almost entirely ceased. America's forest estate stabilized at about 750 million acres, one-third of the Nation's land area. A century of forest conservation and restoration has turned America's forests from a net carbon



A Shared Vision for America's Forests

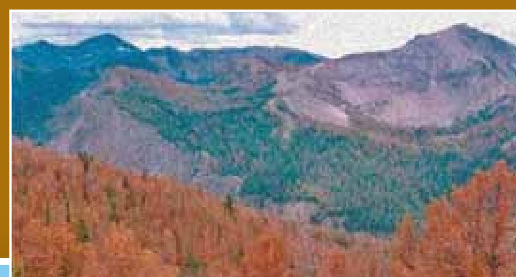
Secretary of Agriculture Tom Vilsack, in a speech in August 2009, articulated a vision for the future of America's forests. America's forests and grasslands are under severe stress. Climate change, wildfire, insects, pathogens, and urban development are among the cross-boundary challenges.

The threats facing our forests don't recognize property boundaries. So, in developing a shared vision around forests, we must also be willing to look across property boundaries. In other words, we must operate at a landscape-scale by taking an all-lands approach.

The Forest Service will work with other Federal agencies, States, tribes, conservation groups, industry, communities, and private landowners to meet shared goals for healthy, resilient ecosystems across landownerships. Through an all-lands approach, America will sustain and restore flourishing forest and grassland ecosystems capable of delivering clean and abundant water, carbon sequestration and storage, sources of renewable energy, habitat for fish and wildlife, opportunities for outdoor recreation, and all the other benefits that Americans want and need.

Climate Change Impacts: Whitebark Pine Decline

Whitebark pine *(Pinus albicaulis)* is a keystone species throughout the high mountain ranges of Western North America. Often the only tree capable of surviving in harsh subalpine areas, whitebark pine is crucial in stabilizing soil and moisture and creating habitats that support a wide variety of plants and animals. Its nuts are a critical food source for grizzly bears as they prepare for winter hibernation. Throughout its range, whitebark pine and other five-needle pines are declining due to a complex of stresses. White pine blister rust, caused by an invasive pathogen *(Cronartium ribicola)*, has caused extensive dieback of older trees and mortality of seedlings. Recently, large outbreaks of the native mountain pine beetle *(Dendroctonus ponderosae)* have affected extensive areas, including sites previously thought too cold for serious beetle outbreaks. Changes in beetle activity have been linked to warmer winter temperatures that have led to quicker development and higher survival rates for overwintering insects. Warmer and moister weather might also favor white pine blister rust by producing frequent "wave years" of conditions that promote massive numbers of infections. Rangewide restoration strategies for whitebark pine are needed to reverse current trends. The Forest Service is collaborating with partners, including the National Park Service, University of Colorado, and University of Montana, to develop and implement restoration and gene conservation strategies for whitebark pine and other threatened tree species. *http://www.fs.fed.us/r1-r4/spf/fhp/whitebark_pine/WBPCover_4.htm.*



source into a net carbon sink. In 2006, America's forests, including the carbon stored in wood products and landfills, offset about 12.5 percent of the carbon dioxide that Americans emitted.

Forest regrowth in the United States and the attendant high rates of carbon sequestration, however, have limits, linked as they are to recovery from past deforestation and logging practices. Greenhouse gas accumulations in the atmosphere will have uncertain effects on carbon sequestration. On the one hand, increasing carbon dioxide might accelerate forest growth and carbon uptake; on the other, climate change will exacerbate drought, wildfire, insects, disease, and other disturbances. Opportunities for effective, sustained climate change mitigation through forestry are therefore limited; many might entail unacceptable risks and tradeoffs. For example, storing carbon in overly dense forests increases the risk of losing the carbon through smoke and decomposition of fire-killed trees following large wildfires.

Taking any tradeoffs into account, the Forest Service will work with partners to sustain or increase carbon sequestration and storage in forest and grassland ecosystems and to generate forest products that reduce and replace fossil fuel use. The Forest Service will balance its mitigation efforts with all other benefits that Americans get from healthy, resilient forests and grasslands, such as wildlife habitat, wood fiber, water quantity and quality, and opportunities for outdoor recreation.

The Western Collective: Implementing Sustainable Consumption Practices in a Place-Based Way

In 2009, five Forest Service western regions (Northern, Rocky Mountain, Southwest, Pacific Northwest, and Intermountain Regions) and the Rocky Mountain Research Station formally chartered the Sustainable Operations Western Collective (WC). Recognizing that sustainable consumption practices require a leadership climate supporting cross boundary and interdisciplinary work, these units are pooling resources, staffing, and strategy to reduce energy, water usage, waste production, fleet emissions, and the overall environmental footprint of operations. Through pooling experimentation and case study effort, learning can be more quickly applied across the West, and propagated across the Nation and with other partners and sister agencies. In 2010, the Western Collective was able to leverage $635,000 of hard cash contributions into about $1.2 million of work that directly supported reductions in consumptions, as well as creating a leadership climate that supports those changes becoming a long-term part of our culture. *http://www.fs.fed.us/sustainableoperations/western-collective.shtml*

Sustainable Consumption

As it faces the enormous challenge of sustaining forests and grasslands under a changing climate, the Forest Service recognizes that it must also become more transparent with the implications of the agency's own use of natural resources. The IPCC and the United Nations Commission on Sustainable Development both suggest that making development more sustainable can enhance synergies between adaptation and mitigation approaches. Our long-term commitment to sustainability involves strategically connecting our land stewardship with practices that reduce the agency's consumption and environmental footprint. The direct relationship between our healthy forests, faucets, heating systems, clean air, modes of transportation, and many other goods and services has never been more apparent. Water and energy conservation, fleet and transportation management, and waste prevention/recycling and purchasing habits are activities that we must now include in our approach of "caring for the land." The work of developing habits that create more sustainable consumption patterns includes working across disciplines and staff groups within the Forest Service as well as with other agencies, partners, and communities. Strategies the Forest Service will use to move towards more sustainable consumption patterns include:

- Incorporate and maintain long-term programs, practices, tools, and policies that integrate sustainable consumption principles throughout the organization by removing barriers and promoting the use of efficient appropriate technologies and behavior changes.
- Institute a culture that emphasizes education, rewards positive actions, and recognizes achievements that reduce our environmental footprint in long lasting ways.
- Integrate sustainable consumption activities into daily decisions, habits, planning, and operations.
- Increase leadership capacity and day-to-day capabilities to implement sustainable consumption patterns at and between all levels of the organization.

The Forest Service's 2007 environmental footprint can be found at: http://www.fs.fed.us/sustainableoperations/documents/fy2007-environmental-footprint.pdf.

As the Forest Service responds to a changing climate, it strives to

Maintain biodiversity

Maintaining diverse, functioning forest and grasslands into the future is critical in dealing with the variable and uncertain impacts of climate change. When possible, the Forest Service should work to conserve existing forests and grasslands, restoring diversity, structure, and functions that may have been lost. While systems are certain to change, having a greater array of ecosystems and species reduces our vulnerability to the impacts of a changing climate.

Sustain multiple benefits

Forests and grasslands provide multiple goods and services—clean and abundant water, clean air, carbon storage, biodiversity, wildlife habitat, timber, food, fiber, fuel, recreation, aesthetic enjoyment, and other public services. Policies should sustain the full range of diverse products and services that forests and grasslands provide to meet society's current and future needs.

Consider scale

Our national forests and grasslands are part of a larger human and ecological landscape comprised of public and private lands. Problems must be addressed at scales that make sense and make a difference. Local objectives need to be balanced with broader goals on a landscape scale. The Forest Service should strategize for ecosystem conservation at the landscape scale, but maintain flexibility to manage locally. One-size-fits-all strategies are unlikely to be efficient or effective.

Embrace partnerships

Achieving a landscape-scale approach to adaptation and mitigation hinges on partnerships with other Federal, State, and local government agencies; tribes; nongovernmental organizations; and the private sector. Through diverse partnerships, the Forest Service can build capacity to promote learning, facilitate the exchange of ideas, and create sustainable solutions based on traditional and scientific knowledge. Institutional and public support for implementing innovative approaches is essential.

Manage risk

Continuous environmental monitoring and incorporation of new science into planning, policies, and decisionmaking processes are critical to adaptation and mitigation in an uncertain climate future. The Forest Service's decision processes require institutional flexibility to manage for risk while acknowledging the uncertainty of the magnitude and nature of climate change impacts on local and regional scales.

Consider human communities

Maintaining the social health and economic prosperity of human communities is a vital part of landscape-scale conservation. Humans shape and depend on forests and grasslands for a variety of benefits and are an intrinsic component of the landscape. Adaptation and mitigation strategies need to explicitly recognize the vulnerabilities of human communities to a changing climate. Strategies should address how changing ecological and climate conditions, and associated policies, affect the array of ecosystem services and products and economic opportunities generated by forests and grasslands.

Build from established programs

Many of the actions needed to address climate change build upon established practices for advancing sustainable forest and grassland management. The Forest Service should build on its knowledge, integrating and refining practices as it learns about the implications of a changing climate. Where knowledge gaps are identified, the agency should continue to emphasize fundamental scientific inquiry into the causes, consequences, and strategies for responding to climate change in forests and grasslands.

Provide incentives and examples

The Forest Service is changing agency behavior to encourage sustainable consumption and, as a result, reduce its environmental footprint. Policies should encourage best practices of employees and the public for reducing carbon emissions through conservation and renewable energy use.

Management Actions

The Forest Service has a long history of managing the national forests and grasslands for sustainability and of working with the States toward sustainable forest management on private lands. Many management actions already address climate change. The Forest Service will continue its ongoing activities while undertaking additional initiatives, both immediate and longer term, to facilitate adaptation and mitigation.

Ongoing Actions

- **Restoring healthy, resilient forest and grassland ecosystems** by doing the following:
  - Treating overgrown forests to make them less vulnerable to wildfire, pathogens, and insect attack.
  - Controlling insects, pathogens, and invasive species that threaten the health and resilience of ecosystems.
  - After major disturbances, quickly restoring ecosystems with species and populations adapted to current and future climates.
- **Protecting infrastructure** by modifying or relocating roads, culverts, trails, campgrounds, and other facilities to resist floods and other major disturbances.
- **Actively managing carbon stocks** in forests, grasslands, and urban areas over time by doing the following:
  - Rapidly reforesting land damaged by fires, hurricanes, and other disturbances, consistent with land management objectives.
  - Conserving working forests and grasslands.
  - Providing technical assistance for programs designed to enhance carbon sequestration potential through afforestation, reforestation, and practices that increase and maintain productivity and ecosystem health.
  - Encouraging communities to retain green space and to plant and maintain trees.
  - Using available tools to understand the impacts of management actions on carbon stocks and fluxes.
- **Facilitating demonstration projects** leading to the development of markets for ecosystem services, including carbon markets.

Climate Change Impacts: Alaska Yellow-Cedar Decline

More than one-half million acres of Alaska yellow-cedar *(Chamaecyparis nootkatensis)* mortality have been mapped during aerial surveys in southeast Alaska. The affected areas contain mixtures of long-dead, recently dead, and dying yellow-cedar trees. Yellow-cedar has extremely valuable wood; thus, the problem has considerable economic consequences. This tree also has ecological and cultural importance: its wood and bark have long been used by indigenous people. Analysis of aerial survey data reveals that tree mortality is concentrated at lower elevations and on wet soil types. Research indicates that the problem began about 100 years ago at the end of the Little Ice Age. Tree death appears to result from root freezing, predisposed by low snow accumulations in the 1900s. Shallow roots in anaerobic soils and a unique vulnerability to cold injury in early spring are associated with the decline. Knowledge of the cause of yellow-cedar decline and associated site risk factors is leading to a conservation strategy for this valuable tree species in the context of a warming climate with reduced snow. For more information, go to *http://www.fs.fed.us/pnw/research/climate-change/yellow-cedar/*.

Climate Change Impacts: Rare Plants

Christ's Indian paintbrush *(Castilleja christii)* is a showy, yellow-flowered perennial endemic to subalpine meadow and sagebrush habitats in the upper elevations of the Albion Mountains in Idaho. This species is known from only a single population on the summit of Mount Harrison. The conservation and protection of this rare population are managed by the Sawtooth National Forest, Minidoka Ranger District. It is currently ranked as one of Idaho's rarest plants.

The plant is now threatened by another Indian paintbrush that has climbed in elevation due to the effects of climate change. Christ's Indian paintbrush is hybridizing with this other native plant. In addition, invasive plants are gaining in elevation and have begun to occupy the habitat of this very rare species. The species will not be able to survive *in situ* for these reasons. Long-term survival will require extraordinary measures, including seed collection and preparation for long-term storage. Living collections in botanical gardens will also be part of this overall *ex situ* conservation plan.

Climate Change Impacts: Animals Adapted to Cold

Many animal species occupy a geographic range within certain thermal limits. Because the Forest Service manages many cold, higher elevation landscapes, it plays an important role in sustaining populations of cold-adapted species. As annual temperatures rise, animals will shift northward or move to higher elevations. For example, many species in the Great Basin, in particular butterflies and pika,will be forced into smaller, more isolated patches of high-elevation habitats. Similarly, many trout and char populations will be forced into smaller, more isolated headwaters; some might disappear. Woodland caribou in northern Idaho occupy the southern extent of their range. Northward migration would eliminate them from the Continental United States. To protect all these species and more, the Forest Service will need to make habitats more resilient to climate change and increase connectivity among them. Failure will mean the disappearance of these species from the National Forest System.

- **Promoting woody biomass utilization** by doing the following:
  - Encouraging the use of woody materials for thermal heat and power production and as a substitute for more energy-intensive building materials.
  - Increasing the reliability of an accessible and sustainable supply of woody biomass from national forests and private lands, where feasible.
  - Providing research, technical assistance, and grants to foster (1) the substitution of wood-based building products for more energy-intensive materials (such as steel and concrete); (2) more use of excess wood from forests and urban areas as renewable sources of heat, power, and transportation fuels; and (3) development of cost-competitive, wood-based liquid transportation fuels and chemicals to reduce fossil fuel use.

- **Reducing the Forest Service's environmental footprint**, including reduced carbon emissions and more efficient use of energy and water resources.
  - Require all new design and construction at owned buildings and leased buildings over 10,000 gross square feet meet the criteria of the U.S. Green Building Council's Leadership in Energy and Environmental Design Silver Certification, where practicable.
  - Install advanced electric meters in agency buildings by 2012 and natural gas/steam meters by 2016.
  - Promote Energy Saving Performance Contracts and Utility Energy Service Contracts, when life-cycle cost effective, to help finance energy and water efficiency projects.
  - Optimize use of vehicles and right-size fleet.

- **Addressing climate change in planning and analysis** by doing the following:
  - Incorporating climate-related vulnerabilities and uncertainties into land management and project-level environmental analyses.
  - Discussing how a range of uncertain future climate conditions might affect the expected consequences of proposed activities.

- **Playing a leadership role** in carbon assessments and climate change monitoring by coordinating with other Federal agencies in assessing and reporting carbon stocks and in monitoring for climate-driven impacts and changing conditions on the ground.
- **Protecting rare and sensitive species** by restoring and reconnecting their habitats.

Immediate Initiatives

- **Develop decision support tools** for adaptation and mitigation.
  - Update data systems for identifying current resource conditions, feedback from past management practices, and future high-priority activities and the feasibility of their implementation.
  - Develop comprehensive tools for priority setting and budgeting that are applicable at all geographic scales using existing data and compatible with data and tools being used by partners.
- **Set priorities** for management actions.
  - Develop a risk-based management system to identify adaptation and mitigation priorities across landscapes and watersheds within bioregions. The system would use risk management concepts to evaluate resource conditions and trends, values at risk, relative vulnerabilities, and other local factors, encouraging balancing risk reduction across multiple risks and costs.
  - Develop new management strategies for reconnecting habitats, maximizing the habitat accessible to native species while minimizing the spread of unwanted species.
- **Refine management practices** for addressing projected climate change impacts and ecosystem dynamics, using the principles of risk management and adaptive management.
- **Develop a web-based sustainable operations information system** that integrates with existing databases to report and monitor energy and water use, green purchasing, fleet and transportations, waste prevention, and recycling activities and provide guidance in achieving goals in reducing the agency's environmental footprint.

- **Connect habitats** to improve adaptive capacity.
  - Collaborate with partners to develop strategies that identify priority locations for maintaining and restoring habitat connectivity. Seek partnerships with private landowners to provide migration corridors across private lands.
  - Remove or modify physical impediments to the movement of species most likely to be affected by climate change.
  - Manage forest and grassland ecosystems to decrease fragmentation.
  - Continue to develop and restore important corridors for fish and wildlife.

Longer Term Initiatives

- **Increase long-term restoration capacity.**
  - Restore disturbed areas, where appropriate, with planting stock from seed sources and species that will be adapted to changing conditions.
  - Develop seed and plant stocks that will be appropriate for revegetation in light of climate change.
  - Implement genetic conservation strategies for at-risk species or populations, including saving and storing seed stocks for trial and study.
- **Develop transition strategies.** Where changing conditions will lead new ecosystems to emerge, develop and implement strategies for facilitating the transition.
- **Develop comprehensive strategies for maintaining and restoring habitat connectivity.**
- **Implement effectiveness monitoring systems** to evaluate the results of management actions designed to facilitate adaptation and mitigation.
- **Take sustainable consumption to the next level.**
  - Beginning in fiscal year (FY) 2020, design all new buildings and those buildings undergoing major renovation to achieve zero-net energy by FY 2030.
  - Facilitate and coordinate the implementation of the Power Track system by 2012. Power Track has the potential to greatly enhance the ability of field units to track their own energy use. This system is designed to capture more consumption data than current National Finance Center systems.

The Way Forward

Climate change is one of the greatest challenges the Nation has ever faced. The implications for both society and natural resources are profound and complex, as are the challenges of integrating adaptation and mitigation responses. A successful approach will be based on thorough assessments and well-tailored policies, engaging a full range of stakeholders across the landscape in activities for adaptation, mitigation, and education.

The Forest Service's *"Strategic Framework for Responding to Climate Change"* has set the stage for the roadmap presented here. The roadmap can help Forest Service units chart a course to the future tailored to local needs, based on three interrelated modes of action (assessing, engaging, and managing) and three sets of activities for each (ongoing, immediate, and longer term). The roadmap points the way to a comprehensive, science-based approach to managing forests and grasslands in an era of climate change.

Land and resource management are inherently fraught with risk and uncertainty. Climate change exacerbates both. In response, the Forest Service must be nimble, willing to learn from mistakes, and must incorporate lessons learned into future agency direction. The agency is ready to work with and learn from others, sharing its knowledge, skills, and experience to make America's forests and grasslands sustainable for present and future generations, even in an era of climate change.

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FOREST RESILIENCE, BIODIVERSITY, AND CLIMATE CHANGE

A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems

Convention on
Biological Diversity

UNEP

FOREST RESILIENCE, BIODIVERSITY, AND CLIMATE CHANGE

A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems

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Glossary

Term	Definition	Source
Adaptation	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.	UNFCCC
Adaptive capacity	The ultimate source of adaptive capacity in an ecosystem is the genetic diversity within the populations of its component	
Biodiversity or biological diversity	The variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, among species, and of ecosystems.	CBD
Biomass	Organic material both above ground and below ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots, etc.	FAO 2006
Biome	A regional ecosystem with a distinct assemblage of vegetation, animals, microbes, and physical environment often reflecting a certain climate and soil	Helms 1998
Carbon sequestration	The process of removing carbon from the atmosphere and depositing it in a reservoir.	UNFCCC
Deforestation	The direct human-induced conversion of forested land to non-forested land.	UNFCCC - Marrakech Accords
Ecological resilience	The ability of a system to absorb impacts before a threshold is reached where the system changes into a different state.	Gunderson 2000
Ecosystem	A community of all plants and animals and their physical environment, functioning together as an interdependent unit.	Helms 1998
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.	CBD
Ecosystem Services (also ecosystem goods and services)	The benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fibre; regulation services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfillment; and supporting services such as soil formation, photosynthesis, and nutrient cycling.	Millennium Ecosystem Assessment
Engineering resilience	The capacity of a system to return to its pre-disturbance state	Gunderson 2000
Forest Degradation	Changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services	FAO 2001
Forest Degradation	A degraded forest is a secondary forest that has lost, through human activities, the structure, function, species composition or productivity normally associated with a natural forest type expected on that site. Hence, a degraded forest delivers a reduced supply of goods and services from the given site and maintains only limited biological diversity. Biological diversity of degraded forests includes many non-tree components, which may dominate in the under-canopy vegetation.	UNEP/CBD

Forest state	Most commonly considered in terms of the dominant assemblage of tree species forming an ecosystem at a location, the functional roles those species play, and the characteristic vegetation structures (height, layers, stems density, etc.) at maturity.	
Functional groups	Assemblages of species performing similar functional roles within an ecosystem, such as pollination, production, or decomposition (i.e., trophic groups), hence providing some redundancy.	Hooper and Vitousek 1997
Fundamental niche	A geographic area with the appropriate set of abiotic factors in which a species could occur.	Hutchinson 1957
Genetic Diversity	Any variation in the nucleotides, genes, chromosomes, or whole genomes of organisms.	
Mitigation	In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases.	UNFCCC
Modified natural forest	Forest/other wooded land of naturally regenerated native species where there are clearly visible indications of human activities. Includes, but is not limited to, selectively logged-over areas, naturally regenerating areas following agricultural land use, areas recovering from human-induced fires, areas where it is not possible to distinguish whether the regeneration has been natural or assisted.	FAO 2006
Monotypic stand	A forest stand containing one tree species.	
Plantation	Forest/other wooded land of introduced species and in some cases native species, established through planting or seeding, mainly for production of wood or non-wood goods	FAO 2006
Primary forest	Forest/other wooded land of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed.	FAO 2006
Productivity or production	The rate at which biomass is produced per unit area by any class of organisms.	Helms 1998
Resilience	The capacity of an ecosystem to return to the pre-condition state following a perturbation, including maintaining its essential characteristics taxonomic composition, structures, ecosystem functions, and process rates.	Holling 1973
Resistance	The capacity of the ecosystem to absorb disturbances and remain largely unchanged.	Holling 1973
Silviculture	The art of producing and tending a forest by manipulating its establishment, composition and growth to best fulfill the objectives of the owner. This may, or may not, include timber production.	Helms 1998
Succession	Progressive changes in species composition and forest community structure caused by natural processes (nonhuman) over time.	Helms 1998
Stability	The capacity of an ecosystem to remain more or less in the same state within bounds, that is, the capacity to maintain a dynamic equilibrium in time while resisting change.	Holling 1973

Foreword

The world's forest ecosystems provide environmental services that benefit, directly or indirectly, all human communities, including watershed protection, regional climatic regulation, fibre, food, drinking water, air purification, carbon storage, recreation, and pharmaceuticals.

Forests harbour an estimated two thirds of all terrestrial species, and a fascinating array of ecological processes. The ecological stability, resistance, resilience, and adaptive capacities of forests depend strongly on their biodiversity. The diversity of genes, species, and ecosystems confers on forests the ability to withstand external pressures, and the capacity to 'bounce back' to their pre-disturbance state or adapt to changing conditions. This review explores these relationships based on published scientific literature.

This publication is a direct response to a request by the ninth meeting of the Conference of the Parties to the CBD to explore the links between biodiversity, forest ecosystem resilience, and climate change. Its findings are relevant for the future implementation of the CBD, but also the United Nations Framework Convention on Climate Change (UNFCCC), the Forest Instrument of the United Nations Forum on Forests (UNFF), and other international and regional forest-related agreements. It provides a compelling rationale for the conservation and sustainable use of biodiversity in any forest-based climate change mitigation and adaptation efforts.

In the present debate on climate change, the carbon storage capacity of forests and their role in mitigation is receiving increasing attention. While the international climate change negotiations have now recognized the value of ecosystem-based adaptation, in reality ecosystem-based mitigation and adaptation are two sides of the same coin. Protecting primary forests and restoring managed or degraded forest ecosystems make a vital contribution to both reducing anthropogenic emissions and aiding societal adaptation to unavoidable climate change. It is the resilience inherent to intact forest ecosystems - fully functional units of plants, animals, micro-organisms, and fungi – that provides the best insurance against climate change and prospects for ensuring forests meet the needs of present and future generations.

Ahmed Djoghlaf
Executive Secretary
Secretariat of the Convention
on Biological Diversity

Summary for Policy-makers

• Resilience is the capacity of a forest to withstand (absorb) external pressures and return, over time, to its pre-disturbance state. When viewed over an appropriate time span, a resilient forest ecosystem is able to maintain its 'identity' in terms of taxonomic composition, structure, ecological functions, and process rates.

• The available scientific evidence strongly supports the conclusion that the capacity of forests to resist change, or recover following disturbance, is dependent on biodiversity at multiple scales.

• Maintaining and restoring biodiversity in forests promotes their resilience to human-induced pressures and is therefore an essential 'insurance policy' and safeguard against expected climate change impacts. Biodiversity should be considered at all scales (stand, landscape, ecosystem, bioregional) and in terms of all elements (genes, species, communities). Increasing the biodiversity in planted and semi-natural forests will have a positive effect on their resilience capacity and often on their productivity (including carbon storage).

• The permanence of efforts under UNFCCC negotiations, such as reducing emissions from deforestation and forest degradation (REDD), and of other forest-based climate change mitigation and adaptation policies and measures, is linked to the resilience of forests, and thus to forest biodiversity. REDD activities therefore should take biodiversity conservation into consideration, as this will help maintain forest ecosystem resilience and the long-term stability of the carbon pool.

• The resilience of a forest ecosystem to changing environmental conditions is determined by its biological and ecological resources, in particular (i) the diversity of species, including micro-organisms, (ii) the genetic variability within species (i.e., the diversity of genetic traits within populations of species), and (iii) the regional pool of species and ecosystems. Resilience is also influenced by the size of forest ecosystems (generally, the larger and less fragmented, the better), and by the condition and character of the surrounding landscape.

• Primary forests are generally more resilient (and stable, resistant, and adaptive) than modified natural forests or plantations. Therefore, policies and measures that promote their protection yield both biodiversity conservation and climate change mitigation benefits, in addition to a full array of ecosystem services. Nevertheless, it must be recognized that certain degraded forests, especially those with invasive alien species, may be stable and resilient, and these forests can become serious management challenges if attempts are made to re-establish the natural ecosystem to recover original goods and services.

• The carbon pool is largest in old primary forests, especially in the wet tropics, which are stable forest systems with high resilience.

• The regional impacts of climate change, especially interacting with other land use pressures, might be sufficient to overcome the resilience of even some large areas of primary forests, pushing them into a permanently changed state. If forest ecosystems are pushed past an ecological 'tipping point', they could be transformed into a different forest type, and, in extreme cases, a new non-forest ecosystem state (e.g. from forest to savannah). In most cases, the new ecosystem state would be poorer in terms of both biological diversity and delivering ecosystem goods and services.

• Some forest ecosystems with naturally low species diversity nevertheless have a high degree of resilience, such as boreal pine forests. These forests, however, are highly adapted to severe disturbances, and their dominant tree species have a broad genetic variability that allows tolerance to a wide range of environmental conditions.

• Plantations and modified natural forests will face greater disturbances and risks for large-scale losses due to climate change than primary forests, because of their generally reduced biodiversity. The risks can partly be mitigated by adhering to a number of forest management recommendations:

  o Maintain genetic diversity in forests by avoiding practices that select only certain trees for harvesting based on site, growth rate, or form.

o Maintain stand and landscape structural complexity, using natural forests and processes as models.

o Maintain connectivity across forest landscapes by reducing fragmentation, recovering lost habitats (forest types), expanding protected area networks, and establishing ecological corridors.

o Maintain functional diversity and eliminate the conversion of diverse natural forests to monotypic or reduced-species plantations.

o Reduce non-natural competition by controlling invasive species and reduce reliance on non-native tree crop species for plantation, afforestation, or reforestation projects.

o Manage plantation and semi-natural forests in an ecologically sustainable way that recognizes and plans for predicted future climates. For example, reduce the odds of long-term failure by apportioning some areas of assisted regeneration for trees from regional provenances and from climates that approximate future climate conditions, based on climate modelling.

o Maintain biodiversity at all scales (stand, landscape, bioregional) and of all elements (genes, species, communities) by, for example, protecting tree populations which are isolated, disjunct, or at margins of their distributions, source habitats, and refuge networks. These populations are most likely to represent pre-adapted gene pools for responding to climate change and could form core populations as conditions change.

o Ensure that there are national and regional networks of scientifically designed, comprehensive, adequate, and representative protected areas. Build these networks into national and regional planning for large-scale landscape connectivity.

1. Introduction

This paper reviews the concepts of ecosystem resilience, resistance, and stability in forests and their relationship to biodiversity, with particular reference to climate change.

The report is a direct response to a request by the ninth meeting of the Conference of the Parties to the CBD, in decision IX/5[1], to explore the links between biodiversity, forest ecosystem resilience, and climate change. Forests are emphasized because they are major reservoirs of terrestrial biodiversity and contain about 50% of the global terrestrial biomass carbon stocks (IPCC 2007, FAO 2000). Emissions from deforestation and degradation remain a significant (ca. 18-20%) source of annual greenhouse gas emissions into the atmosphere (IPCC 2007), and therefore the conservation, appropriate management and restoration of forests will make a significant contribution to climate change mitigation. Further, forests have a certain natural capacity to adapt to climate change because of their biodiversity. Some animals have important roles in ecosystem processes and organization, such as pollination, seed dispersal, and herbivory, and the loss of these species has clear negative consequences for ecosystem resilience (e.g., Elmqvist et al. 2003). Here, however, we limit our discussion to botanical aspects of forests, with the exception of some discussion of insect pests and diseases as these influence forest resilience and stability.

Forests have many unique properties, related to their high rates of primary productivity and biodiversity, which distinguish them ecologically from other ecosystems. Such properties include biological structures that develop in vertical and horizontal layers of live and dead plants, complex processes at multiple vertical levels from within soil layers up to the canopy, the capacity for self-renewal in the face of constant small and large disturbances, co-evolved plant-animal and plant-plant interactions, and the influence forest landscapes can have on micro- and regional climates, especially in closed-canopy tropical forests. Forests are comprised of multiple ecosystems that are associated with variable edaphic and microclimate conditions across broad landscapes.

In the annex to decision II/9, the Conference of the Parties to the Convention on Biological Diversity recognized that "*Forest biological diversity results from evolutionary processes over thousands and even millions of years which, in themselves, are driven by ecological forces such as climate, fire, competition and disturbance. Furthermore, the diversity of forest ecosystems (in both physical and biological features) results in high levels of adaptation, a feature of forest ecosystems which is an integral component of their biological diversity. Within specific forest ecosystems, the maintenance of ecological processes is dependent upon the maintenance of their biological diversity*".

Humans are having long-term cumulative impacts on Earth's ecosystems through a range of consumptive, exploitive, and indirect mechanisms, even to the extent of influencing the global climate (IPCC 2007). The major impacts of humans on forest ecosystems include loss of forest area, habitat fragmentation, soil degradation, depletion of biomass and associated carbon stocks, transformation of stand age and species composition, species loss, species introductions, and the ensuing cascading effects, such as increasing exposure to risk of fire (Uhl and Kauffman 1999, Gerwing 2002). As a result, there has long been global concern about the long-term capacity of forests to maintain their biodiversity and associated rates of supply of goods and services (including carbon storage, food, clean water, and recreation). This concern has been amplified following observed impacts occurring to global forests as a result of climate change (e.g., Phillips 1997, Kellomaki et al. 2008, Phillips et al. 2009, Malhi et al. 2009).

1.1 Forests, climate, and climate change

Superimposed on the many other anthropogenic impacts on forest ecosystems noted above is human-forced global climate change. Climate has a major influence on rates of photosynthesis and respiration (Woodward et al. 1995, Kueppers et al. 2004, Law et al. 2007), and on other forest processes, acting through temperature, radiation, and moisture regimes over medium and long time periods. Climate and weather conditions also directly influence shorter-term processes in forests, such as frequency of storms and wildfires, herbivory, and species migration (Gundersen and Holling 2002). As the global climate changes, forest ecosystems will change because species' physiological tolerances may be exceeded and the rates of biophysical forest processes will be altered (Olesen et al. 2007, Kellomaki et al. 2008, Malhi et al. 2008).

Forests can be usefully conceived as complex, self-organizing systems with multiple natural processes

1. Decision IX/5 requests the Executive Secretary to: "Collect, compile and disseminate information on the relation between forest ecosystem resistance and resilience, forest biodiversity, and climate change, through the clearing-house mechanism and other relevant means."

that respond autonomously to internal and external drivers. For example, as available water becomes limiting, the height and density of the tree canopies is reduced because of basic ecophysiological relationships governing environmental controls on plant growth (Berry and Roderick 2002). If climate change results in a significant reduction in water availability, then the forest system will naturally change species composition (or state – see definition below). For example, the vegetation will reach a threshold beyond which the vegetation structure is not sufficiently tall and dense to comprise a forest, along with the concomitant changes in the dominant taxonomic composition of the plant community (Stephenson 1990). Under severe drying conditions, forests may be replaced by savannahs or grasslands (or even desert), while under increased temperature, open taiga can be replaced by closed boreal forests (assuming that there is sufficient moisture to support plant growth during the newly extended growing season) (e.g., Price and Scott 2006, Kellomaki et al. 2008).

Forests can also influence regional climates, depending on their extent and this is particularly true of the Amazon forest (Betts et al. 2008, Phillips et al. 2009). Hence, numerous feedbacks exist between climate and forests as the climate changes (Bonan et al. 2003, Callaghan et al. 2004, Euskirchen et al. 2009). These feedbacks are mediated through changes to albedo (Euskirchen et al. 2009), altered carbon cycle dynamics (Heath et al. 2005, Phillips et al. 2009), energy fluxes and moisture exchange (Wildson and Agnew 1992, Bonan et al. 2003), and herbivory resulting in increased fires (Ayres and Lomardero 2000). Hence, maintaining forest resilience can be an important mechanism to mitigate and adapt to climate change.

1.2 Definitions of and related to resilience

We discuss several closely related terms throughout this paper and define them here, including resilience, resistance, state, and stability. We define **resilience** as the capacity of an ecosystem (i.e., forest type, in this paper) to return to the original state following a perturbation, maintaining its essential characteristic taxonomic composition, structures, ecosystem functions, and process rates (Holling 1973). Similarly, Walker and Salt (2006) defined resilience as the capacity of a system to absorb disturbance and still retain its basic function and structure, and therefore its identity (i.e., recognizable as the same by humans).

A forest ecosystem can respond in different ways to disturbances and perturbations. Depending on the capacity of forests to cope with the degree of change, the characteristic taxonomic composition, vegetation structure, and rates of ecosystem processes may or may not be altered; that is, the resilience of the forest ecosystem may or may not be overcome. Forest characteristics can be used individually or in combination to define a forest ecosystem **state**. Most commonly, a forest state is considered in terms of the dominant assemblage of tree species forming an ecosystem at a location, along with the functional roles those species play, and the characteristic vegetation structures (height, layers, stems density, etc.) at maturity. So, a given mature forest type has a particular suite of characteristics that identify its state. (Note that we use the terms 'system' and 'ecosystem' synonymously throughout.)

A difference has been made in the scientific literature between "engineering resilience" and "ecological resilience" (Holling 1973, Peterson et al. 1998, Gunderson 2000, Walker et al. 2004). Engineering resilience is related to the capacity of a system to return to its more-or-less exact pre-disturbance state, and the assumption is that there is only one steady state. The latter concept has also been more recently referred to as equilibrium dynamics. Ecological resilience is defined as the ability of a system to absorb impacts before a threshold is reached where the system changes into a different state altogether. For example, in the case of increasing climatic drought, a resilient forest ecosystem according to the "engineering" definition is one that would recover from drought stress, with little or no change in species composition. If the ecological definition is used, then it is acknowledged that more than one stable system state is possible, with resilience being the measure of a forest ecosystem's capacity to withstand a prolonged drought before being converted into a different vegetation ecosystem (e.g., non-forest); though it might go through several other different but stable forest states with new species compositions, before the conversion to grassland. Many of those successive forest states might be able to provide most or all of the goods and services provided by the initial state, and all would be recognizable as a forest type. This is also referred to as non-equilibrium dynamics.

Forests are engineering resilient in the sense that they may recover, after a period of time, from a catastrophic disturbance to their original, pre-disturbance state maintaining, more-or-less, the original species composition. The main ecosystem states of interest are defined by the dominant floristic (tree) composition and stand structure. However, it is also useful to consider the question of ecological resilience with respect to the capacity of a forest to continue to provide certain (most or all) ecosystem goods and services, even if the forest composition and structure are permanently altered by disturbances.

Resilience is an emergent property of ecosystems that is conferred at multiple scales by genes, species, functional groups of species (see definition below), and processes within the system (Gunderson 2000, Drever et al. 2006). Maintaining or restoring forest resilience is often cited as a necessary societal adaptation to climate change (e.g., Millar et al. 2007, Chapin et al. 2007). Drever et al. (2006) noted the importance of clarifying the questions: resilience of what and resilience to what? Here, the "of what" are particular characteristics of forest ecosystems (e.g., carbon sequestration, water use/yield), and the "to what" are environmental and human-caused disturbances, especially climate change. For example, an individual species' physiological tolerances may be exceeded by natural environmental change or human-caused events. Consequently, the species composition of a forest may change while other ecosystem characteristics persist.

Forest resilience as illustrated by the recovery of mixedwood forest in eastern Canada as a result of red pine plantation on a logged site, with natural infilling by deciduous species over a period of about 50-80 years.

Forests are generally **resistant** to change, that is, they change little within bounds as a result of non-catastrophic disturbances, such as chronic endemic insect herbivory or minor blowdown and canopy gaps created by the death of individual or small groups of trees. Forests may also be resistant to certain environmental changes, such as weather patterns over time, owing to redundancy at various levels among functional species (as discussed further below, redundancy refers to the overlap and duplication in ecological functions performed by the diversity of genomes and species in an ecosystem). Ecosystems may be highly resilient but have low resistance to a given perturbation. For example, grasslands are not resistant, but are highly resilient, to fire. However, most well-developed forests, especially primary old forests, are both resilient and resistant to changes (e.g., Holling 1973, Drever et al. 2006).

Resistance is related to the concept of **stability** in the sense that, in response to minor perturbations, a forest ecosystem returns to within a range of variation around a specified ecosystem state. Stability reflects the capacity of an ecosystem to remain more or less in the same state within bounds, that is, the capacity to maintain a dynamic equilibrium over time while resisting change to a different state. A stable ecosystem **persists** when it has the capacity to absorb disturbances and remain largely unchanged over long periods of time.

Species stability refers to consistent species composition over time. Drever et al. (2006) suggested that forest types that naturally progress through successional compositional changes are not necessarily changing state. On the other hand, a forest that was once dominated by a certain suite of species and that has changed as a result of new environmental conditions or human interference has changed ecosystem states. For example, if a harvested boreal spruce-pine-dominated forest regenerates to a mixedwood, or if selective logging or disease eliminates species from a forest system, we would suggest that the system has indeed changed states. That is, even though it is still a forest, the ecosystem state, as defined by the dominant taxonomic composition of the canopy trees, has changed, along with various processes such as rates of growth and types of pollination. Furthermore, in this new state, some or many of the goods and services will also have changed and there may be effects on other elements of biodiversity resulting from changes in the provision of habitats and therefore the persistence of dependent animal species. Ecosystems may change states in response to disturbances, and the new state may or may not supply the same goods and services as the original state. Further, if species diversity is positively related to stability and resilience of forest systems, then species losses will likely have consequences for the long-term production of goods and services. Consequently, there is considerable interest in developing the capacity to understand and predict the mechanisms associated with resilience as it relates to the ways in which forests ecosystems respond to degradation, loss of species, and climate change (e.g., Kinzig et al. 2001, Scherer-Lorenzen et al. 2005). While many ecosystem processes are derived through the actions of animals (e.g., decomposers, pollinators, large herbivores), we primarily consider botanical influences and relationships here.

1.3 Components of biodiversity and definitions

Biodiversity is often considered, especially within the forest management community, as simply a list of species present at a location. The term can also be used in the context of providing habitats for species of some particular value of interest to people, and in this sense biodiversity is a 'good' produced by the ecosystem. While **biodiversity** encompasses both these latter meanings, it is actually a broader term intended to encompass various measures of the full richness of life on Earth. As defined by the Convention on Biological Diversity, "biological diversity" means the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, among species, and of ecosystems. Allen and Hoekstra (1992) defined biodiversity even more broadly to include the variety of life at multiple scales of ecological organization, including genes, species, ecosystems, landscapes, and biomes. Here we consider biodiversity in terms of specific components that are particularly relevant to forest ecosystems and equate them with the scale at which they are classified and mapped by humans. In so doing, we refer to standard metrics including genetic diversity and species richness that relate to the dominant plant and animal species that characterize a given forest ecosystem. We also refer to terms that describe the vegetation structure (height, density, complexity) and age.

We make reference to functional redundancy, functional types or species, and functional groups. Several studies have established that resilience in ecosystems is related to the biological diversity in the system and the capacity that it confers to maintain ecosystem processes (Walker 1995, Peterson et al. 1998, Loreau et al. 2001, Hooper et al. 2005, Drever et al. 2006, Bodin and Wimen 2007). Most ecosystem processes are controlled by, or are the result of, biodiversity. However, not all species are necessarily equally important in maintaining these processes (Walker 1992, 1995, Diaz et al. 2003) and there is some redundancy at multiple levels within most ecosystems (Hooper et al. 2005). **Functional groups** are assemblages of species performing similar functional roles within an ecosystem, such as pollination, production, or decomposition, hence providing the ecosystem with a level of redundancy (e.g., see Hooper et al. 2002). As discussed further below, functional diversity is not necessarily correlated with species richness (Diaz and Cabido 2001, Hooper et al. 2005). Functional species that dominate ecosystem processes are not inevitably the most numerous species in the system (e.g., Hooper and Vitousek 1997, Diaz et al. 2003), and it is important to understand which species are contributing most to maintaining the flows of goods and services if management or protection is an objective. We are especially interested in functional diversity (within functional groups) in ecosystems because evidence has accumulated, especially in grassland systems, which implicates a relationship between functional diversity and ecosystem properties, including resilience and the related system attributes of stability and resistance (Diaz and Cabido 2001, Hooper et al. 2005). Under changed conditions, however, species that had a limited or no functional role ("passenger" species) may become functionally dominant ("driver" species), hence buffering the ecosystem against large changes and conferring resilience; that is, passengers can become the drivers (Walker 1995). This variable response has also been termed 'functional response diversity' and is critical to ecosystem resilience (Chapin et al. 1997, Elmqvist et al. 2003).

Many boreal conifer forests are prone to fire, however the species are well-adapted to this disturbance and the forest ecosystem rapidly regenerates. Hence, this kind of forest is not resistant to fire but it is highly resilient.

Loss of functional species in the absence of redundancy has negative consequences for the ecosystem to the point of ecosystem collapse (Chapin et al. 1997). Hooper et al. (2005) noted that there is a clear need for continued research into the relationship between species richness and ecosystem stability.

1.4 Issues of scale and resilience

Proper scaling is essential in the application of a theoretical framework. Most ecosystems are subject to disturbance regimes that occur across a range of temporal and spatial scales. Single communities in forests may occur across several tens to hundreds of hectares, while forests may be considered across hundreds to thousands of square kilometres. Forest stands may change continuously as a result of small-scale chronic disturbances that do little to affect the system, or they may change considerably at large scales owing to severe disturbances. Scaling is an important factor in defining ecosystem resilience, but scale and resilience are often investigated for different purposes. Resilience studies generally focus on how and why individual ecosystems maintain or change states, while scaling studies often examine ecological phenomena assuming steady-state ecosystems (Holling 1973). However, resilience is a scale-dependent phenomenon. Ecosystems are both temporally and spatially resilient when ecological interactions reinforce each other to reduce the impact of disturbances over time. This condition can be achieved through a range of mechanisms including species functional redundancy, or offsetting differences among species.

At larger scales in forests, there is also a level of potential role for species-level beta diversity (i.e. spatial turnover in species composition of communities) in enhancing ecosystem resilience in the face of large-scaled environmental change. Regional species pools provide a level of redundancy at large scales that may confer resilience if the capacity to migrate across the landscape persists. This concept has not been well-examined in the literature.

Defining resilience requires a temporal component that is related to disturbance frequency and recovery of the ecosystem. For most forests, we tend to consider resilience over many decades to centuries. While some existing terrestrial ecosystems seem to have persisted largely unchanged for thousands of years (Hopper and Gioia 2004), environmental change and disturbance of sufficient magnitude eventually alter all ecosystems. Resilient forest ecosystems, in response to a disturbance, follow a successional pathway that returns the ecosystem to its pre-disturbance state, at least structurally and functionally. This is particularly the case for forests dominated by small-scaled disturbances. A disturbance may be sufficiently severe to reorganize an ecosystem into a state, which in the short term (i.e., decades), may have a different resistance, but in the long term (i.e., centuries) may be equally as resilient as the original state. Furthermore, in the very long-term, the altered state of the ecosystem may simply be part of a long-term dynamical process.

Of course, ecosystems and forests are comprised of assemblages of individual species. Across regions, individual species' ranges reflect their physiological and ecological niches, with the latter reflecting the conditions where they have, among other things, a competitive advantage (Hutchinson 1958). Species with broad physiological niche requirements may be highly resilient to even significant global climate change. Likewise, species with a narrow ecological niche may be more resilient than they appear, if changed conditions provide them with an advantage at the expense of competitors. In either case, this only applies to species which have large enough gene pools and the ability to migrate. Where population sizes and genetic diversity have been reduced, and/or the mobility of species is restricted through habitat fragmentation or by natural lack of species mobility, the likelihood of successful adaptation to environmental change, such as climate change, is diminished.

2. Genetic diversity and resilience to change

While resilience can be attributed to many levels of organization of biodiversity, the genetic composition of species is the most fundamental. Molecular genetic diversity within a species, species diversity within a forested community, and community or ecosystem diversity across a landscape and bioregion represent expressions of biological diversity at different scales. The basis of all expressions of biological diversity is the genotypic variation found in populations. The individuals that comprise populations at each level of ecological organization are subject to natural selection and contribute to the adaptive capacity or resilience of tree species and forest ecosystems (Muller-Starck et al. 2005). Diversity at each of these levels has fostered natural (and artificial) regeneration of forest ecosystems and facilitated their adaptation to dramatic climate changes that occurred during the quaternary period (review by: DeHayes et al. 2000); this diversity must be maintained in the face of anticipated changes from anthropogenic climate warming.

Genetic diversity (e.g., additive genetic variance) within a species is important because it is the basis for the natural selection of genotypes within populations and species as they respond or adapt to environmental changes (Fisher 1930, Pitelka 1988, Pease et al. 1989, Burger and Lynch 1995, Burdon and Thrall, 2001, Etterson 2004, Reusch et al. 2005, Schaberg et al. 2008). The potential for evolutionary change has been demonstrated in numerous long-term programmes based on artificial selection (Falconer 1989), and genetic strategies for reforestation in the presence of rapid climate change must focus on maintaining species diversity and genetic diversity within species (Ledig and Kitzmiller 1992). In the face of rapid environmental change, it is important to understand that the genetic diversity and adaptive capacity of forested ecosystems depends largely on in situ genetic variation within each population of a species (Bradshaw 1991). Populations exposed to a rate of environmental change exceeding the rate at which populations can adapt, or disperse, may be doomed to extinction (Lynch and Lande 1993, Burger and Lynch 1995). Genetic diversity determines the range of fundamental eco-physiological tolerances of a species. It governs inter-specific competitive interactions, which, together with dispersal mechanisms, constitute the fundamental determinants of potential species responses to change (Pease et al. 1989, Halpin 1997). In the past, plants have responded to dramatic changes in climate both through adaptation and migration (Davis and Shaw 2001).

The capacity for long-distance migration of plants by seed dispersal is particularly important in the event of rapid environmental change. Most, and probably all, species are capable of long-distance seed dispersal, despite morphological dispersal syndromes that would indicate morphological adaptations primarily for short-distance dispersal (Cwyner and MacDonald 1986, Higgins et al. 2003). Assessments of mean migration rates found no significant differences between wind and animal dispersed plants (Wilkinson 1997, Higgins et al. 2003). Long-distance migration can also be strongly influenced by habitat suitability (Higgins and Richardson 1999) suggesting that rapid migration may become more frequent and visible with rapid changes in habitat suitability under scenarios of rapid climate change. The discrepancy between estimated and observed migration rates during re-colonization of northern temperate forests following the retreat of glaciers can be accounted for by the underestimation of long-distance dispersal rates and events (Brunet and von Oheimb 1998, Clark 1998, Cain et al. 1998, 2000). Nevertheless, concerns persist that potential migration and ad-


In many tropical regions such as the Caribbean, forests are adapted to periodic major disturbances by hurricanes. The resilience of these tropical forests enable their rapid recovery of structural and functional attributes. These photos of El Yunque National Forest, Puerto Rico, were taken two months after Hurricane Hugo in 1989.

aptation rates of many tree species may not be able to keep pace with projected global warming (Davis 1989, Huntley 1991, Dyer 1995, Collingham et al. 1996, Malcolm et al. 2002). However, these models refer to fundamental niches and generally ignore the ecological interactions that also govern species distributions.

One of the best approaches, when dealing with an uncertain future, is diversification because no single approach will fit all situations, and this applies also to the development of forest management strategies (Ledig and Kitzmiller 1992, Millar et al. 2007). In the biological realm, maintaining species and genetic diversity addresses the need to be prepared for whatever environmental changes might happen, and this is fundamental to the concept of resilience. Species have two main means by which they adapt to change: they can either disperse by seed or vegetative propagules in the direction of a more favourable environment, or they can change their gene frequencies to favour genotypes (genetic constitutions) that are better adapted to the changed environment (Burdon and Thrall 2001, Reusch et al. 2005). Species may also adapt through phenotypic plasticity, if their genotype entails a range of permissible responses (with respect to the species morphological, physiological, behavioural or life history strategies and traits) that are suited to the new conditions (Nussey et al. 2005).

Seed and pollen dispersal, and gene frequency changes can occur simultaneously and interact in the process of adaptation. For instance, dispersal often promotes gene flow among highly fragmented tree populations; thereby maintaining within-population levels of genetic diversity and preventing the genetic drift and loss of genetic diversity that can occur through inbreeding within small, isolated or fragmented tree populations (Hall et al. 1996, Young et al. 1996, Nason and Hamrick 1997, Cascante et al. 2002, Rajora et al. 2002, Fuchs et al. 2003, Mosseler et al. 2004, Degen et al. 2006, Clouthier et al. 2007, O'Connell et al. 2007, Farwig et al. 2008). Seed dispersal can occur through wind and water, or via animals such as birds, mammals, etc. Operational forestry experience and observations have shown that seeds can be dispersed over surprisingly long distances over relatively short time frames. Seeds of light-seeded species, such as conifers, can travel long distances from the nearest population centres (Cwynar and MacDonald 1987). Conifers with semi-serotinous cones, such as black spruce (*Picea mariana*), red pine (*Pinus resinosa*), and pitch pine (*Pinus rigida*), for example, seem particularly well adapted for such long-distance dispersal over hard-packed snow and ice. Ritchie and MacDonald (1986) have suggested that wind dispersal over snow may also explain the rapid post-glacial migration rates of conifers that have non-serotinous cones, such as white spruce (*Picea glauca*). However, long-distance seed dispersal of typically wind-dispersed conifers could also be explained through dispersal by birds (Wilkinson 1997). Large or heavy-seeded species, such as those found in mangroves (Geng et al. 2008), and especially those in highly fragmented environments, may have greater difficulty travelling across landscapes (e.g., walnuts [*Juglans spp*.], hickories [*Carya spp*.]). Nevertheless, oaks (*Quercus spp.*) (Skellam 1951, Davis 1981) and American beech (*Fagus grandifolia*) (Bennett 1985) are capable of rapid and widespread dispersal given the presence of certain animal species.

Generally, by dispersing their seeds and pollen, forest species can maintain their genetic diversity, and hence their long-term resilience to change over space and time, by re-establishing themselves elsewhere in favourable climates. However, anthropogenic changes to landscapes and gene pools may have reduced this capacity, and population fragmentation has the potential to adversely affect the genetic and reproductive status of populations.

We are also concerned with the idea of *in situ* resilience, based on the potential for genetic adaptation, that is, the ability of a forest to maintain itself *in situ* following a disturbance, and therefore we focus more specifically on the role of genetic diversity as a factor in the capacity to adapt to a disturbance. Adaptation in the genetic or evolutionary sense, whereby gene frequencies are changed to promote successful growth and reproduction in a changed environment, has both short- and long-term components. It is important to understand the different rates at which populations respond to environmental changes. Trees are among the most genetically diverse of all organisms (Hamrick and Godt 1990) and this diversity within natural populations provides the foundation for population stability in variable environments (Gregorius 1996). This concept has been well demonstrated with respect to adaptation to potential pollutants (Pitelka 1988, Berrang et al. 1989, Scholtz et al. 1989, Bazazz et al. 1995, Kull et al. 1996, Cantin et al. 1997), to pest populations (Burdon and Thrall 2001), and to various other physiological stresses. High levels of genetic diversity within a larger, local population or gene pool of a given tree species (e.g., typical boreal or temperate biome populations) allows for a relatively rapid adaptive response to an environmental challenge. Differential survival through natural selection pressures may result in a narrowing of the gene pool to promote those genotypes best able to survive disturbances, such as toxic chemicals, pest infestations or other types of interspecific competition, climate change, or soil water and nutrient conditions. In this sense, these local populations may contain a subset of genotypes that are 'pre-adapted' (*sensu* Davis and Shaw 2001, Jump and Penuelas 2005) to environmental changes. Using experimental populations of yellow birch (*Betula alleghaniensis*), Bazazz et al. (1995) demonstrated the potential for populations to respond to varying levels of CO_2, and the genetic complexity and magnitude of genetic responses to population factors such as density and competitive interactions. Such experiments demonstrate the overall capacity for resilience of forest tree populations to anticipated increases in CO_2 or ozone (Berrang et al. 1989; e.g., in aspen [*Populus tremuloides*]) or combinations of these gases (Kull et al. 1996) based on extant levels of genetic diversity within populations at any given time. These kinds of experiments also indicate how difficult it is to predict the way in which species will respond to anthropogenically-caused changes (Bazazz et al. 1995), or to other environmental changes in the future (DeHayes et al. 2000).

Concerns have been expressed that predicted climate changes (IPCC 2007) may occur too quickly for species to adapt (Huntley 1991, Davis and Shaw 2001, Jump and Penuelas 2005), but genetically diverse species are capable of rapid evolution (Geber and Dawson 1993). Many species have adapted to rapid changes and have done so repeatedly over geological time through dispersal and genetic changes based on the extant genetic diversity within local or regional gene pools, suggesting long-term genetic-based resilience to change. There is considerable evidence for adaptation in the geological and fossil record (Bernabo and Webb 1977, Webb 1981, Davis 1983, Huntley and Birks 1983, and review by Geber and Dawson 1993). Such adaptation has been demonstrated by forest plants during or following past glacial and interglacial episodes, which were characterized by relatively rapid climate change (Huntley and Webb 1988).

Nevertheless, a common misunderstanding persists about the nature of genetic adaptation in species with long generation times. The general perception seems to be that, given the long-generation times of many long-lived tree species, trees are at a severe disadvantage in terms of a suitably rapid response to environmental challenges. However, trees are not entirely dependent on their generation time to demonstrate an adaptive or evolutionary response, but can respond reasonably rapidly based on the inherently high levels of genetic diversity that characterize most tree species. If evolution and adaptation in species with long generation times were dependent on generation time, there would be no trees left on Earth – with the possible exception of those that have generation times approaching those of their predators and parasites (e.g., willows, *Salix* spp.) - many of which have generation times of less than a year. Understanding this point is crucial to understanding how trees adapt and why maintaining natural levels of genetic diversity is so important.

Genetic changes to the gene pool based on the actions of natural selection on the extant genetic diversity of *in situ* gene pools can follow a relatively rapid population decline or collapse following a disturbance, such as a major pest infestation. This process can then be reinforced by a longer-term process, whereby gene frequencies change more slowly in the directions forced by natural selection over many generations of subsequent breeding and reproduction. Individuals surviving a disturbance interbreed and propagate, favouring the gene frequencies of the surviving individuals. Over time, these gene frequency changes are enhanced and refined to create a better-adapted population. However, species that have inherently low levels of natural genetic diversity may not be able to adapt to relatively sudden challenges. For example, red pine is a tree species native to eastern North America that shows extremely low levels of detectable genetic diversity (Mosseler et al. 1991, 1992, DeVerno and Mosseler 1997). Natural populations of this species are vulnerable to pest infestations and infections by fungal pathogen such as *Armillaria* spp. and *Sclerroderris lagerbergii*, which can eliminate entire populations (e.g., McLaughlin 2001).

Evergreen trees on a mountainside in Banff National Park, Alberta, Canada

Natural regeneration of lowland Amazonian rainforest 18 years after clearcutting. Regrowth primarily from soil seed bank and resprouting of harvested trees. Porto Trombetas, Brazil.

Diversity at the genetic level must also be complemented by diversity at the species level, particularly by species groups such as pollinators (e.g., insects, bats, birds) and seed-dispersal organisms (e.g., many birds and mammals) that may affect the long-term resilience of forest ecosystems. Without these associated species groups, tree species may be restricted in their ability to adapt to change through seed dispersal, pollination, and gene flow – important processes for maintaining genetic diversity and reproductive success within populations. For example, a certain amount of gene flow among populations is required to minimize the adverse effects of in-breeding and in-breeding depression on growth, reproduction, survival, and genetic diversity in small, isolated populations of species in highly fragmented landscapes. Small, isolated populations at the margins of the geographic range may also be of special importance to the resilience of forests under climate-change scenarios because such population islands often serve as well-adapted seed sources for population migration under environmental change (Cwynar and MacDonald 1987). It can be assumed that such populations at the geographic-range margins have experienced some physiological stresses while living at the limits of their eco-physiological tolerances. Such populations may have become adapted through natural selection and some degree of genetic isolation (Garcia-Ramos and Kirkpatrick 1997) and contain special adaptations that may enhance their value as special genetic resources for adaptation and resilience to change.

3. The relationships among biodiversity, productivity and function, and resilience and stability

We review published information on the relationship between biodiversity and productivity to provide an understanding of the mechanisms that may be important to function in forests systems. Through this review, we suggest below that there is a fundamental relationship among biodiversity, production, and resilience and stability in forests and that this relationship is important with respect to adaptive management in forests under climate change. Here we consider climate, weather conditions, soil parent material as extrinsic (exogenous) physical inputs to terrestrial ecosystems and the role of species as intrinsic (endogenous) to ecosystem functioning. There is considerable ongoing debate over the role that biodiversity plays in ecosystem function and stability owing to the highly complex nature of the relationships among species and the synergistic roles of extrinsic factors and intrinsic factors, including genetic factors, in ecosystems (see e.g., Waide et al. 1999, Kinzig et al. 2001, Loreau et al. 2002, for summary discussions). Nevertheless, in the absence of biodiversity there would be no ecosystems and no functioning. Further, there is evidence that complex forest ecosystems are more productive than less diverse ones (under the same conditions) (e.g., Phillips et al. 1994), and generally that forest systems comprised of few species are highly prone to various catastrophes including disease and invasion (Scherer-Lorenzen et al. 2005).

3.1 Theoretical background

The relationship between diversity and productivity is variable (Waide et al. 1999) and dependent on the scale considered (Chase and Leibold 2002). Much of the work done to understand the relationship between species diversity, ecosystem processes, and production has necessarily been done in highly controlled low-diversity systems at small scales, especially using grasses (e.g., Tilman and Downing 1994, Tilman et al. 1996, Hector et al. 1999, Hector 2002), or in other controlled systems (e.g., Naeem et al. 1995). Few studies have examined more connected systems with multiple trophic levels and complex production webs, such as forests, nor have they considered larger scales. While the work on simple trophic systems has, at best, limited applicability in forests, it does present theoretical predictions for what species do in ecosystems and so is briefly discussed here. In particular, two main competing hypotheses have been identified to predict the relationship between biodiversity and productivity in ecosystems: the niche complementarity hypothesis (Tilman et al. 1996, Tilman and Lehman 2001) and the sampling effect hypothesis (Aarssen 1997, Doak et al. 1998). Under either hypothesis, a certain level of saturation is expected where no more effective use of resources can be achieved regardless of increased species richness (Hooper et al. 2005).

These hypotheses are related to some earlier alternate constructs, including: the rivet hypothesis, where individual species are suggested to perform additive roles (Ehrlich and Ehrlich 1961); the keystone hypothesis, postulating that some species are substantially more important than others in controlling productivity, and which is closely related to the redundancy hypothesis, which suggests that most species live off excess energy in the system or play minor roles in production and so are largely insignificant in ecosystem function.

The niche complementarity (or niche differentiation) hypothesis (see above) predicts that as species are added to a system, the productivity in the system will increase until vacant niches are filled because of effective partitioning of resources. The coexistence of species then is assured through interspecific differentiation as a direct response to competition for resources. If species are able to avoid competition by occupying different niches, then production in the system will increase accordingly (e.g., Tilman and Lehman 2001, Tilman et al. 2002). Niche differentiation models also consider the concept of facilitation, where one or more species may enhance the capacity of another species to survive and reproduce (e.g., ectomycorrhizal fungi on tree roots or legumes in grasslands). However, few keystone functional roles among plants are known (e.g., C3 and C4 grasses, nitrogen fixers).

A competing model, the sampling (or selection) effect hypothesis, suggests that dominant competitors ("sampled" from the regional species pool) will play the greatest roles in ecosystem functioning and as diversity increases, functioning in the system will be controlled by these dominant species because of their greater likelihood of being present in a diverse system (e.g., Aarssen 1997, Huston 1997). This result is achieved because the best competitors will always control resources within a system. Niche differentiation models predict coexistence among species, while sampling effect models predict dominance by one or a few species, especially for systems in equilibrium. Various studies suggest support for one or the other of these models (e.g., Hooper and Vitousek 1997, Tilman at al. 2002, Hooper and Dukes 2004) or suggest that the capacity to conduct the experiments has been limited by almost intractable design problems or analysis constraints (e.g., Huston 1997, Allison 1999, Schmid et al. 2002).

These two competing hypotheses will be affected by scale of observation (Waide et al. 1999) and little information is available at large scales such as forest landscapes. Chase and Leibold (2002) working with production in pond systems found productivity declined with species richness at a local scale (unimodal) but was monotonically increasing at regional scales, but these patterns differ depending n the ecosystem type (e.g., Waide et al. 1999). Measurement of forest production will be similarly influenced by the scale of measurement. Mechanisms for different responses at small and large scales might include regional heterogeneity in environmental or edaphic conditions, different forest communities, or multiple stable states for the same forest system.

3.2 Evidence of a diversity-productivity relationship in forests

Testing the theories of the relationship between diversity, productivity, and resilience in forests is difficult owing to the inability to control either extrinsic or intrinsic variables within these complex ecosystems. Furthermore, niche partitioning is well-known in forests (e.g., Leigh et al. 2004, Pretzsch 2005), with many uncomplicated examples such as tap and diffuse rooting systems, shade tolerant and canopy species, and xeric and hydric species. Some confounding effects also affecting production in forests include successional stage, site differences, and history of management (Vila et al. 2005). Species mixtures change with successional stage in forests, from those rapidly-growing species favouring open canopy environments to those capable of reproducing and surviving in a more shaded canopy environment. Various plant species are adapted to

Forest fires in wet tropical forests can overcome the resilience of the ecosystem if they occur too frequently or over very large areas

site types that are defined by soils, topography, and moisture levels, but opportunistically may be found across a range of sites. Many forests, including most temperate forests, have undergone many direct anthropogenic-related changes and so an understanding of community structure must be in the context of the human history related to the stand. For example, long-term selection harvesting may have reduced relative abundances among tree species in a given stand, thereby altering the competitive conditions and stand production. Developing a clear understanding of the species-productivity relationship in forests must take these several factors into account, use a very broad sampling approach, and/or test the relationship experimentally to control the various factors.

Following natural or anthropogenic disturbances creating forest gaps, regeneration from soil seed banks play a critical role in recovery of biodiversity in tropical forests. Location – Porto Trombetas, Pará State, Brazil.

Several forest studies have found a positive relationship between diversity and production in stands, while fewer have not. Of the 21 studies considered in our review (excluding studies using herbicides, thinning, fertilization, and N-fixing facilitation to eliminate confounding effects), 76% suggested a positive effect of mixed species (i.e., number of species) on ecosystem production (table 1). In plantations, the effects of mixing species can be neutral owing to competition and so the results of such experiments can be directly related to the species mixtures that were selected. On the other hand, facilitation and additive effects on mean annual increment were seen in many studies (Kelty 2006, Piotto 2008), especially in studies where an nitrogen-fixing species was included (Forrester et al. 2006, Piotto 2008)

In Costa Rica, Ewel et al. (1991) experimentally developed forest communities on burned plots. Three treatments involved various successional communities, while a fourth limited production to a sequence of monocultures. They found that the multi-species plots developed much higher soil fertility over time than did monocultures, indicating superior production and nutrient retention in complex systems. Ewel et al. (1991) also noted much greater depletion of soil nutrients in short-lived monocultures than in stands using perennial plants.

Also in Costa Rica, tree species richness was correlated to increased production in afforestation experiments by Montagnini (2000), a result also reported by Erskine et al. (2006) for Australian tropical plantations of individual and mixed species. In one of the few published studies not to report a positive relationship between production and diversity, Finn et al. (2007) found that Australian tropical plantations that had been invaded by endemic species from nearby natural forests did not result in increased production, presumably because of inter-specific competition effects. Parrotta (1999) was able to show facilitation effects in mixed plantings of tree species in experimental tropical plantations, with mixed species plots producing almost double the biomass. Pretzsch (2005) and Jones et al. (2005) provided separate examples of complementarity between tree species in long-term, simple two species mixture experiments. Vila et al. (2005) found that overall production in Catalonian open canopy forests was superior for mixed species stands than for pure stands, although individual production within the dominant species was not higher, indicating an ecosystem rather than an individual response. Schulze et al. (1996) found no evidence that mixed species had a positive effect on production in European temperate stands and Enquist and Niklas (2001) reported no relationship between plant diversity and total biomass in their stands. Using experimental tropical tree plantations, Healy et al. (2008) used redundancy analysis to suggest that diversity explained 23-30% of the variance in productivity (environmental factors explained the rest). In boreal forests, jack pine (*Pinus banksiana*) was observed to have greater diameter when growing in mixedwood stands, as opposed to in pure stands on similar sites and at the same ages (Longpré et al. 1994), suggesting a level of complementarity. Wardle et al. (1997) found a relationship between increasing plant functional

Table 1: Summary of published studies in forests that tested the relationship between species richness and some measure of production (e.g., biomass increment, soil C, etc.).

Studies testing effects of herbicides, thinning, fertilization, and nitrogen-fixing plant facilitation were excluded. Observational refers to studies where data were gathered from existing forest stands and experimental refers to directed planting or removal experiments. See text for details of individual studies.

Effect of multiple species on stand production				
Author/year	**Forest type**	**Observational or Experimental**	**Positive**	**Neutral**
Prokopev 1976	Boreal	Expt	X	
Ewel et al. 1991	Tropical	Expt	X	
Longpré et al. 1994	Boreal	Obs	X	
Schultze et al. 1996	Temperate	Obs		X
Wardle et al. 1997	Temperate	Expt		X
Parrotta 1999	Tropical	Expt	X	
Enquist and Niklaus 2001	Temperate	Obs		X
Casparsen and Pacala 2001	Temperate	Obs	X	
Schroth et al. 2002	Tropical	Expt	X	
Petit and Montagnini 2004	Tropical	Expt	X	
Pretsch 2004	Temperate	Expt	X	
Jones et al. 2004	Temperate	Expt	X	
Vilà et al. 2004	Temperate	Obs	X	
Erskine et al. 2006	Tropical	Expt	X	
Bristow et al. 2006	Tropical	Expt	X	
Finn et al. 2007	Tropical	Expt	X	
Kirby and Potvin 2007	Tropical	Obs		X
Healy et al. 2008	Tropical	Expt	X	
Murphy et al. 2008	Tropical	Expt		X
Piotto 2008	Meta-analysis of 14 plantation studies	Expt	X	

diversity and forest production (including biomass accumulation) following varied fire frequency, on island systems in hemiboreal Sweden. Caspersen and Pacala (2001) found a positive relationship between carbon storage and high tree species diversity, compared to lower carbon storage in stands with low tree species diversity, across multiple types of forests. They concluded that forest managers should attempt to retain species diversity to increase production and especially manage for species that maximize functions of interest, such as carbon storage.

Some of the above studies are within-site types and some are across-site types. Across-site comparisons provide more variable results than do the within-site comparisons, as might be expected because larger scales include potentially confounding effects of habitat variability, range boundaries, and different climates. Depending on scale, these studies provide evidence that more diverse forests are generally more productive than forests with low species diversity. Further, many studies indicated that carbon sequestration, a frequently measured variable among the studies, is enhanced by the presence of multiple complex levels of functional groups in forests. This notion is further supported by several recent studies showing that complex old-growth forests provide high-value carbon sinks and may continue to do so for centuries in all forest biomes, unless disturbed (Phillips et al. 1998, Baker et al. 2004, Luyssaert et al. 2008, Lewis et al. 2009). In only one of these cases (table 1) was the direct additive or synergistic relationship between number of species (or functional species) and ecosystem productivity quantifiable, owing to the complexity of these systems. The experimental data (table 1) all come from two-or few-species plantations, somewhat similar to the evidence from highly controlled grassland systems. Nevertheless, it is doubtful that evidence of a biodiversity-productivity relationship in forests can be derived experimentally in natural forests through removal experiments, owing to the large number of uncontrollable variables, such as site differences and tree densities.

Mechanisms of complementarity effects observed in mixed species forest stands may be nutritional, as a function of improved soil condition (e.g., Ewel et al. 1991, Brantberg et al. 2000, Hattenschwiler 2005), or related to improved partitioning of resources through different rooting patterns and depths (Schmid and Kazda 2001). While Scherer-Lorenzen et al. (2005) suggested that diversity matters less than expected with respect to its contribution to biogeochemical cycles, Hooper et al. (2005) concluded that certain combinations of species are indeed superior in terms of soil nutrient retention and production. Clearly more evidence is required to reduce the uncertainty associated with how complementarity operates in forests. Arguably these various results may support either the niche differentiation hypothesis or the sampling effect hypothesis and the evidence supporting one over the other is sparse. However, the common theme from most studies is that diverse forests are more productive than low-richness forests and that functional diversity within systems matters considerably. The evidence broadly supports the concept that diverse forests provide more goods and services than do forests with low species richness, especially planted forest monocultures (e.g., Pearce and Moran 1994, Srivasteva and Velland 2005, Diaz et al. 2005, Dobson et al. 2006).

Many authors have advocated, and indeed demonstrated, that it is not diversity *per se* that influences production and resource dynamics but rather it is the number of functional species (or functional diversity) that is important (e.g., Phillips and Gentry 1994). While studies have indicated a link between plant species richness and ecosystem productivity (Phillips and Gentry 1994, Symstad et al. 1998, Wardle et al. 1999, Schwartz et al. 2000, Schmid et al. 2002, Tilman et al. 2002, Hector 2002), species richness and functional richness are not necessarily correlated (Diaz and Cabido 2001, Hooper et al. 2005). Certainly, some species play much greater functional roles in systems than do others (Walker 1994, Schlapfer and Schmid 1999, Chapin et al. 2000, Diaz and Cabido 2001), but species-specific functional roles may be idiosyncratic, with different key species among similar ecosystems (Phillips et al. 1994, Hooper et al. 2005). Nevertheless, most data and almost all examples in the summary by Diaz and Cabido (2001) come from manipulated controlled systems, especially relatively simple grasslands. The concept of functional diversity is compatible with either the niche complementarity or sampling effect hypotheses. Different functional types could compete for the same resource or be sufficiently dissimilar to occupy different niches within the same system.

3.2.1 Diversity-productivity relationships and forest resilience

Stone et al. (1996) concluded that more productive ecosystems are more resilient than less productive ones, and hence recover more rapidly from disturbances. Functional diversity in forests is related to production in the ecosystem (Chapin et al. 1997, Diaz and Cabido 2003), and many species in forests appear to be redundant in terms of total production (Pretzche 2005). Redundancy, which is also referred to as the insurance hypothesis (Naeem 1998, Yachi and Loreau 1999), appears to be a common and important trait in most forest systems, contributing to their resilience following various disturbances, protecting against effects of species loss, or responding to environmental change. For example, several tree species have been lost, or substantially reduced in abundance, in temperate forest ecosystems, with little or no loss of productivity in that broad forest system (e.g., Pretzsch 2005), suggesting compensation by other species. Therefore, the redundancy provided resilience in terms of maintaining productivity in the face of species loss. Redundancy can also confer system resilience and/or resistance in response to the impact of disease and pests (see below: Jactel et al. 2005, Pautasso et al. 2005). The resilience that redundancy provides in maintaining system productivity in response to species loss, disease and pests, may not necessarily compensate for other ecosystem goods and services. For example, loss of a particular species that had specific cultural or economic importance would mean a less valuable forest (e.g., Hooper et al. 2005). Furthermore, there may not necessarily be redundancy for certain functional species, such as nitrogen-fixers, and their loss would then have consequences for ecosystem processes (Brown et al. 2001).

While the evidence above supports the notion that mixed-species forest ecosystems are more resilient than monotypic stands, some natural monotypic, or nearly monotypic, forests do occur. For example, in the boreal biome, natural stands of jack pine (*Pinus banksiana*), Scots pine (*P. sylvestris*), lodgepole pine (*P. contorta*), and Dahurian larch (*Larix gmelinii*) are commonly dominated by single species. These stands self-replace usually following fire over large landscapes, with no change in production over time. Similarly, in wet boreal systems where fire is absent, monotypic stands of a single species of fir (*Abies* spp.) occur and generally self-replace following insect-caused mortality. Generally, these monodominant boreal forest ecosystems tend to be relatively short-lived and are prone to fire or insect infestation, and so while not very resistant (relative to other forest types), they are highly resilient ecosystems despite their lack of functional types and redundancy. The high degree of seasonality in boreal forests may contribute to the resilience among boreal monotypic stands, compared to in temperate and tropical biomes (Leigh et al. 2004), where forest species

Cloud of smoke rising from the Angora forest fire in south Lake Tahoe, California

richness is considerably higher (greater than an order of magnitude) than in the boreal biome. Only a few types of monodominant canopy stands are also found in temperate forest types, such as pines and eucalypts, or in tropical forests (e.g, *Gilbertiodendron* sp.).

3.3 Diversity and stability

For a system to have resilience, the state of interest (e.g., the mature forest type) must be stable over a certain time period. Considerable research has explored the concept that species diversity enhances stability, defined as variation within defined bounds (time and space) or dynamic equilibrium, in ecosystem processes in response to environmental change (e.g., Loreau 2000, Hughes et al. 2002). The relationship between diversity and stability is complex and may resist generalization. Confusion over this issue stems from debate over whether stability refers to individual populations within ecosystems or the stability of ecosystems and their processes. For example, relatively recent work has suggested that as diversity increases, stability within individual population declines (e.g., Moffat 1996, Tilman and Lehman 2001).

Ecosystems respond to environmental change through functional compensation, or the dynamic capacity of systems to maintain production, even though levels of output among individual species may change (e.g., Loreau 2000). This concept is closely linked to that of functional redundancy in diverse ecosystems (Naeem 1998, Yachi and Loreau 1999). Dynamic responses in diverse ecosystems that maintain stability to environmental change over time may occur at genetic, species, or population levels. There appears to be low variability among ecosystem properties in response to change in diverse systems compared to those systems with low diversity, where higher variance is observed (Hooper et al. 1995, Ives et al. 1999, Lehman and Tilman 2000, Hughes et al. 2002).

Loreau et al. (2002) noted the importance of regional species richness that enables migration into systems as a means to enhance ecosystem adaptability to change over time. Immigration could enhance both genotypic and phenotypic responses to environmental change enabling resilience in the system through compensation. Overall, the evidence is consistent with the concept that diversity enhances the stability of ecosystem processes (Hooper et al. 2005) and the flow of goods and services.

Ecosystems may exist in more than one stable state (Holling 1973), a fact supported by some experimental evidence largely from closely controlled experiments (Schroder et al. 2005). Drever et al. (2006) provided several examples of alternate stable states among the forest biomes. It seems intuitive that forest ecosystems have multiple stable states that depend on the kinds of disturbances that forests regularly undergo (Marks and Bormann 1972, Mayer and Rietkerk 2004, Schroder et al. 2005) and that many or all of these alternative states may deliver similar goods and services. For example, regeneration trajectories following wildfire differ in many forest types depending on previous disturbances, intensity of the fire, time since last fire, whether or not a fire occurs in a year with abundant tree seed, level of endemic insect infestation, age of the trees, and many other factors (Payette 1992, Little et al. 1994, Hobbs 2003, Baeza et al. 2007). While the engineering resilience may be low, in that the identical or similar species mix may not result following recovery from the disturbance, the ecological resilience is high because a forest ecosystem is restored. Lack of convergence to pre-disturbance floristic composition does not necessarily imply a lack of resilience with respect to other forest system characteristics. Rather it implies that successional patterns differ depending on circumstances but that the system is ecologically resilient, even though the dominant canopy species composition has changed along with certain ecological processes.

The capacity of an ecosystem to stay within stable bounds is related to slow processes that can move the system to another state, sometimes a state that is undesirable, from a human perspective (Scheffer and Carpenter 2003). Folke et al. (2004) suggested that biodiversity is one of those slow-changing variables that have consequences for ecosystem state, acting primarily through species with strong functional roles. The capacity of systems to maintain stability in the face of environmental change is also related to the capacity of individuals within species to meet challenges and to the possibility that other species may increase their functionality under changed regimes (biodiversity as insurance). A major factor impeding the recovery and stability of forest ecosystems is degradation and loss of functional species and reduced redundancy caused by land use practices, including unsustainable harvesting. Degradation results in the ecosystem moving to an undesirable state that may have its own high resilience but be undesirable in terms of the reduced goods and services that it provides.

3.3.1 Diversity and invasion of ecosystems

Another measure of stability, and ultimately of resilience in the case of forest pests, is the capacity of an ecosystem to resist invasion by non-local species (i.e., community invasibility). Various factors, both extrinsic and intrinsic to an ecosystem, such as availability of niches, system degradation, and fragmentation, may affect the capacity of alien species to invade. Another factor which may promote invasion is the lack of enemies of the invading species in the new range (Williamson 1996). Most experimental evidence of a diversity-stability relationship in ecosystems again comes from highly controlled experiments using grasses, and many studies are the same as those assessing the diversity-production relationship (e.g., Tilman 1996, Levine 2000, Symstad 2000, Kennedy et al. 2002). Loreau et al. (2002) reviewed numerous studies of the relationship between resistance, diversity, and invasibility, and found that most supported a negative relationship, with the majority again in grasslands. Many of these studies have been criticized based on uncontrolled effects (e.g., Huston 1997, and see Loreau et al. 2002, Vila et al. 2005, Fridley et al. 2007 for summaries of critiques). Liao et al. (2008) conducted a meta-analysis of the effects of plant invasion into various ecosystems, including many forest systems. They found profound effects of invasion on the carbon and nitrogen-related processes in all systems, usually positive in terms of carbon sequestration rates with both positive and negative effects for nitrogen. They did not provide information about the levels of past disturbance in the systems, but for these results to have occurred, the invading species apparently occupied vacant niches, possibly made available from past disturbances. Thus evidence relating resistance to invasion success is based on the capacity of species in more diverse systems to better use and/or partition resources, compared to simple systems, where vacant niches are likely available (e.g., Elton 1958, Post and Pimm 1983, Levine et al. 2002, Hooper et al. 2005).

Invasion by non-native (alien) plant species into forests is occurring globally. Numerous examples of introduced trees invading forest ecosystems exist (Richardson 1998), suggesting that most forests are not especially resistant to invasion and that many invading species are superior competitors to many key endemic species and/or that forest plant communities are not saturated. However, Simberloff et al. (2002) suggested that in undisturbed tropical forests, at least, invasions are rare. Lack of resistance to invasion, especially in temperate forests, may be a long-term result of a reduced number of endemic species following ice ages coupled with loss of species owing to invasive diseases anthropogenic effects, which have resulted in vacant niches (Simberloff et al. 2002, Petit et al. 2004). Some examples, among many, of successful invasions include: Norway maple (*Acer platanoides*) into eastern US deciduous forests (Webb et al. 2000) and into western US riparian zones (Reinhart et al. 2005), Monterrey pine (*Pinus radiata*) invasion into Australian eucalyptus forests (Williams and Wardle 2007), and wattles (*Acacia* spp.) invading into various South Africa forest and *fynbos* ecosystem types (Richardson and van Wilgen 2004). It should be noted that in all cited cases, the forests had been disturbed by unsustainable forest management. Sakai et al. (2001) suggested that fire and forest management reduce the capacity of forests to resist invasion, acting through fragmentation, degraded habitats, and altered moisture conditions, for example.

Generally, there have been equivocal results when the number of native plants in a system is compared to the number of introduced plant species in a system (e.g., Levine 2000, Macdonald et al. 1989, Keeley et al. 2003). The issue of invasion, however, is complicated by the level of disturbance in a given ecosystem, the extent of the undisturbed area owing to edge effects, and the scale of measurement, for example, and, as a result, deriving a general hypothesis for forests is confounded. Evidence clearly indicates that disturbed systems are more prone to invasion than undisturbed systems and that diverse tropical ecosystems are not prone to invasion (e.g., Lonsdale 1999, Fridley et al. 2007).

Black wattle has become an invasive species, altering riparian forest communities in many areas, such as South Africa

The scale at which invasion is measured appears to complicate the pattern resulting in an invasion paradox. At small scales (i.e., m^2), there is a negative relationship between native diversity and exotics, while at large scale (i.e., >1 km^2) there is a positive relationship (e.g., Fridley et al. 2007). These latter authors concluded that high diversity areas also had high exotics but that a decrease in native species resulted in a consequent increase in exotics, across a wide range of ecosystems. However, at very large scales (i.e., 100s of km^2), intact diverse tropical forests support very few exotics (Sax 2001).

3.3.2 Diversity and insect pests

One type of disturbance that is universal in forests is insect herbivory. There may be an inverse relationship between insect infestation and stand diversity (Elton 1958, McCann 2000). Reviews by Gibson and Jones (1977), Barthod (1994), and Jactel et al. (2005) supported the hypothesis that monotypic stands, especially plantations, are more prone to herbivore infestations than are diverse forests. On the other hand, Powers (1999) and Gadgil and Bain (1999) noted than many non-native plantation monocultures had low incidences of pests or diseases, which they attributed to intensive management and the lack of native insect pests to attack the trees.

Natural monotypic stands are fairly common in boreal forests, suggesting that these forests, at least, are resilient to insect attack over the long term, although they may have low resistance in the short term (e.g., Porter et al. 2004). Certainly the relationship between natural old-age boreal forests, insect infestation, and forest fire has been discussed at length (Bergeron and Leduc 1998, McCullough et al. 1998). Jactel et al. (2005) used a rigorous meta-analysis procedure to indicate that the effect of invasion and herbivory was significantly higher for planted monocultures as opposed to the effect observed from mixed-species stands. Their results were positive regardless of forest biome but greatest in boreal forests. There are several likely mechanisms to explain this observation including: greater concentration of uniform food resources in monotypic stands (Karieva 1983); concealment of particular host plant species (Watt 1992) or emission of multiple chemicals (Zhang et al. 2001) in mixed stands; phenological mismatch of insect life history and bud-burst in mixed stands (Jactel et al. 2005); increased predators and parasitoids in diverse systems (Root 1973); or possible absence of alternative hosts in monotypic stands (Jactel et al. 2005). Diverse forest landscapes (multiple types of ecosystems across a landscape) are also expected to reduce forest pest damage based on metapopulation dynamics (Pimm 1991). Similarly, Pautasso et al. (2005) suggested that the evidence broadly supports the concept that diversity of tree species in a stand reduces the susceptibility of the stand to disease. Trembling aspen (*Populus tremuloides*) has the largest range of any North American tree species, but its monotypic natural and clonal reproductive strategy make monotypic ecosystems of this tree less resilient than mixed tree species ecosystems. Large areas of aspen forest may all be connected via their integrated root system (Mitten and Grant 1996). Therefore, any root born insect or disease (e.g. *Armillaria*) could destroy an entire stand (i.e., lowered resistance), with stand regeneration hampered by the continued presence of the disease, resulting in lowered forest resilience (e.g., Brandt et al. 2003). Clearly, at stand and landscape scales, diversity can reduce the effects of damage by pests and diseases to forests, suggesting stability and resistance are a characteristic of diverse forests but lacking in planted monotypic stands.

3.3.3 Diversity and stability of processes in forests

Forests are dynamic mixtures of ecosystems over time and across landscapes. Stability of ecosystem processes in the face of disturbances may be positively related to diversity in these ecosystems (Pimm 1984, McCann 2000). Good examples come from removal experiments in soil decomposer communities that resulted in no net effects on rates of decomposition, indicating a high level of redundancy in the system (Ingham et al. 1985, Liiri et al. 2002). This is related to the disturbance or 'passengers and drivers' hypotheses, whereby certain species may assume greater functional roles under different environmental conditions (Walker 1995, Loreau et al. 2002). Brown and Ewel (1987) found support for the insurance hypothesis in tropical forest plantations, but a study by Berish and Ewel (1988) did not support a diversity effect, as measured by the production of fine roots in successional tropical forests. Hooper et al. (2005) suggested that the majority of evidence supports the notion that a range of species, which respond in different ways to changes, confer stability to ecosystem processes. Nevertheless, there is only limited evidence on the relationship between diversity and stability of production in forests.

3.4 Summary of diversity-resilience processes

In reviewing the various concepts about, and relationships between forest biodiversity and related ecosystem processes from the case-studies, we have identified a summary set of scale-related biodiversity attributes and processes that confer resilience on forests (table 2). Some of these attributes relate to theories that account for species richness, others to properties of biodiversity that emerge at particular scales. Others are natural attributes of populations or community organization and can constitute feedbacks between the biota and physical environment.

4. Resilience, biodiversity, and forest carbon dynamics

The ecosystem service of most current interest to the international community is the role of forests in carbon sequestration and storage. This section considers the questions: 1.) how important to regulating atmospheric greenhouse gases is the carbon sequestered and stored by terrestrial forest ecosystems; and 2.) in what ways does biodiversity confer resilience on this ecosystem process? To answer these questions we first provide a brief overview of the role of forests in the global carbon cycle.

4.1 Forests and the global carbon cycle

The main reservoirs of carbon are fossil fuel reserves, the atmosphere, oceans, ocean sediment, and terrestrial ecosystems. The biospheric flux and storage in terrestrial ecosystems and oceans is a highly significant component of the carbon cycle. Terrestrial ecosystems currently store about 2,400 Gt C and have an annual gross carbon exchange with the atmosphere of some 200 Gt C (IPCC 2002). About 50% of terrestrial carbon stocks reside in forest ecosystems (biomass living and dead, both above and below ground; and soil carbon) (FAO 2000, IPCC 2002), with much of the remainder in peatlands and wetlands. About half the world's forests have

Table 2: Summary of biodiversity attributes and related processes that confer resilience on a forest ecosystem

a) see text for description and examples of types; b) the scale at which the attribute or process operates, where stand, landscape, regional scales are comparable to alpha, beta, gamma diversity, respectively; c) the potential impact of climate change on the effectiveness of the characteristics and processes to confer resilience. Note that whether the impact is positive or negative for resilience will depend on the direction and magnitude of change in regional climatic conditions, particular in terms of rainfall (annual total, seasonality) and evaporation.

a) Biodiversity attribute or process	b) Spatial scale	c) Potential impact of climate change
Niche selection or differentiation	Stand	• Changes conditions shift outside driver species optimal conditions, making passenger species more competitive • Changed conditions produce new niches
Functional complementarity	Stand	• Loss of historic synergies and development of new ones with changing climatic stress
Functional diversity	Stand	• Loss of historic diversity and development of new ones with changing climatic stress, some 'passengers' become 'drivers'
Adaptive selection	Stand	• Changed environmental stresses could be too rapid for natural adaptive selection to occur
Phenotypic plasticity	Stand	• Changed conditions induce structural changes in dominant canopy species
Microevolution	Stand/ landscape	• Driver species evolve new adaptive traits that enable them to remain competitive in face of changed conditions
Microhabitat buffering	Stand/ landscape	• Changes in canopy density from new climatic conditions alters environmental conditions for ground-dwelling fauna habitats
Source habitats	Landscape/ Regional	• Changed climate may disrupt viability of historic source habitats or make them more productive
Refugia habitats	Landscape/ Regional	• Under new climatic conditions, previously common habitat becomes reduced to a network of locations where topography provides microhabitat buffering, and populations can persist
Regional species pool	Regional	• Migration from source habitats may not be able to keep pace with rapidly changing climate
Synergistic interactions	Stand/ landscape/	• Unknown interaction of stress on ecosystem resilience are likely but difficult to predict

been converted to agriculture and other land uses (Ravindranath et al. 2008); as have substantial areas of other carbon dense ecosystem types. Therefore, given this conversion and emissions associated with degradation, the current terrestrial stock of ~2,400 Gt is possibly about 40% below the natural reservoir when at equilibrium with current climate.

Oxygenic or photosynthetically-based ecosystems have persisted on Earth for at least 2.8 billion years, and forests will continue to uptake and store carbon so long as there is adequate water and solar radiation for photosynthesis; even though the genetic and taxonomic composition of forest ecosystems changes over time (Des Marais 2000). In the past, increase in the size of the terrestrial buffer has occurred naturally as a negative feedback response to increasing CO_2 levels and associated global warming and wetting (there is ~5% increase in global rainfall for every 10K degree increase temperature) (Zhang et al. 2007).

Humans are forcing the global carbon cycle into disequilibrium by increasing the atmospheric pool of greenhouse gases at a faster rate than it can be reduced by removal of CO_2 through natural processes. About 70% of the additional CO_2 in the atmosphere is the result of burning fossil fuel while 30% is from land conversion. Currently, emissions from deforestation are estimated to contribute ~17% of annual anthropogenic emissions (IPCC 2007).

The lifetime of the airborne fraction of a CO_2 pulse is surprisingly long; about 300 years for 75%, with the remaining 25% continuing to interact with the climate system for thousands of years (Archer et al. 2009). The exchange of carbon between the atmosphere and both terrestrial ecosystems and the ocean provides a vital buffering capacity that reduces atmospheric CO_2 concentrations. The residency time of carbon in long-lived trees and non-labile forms of soil carbon (1×10^2 -10^4; e.g. Roxburgh et al. 2006a, 2006b) is sufficiently long to enable forests to have a significant regulatory influence on the global carbon cycle. Furthermore, the less carbon there is stored in forests, the more there is circulating through the atmospheric-ocean exchanges and the sooner the ocean's buffering capacity is exceeded.

The significance of the forest carbon reservoir is such that protecting the current stock of carbon in forests and other natural ecosystems is necessary, along with deep cuts in fossil fuel emissions, if total global anthropogenic emissions are to be reduced to a level that avoids dangerous climate change (Cramer et al. 2001, Lewis 2006). Given the significance of the forest carbon stock, the increasing disruptions to it from human land-use activities, and the prospects for climate change impacts, there is special interest in the role that biodiversity has in conferring resilience on forest-carbon dynamics and on the stability of forest carbon stocks.

4.2 Biodiversity and resilience of forest-carbon dynamics

At the global scale, the role of biodiversity in the resilience of forest-carbon dynamics is evidenced by the specialized species that have evolved and characterize the distinctive forest ecosystems found in the major climatic and forest domains – tropical, temperate, and boreal (Figure 1). Over time, evolution results in new plant traits, which through the filter of natural selection, and aided by ecological processes such as dispersal, result in forests comprising species that function optimally under the climatic conditions and disturbance regimes prevalent in each domain.

Forest-carbon dynamics (the rate of fluxes and the stock resulting from net carbon exchanges) are driven by the climatic inputs which govern the rates of photosynthesis and respiration/decay. Rates of photosynthesis scale with increasing water availability, so long as thermal and radiation regimes are sufficient to support plant growth. Holding wetness constant results in respiration-decomposition rates scaling with temperature; generally, the rate of biochemical processes doubles with every degree Celsius. Differences in the chemical and physical characteristics of substrates also influence growth rates due to locally-scaled variations in sub-surface water availability and soil parent material mineral nutrient status (Law et al. 2002, Chanbers et al. 2000).

At the level of biome recognized by the IPCC, major differences occur in forest carbon dynamics (Table 3). Tropical forests have the least dead and soil biomass carbon because of higher respiration and turn-over rates associated with increasing temperature, while boreal have the converse (note that the Table 3 default biome values represent spatial averages). Particular forest ecosystems can store significantly more carbon in both living and dead biomass as the result of local conditions, and carbon stocks can be low due to the impacts of land-use history (Keith et al. 2009).

Tropical forests have higher levels of biodiversity than temperate and boreal forests. Various hypotheses have been proposed to explain this diversity, including the metabolic theory of ecology (Brown et al. 2004), neutral theory, Hubbell (2005), and landscape heterogeneity (Ruokolainen et al. 2005); all of which probably contribute in some way to the overall understanding. Stand-level (alpha diversity) richness of tree species is between 100-300 in tropical forests, with regional (gamma) species richness of 4,000+ (Ruokolainen et al. 2005). Geographic variation in tropical forest biodiversity has been shown to be correlated with climatic, substrate and topographic gradients, indicating species distributions to some extent reflect environmental optima (Condit et al. 2005, Mackey 1994, Schneider and Williams 2005). Such high levels of species richness at all spatial scales means that many of the biodiversity-related processes detailed in table 2 operate in a powerful way in tropical forests, especially niche selection, functional complementarity, and functional diversity.

Micro-habitat buffering plays a critical role in all forests but perhaps reaches its strongest expression in tropical forests (Kennedy 1997, Malhi et al. 2009). Primary tropical forests create a microclimate that virtually eliminates the probability of fire, whereas secondary growth forests in the eastern Amazon area were found to burn after 8 to 10 rainless days (Uhl and Kauffman 1990). The synergistic effects of biodiversity on primary productivity are also most evident in primary tropical forests with respect to nutrient cycling. Many tropical forests naturally form on nutrient-poor substrates. However, these ecosystems have developed through natural selection such that they can harvest from rainwater the nutrients lacking in the soils. Furthermore,

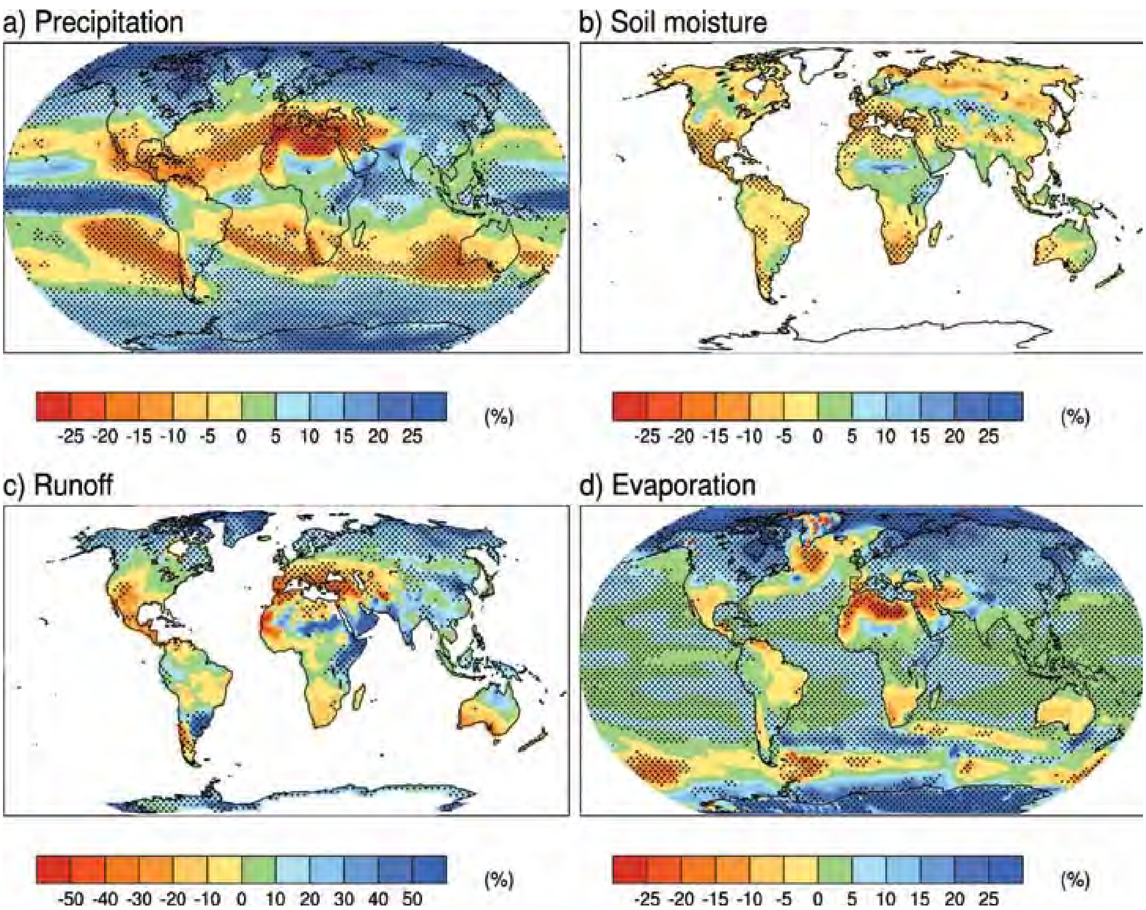

Figure 1. Fifteen-model mean changes in (a) precipitation (%), (b) soil moisture content (%), (c) runoff (%), and (d) evaporation (%). To indicate consistency of sign of change, regions are stippled where at least 80% of models agree on the sign of the mean change. Changes are annual means for the scenario SRES A1B for the period 2080–2099 relative to 1980–1999. Soil moisture and runoff changes are shown at land points with valid data from at least ten models. Source: IPCC 2007, WGI Figure 10.12.

through retention and recycling they build up the stock of nutrients needed to support the high levels of plant growth enabled by moist tropical climates. Plants have special adaptations that serve to conserve nutrients and a myriad of other fungal, bacterial and animal species aid in their efficient and rapid recycling (Golley 1983). Overall, biodiversity-related processes serve to increase the productivity and resilience of carbon dynamics in tropical forests.

The role of biodiversity in conferring resilience to forest-carbon dynamics varies between climatic domains, and climate change will alter forest-carbon dynamics with respect to rates of both photosynthesis

Table 3: Default biomass carbon values for major forest biomes, exclusive of soil carbon.

Source: adapted from Keith et al. (in press, 2009) and compiled from IPCC (2006, 2003).

	Climate region	**Aboveground living biomass carbon (tC ha^{-1}) biome default values**	**Root+dead biomass carbon (tC ha^{-1}) biome default values**	**Total living+dead biomass carbon (tC ha^{-1}) biome default values**
Tropical	Tropical wet	146	67	213
	Tropical moist	112	30	142
	Tropical dry	73	32	105
	Tropical montane	71	60	112
Sub-tropical	Warm temperate moist	108	63	171
	Warm temperate dry	75	65	140
	Warm temperate montane	69	63	132
Temperate	Cool temperate moist	155	78	233
	Cool temperate dry	59	62	121
	Cool temperate montane	61	63	124
Boreal	Boreal moist	24	75	99
	Boreal dry	8	52	60
	Boreal montane	21	55	76

and respiration-decay, and thus carbon stocks. However, whether total ecosystem carbon increases or decreases, or whether there are changes in the size of living biomass, dead biomass and soil carbon, will depend on (1) the magnitude of increase in temperature and (2) the direction and magnitude of change in climatic wetness (i.e., rainfall minus evaporation). While regional trends in temperature can be projected with reasonable reliability, there is greater uncertainty around wetness. Projected regional changes in climatic wetness are highly variable and for many regions models differ in the direction of change (IPCC 2007, Lim and Roderick 2009). However, models suggest significant regional-scaled impacts are likely (Malhi et al. 2009).

In summary, within a given biome, diverse forests are more biologically productive and provide larger and more reliable carbon stocks, especially in old-age stable forest systems (see table 1 and associated text above). Hence, protecting and restoring biodiversity serves to maintain resilience in forests, in time and space, and their ongoing capacity to reliably sequester and store carbon. Carbon sequestration is an ecosystem service that provides a vital contribution to climate change mitigation and this service can be enhanced by maintaining ecosystem resilience in space and time.

5. Case-studies of forest resilience and comparisons under climate change by forest biome

Forests are all variously driven by disturbances, whether the disturbance is in the form of minor blowdown events at a scale of <1 ha or landscape-altering wildfires affecting hundreds of thousands of hectares. Species that occur in these systems must necessarily be adapted to such changes because they recur over time and space and individual species adaptations to disturbance types are legion. Some forest ecosystems that have been disturbed by humans may exhibit engineering resilience, or equilibrium dynamics, to the disturbances under many conditions in all forest biomes (Attiwill 1994, Drever et al. 2006, Phillips et al. 2006, Norden et al. 2009). However, any ecosystem may change states when disturbed by a novel and/or severe disturbance, under altered interval time between disturbances, or with multiple simultaneous disturbances. Climate change may present such a serious challenge to the resilience of forest ecosystems globally.

Concentrations of atmospheric CO_2 have been rising for >150 years (IPCC 2007) largely as a result of fossil fuel burning (IPCC 2007). In addition to reducing anthropogenic CO_2 emissions, land managers are assessing the potential to increase forest carbon sequestration and storage as a mitigation strategy. In theory, improvements in ecosystem management should allow forests to sequester more CO2 as the forest growth rate improves, and thus help to mitigate anthropogenic CO_2 emissions.

Biological processes accelerate as air temperature increases. Increases in tree respiration and metabolism can shorten leaf retention time as temperature increases. Litter decomposition, soil nitrogen mineralization, and soil nitrification also increase with increasing temperature (Mellio et al. 1982), so climate change could significantly affect all of the biological functions of forests. Increased air temperature is projected to increase fire risk and return interval (Dale et al. 2001). Episodic drought will favour more drought tolerant species over more water demanding ones (Dale et al. 2001). Even if a forest remains intact (albeit with possible changes in the mix of dominant species), many functional aspects of the forest and its goods and services are likely to change. As the spatial scale increases, the potential for climate change alterations in ecosystem structure and function increases. Therefore, changes in water use and yield, and carbon storage in some sites, stands or even watersheds may be highly resilient to climate change, while bio/ecoregionally these processes will almost assuredly be less resilient.

Below we consider a set of case-studies that examine the resilience of a sample of the world's forests. We have selected the case-studies by major forest biome and assess resilience to current climate and the normal disturbances in the system, and follow this for each by assessing the changes that are predicted to occur as a result of climate change. These studies, in one way or another, reflect the amount of change and the capacity of the ecosystem biodiversity to maintain the system in the face of predicted effects of climate change.

5.1 Boreal forest biome

The circumpolar boreal biome occurs across North America, Europe and Asia and has 33% of the Earth's forested area. Boreal forests are characterized by a small number of common tree species, any of which may dominate over a vast area (Mooney et al. 1996). Annual temperature ranges from -5 to 5ºC with annual precipitation ranging from 300-1500 mm. The mean maximum of the warmest month is 10°C. Forests in the boreal biome are relatively young, assembling after the quaternary ice ages, and so may be <7000 years old (Liu 1990). Boreal forests are primarily driven by disturbance at landscape scales where, depending on the moisture conditions, fire interval ranges from 50-500+ years (Johnson 1992, Li 2000) and several major insect pests are chronic to regularly epidemic (Drever et al. 2006, Soja et al. 2007). As a result, boreal forests are highly ecologically resilient under current conditions because the species in these systems are adapted to recover following regular disturbances (niche selection, table 2). In North America, between 0.5 and 2% of the overall boreal landscape burns annually in wildfires of various sizes and intensities (Johnson 1992).

5.1.1 Climate change and boreal forest resilience

The boreal forest biome is predicted to undergo the greatest increase in temperature under climate change scenarios (IPCC 2007). Using global climate change scenarios 'growth' (>+4-5°C) and 'stable' (+2-3°C), Fischlin et al. (2009) and Sitch et al. (2003), reported predicted broad gains northward for boreal forest distribution, although with conversion of boreal forests to temperate forests and grasslands at southern and central areas of Canada and Russia. Soja et al. (2007) summarized published predicted changes for the boreal forest as: increased fire, increased infestation, northward expansion, and altered stand composition and structure. To that list we add reduced old-growth forest and conversion to grasslands and steppe of southern-central dry forests (Thompson et al. 1998, Price and Scott 2006). Warming climate has been implicated as a cause for current extensive outbreaks of mountain pine beetle (*Dendroctonus ponderosae*) in western Canada and the USA (Taylor et al. 2006). Productivity is expected to rise, but net carbon losses are likely to occur before the end of the century, owing to increased disturbances and higher rate of respiration (Kurz et al. 2008). However, significant stocks of biomass and soil carbon will remain. The net exchange and resultant standing stock will depend on, among other things, changes in fire regimes and forest management activities (Chen et al. 2008). Some areas of the boreal forest are predicted to become wetter and others drier, with consequently more or less fire (Johnson 1992, Bergeron and Flannigan 1995, Kellomaki et al. 2008). Generally fire frequency has been predicted to increase in the boreal biome (Flannigan et al. 1998) and evidence has accumulated confirming this prediction in

Lodgepole pine (*Pinus contorta*)killed by the mountain pine beetle (in red) in British Columbia, Canada

North America and Russia (Gillette et al. 2004, Soja et al. 2007). Our first case-study on lodgepole pine (*Pinus contorta*) reflects that prediction (table 4).

5.1.2 Case-study: western North American lodgepole pine

Lodgepole pine forests are a self-replacing, fire-driven ecosystems (Brown 1975) and climate change is generally predicted to reduce the fire interval over much of their distribution (Flannigan et al. 2005). However, ecosystem models suggest that stands may remain as carbon sinks even under increased fire regimes, in part because of the increase in production in response to temperature, but also depending on the model selected and the climate change regime that is modelled (Kashian et al. 2006, Smithwick et al. 2009). Insect infestation, notably mountain pine beetle (*Dendroctonus ponderosae*) can significantly alter the dynamic influence of fire, to the point of being the dominant factor responsible for stand renewal over huge landscapes (Logan and Powell 2001), and the combination of fires and insect infestation may lead to new forest states (Shore et al. 2006). If the insect-killed stands do not burn, then a large amount of carbon would enter the detrital pool. In lodgepole pine forests, the impact of climate change on carbon stocks may be marginal depending on infestation levels and this forest ecosystem may be resilient during at least the next 50-100 years.

5.1.3 Case study: North American boreal mixedwoods

A second boreal case-study is from a moister ecosystem where fire has an influence but the fire regime is much more protracted, resulting in broad expanses of mixed species (hardwood and softwood) forests (table 5). Here, the relatively large number

Table 4. A case study of expected forest resilience in boreal lodgepole pine (*Pinus contorta*) forests of western North America under current climate (A) and expected under climate change (B). Numbers refer to time (yrs) to recover from disturbance (i.e., resilience). A zero suggests that the forest will only recover to a new state and/or not recover the attribute in question.

Biome: Boreal
Ecosystem: Boreal lodgepole pine forest ecosystem

A. Current Climate
Natural disturbance regimes:
(a) Fire - stand replacing fires <100 years, 200 -100,000 ha
(b) Epidemic insect infestations.
Resilience to natural disturbance or sustainable forest management:

Resilient at ≤ 50 yrs, ≤100 yrs, >100 yrs, 0=not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand (species and structures)	Landscape and/or watershed (stand mixtures and age structure)	Bioregion/ecoregion
Dominant canopy species	≤100	≤100	Resilient
Stand structure (canopy height + density; layers)	≤50	>100	Resilient
Ecosystem services			
1. Total carbon	≤50	Resilient	Resilient
2. Water	≤50	≤50	Resistant
3. Habitat	≤100	Resilient	Resilient

B. Expected under Climate Change
Natural disturbance regimes: Fire - stand replacing fires <50 years, 200-500,000 ha
Resilience is relative to the 2000 expectation

Resilient by ≤ 50 yrs, ≤100 yrs, >100 yrs, 0= not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand	Landscape and/or watershed	Bio(eco)region
Dominant canopy species	≤50	≤50	≤ 50
Stand structure (canopy height + density; layers)	0	0	0
Ecosystem services			
1. Total carbon	≤50 (+9 to -37% of original C stocks)	≤50	≤50
2. Water	≤ 50	≤ 50	≤ 50
3. Habitat	≤100	≤100	≤100

Table 5. A case-study of expected forest resilience in boreal mixedwoods forests of central Canada, under current climate (A) and expected under climate change (B). Numbers refer to time (yrs) to recover from disturbance (i.e., resilience). A zero suggests that the forest will only recover to a new state and/or not recover the attribute in question.

Biome: Boreal
Ecosystem: Boreal upland mixedwood forest ecosystem, central Canada

A. Current Climate
Natural disturbance regimes:
a) Fire - stand replacing fires >100 years, 200 -100,000 ha
b) Epidemic insect infestations on conifer component
Resilience to natural disturbance or SFM:

Resilient at ≤ 50 yrs, ≤100 yrs, >100 yrs, 0=not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand (species and structures)	Landscape and/or watershed (stand mixtures and age structure)	Bioregion/ecoregion
Dominant canopy species	>100	>100	Resilient
Stand structure (canopy height + density; layers)	>100	>100	Resilient
Ecosystem services			
1. Total carbon	>100	Resilient	Resilient
2. Water	≤ 50	≤ 50	Resistant
3. Habitat	>100	Resilient	Resilient

B. Expected Climate
Natural disturbance regimes: Fire - stand replacing fires <100 years, 200-500,000 ha
Resilience is relative to the 2000 expectation.

Resilient by ≤ 50 yrs, ≤100 yrs, >100 yrs, 0= not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand	Landscape and/or watershed	Bio(eco)region
Dominant canopy species	≤ 50	≤ 50	≤ 50
Stand structure (canopy height + density; layers)	0	0	0
Ecosystem services			
1. Total carbon	0 (ca. 50% of original C stocks)	0	0
2. Water	≤ 50	≤ 50	resilient
3. Habitat	0 (50% of original habitat values)	0	0

of species, relative to many other boreal types, appears to increase the resilience of these forests (Girard et al. 2008). However, even in these more moist systems, fire frequency is predicted to increase by 50-80% in boreal mixedwoods in the next 50+ years, in North America (Krawchuk et al. 2009). Under a high disturbance regime, carbon stocks in mixedwood forests are predicted to be about 16-50% or more of current stocks, depending on location (Price et al. 1999, Bhatti et al. 2001, Ni, 2002, Yarie and Parton 2005). These forests will still provide habitat and most of the same goods and services, but they will most likely change states in response to the increased disturbance regime. While the case-study presented is from central Canada, in Finland, increased moisture and elevated temperatures are expected to result in an increase in production and carbon sequestration (Kellomaki et al. 2008).

5.2 *Temperate forest biome*

Temperate deciduous forests can be found across central-western and eastern North America, central and western Europe, and northern Asia. These forests have a four distinct seasons, and a growing season lasting 150-200 days. The continental climate is subject to a wide range of air temperature variation (i.e. 30ºC to -30ºC), and annual precipitation of 750 to 2500 mm is evenly distributed during the year) (Whittaker 1970). While these conditions typify much of the temperate forest region, some areas of the temperate forest region have less distinct seasons, more or less rain, and less variation in annual air temperatures. Temperate forests generally have a high number of dominant tree species compared to the tropics (many species with few that dominate) or boreal forests (few species and most can dominate) (Mooney et al. 1996). The high number of dominant species is a significant factor contributing to resilience in temperate forests.

Goods and services from temperate forests are important in large part owing to the large number of people living in close proximity to these forests. Clean water, wood products, and recreation opportunities have been some of the primary products from temperate forests. While these goods and services remain important, forest carbon sequestration is a newly valued service that these forests provide, in the wake of increasing atmospheric CO_2 levels and global warming. Major ecosystem perturbations can significantly and often negatively alter an ecosystem's productivity capacity and affect the flows of goods and services.

5.2.1 Temperate Forests and Environmental Stressors

History is replete with both naturally- and anthropogenically-induced disturbances leading to an altered re-stabilization of forest processes at a different and often lower state (i.e., less timber productivity, less water demand, less biodiversity). Natural climatic change has previously caused some forest areas to become more or less productive over time. For example, 6,000 years before present (BP), the Northern Chad region of the Sahara was a tropical rain forest, but over the course of <4,000 years these forest areas were completely converted to desert (Kröpelin et al. 2008).

Over the past 4,000 years, climate change, unsustainable forest use, and land clearing has lead to significant changes in global temperate forest cover. The Caledonian forests of Scotland originally may have covered as much as 1.5 million ha. However climate change (4,500 BP), and probably land clearing (starting ca. 4,000 BP) removed the vast majority of this forest type, and the forests have never recovered. Forest vegetation is only now beginning to return to some of these areas following changes in land management practices over 150 years ago (Hobbs 2009). The resilience of a forest is a function of the absolute ability of the forest to recover from a wide range of environmental stresses and disturbances. From the previous examples, it is clear that forest resilience can be overcome and that not all forest types or tree species recover equally well to all forms and combinations of stressors. Under a changing climate, some stress and combinations of stressors, such as temperature and drought, may become more or less common or severe over time.

5.2.2 Case-study: Moist evergreen temperate forests

Moist evergreen temperate forests, as their name suggests, occur at the wetter end of the temperate forest climatic domain, with total annual rainfall of 1,000mm+. In addition to southeastern Australia, moist temperate forests are also found on the Pacific coast of North America, Chile, and New Zealand. While taxonomic composition differs among these forests due to their evolutionary biogeography, they share similar levels of biodiversity, climatic conditions, rates of primary productivity and respiration, and thus comparable forest-carbon dynamics. They are the most carbon-dense forests on Earth, having larger living and dead biomass stocks compared even to tropical forests, even though they are far more fire prone than tropical forests (Keith et al 2009).

While Australian moist temperate evergreen forests experience shorter mean fire intervals than tropical forests, they are among the most resilient to fire of any ecosystem type (table 6). The canopies of these forests are dominated by the *Eucalyptus* genus. Most eucalypt species are highly resistant to fire and can rapidly regenerate leaves from stem and branch epicormic growth. A few species, in particular, *E. regnans*, which dominate certain tall wet forests in south-eastern Australia, will die if their entire canopy is scorched but then shed seeds that germinate in the post-fire ash beds. A long evolutionary history means that these forests are dominated by species that are optimal for prevailing environmental conditions, and the relatively high levels of tree species richness (there are >700 *Eucalyptus* species), along with networks of relictual and refugia habitats, provide a rich regional pool of species that can potentially fill new niches under changing change.

Most temperate forests are expected to continue increasing their carbon sequestration for at least the next two decades (e.g. Fischlin et al. 2009). Models predict continuing trends of modestly increasing forest productivity in eastern North America and western Europe over the next century (Field et al. 2007, Alcamo et al. 2007, Alo et al. 2008). Regional declines in forest productivity have also been seen in some areas of temperate forests due primarily to limitations of water related to recent droughts in Australia (Pitman et al. 2007) and in western North America (Breshears et al. 2005).

As the drier regions of the temperate domain covering semi-arid to subhumic climates in regions adjacent to the subtropical domain continue to experience more droughts, productivity is expected to decrease in those forests. However, as noted earlier, regional-scale prediction of changes in future climatic wetness come with a high degree of uncertainty, in many cases, about even the direction of change.

Biological processes accelerate as air temperature increases. Increases in tree respiration and metabolism can shorten leaf retention time as temperature increases. Litter decomposition, soil nitrogen mineralization, and soil nitrification also increase with increasing temperature (Mellio et al. 1982). Therefore, climate change could significantly affect the biological function of temperate forests. Increased air temperature is projected to increase fire risk and return interval (Dale et al. 2001). Episodic drought will favor more drought tolerant temperate species over more water demanding ones (Dale et al. 2001). The wide geographic range of the temperate forest types will provide a large selection of species that can adapt to changing environmental conditions.

However, even if a temperate forest remains intact (albeit with a possible changes in the mix of dominant species), many functional aspects of the forest and its goods and services are likely to change. For example, some areas of this biome are projected to receive reduced annual and or growing-season precipitation (IPCC 2007). Although, precipitation may still be sufficient to allow for the continued existence of most of the tree species that were present before the onset of anthropogenically induced climate change, there may be insufficient soil moisture to maintain the current species density. As trees die, the gaps created may not be filled or be filled more slowly than has historically occurred. A reduction in stand leaf area would (all other factors being equal), reduces forest evapotranspiration, and increases water yield from the forest (Lu et al. 2005, Sun et al. 2005). Additionally, increases in atmospheric CO2 concentrations may further improve forest water use efficiency offsetting some of the water yield reductions that would be associated with reduced precipitation (McNulty and Swank 1995).

Water is one of the principle determinants of ecosystem type. Average annual precipitation in temperate forests ranges from 500 to 2500 mm per year (Whittaker 1970). Millennia of plant competition have favored vegetative species that best adapt to limited resources (including water). Short-term (i.e., <2 years) drought can cause reduced ecosystem productivity (Hanson and Weltzin 2000) and reduced leaf area (Gholz 1990). Long-term (i.e., >2 years) droughts can cause additional ecosystem disruptions. Long-term droughts have all of the characteristics of short-term drought (described above) plus the potential for tree mortality due to water stress (Kloeppel 2003), increased insect outbreak potential (McNulty and Boggs, In press), and increased fire risk (Flannigan and Wotton 2001). A shift in the either insect species, insect or fire return interval, or severity could shift competitive advantages among temperate tree species and thus make some species and forest types less resistant.

Table 6. A case-study in moist temperate forests of Australia under current and expected climate regimes. Numbers refer to time (yrs) to recover from disturbance (i.e., resilience). A zero suggests that the forest will only recover to a new state and/or not recover the attribute in question.

Biome: Temperate
Ecosystem: Mountain Ash forest, Victoria, Australia
Climate scenario: Current climatic conditions
Natural disturbance regimes:
a) Intense tree killing fire frequency 75-150 years
b) Annual area burnt up to 70,000 ha (Mackey et al. 2002)
Resilience is relative to the 2000 expectation
Resilient by ≤ 50 yrs, ≤100 yrs, >100 yrs, 0=not resilient (state change)

	Spatial scale		
Attributes that are indicators of system change			
Dominant canopy species	Resilient if intense fire frequency >20<400 yearsa	80% catchment remains *E. regnans* if mean intense fire interval 26-290 years	Resilient
Stand structure (canopy height + density; layers)	Resilient if mean interval of all fires (not just intense tree killing fires) ~50 assuming ~35 trees survive fires	Resilient	Resilient
Ecosystem services			
1. Total carbon Keith et al. (2009)	Around 90% of total carbon can remain after an intense fire, but significant amount of biomass carbon will be moved from living to dead biomass pools	Resilient	Resilient
2. Water Australian Government (1994)	(not a site-level processes)	Decreasing water flows for ~ 30 follow in intense fire; after 130 years water flow returns to pre-disturbance stateb	Resilient because of patchiness in fire regimes at bioregional scale
3. Habitat	Maximum habitat value obtained if mean intense-fire interval >150-250 yearsc	Resilient due to network of fire refugia (areas burnt less intensely or frequently) enabling persistence of habitat resources	Resilient

a Reproductive age of *E. regnans*
b High rates of transpiration by dense regeneration reduces catchment water flow
c Large number of hollow-dependent vertebrate fauna and habitat hollows do not start forming in *E. regnans* until trees are ~120-150 years old

Potential climate change impacts on Ash forests: The Mountain Ash forests which are the focus of this case-study are located about 120km N.E. of the city of Melbourne, the capital of the Australian State of Victoria. These forests are located in a region called the Central Highlands of Victoria. In general terms, under high emission growth scenarios, this region's climate is expected to change by 2070 as follows: the greatest increases in temperature will occur in summer (3°C warmer); the greatest decreases in rainfall are expected in spring (21% decrease); there will likely be few rainy days (-19%) but increasing rainfall intensity (+4.5%); and runoff into the major river systems is expected to decrease by around 50%. Mackey et al. (2002) showed that, whilst the empirical relations are tenuous, FFDI and annual area burnt in this region scale with daily 3 p.m. temperature and annual rainfall respectively. The projected climate change for the Central Highlands will therefore likely alter fire regimes, all other factors being equal. Reductions in the mean fire interval as the result of increasing temperatures and dryness may therefore cause, over the course of time, changes in the forest composition towards more fire-tolerant cohorts of other *Eculayptus* species such as Messmate (*Euclayptus obliqua*); with subsequent changes in the abundance of tree hollows, carbon dynamics and water flow.

5.2.3 Case-study: southern Europe

Southern European forests tend to be dry and driven over the long term by fire and over the short term by blowdown (Schelhaas et al. 2003). As climates warm, the prediction is for fire to increase in some of these forests, especially in the Mediterranean area (Milne and Ouijen 2005, Dios et al. 2007). As a result, Morales et al. (2007) suggested that there will be a net loss of forest area and of total carbon from these systems. As the forests burn, more will likely change states to savannahs or grasslands suggesting little habitat resilience. Similarly, Lindroth et al. (2009) suggested that increasing blowdown will reduce overall production in temperate forests.

Although temperate deciduous forests are the most widely distributed of the temperate forest type, there are other temperate forest types such as the Mediterranean Forest. While high moisture characterizes many areas of the temperate forest biome, the Mediterranean area is an especially dry temperate system as illustrated in the following case-study (table 7). Like moist conifer forests, Mediterranean forests have a dry period during the summer months. However, Mediterranean forests are more similar to dry conifer forests with regard to total annual precipitation. The combination of precipitation is concentrated in winter, and totals <1000 mm per year (Whitaker, 1972).

Long summer droughts predispose the region to fires so the forests of Aleppo pine (*Pinus halepensis*), stone pine (*P. pinea*), maritime pine (*P. pinaster*), Corsican pine (*P. nigra*), and Turkish pine (*P. brutia*) are all fire adapted species, meaning that they usually require fire for reproductive success (i.e., cone opening). Additionally, these pines have very high concentrations of resin and therefore burn readily when fires occur. While intense fires will kill the mature pines, they may also kill other tree species, and thus provide both needed nutrients (via the ash and substrate created) and reduced competition for limited water supply for the emerging pine seedlings. The eucalypt (*Eucalyptus regnans* and *E. delegatensis*) of Australia use a similar survival strategy.

As an alternative survival mechanism, the evergreen sclerophyll oaks (e.g., holm oak (*Quercus ilex*), cork oak (*Q. suber*, *Q. coccifera*) have developed morphological traits that reduce their susceptibility to wildfire (i.e., increased resistance as opposed to increased resilience). The thick bark of cork oak protects the cambial layer from moderate intensity fires, increasing the probability of tree survival. If the fire is sufficiently intense to burn the above-ground vegetation, dormant buds will be activated and regenerate new shoots and sprouts following the fire.

As in dry coniferous forests, increased air temperature could lead to increasing wildfire severity and occurrence. However, unlike those of the dry coniferous forests, the tree species of the Mediterranean forests have two alternative survival strategies. The pine species may become competitively disadvantaged compared to the oak species if fire reoccurrence intervals do not allow for the regeneration of reproductive age pines. Alternatively, the oaks have both a primary (i.e., thick bark) and a secondary (stump sprouting) survival mechanism. Therefore, the oak species may be more resilient than the pine species to a change in the fire regime.

The oaks and pines of the Mediterranean forest type are well-adapted to these harsh environmental conditions and are historically resilient to disturbance (table 7). The slow growth rates require a longer time for these forests to return to a pre-disturbance productivity or carbon state, but the ecosystem is ecologically stable. Climate change will likely increase the severity of environmental conditions in these forests. As the environment changes, so may ecosystem resilience. These forests have evolved under very harsh conditions, and in that sense, they are adapted to cope with some additional stress from climate change. However, there are limits to even ecological resilience. Mediterranean deciduous forests will unlikely be able to maintain their current stand structure, and total carbon sequestration and storage potential owing to increased drought and fire, and it is likely that these forests may change states considerably under climate change (table 7).

5.2.4 Case-study: eastern North American deciduous forests

During the first decade of the twentieth Century, the chestnut blight fungus (*Cryphonectria parasitica*) was introduced to the eastern USA and Canada. Prior to the introduction, American chestnut (*Castanea dentata*) was a dominant tree species in North American temperate deciduous forests ecosystems (Douglass and Severeid 2003). However, over the course of a few decades, virtually all of the stands with mature chestnuts were killed. The blight largely affects older trees, so chestnut is still present across much of its former range but was reduced to an understory tree (i.e., shrub/sapling).

Table 7. Case-study of temperate Mediterranean forest resiliency under current climate (A) and expected under climate change (B). Numbers refer to time (yrs) to recover from disturbance (i.e., resilience). A zero suggests that the forest will only recover to a new state and/or not recover the attribute in question.

Biome: Temperate
Ecosystem: Mediterranean forest

A. Current Climate
Natural disturbance regimes:
a) Fire - stand replacing fires > 100 years, 200-10,000 ha
b) Wind <100 ha

Resilient at ≤ 50 yrs, ≤100 yrs, >100 yrs, 0=not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand (species and structures)	Landscape and/or watershed (stand mixtures and age structure)	Bioregion/ecoregion
Dominant canopy species	>100	>100	Resilient
Stand structure (canopy height + density; layers)	>100	>100	Resilient
Ecosystem services			
1. Total carbon	>100	Resilient	Resilient
2. Water	≤ 50	≤ 50	Resilient
3. Habitat	≥100	Resilient	Resilient

B. Expected Climate
Natural disturbance regimes:
a) Fire - stand replacing fires < 100 years, 200- 20,000 ha
b) Wind <100 ha

Resilient by ≤ 50 yrs, ≤100 yrs, >100 yrs, 0= not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand	Landscape and/or watershed	Bio(eco)region
Dominant canopy species	0	0	0
Stand structure (canopy height + density; layers)	>100	>100	0
Ecosystem services			
1. Total carbon	0	0	0
2. Water	<50	<50	<50
3. Habitat	0	0	0

Even as the chestnut was being removed as a major ecosystem component, oaks (*Quercus* spp.), maples (*Acer* spp.), ashes (*Fraxinus* spp.), and other species were filling the gaps left by the chestnuts. *Fraxinus* sp., *Quercus* sp., *Carya* sp., and *Acer* sp. all have wide natural ranges and each is highly adaptable to individual site conditions. These forests regenerated quickly following the disturbance, and over time, tree species replacement within the stand filled the functional role of lost species, suggesting high engineering resilience. Additionally, these forests exist within a relatively stable climate zone, not prone to extremes in temperature or precipitation. Adequate moisture reduces the reoccurrence interval for wildfire (Westerling et al. 2006). The combination of moderate climate tolerance and functional overlap of many dominant species explains why North American temperate deciduous forests are so resilient. At the stand and watershed levels, most stand attributes and ecosystem services return to pre-disturbance conditions within 50 years (table 8).

Xiao et al. (2008) estimated that the temperate forests in the USA sequestered 200 to 800 grams of carbon per square metre per year, amounting to a total carbon uptake of 0.51 to 0.70 petagrams (Pg) per year from 2001-2006. The variation in inter-annual carbon sequestration is a function of variable growing conditions and disturbance impacts (Xiao et al. 2008), in part because releases of carbon from wildfires and hurricanes can significantly affect long-term carbon budgets. Felzer et al. (2005), predicted that future climate variability, CO2 fertilization, nitrogen deposition, and ozone pollution would enhance plant growth in temperate ecosystems and increase carbon sequestration. However, other studies have suggested that increasing extreme climate events and disturbances are likely to more than offset such fertilization effects in the USA (McNulty 2002), and actually exert a positive feedback to the climate (Gruber et al. 2004). Temperate deciduous forests should continue to provide most of the same goods and services under climate change as currently, although the state, especially the species composition, will be altered (e.g., Fischlin et al. 2009), suggesting at least ecological resilience.

5.3 Tropical forests

Tropical forests are found between 25°N and 25°S and cover an area of about 17.5 million km^2 (Fischlin et al. 2007). Tropical forests are characterized by high alpha diversity, with few highly dominant species, especially in rainforests (Mooney et al. 1996). These forests range from wet to dry and include evergreen rainforests, tropical seasonal drought-deciduous forests (moist savannahs), and tropical dry forests (dry savannahs). Rainforests are characterized by an annual mean temperature above 24°C and ≥2.5 m/yr regular precipitation during the year, while other tropical forests remain above 15.5°C throughout the year (Prentice et al. 1992). Precipitation in rainforests is at least twice the potential evapotranspiration (Fischlin et al. 2007). Nevertheless, not all rainforests receive the same precipitation, with African forests being considerably drier than many parts of the Amazon, for example. Even within the Amazon basin, there exist gradients in precipitation. Tropical seasonal forests receive most of their rainfall during a wet season and have a ratio of precipitation to potential evapotranspiration between 2 and 1. Seasonal forests are found in tropical monsoon regions or other seasonal tropical wet-dry climate zones and are moist deciduous, i.e., the trees shed their leaves in the dry season. Tropical dry forests are characterized by a precipitation to potential evapotranspiration ratio <1 (Fischlin et al. 2007, 2009). Tropical forests are found in Australia, Asia, Africa, and South/Central America.

Tropical forests provide a wide range of goods and services, many of which are of global significance. In particular, rainforests are estimated to support the highest biodiversity of all terrestrial ecosystems (e.g. Gentry 1992, Leigh et al. 2004), including an estimated half of terrestrial and 25% of global biodiversity (Myers et al. 2000). This biodiversity provides a vast array of goods and services to people (e.g. Fearnside 1999), including shelter, food, and fuel in local communities. Tropical forests contribute 30% of the global net primary production (Field et al. 1998). A key service provided by tropical forests is globally significant climate regulation and production of oxygen. For example, the Amazon rainforest alone is suggested to produce about 20% of the global oxygen (Hakoum and Souza 2007). Tropical forests regulate continent-wide climates by sustaining higher precipitation levels compared to regions without a forest canopy (e.g. Laurance and Williamson 2001, Betts et al. 2004, Malhi et al. 2008). Primary tropical forests are a significant global carbon sink and the rate is currently increasing (Lewis et al. 2009). In the Amazon, the above-ground carbon sequestered has increased by an estimated at 0.5 to 0.8 Pg C/yr (Phillips et al. 2008) and for African tropical forests, the increase is estimated to be 0.34 Pg C/yr. The mean total sequestered for all tropical forests is currently about 1.3 Pg C/yr (Lewis et al. 2009). Malhi et al. (2008) found that intact primary tropical

Table 8. A case-study of forest resilience in temperate deciduous forest and expected under climate change. Numbers refer to time (yrs) to recover from disturbance (i.e., resilience). A zero suggests that the forest will only recover to a new state and/or not recover the attribute in question.

Biome: Temperate
Ecosystem: North American Deciduous Forest

A. Current Climate
Natural disturbance regimes:

a) Fire - stand replacing fires >100 years, 200 -10,000 ha
b) Wind – blowdown events annual single tree to 10,000 ha (related to disease)

Resilience to natural disturbance or SFM:

Resilient at ≤ 50 yrs, ≤100 yrs, >100 yrs, 0=not resilient (state change)	Spatial scale		
Attributes that are indicators of system change	Site/stand (species and structures)	Landscape and/or watershed (stand mixtures and age structure)	Bioregion/ecoregion
Dominant canopy species	>100	>100	Resilient
Stand structure (canopy height + density; layers)	>100	>100	Resilient
Ecosystem services			
1. Total carbon	>100	Resilient	Resilient
2. Water	≤ 50	≤ 50	Resistant
3. Habitat	≥100	Resilient	Resilient

B. Expected Climate
Natural disturbance regimes:

a) Fire - stand replacing fires <500 years, 200-20,000 ha
b) Blowdown, storms, drought, herbivory (especially invasive species)

Resilience is relative to the 2000 expectation

Resilient by ≤ 50 yrs, ≤100 yrs, >100 yrs, 0= not resilient (state change)	Spatial scale		
Attributes that are indicators of system change	Site/stand	Landscape and/or watershed	Bio(eco)region
Dominant canopy species	>100	>100	0
Stand structure (canopy height + density; layers)	>100	>100	Resilient
Ecosystem services			
1. Total carbon	0	0	0
2. Water	≤50	≤50	Resilient
3. Habitat	>100	Resilient	Resilient

forests provide the best carbon sink, compared to second-growth or fragmented tropical forest stands. This carbon sink is dramatically altered by land-clearing for agriculture and plantation forests, which sequester and maintain far less carbon than primary forests (e.g., Cramer et al. 2004, Malhi et al. 2008, Lewis et al. 2009). Furthermore, Bunker et al. (2005) suggested that tropical forests depleted of species will have much lower carbon storage capacity than the original forests.

5.3.1 Climate change and tropical forest resilience

Most evidence suggests that tropical forests may not be resilient to climate change over the long term, primarily owing to a predicted reduction in rainfall and increased drought (IPCC 2007, Malhi et al. 2009). In the short term, evidence suggests a positive effect of CO_2 fertilization on tropical forest production as a result of present climate change (Boisvenue and Running 2006, Lewis et al. 2009), although importantly this has involved some changes in species composition, indicating resilience to current change. Future capacity of these forests to maintain this service is highly uncertain (Cramer et al. 2004) as a result of altered moisture regimes possibly leading to increased fire and drought (e.g., Malhi et al. 2009). Loss of tropical forests will have consequences for global hydrology, among other consequences of global relevance (Fischlin et al. 2009).

There is considerable evidence that climate change may lead to large losses in biodiversity in all tropical forests (e.g. Bazzaz 1998, Miles et al. 2004, Possingham and Wilson 2005, Rull and Vegas-Vilarrubia 2006, Fitzherbert et al. 2008, Malhi et al. 2008), with consequent effects on the flow of goods and services from these forests. This will be especially true for montane and cloud forests, owing to a lack of surrogate habitats for species, and where evidence of biodiversity loss has already accumulated (Bunker et al. 2005, Rull and Vegas-Vilarrubia 2006, Colwell 2008). Wilson and Agnew (1992) provided an example of permanent regime shift in tropical cloud forests following unsustainable harvesting that resulted in a negative feedback involving the needed condensation moisture for remaining trees to survive; climate drying would have an identical effect. Tropical forests are at a substantial risk for biodiversity loss under climate change for several reasons including disruptions to complex ecosystem dynamics, the high degree of specialization and narrow niches for many tropical species, and because climate change will exacerbate an already high rate of deforestation (Bazzaz 1998). Large-scale loss of biodiversity will have dramatic negative effects on carbon sequestration capacity by tropical forests (Cramer et al. 2004, Fischlin et al. 2009).

5.3.2 Case-study: Amazon rain forest

The Amazon rain forest is an extensive forest system about as large as the United States occurring in eight South American countries. It contains many forest types, depending on soils, topography, and climate, but there is a large area of evergreen forest with little seasonality where 200-900 cm of rain falls annually. These forests are highly resilient to the chronic disturbances of herbivory and blowdown typical of the region (table 9). However, land-clearing and logging had reduced the original extent of the Amazon forest by 15% by 2003 (Soares-Filho et al. 2006). Recent occasional drought episodes have exacerbated the human impacts by increasing forest fires (Malhi et al. 2008). Climate change is predicted to have long-term effects on forest structure and function by changing the mortality and growth rates of trees and increase the frequency of disturbances, especially an increasing fire frequency under a drier climate regime (Malhi et al. 2008, Phillips et al. 2008). Increased carbon dioxide concentrations seem to be having a direct positive impact on the productivity and relative competitive success among tropical plant species (Baker et al. 2004, Malhi et al. 2009).

Modelling global warming of >3°C, as expected in tropical areas, reduces the tropical forest sink by mid-century, and results in a net carbon source towards the end of this century (Scholze et al. 2006, Fischlin et al. 2009). The most likely impact of climate change on Amazon forests will be drought and the development of seasonality in the rainforest (Malhi et al. 2009, Phillips et al. 2009), although models are far from certain in their prediction of rainfall. The predicted decreased rainfall and ground moisture will increase the likelihood of fire and shift the rainforest into drier seasonal forest. This process has a positive feedback owing to the loss the rainforest canopy that otherwise tends to maintain regional moisture levels (Laurance and Williamson 2001). As a result, much of the rainforest will change states to drier and possibly more open forests, reducing habitats, lowering regional water supplies, and becoming a far less productive forest (Malhi et al. 2009, Cochrane and Barber 2009). Climate change will exacerbate the many negative effects of ongoing deforestation and forest loss (Laurance 1998, Cook and Vizy 2008, Cochrane and Barber 2009), and the

Table 9. Amazon rain forest resiliency under current climate (A.) and expected under climate change (B.). Numbers refer to time (yrs) to recover from disturbance (i.e., resilience). A zero suggests that the forest will only recover to a new state and/or not recover the attribute in question.

Biome: Tropical
Ecosystem: Amazon rain forest ecosystem

A. Current Climate
Natural disturbance regimes:
a) Wind – up to 10,000 ha; events infrequent
b) Herbivory

Resilient at ≤ 50 yrs, ≤100 yrs, >100 yrs, 0=not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand (species and structures)	Landscape and/or watershed (stand mixtures and age structure)	Bioregion/ecoregion
Dominant canopy species	<50	<50	Resilient
Stand structure (canopy height + density; layers)	>50	>50	Resilient
Ecosystem services			
1. Total carbon	<50	Resilient	Resilient
2. Water	≤50	≤50	Resilient
3. Habitat	<u><50</u>	Resilient	Resilient

B. Expected Climate
Natural disturbance regimes:
a) Fire - stand replacing fires <50 years, 200-20,000 ha
b) Drought - common
c) Wind – up to 10,000 ha; events more frequent
d) Increased herbivory
Resilience is relative to the 2000 expectation

Resilient by ≤ 50 yrs, ≤100 yrs, >100 yrs, 0= not resilient (state change)	**Spatial scale**		
Attributes that are indicators of system change	Site/stand	Landscape and/or watershed	Bio(eco)region
Dominant canopy species	0	0	0
Stand structure (canopy height + density; layers)	0	0	0
Ecosystem services			
1. Total carbon	0	0	0
2. Water	0	0	0
3. Habitat	0	0	0

forests will be considerably different than at present.

5.4 Summary among forest biomes

All forest types will undergo some change as a result of altered climate conditions; some of these changes are already occurring but widespread change is expected over the next 50-100 years (e.g., Alcamo et al. 2007, Fischlin et al. 2009). From the case-studies, it is clear that some forests are considerably more vulnerable (less resilient) than others as a result of altered disturbance regimes that are predicted under climate change. This is especially the case for forests where previously rarely-seen disturbances will become more common, such as fire in rainforests. In some cases, even ecological resilience will be overcome and forests are expected to change states to non-forest or savannah (IPCC 2007), as has happened in many areas previously, such as the northern Sahara area of Africa (Kröpelin et al. 2008). In many cases, forests will change states, however, at least among most boreal and some temperate forests, ecological resilience is expected. In many tropical forests, however, many rainforests may become dry tropical forests with reduced carbon storage capacity (case-studies, Fischlin et al. 2009). The diversity in these tropical regions suggests that some form of forest will continue to exist even with severe disturbance, but that many of the functions will change owing to the lack of resilience and new states, in general, will produce considerably less goods and services while supporting less biodiversity than at present.

6. Conclusions and ecological principles

The biodiversity in a forest is linked to and underpins the ecosystem's productivity, resilience, and stability over time and space. Biodiversity increases the long-term resilience and resistance of forest ecosystem states, increases their primary production, and enhances ecosystem stability at all scales. While not all species play important functional roles in ecosystems, many do, and we may not know or understand the role of a given species. Further, under changed environmental conditions, species with previously minimal functional responsibilities may become highly functional. The persistence of these functional groups within ecosystems is essential for ecosystem functioning and resilience. Capacity for resilience and ecosystem stability is required to maintain essential ecosystem goods and services over space and time. Loss of resilience may be caused by the loss of functional groups, environmental change such as climate change, or alteration of natural disturbance regimes (Folke et al. 2004). Loss of resilience results in a regime shift, often to a state of the ecosystem that is undesirable and irreversible. Resilience needs to be viewed as the capacity of natural systems to self-repair based on their biodiversity, hence the loss of biodiversity could mean a reduction of that capacity. This review, together with those of Loreau et al. (2001), Hooper et al. (2005), and Drever et al. (2006), suggested strong support for the following concepts specific to forest ecosystems and their resilience:

1. Resilience is an emergent ecosystem property conferred at multiple scales by the biodiversity in the forest system. More specifically, forest resilience is related to genetic diversity, functional species diversity, and ecosystem diversity (beta diversity) across a forest landscape and over time (table 2).

2. Most natural forests are highly resilient ecosystems, adapted to various kinds of perturbations and disturbance regimes; but if disturbance exceeds the capacity of the forest to recover (forest degradation owing to human use, for example, which reduces functional components), the system will recover to a different state that may or may not also be highly resilient, but which is unlikely to provide the former level of goods and services.

3. Complex forest ecosystems are generally more productive and provide more goods and services than those with low species richness. Productive forests dominated by mature trees are generally highly stable ecosystems.

4. There is niche differentiation among some tree species in a forest, as well as competition, leading to complexity and variability within and among forest ecosystems and their processes. Some of this variability is related to idiosyncratic local site conditions.

5. Redundancy of functional species is common in complex forest ecosystems and is directly related to ecosystem resilience. Redundancy provides insurance against changing environmental conditions, and species with limited functions under one set of conditions may become driver species under an altered set of conditions.

6. Diverse forest systems are more stable (within defined bounds) than less diverse systems and this is partly related to a robust regional species pool and the beta diversity among ecosystems.

7. Nevertheless, even high diversity is no guarantee for ecosystem resilience once climate conditions move beyond those experienced by most of the component species.

8. Although a forest may change states in response to disturbances, the flow of goods and services may not necessarily be highly altered, suggesting that the ecosystem is ecologically resilient, even though the forest community structure may have changed. Ecological resilience is unlikely, however, in a system that has low redundancy, such as degraded forests.

9. There is a negative relationship between species diversity, landscape diversity, and the capacity of a forest system to be invaded, especially by pests and diseases.

10. Not all forest ecosystems are equally resilient to disturbances, including climate change. Effects of climate change will vary in forests depending on biome, tree species composition, natural disturbance regime, and moisture, temperature and edaphic responses to climate change.

11. Resilience is necessary to maintain desirable ecosystem states under variable environmental conditions.

6.1 Ecological principles to foster forest ecosystem resilience and stability under climate change

Forests have a capacity to resist environmental change owing to their multiple species and complex multiple processes. However, a reduction in biodiversity in forest systems has clear implications for the functioning of the system and the amounts of goods and services that these systems are able to produce. While it is relatively simple to plant trees and produce a short-term wood crop, the lack of diversity at all levels (i.e., gene, species of flora and fauna, and landscape) in these systems reduces resilience, degrades the provision of goods and services that the system can provide, and renders it vulnerable to catastrophic disturbance.

Specifically, with respect to mitigating CO2 emissions from deforestation and degradation, maintaining long-term stable forest ecosystems will be critical, as opposed to for example, rapidly growing simple low diversity forests that have limited longevity, resistance, resilience or adaptive capacity. Further, the application of ecological sustainability principles in the recovery of degraded forests to redevelop their resilience and their former goods and services will provide part of a long-term approach to mitigating and adapting to climate change (e.g., Lamb et al. 2005, Innes et al. 2009). Hence, maintaining resilience in forests, in time and space, is important to maintain their function as an important "buffer" in the global carbon cycle by maximizing their potential to sequester and store carbon; along with the ongoing capacity to provide the other goods and services that humans require. To this end, human use of forests will need to change in order to ensure their conservation, sustainable use, and restoration.

In managed forests, it is imperative that biodiversity and ecosystem resilience be maintained. The principles of sustainable forest management are to maintain ecosystem processes by matching management practices to natural processes (or expected processes, modified under climate change) at multiple scales (e.g., Attiwill 1994, Perera et al. 2004). Restoration of degraded forest landscapes can take advantage of the linkage between biodiversity and ecosystem resilience, by planting to enhance species richness and through the addition of functional species (e.g., N-fixing species) where known (see: Lamb et al. 2005, Brockerhoff et al. 2008, for management recommendations). Various options for policies and measures are available to promote forest conservation and biodiversity, particularly at landscape and regional scales, in addition to conventional protected areas, including payments for land stewardship and ecosystem services (USDA 2007), connectivity conservation programmes (Crooks and Sanjayan 2006), and schemes built around recognition of Indigenous and traditional lands (Australian Government 2007).

The capacity to conserve, sustainably use and restore forests rests on our understanding and interpretation of pattern and process at several scales, the recognition of thresholds, and the ability to translate knowledge into appropriate management actions in an adaptive manner (Frelich and Reich 1998, Gauthier et al. 2008). Caring for forests in ways that maintain their diversity and resilience is being made even more complex owing to climate change (e.g., Chapin et al. 2007, Kellomaki et al. 2008). We suggest the following as ecological principles that can be employed to maintain and enhance long-term forest resilience, especially under climate change (e.g., Thompson et al. 2002, Fischer et al. 2006, Millar et al. 2007, Innes et al. 2009):

1. Maintain genetic diversity in forests through practices that do not select only certain trees for

harvesting based on site, growth rate, or form (see e.g., Schaberg et al. 2008).

2. Maintain stand and landscape structural complexity using natural forests as models and benchmarks.

3. Maintain connectivity across forest landscapes by reducing fragmentation, recovering lost habitats (forest types), and expanding protected area networks (see 8. below).

4. Maintain functional diversity (and redundancy) and eliminate conversion of diverse natural forests to monotypic or reduced species plantations.

5. Reduce non-natural competition by controlling invasive species and reduce reliance on non-native tree crop species for plantation, afforestation, or reforestation projects.

6. Reduce the possibility of negative outcomes by apportioning some areas of assisted regeneration with trees from regional provenances and from climates of the same region that approximate expected conditions in the future.

7. Maintain biodiversity at all scales (stand, landscape, bioregional) and of all elements (genetic, species, community) and by taking specific actions including protecting isolated or disjunct populations of organisms, populations at margins of their distributions, source habitats and refugia networks. These populations are the most likely to represent pre-adapted gene pools for responding to climate change (Cwynar and MacDonald 1987) and could form core populations as conditions change.

8. Ensure that there are national and regional networks of scientifically designed, comprehensive, adequate, and representative protected areas (Margules and Pressey 2000). Build these networks into national and regional planning for large-scale landscape connectivity.

7. Literature Cited

Aarssen, L.W. 1997. High productivity in grassland ecosystem: affected by diversity or productive species? Oikos 80: 183-184.

Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen and A. Shvidenko. 2007. Europe. Pages 541-580 in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E Hanson, (eds.), Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK. p. 541–580.

Allen, T.F.H. and T.W. Hoekstra. 1992. Toward and unified ecology. Complexity in ecological systems series. Columbia University Press, NY, USA.

Allison, G.W. 1999. The implications of experimental design for biodiversity manipulations. Amer. Nat. 153: 26-45.

Alo, C.A. and G.L. Wang. 2008. Potential future changes of the terrestrial ecosystem based on climate projections by eight general circulation models. Jour. Geophys. Res. G 113(G1).

Angelstam, P.K. 1998. Maintaining and restoring biodiversity in European boreal forests by developing natural disturbance regimes. Jour. Vege. Science 9: 593-603.

Archer, D., M. Eby, V. Brovkin, A. Ridgwell, L. Cao, U. Mikolajewicz, K. Caldeira, K. Matsumoto, G. Munhoven, A. Montenegro and K. Tokos. 2009. Atmospheric lifetime of fossil fuel carbon dioxide. Ann. Rev. of Earth and Planetary Sci. 37: 117-134.

Attiwill, P.M. 1994. The disturbance of forest ecosystems: the ecological basis for forest management. For. Ecol. Manage. 63: 247-300.

Australian Government (1994). State of Environment Report. Chapter 7 Inland water. Available from URL: http://www.environment.gov.au/soe/1996/publications/report/pubs/chap07.pdf

Australian Government (2007) Growing up Strong: The first 10 years of Indigenous Protected Areas in Australia. Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia, Canberra.

Ayres, M.P. and M.J. Lombardero. 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Sci. of the Total Envir. 262: 263-286.

Baeza, M. J., A. Valdecantos, J.A. Alloza and V.R. Vallejo. 2007. Human disturbance and environmental factors as drivers of long-term post-fire regeneration patterns in Mediterranean forests. Jour. Vege. Sci. 18: 243-252.

Baker, T.R., O.L. Phillips, Y. Malhi, S. Almeida, L. Arroyo, A. Di Fiore, A. T. Erwin, N. Higuchi, T.J. Killeen, S.G. Laurance, W.F. Laurance, S.L. Lewis, A. Monteagudo, D.A. Neill, P. Núñez Vargas, N.C.A. Pitman, J.N.M. Silva and R. Vásquez Martínez. 2004. Increasing biomass in Amazonian forest plots. Phil. Trans. Roy. Soc. Lond. B 359: 353-365.

Barthod, C. 1994. Sylviculture et risques sanitaires dans les forêts tempérées. Rev. For. Fran. 46: 609-628.

Bazzaz, F.A. 1998. Tropical forests in a future climate: Changes in biological diversity and impact on the global carbon cycle. Climate Change 39: 317–336.

Bazazz, F.A., M. Jasienski, S.C. Thomas, and P. Wayne. 1995. Micro-evolutionary responses in experimental populations of plants to CO2-enriched environments: parallel results from two model systems. Proc. Nat. Acad. Sci. USA 92: 8161-8165.

Bhatti, J.S., M.J. Apps, and H. Jiang. 2001. Examining the carbon stocks of boreal forest ecosystems at stand and regional scales. Pages 513-532 in R. Lal, J.M. Kimble, R.F. Follett and B.A. Stewart (eds.), Assessment methods for soil carbon. Lewis Publ., Boca Raton, FL, USA.

Bennett, K.D. 1985. The spread of Fagus grandifolia across eastern North America during the last 18,000 years. Jour. Biogeogr. 12: 147-164.

Bergeron, Y. and A. Leduc. 1998. Relationships between change in fire frequency and mortality due to spruce budworm outbreak in the southeastern Canadian boreal forest. Jour. Vege. Sci. 9: 493-500.

Bergeron, Y. and M.D. Flannigan. 1995. Predicting the effects of climate change on fire frequency in the southeastern Canadian boreal forest. Water, Air, and Soil Poll. 82: 437-444.

Berish, C.W. and J.J. Ewel. 1988. Root development in simple and complex tropical successional ecosystems. Plant and Soil 106: 73-84.

Bernabo J.C. and T. Webb. 1977. Changing patterns of the Holocene pollen record of northeastern North America: a mapped summary. Quaternary Res. 8:64-96.

Berrang, P., D.F. Karnosky and J.P. Bennett. 1989. Natural selection for ozone tolerance in Populus tremuloides: field verification. Can. Jour. For. Res. 19:519-522.

Berry, S.L. and M.L. Roderick. 2002. Estimating mixtures of leaf functional types using continental scale satellite and climatic data. Glob. Ecol. and Biogeogr. 11: 23–39.

Betts, R., M. Sanderson, S. Woodward, Y. Malhi, T. Roberts and R.A. Betts. 2008. Effects of large-scale Amazon forest degradation on climate and air quality through fluxes of carbon dioxide, water, energy, mineral dust and isoprene. Phil. Trans. Roy. Soc. Lond. B 363: 1873-1880.

Betts, R.A., P.M. Cox, M. Collins, P.P Harris, C. Huntingford and C.D. Jones. 2004. The role of ecosystem–atmosphere interactions in simulated Amazonian precipitation decrease and forest dieback under global climate warming. Theor. Appl. Climatol. 78: 157–175.

Boisvenue, C. and S.W. Running. 2006. Impacts of climate change on natural forest productivity- evidence since the middle of the 20th century. Global Change Biol. 12: 862-882.

Bodin, P. and B.L.B. Wimen. 2007. The usefulness of stability concepts in forest management when coping with increasing climate uncertainties. For. Ecol. Manage. 242: 541-552.

Bonan, G.B., S. Levis, S. Sitch, M. Vertenstein and K.W. Oleson. 2003. A dynamic global vegetation model for use with climate models: concepts and description of simulated vegetation dynamics. Global Change Biol. 9: 1543-1566.

Bradshaw, A.D. 1991. Genostasis and the limits to evolution. Phil. Trans. Royal Soc. Lond. 333: 289-305.

Brandt, J..P., H.F. Cerezke, K.I. Mallett, W.J. Volney and J.D. Weber. 2003. Factors affecting trembling aspen health in the boreal forest of Alberta, Saskatchewan, and Manitoba, Canada. For. Ecol. Manage. 178: 287-300.

Brantberg, P.-O., H. Lundqvist and J. Bengtsson. 2000. Changes in the forest floor chemistry caused by birch admixture in Norway spruce stands. For. Ecol. Manage. 130: 253-264.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. Proc. Nat. Acad. Sci. USA 102: 15144–15148.

Bristow, M., J.K. Vanclay, L. Brooks and M. Hunt. 2006. Growth and species interactions of Eucalyptus pellita in a mixed and monoculture plantation in the humid tropics of north Queensland. For. Ecol. Manage. 233: 285-294.

Brockerhoff, E.G., H. Jactel, J.A. Parrotta, C.P. Quine, and J. Sayer. 2008. Plantation forest and biodiversity: oxymoron or opportunity? Biodivers. Conserv.17: 925-951.

Brown, J.K. 1975. Fire cycles and community dynamics in lodgepole pine forests. Pages 430-457 in D.M. Baumgartner (ed.), Management of lodgepole pine ecosystems. Washington State Univ. Press, Washington, USA.

Brown, B.J. and J.J. Ewel. 1987. Herbivory in complex and simple tropical successional ecosystems. Ecology 68: 108-116.

Brown, J.H., S.K.M. Ernest, J.M. Parody and J.P. Haskell. 2001. Regulation of diversity: maintenance of species richness in changing environments. Oecologia 126: 321-332.

Brunet, J. and G. von Oheimb. 1998. Migration of vascular plants to secondary woodlands in southern Sweden. Jour. Ecol. 86: 429-438.

Bunker, D.E., F. DeClerck, J.C. Bradford, R.K. Colwell, I. Perfecto, O.L. Phillips, M. Sankaran and S. Naeem. 2005. Species loss and aboveground carbon storage in a tropical forest. Science 310: 1029-1031.

Burdon, J.J. and P.H. Thrall. 2001. The demography and genetics of host-pathogen interactions. Pages197-217 in J. Silvertown and J. Antonovics (eds.), Integrating ecology and evolution in a spatial context. Blackwell Science Ltd., London.

Burger, R. and M. Lynch. M. 1995. Evolution and extinction in a changing environment: a quantitative genetic analysis. Evolution 49: 151-163.

Cain, M. L., H. Damman and A. Muir. 1998. Seed dispersal and the Holocene migration of woodland herbs. Ecol. Monogr. 68: 325–347.

Cain, M.L., B.G. Milligan and A.E. Strand. 2000. Long-distance seed dispersal in plant populations. Amer. Jour. Bot. 87: 1217-1227.

Callaghan, T.V., L.O. Bjorn, Y. Chernov, T. Chapin, T.R. Christensen, B. Huntley, R.A. Ims, M. Johansson, D. Jolly, S. Jonasson, N. Matveyeva, N. Panikov, W. Oechel, G. Shaver, S. Schaphoff and S. Sitch. 2004. Effects of changes in climate on landscape and regional processes, and feedbacks to the climate system. Ambio 33: 459-468.

Cantin, D., M.F. Tremblay, M.J. Lechowicz and C. Potvin. 1997. Effects of CO2 enrichment, elevated temperature, and nitrogen availability on the growth and gas exchange of different families of jack pine seedlings. Can. Jour. For. Res. 27: 510-520.

Cascante, A., M. Quesada, J.J. Lobo, and E.A. Fuchs. 2002. Effects of dry tropical forest fragmentation on the reproductive success and genetic structure of the tree Samanea saman. Conserv. Biol. 16: 137-147.

Casparsen, J.P. and S.W. Pacala. 2001. Successional diversity and forest ecosystem function. Ecol. Res. 16: 895-904.

Chambers, Q.C., N. Higuchi, J.P. Schimel, L.V. Ferreira and J.M. Melack. 2000. Decomposition and carbon cycling of dead trees in tropical forests of the Central Amazon. Oceologia 122: 380-388.

Chapin, F.S., K. Danell, T. Elmqvist, C. Folke and N. Fresco. 2007. Managing climate change impacts to enhance the resilience and sustainability of Fennoscandian forests. Ambio 36: 528-533.

Chapin, F.S. E.S. Zavaleta, V.T. Eviner, R.L. Naylor, P.M. Vitousek, H.L. Reynolds, D.U. Hooper, S. Lavorel, O.E. Sala, S.E. Hobbie, M.C. Mack and S. Diaz. 2000. Consequences of changing biodiversity. Nature 405: 234-242.

Chapin, F.S., B.H. Walker, R.J. Hobbs, D.U. Hooper, J.H. Lawton, O.E. Sala and D. Tilman. 1997. Biotic control over the functioning of ecosystems. Science 277: 500-504.

Chase, J.M. and M.A. Leibold. Spatial scale dictates the productivity-biodiversity relationship. Nature 416: 427-430.

Chen, J., S.J. Colombo, M. Ter-Mikaelian and L.S. Heath. 2008. Future carbon storage in harvested wood products from Ontario's Crown forests. Can. Jour. For. Res. 38: 1947-1958.

Clark, J.S., Why trees migrate so fast: confronting theory with dispersal biology and the paleorecord. Amer. Natur. 152: 204-224.

Cloutier, D., O.J. Hardy, H. Caron, A.Y. Ciampi, B. Degen, M. Kanashiro and D.J. Schoen. 2007. Low inbreeding and high pollen dispersal distance in populations of two Amazonian forest tree species. Biotropica 39: 406-415.

Collingham, Y.C., M.O. Hill and B. Huntley. 1996. The migration of sessile organisms: a simulation model with measureable parameters. Jour. Vege. Sci. 7: 831-846.

Condit, R., S. Aguilar, A. Hernandez, R. Perez, S. Lao and C. Pyke. 2005. Spatial changes in tree composition of high-diversity forests: how much is predictable? Pages 271-294 in E. Bermingham, C.W. Dick and C. Moritz (eds.), Tropical Forests: past, present and future. Univ. of Chicago Press, Chicago, IL, USA..

Cochrane, M. A. and C.P. Barber. 2009. Climate change, human land use and future fires in the Amazon. Global Change Biol. 15: 601-612

Colwell, R.K., G. Brehm, C.L. Cardelis, A.C. Gilman and J.T. Longino. 2008. Global warming, elevational range shifts, and lowland biotic attrition in the wet tropics. Science 322: 258-260.

Cook, K.H. and E.K. Vizy. 2008. Effects of twenty-first-century climate change on the Amazon Rain Forest. Jour. Climate 21: 542-560

Cramer, W., A. Bondeau, S. Schaphoff, W. Lucht, B Smith and S. Sitch 2004. Tropical forests and the global carbon cycle: impacts of atmospheric carbon dioxide, climate change and rate of deforestation. Phil. Trans. Roy. Soc. Lond. B 359: 331-343.

Cramer, C.,. W. Cramer, A. Bondeau,. F.I. Woodward, I.C. Prentice, R. Betts, V. Brovkin, P.M. Cox, V. Fisher, J.A. Foley, A.D. Friend, C. Kucharik, M.R. Lomas, N. Ramankutty, S. Sitch, B. Smith, A. White and C. Young-Molling, C. 2001. Global response of terrestrial ecosystem structure and function to CO2 and climate change: results from six dynamic global vegetation models. Global Change Biol. 7: 357-353.

Crooks, K.R. and M. Sanjayan (eds.). 2006. Conservation Connectivity. Conservation Biology 14. Cambridge University Press, Cambridge, UK.

Cwynar, L.C. and G.M. MacDonald. 1987. Geographical variation of lodgepole pine in relation to population history 1987. Amer. Natur. 129:463-469.

Dale, V.H., L.A. Joyce, S. McNulty, R.P. Neilson, M.P. Ayres, M.D. Flannigan, P.J. Hanson, L.C. Irland, A.E. Lugo, C.J. Peterson, D. Simberloff, F.J. Swanson, B.J. Stocks and B.M. Wotton. 2001. Climate Change and Forest Disturbances. BioScience 51:723-734.

Davis, M.B. 1981. Quaternary history and the stability of forest communities. Pages132-153 in D.C. West, H.H. Shugart and D.R. Botkin, (eds.), Forest succession: concepts and applications. Springer-Verlag, New York.

Davis, M.B. 1983. Quaternary history of deciduous forests of eastern North America and Europe. Ann. Missouri Bot. Gardens 70: 550-563.

Davis, M.B. 1989. Lags in vegetation response to greenhouse gasses. Climate Change 15: 75-82.

Davis, M.B. and R.G. Shaw. 2001. Range shifts and adaptive responses to Quaternary climate change. Science 292: 673-679.

Degen, B., L. Blanc, H. Caron, L. Maggia, A. Kremer and S. Gourlet-Fleury. 2006. Impact of selective logging on genetic composition and demographic structure of four tropical tree species. Biol. Cons. 131: 386-401.

DeHayes, D.H., G.L. Jacobson Jr., P.G. Schaberg, B. Bongarten, L. Iverson and A.C. Dieffenbacher-Krall. 2000. Forest responses to changing climate: lessons from the past and uncertainty for the future. Pages 495-539 in R.A. Mickler, R.A Birdsey and J.L Hom (eds.), Responses of northern U.S. forests to environmental change. Springer-Verlag, NY.

Des Marais, D. 2000. Evolution: when did photosynthesis emerge on Earth? Science 289: 1703-1705.

DeVerno, L.L. and A. Mosseler. 1997. Genetic variation in red pine (Pinus resinosa Ait.) revealed by RAPD and RAPD-RFLP analysis. Can. Jour. For. Res. 27: 1316-1320.

Diaz, S., D. Tilman, J. Fargione, F.S. Chapin, R. Dirzo, T. Kitzberger, B. Gemmill, M. Zobel, M. Vila, C. Mitchell, A. Wilby, G.C. Daly, M. Galetti, W.F. Laurence, J. Pretty, R. Naylor, A. Power, D. Harvell, S. Potts, C. Kremen, T. Griswold and C. Eardley. 2005. Biodiversity regulation of ecosystem services . Pages 297-329 in R. Hassan, R. Scholes and N. Ash, (eds.), Ecosystems and human well-being: current state and trends, Millennium ecosystem assessment Vol 1. Island Press, Washington, DC, USA.

Diaz, S., A.J. Symstad, F.S. Chapin, D.A. Wardle and L.F. Huenneke. 2003. Functional diversity revealed by removal experiments. Trends Ecol. Evol. 18: 140-146.

Diaz, S. and M. Cabido. 2001. Vive la différence: plant functional diversity matters to ecosystem processes. Trends Ecol. Evol. 16: 646-655.

Dios, V. R. de, C. Fischer and C. Colinas. 2007. Climate change effects on Mediterranean forests and preventive measures. New Forests 33: 29-40.

Doak, D.F., D. Bigger, E.K. Harding, M.A. Marvier, R.F. O'Malley and D. Thomson. 1998. The statistical inevitability of stability-diversity relationships in community ecology. Amer. Natur. 151: 264-276.

Dobson, A. D. Lodge, J. Alder, G.S. Cumming, J. Keymer, J. McGlade, H. Mooney, J.A. Rusak, O. Sala, V. Walters, D. Wall, R. Winfree and M.A. Xenopoulos. 2006. Habitat loss, trophic collapse, and the decline of ecosystem services. Ecology 87: 1915-1924.

Doyle, J.C., D.L. Alderson, L. Li, S. Low, M. Roughan, S. Shalunov, R. Tanaka and W. Willinger. 2005. The "robust yet fragile" nature of the Internet. Proc. Nat. Acad. Sci. 102: 14497–14502

Drever, C.R., G. Peterson, C. Messier, Y. Bergeron and M.D. Flannigan. 2006. Can forests management based on natural disturbances maintain ecological resilience? Can. Jour. For. Res. 36: 2285-2299.

Dyer, J.M. 1995. Assessment of climate warming using a model of forest species migration. Ecol. Model. 79: 199-219.

Elmqvist, T., C. Folke, M. Nystrom, G. Peterson, J. Bengston, B. Walker abd J. Norberg. 2003. Response diversity and ecosystem resilience. Front. Ecol. Environ. 1: 488-494.

Elton, C.S. 1958. The ecology of invasions by animals and plants. Methuen, London, UK.

Enquist, B.J. and K.J. Niklas. 2001. Invariant scaling relationship across tree-dominated communities. Nature 410: 655-660.

Erskine, P.D., D. Lamb and M. Bristow. 2006. Tree species diversity and ecosystem function: can tropical multi-species plantations generate greater productivity? For. Ecol. Manage. 233: 205-210.

Etterson, J.R. 2004. Evolutionary potential of Chamaecrista fasciculate in relation to climate change. I. clinal patterns of selection along an environmental gradient in the Great Plains. Evolution 58: 1446-1458.

Euskirchen, E.S., A.D. Mcguire, F.S. Chapin, S. Yi and C.C. Thompson. 2009. Changes in vegetation in northern Alaska under scenarios of climate change 2003-2010: implications for climate feedbacks. Ecol. Appl. 19: 1022-1043.

Ewel, J.J., M.J. Mazzarino and C.W. Berish. 1991. tropical soil fertility changes under monocultures and successional communities of different structure. Ecol. Appl. 1: 289-302.

Falconer, D.S. 1989. Introduction to quantitative genetics. 3rd ed. Longman, New York.

FAO (Food and Agriculture Organization of the United Nations). 2000. Global forest resources assessment. FAO Forestry Paper 140. Rome.

FAO (Food and Agriculture Organization of the United Nations). 2001. Global forest resources assessment 2000. Rome.

FAO (Food and Agriculture Organization of the United Nations). 2006. Global forest resources assessment 2005. Rome.

Farwig, N., C. Braun and K. Boehning-Gaese. 2008. Human disturbance reduces genetic diversity of an endangered tropical tree, Prunus Africana (Rosaceae). Conserv. Genetics 9: 317-326.

Fischlin, A., M. Ayres, D. Karnosky, S. Kellomaki, B. Louman, C. Ong, G.-K. Palttner, H. Santoso and I. Thompson. 2009. Future environmental impacts and vulnerabilities. Pages 53-100 in R. Seppala, A. Buck and P. Katila (eds.), Adaptation of forests and people to climate change: a global assessment report. IUFRO World Series Vol. 22, Helsinki.

Fearnside, P.M. 1999. Biodiversity as an environmental service in Brazil's Amazonian forests: risks, value and conservation. Environ. Conserv. 26: 305–321.

Felzer, B., J. Reilly, J. Melillo, D. Kicklighter, M. Sarofim, C. Wang, R. Prinn and Q. Zhuang. 2005. Future effects of ozone on carbon sequestration and climate change policy using a global biogeochemical model. Climatic Change 73: 345-373.

Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. Pages 617-652 in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.), Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK.

Finn, J., P.D. Erskine and D. Lamb. 2007. Woody species diversity influences productivity and soil nutrient availability in tropical plantations. Oecologia 154: 521-533.

Fischer, J., D.B. Lindenmeyer and A.D. Manning. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. Frontiers Ecol. Envir. 4: 80-86.

Fisher, R.A. 1930. The genetical theory of natural selection. Oxford University Press, Oxford, U.K.

Fitzhebert, E.B., M.J. Struebig, A. Morel, F. Danielson, C.A. Bruhl, P.F. Donald and B. Phalan. 2008. How will oil palm expansion affect biodiversity? Trends Ecol. Evol. 23: 538-545.

Flannigan, M., K. Logan, B. Amior, W. Skinner and B. Stocks. 2005. Future area burned in Canada. Climatic Change 72: 1-16.

Flannigan, M.D., and B.M. Wotton. 2001. Climate, weather and area burned. Pages 335-357 in E.A. Johnson and K Miyanishi, (eds), Forest fires: behavior and ecological effects. Academic Press, New York, USA.

Flannigan, M.D., Y. Bergeron, O. Engelmark and B.M. Wotton. 1998. Future wildfire in circumboreal forests in relation to climate change. Jour. Vege. Sci. 9: 468-476.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson and C.S. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. Ann. Rev. Ecol. Syst. 35: 557-581.

Forrester, D.I, J. Bauhus, A.L. Cowie and J.K. Vanclay. 2006. Mixed species plantations of Eucalyptus with nitrogen-fixing trees: a review. For. Ecol. Manage. 233: 211-230.

Frelich, L.E. and P.B. Reich. 1998. Disturbance severity and threshold responses in the boreal forest. Conserv. Ecol. 2: art. 7.

Fridley, J.D., J.J. Stachowicz, S. Naeem, D.F. Sax, E.W. Seabloom, M.D. Smith, T.J. Stohlgren, D. Tilman and B. Von Holle. 2007. The invasion paradox: reconciling pattern and process in species invasions. Ecology 88: 3-17.

Fuchs, E.J., J.A. Lobo and M. Quesada. 2003. Effects of forest fragmentation and flowering phenology on the reproductive success and mating patterns of the tropical dry forest tree Pachira quinata. Cons. Biol. 17:149-157.

Fyllas, N.M., O.L. Phillips, W.E. Kunin, Y.G. Matsinos and A.I. Troumbis. 2007. Development and parameterization of a general forest gap dynamics simulator for the north-eastern Mediterranean Basin (Greek Forest Species). Ecol. Model. 204: 439-456.

Gadgil, P.D. and J. Bain. 1999. Vulnerability of planted forests to biotic and abiotic diseases. New Forests 17: 227-238.

Gauthier, S., M.-A. Vaillancourt, A. Leduc, L. De Grandpré, D. Kneeshaw, H. Morin, P. Drapeau and Y. Bergeron (eds.). 2009. Ecosystem Management in the boreal forest. Presses de l'Université du Québec, Québec, Can.

Geber, M.A. and T.E. Dawson. 1993. Evolutionary responses of plants to global change. Pages 179-197 in P.M. Kareiva, J.G. Kingsolver and R.B. Huey (eds.), Biotic interactions and global change. Sinauer Assoc., Sunderland, MA.

Geng, Q., C. Lian, S. Goto, J. Tao, M. Kimura, M.D. Islam and T. Hogetsu. 2008. Mating system, pollen and propagule dispersal and spatial genetic structure in a high-density population of the mangrove tree Kandelia cande. Molecular Ecol. 17: 4724-4739.

Gentry, A.H. 1992. Tropical forest biodiversity – distributional patterns and their conservational significance. Oikos 63: 19–28.

Gerwing, J.J. 2002. Degradation of forests through logging and fire in the eastern Brazilian Amazon. For. Ecol. Manage. 157: 131-141.

Gholz, H.L., R..O. Teskey and K.C. Ewel. 1990. Dynamics of the water resource in relation to forest productivity. For. Ecol. Manage. 29/30: 1-18.
Gibson, I.A.S. and T.M. Jones. 1977. Monoculture as the origin of major pests and diseases. Pages 139-161 in J.M. Cherrett and G.R. Sugar (eds.), origins of pest, parasite, disease and weed problems. Blackwell, Oxford, UK.

Gillett, N.P., A.J. Weaver, F.W. Zwiers and M.D. Flannigan. 2004. Detecting the effect of climate change on Canadian forest fires. Geophysical Res. Letters. 31(18).

Girard, F., S. Payette, and R. Gagnon. 2008. Rapid expansion of lichen woodlands within the closed crown boreal forest zone over the past 50 years caused by stand disturbances in eastern Canada. Jour. Biogeogr. 35: 529-537.

Gregorius, H.R. 1996. The contribution of the genetics of populations to ecosystem stability. Silvae Genetica 45: 267-271.

Golley, F.B. 1983. Nutrient cycling and nutrient conservation. Pages 137-156 in F.B. Golley (ed.), Ecosystems of the World 14A: Tropical rainforest ecosystems: Structure and function. Elsevier, Amsterdam.

Gruber, N., P. Friedlingstein, C.B. Field, R. Valentini, M. Heimann, J.E. Richey, P.R. Lankao, E.D. Schulze and C.T.A. Chen. 2004. The vulnerability of the carbon cycle in the 21st century: an assessment of carbon-climate-human interactions. Pages 46-76 in C.B. Field and M.R. Raupach (eds.), The global carbon cycle: integrating humans, climate, and the natural world. Island Press, Washington, DC.

Gunderson, L. 2000. Ecological resilience: in theory and application. Ann. Rev. Ecol. Syst. 31: 425-439.

Hall, P., S. Walker and K. Bawa. 1996. Effect of forest fragmentation on genetic diversity and mating system in a tropical tree, Pithecellobium elegans. Cons. Biol. 10: 757-768.

Halpin, P.N. 1997. Global climate change and natural-area protection: Management responses and research directions. Ecol. Appl. 7: 828-843.

Hamrick, J.L. and M.J. Godt. 1990. Allozyme diversity in plant species. Pages 43-63 in A.H.D. Brown, M.T. Clegg, A.L. Kahler and B.S. Weir (eds.), Plant population genetics, breeding and genetic resources. Sinauer Associates, Sunderland, MA.

Hamilton, J.G., E.H. DeLucia, K. George, S.L. Naidu, A.C. Finzi and W.H. Schlesinger. 2002. Forest carbon balance under elevated CO2. Oecologia 131:250-260.

Hanson P.J. and J.F. Weltzin. 2000. Drought disturbance from climate change: response of United States forests. Sci. of the Total Env. 262:205-220.

Hatoum, M and M. Souza. 2007. The Amazon rainforest: the last frontier on Earth.

Hättenschwiler, S. 2005. Effects of tree species diversity in litter quality and decomposition. Pages 148-164 in M. Sherer-Lorenzen, C. Körner and E.D. Schulze. (eds.), Ecological Studies 176, Forest diversity and function: temperate and boreal systems. Springer-Verlag, Berlin.

Healy, C., N.J. Gotelli and C. Potvin. 2008. Partitioning the effects of biodiversity and environmental heterogeneity for productivity and mortality in a tropical tree plantation. Jour. Ecol. 96: 908-913.

Heath, J., E. Ayres, M. Possell, R.D. Bardgett, H.I.J. Black, H. Grant, P. ineson and G. Kerstiens. 2005. Rising atmospheric CO2 reduces sequestration of root-derived carbon. Science 309: 1711-1713.

Hector, A. 2002. Biodiversity and the functioning of grassland ecosystem: multi-site comparisons. Pages 71-95 in A. Kinzig, D. Tilman and S. Pacala (eds.), Functional consequences of biodiversity: experimental progress and theoretical extensions. Princeton University Press, Princeton, NJ, USA.

Hector, A., B. Schmid, C. Beierkuhnlein, M.C. Caldeira, M. Diemer, P.G. Dimitrakopoulos, J.A. Finn, H. Freitas, P.S. Giller, J. Good, R. Harris, P. Högberg, K. Huss-Danell, J. Joshi, A. Jumpponen, C. Körner, P.W. Leadley, M. Loreau, A. Minns, C. P. H. Mulder, G. O'Donovan, S.J. Otway, J.S. Pereira, A. Prinz, D.J. Read, M. Scherer-Lorenzen, E.-D. Schulze, A.-S. D. Siamantziouras, E.M. Spehn, A.C. Terry, A.Y. Troumbis, F.I. Woodward, S. Yachi and J.H. Lawton. 1999. Plant diversity and productivity experiments in European grasslands. Science 286: 1123-1127.

Held, I.M. and B.J. Soden. 2006. Robust Responses of the Hydrological Cycle to Global Warming. Jour. Climate 19: 5686-5699

Helms J.A. (Ed). 1998. The Dictionary of Forestry. The Society of American Foresters. 210 pages.

Hill, R.S., D. M. Harwood and P. N. Webb. 1996. Nothofagus beardmorensis (Nothofagaceae), a new species based on leaves from the Pliocene Sirius Group, Transantarctic Mountains, Antarctica. Rev. Palaeobotany and Palynology
94:11-24.

Higgins, S.I., R. Nathan and M.L. Cain. 2003. Are long-distance dispersal events in plants usually caused by nonstandard means of dispersal? Ecology 84: 1945-1956.

Higgins, S. I. and D.M. Richardson. 1999. Predicting plant migration rates in a changing world: the role of long-distance dispersal. Amer. Natur. 153: 464-475.

Hobb, R. 2009. Woodland restoration in Scotland: Ecology, history, culture, economics, politics and change. Jour. Environ. Manage. (In Press).

Hobbs, R. J. 2003. How fire regimes interact with other forms of ecosystem disturbance and modification. Pages 421-436 in Fire in ecosystems of south-west Western Australia: impacts and management. Symposium proceedings (Volume I), Perth, Australia, 16-18 April 2002. Backhuys Publishers, Leiden.

Holling, C.S. 1973. Resilience and stability of ecosystems. Ann. Rev. Ecol. Syst. 4: 1-23.

Hooper, D.U., F.S. Chapin, J.J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J.H. Lawton, D.M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setala, A.J. Symstad, J. Vandermeer and D.A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecol. Monogr. 75: 3-35.

Hooper, D.U. and J.S. Dukes. 2004. Over-yielding among plant functional groups in a long-term experiment. Ecol. Letters: 7: 95-105.

Hooper, D.U., M. Solan, A. Symstad, S. Diaz, M.O. Gessner, N. Buchmann, V. Desgrange, P. Grime, F. Hulot, F. Mermillod-Blondin, J. Roy, E. Spehn and L. van Peter. 2002. Species diversity, functional diversity and ecosystem functioning. Pages 195-208 in M. Loreau, S. Naeem and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Pres, Oxford, UK.

Hooper D.U. and P.M. Vitousek. 1997. The effects of plant composition and diversity on ecosystem processes. Science 277: 1302-1305.

Hooper, D.U., D. Hawksworth and S. Dhillion. 1995. Microbial diversity and ecosystem processes. Pages 433-443 in Global biodiversity assessment. UNEP. Cambridge Univ. Press, Cambridge, UK.

Hopper, S. and P. Gioia. 2004. The Southwest Australian Floristic Region: evolution and conservation of a global hot spot of biodiversity. Ann. Rev. Evol. Syst. 35: 623-50.

Hubbell, S.P. (2005). Large-scale diversity and species-area relationships in tropical tree communities under the neutral theory. Pages 41-77 in E. Bermingham, C.W. Dick and C. Moritz (eds.), Tropical Forests: past, present and future. The University of Chicago Press, Chicago, IL, USA.

Hughes, J.B., A.R. Ives and J. Norberg. 2002. Do species interactions buffer environmental variation (in theory)? Pages 92-101 in M. Loreau, S. Naeem, and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Press, Oxford, UK.

Huntley, B. 1991. How plants respond to climate change – migration rates, individualism, and the consequences for plant communities. Ann. Bot. (Lond.) 67: 15-22.

Huntley, B. and H.J.B. Birks. 1983. An atlas of past and present pollen for Europe 0-13,000 years ago. Cambridge University Press, Cambridge.

Huntley, B. and T. Webb. 1988. Vegetation history. Kluwer Academic Press, Dordrecht.

Huston, M.A. 1997. Hidden treatments in ecological experiments: re-evaluating the ecosystem function of biodiversity. Oecologia 110: 449-460.

Hutchinson, G.E. 1957. Concluding remarks. Cold Spring Harbor Symposium on Quantitative Biology 22: 415-427

Innes, J., L.A. Joyce, S. Kellomaki, B. Loumann, A. Ogden, J. Parrotta and I. Thompson. 2009. Management for adaptation. Pages 135-169 in R. Seppala, A. Buck, and P. Katila (eds.), Adaptation of forests and people to climate change: a global assessment report. IUFRO World Series Vol. 22.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Online at: http://www.ipcc.ch/ipccreports/ar4-wg1.htm

Ingham, R.E., J.A. Trofymow, E.R. Ingham and D.C. Coleman. 1985. Interactions of bacteria, fungi, and their nematode grazers: effects on nutrient cycling and plant growth. Ecol. Monogr. 55: 119-140.

Ives, A.R., K. Gross and J.L. Klug. 1999. Stability and variability in competitive communities. Science 286: 542-544.

Jacobs, D.F. and L.R. Severeid. 2003. Dominance of interplanted American chestnut (Castanea dentata) in southwestern Wisconsin, USA. For. Ecol. Manage. 191: 111-120.

Jactel, H., E. Brockerhoff and P. Duelli. 2005. A test of the biodiversity-stability theory: meta-analysis of tree species diversity effects on insect pest infestations, and re-examination of responsible factors. Pages 235-262 in M. Scherer-Lorenzen, C. Körner and E.-D. Schulze (eds.), Forest diversity and function: temperate and boreal systems. Springer, Berlin.

Johnson, E.A. 1992. Fire and vegetation dynamics: studies from the North American boreal forest. Cambridge Univ. Press, Cambridge, UK.

Jones, H.E., N. McNamara and W.L. Mason. 2005. Functioning of mixed-species stands: evidence from a long-term forest experiment. Pages 111-130 in M. Scherer-Lorenzen, C. Körner and E.-D. Schulze (eds.). Forest diversity and function: temperate and boreal systems. Springer, Berlin.

Jump, A.S. and J. Penuelas. 2005. Running to stand still: adaptation and the response of plants to rapid climate change. Ecol. Letters 8: 1010-1020.

Karieva, P. 1983. Influence of vegetation texture on herbivore populations: resource concentration and herbivore movement. Pages 259-289 in R.F. Denno and M.S. McClure (eds.), Variable plants and herbivores in natural and managed systems. Academic Press, NY, USA.

Kashian, D.M., W.H. Romme, D.B. Tinker, M.G. Turner and M.G. Ryan. 2006. Carbon storage on landscapes with stand replacing fires. Bioscience 56: 598-606.

Kelty, M.J. 2006. The role of species mixtures in plantation forestry. Forest Ecol. and Manage. 233: 195-204.

Keeley, J.E., D. Lubin and C.J. Fotheringham. 2003. Fire and grazing impacts on plant diversity and alien plant invasions in southern Sierra Nevada. Ecol. Applic. 13: 1355-1374.

Keith, H., B.G. Mackey and D.B. Lindenmayer. 2009. Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. Proc. Nat. Acad. Sci. 106: 11625-11640.

Kennedy, A.D. 1997. Bridging the gap between general circulation model (GCM) output and biological microenvironments. Int. Jour. Biometeorol. 40: 119-122.

Kennedy, T.A., S. Naeem, K.M. Howe, J.M.H. Knops, D. Tilman and P. Reich. 2002. Biodiversity as a barrier to ecological invasion. Nature 417: 636-638.

Kellomaki, S., H. Peltola, T. Nuutinen, K.T. Korhonen and H. Strandman. 2008. Sensitivity of managed boreal forests in Finland to climate change, with implications for adaptive management. Phil. Trans. Roy. Soc. B: 363: 2341-2351.

Kinzig, A.P., S.W. Pacala and D. Tilman, (eds.). 2001. The functional consequences of biodiversity: empirical progress and theoretical extensions. Princeton Univ. Press, Princeton, NJ, USA.

Kirby, K.R. and C. Potvin. 2007. Variation in carbon storage among tree species: implications for the management of a small scale carbon sink project. For. Ecol. Manage. 246: 208-221.

Kloeppel, B.D., B.D. Clinton, J.M. Vose and A.R. Cooper. 2003. Drought impacts on tree growth and mortality of southern Appalachian forests. Pages 43-55 in D. Greenland, D. Goodin and R. Smith, (eds.), Climate variability and ecosystem response at long-term ecological research sites. Oxford University Press, New York.

Krawchuk, M.A., S.G. Cumming and M. Flannigan. 2009. Predicted changes in fire weather suggest increases in lightning fire initiation and future area burned in the mixedwood boreal forest. Climatic Change 92: 83-98.

Kröpelin, S., D. Verschuren, A.-M. Lézine, H. Eggermont, C. Cocquyt, P. Francus, J.-P. Cazet, M. Fagot, B. Rumes, J.M. Russell, F. Darius, D.J. Conley, M. Schuster, H. von Suchodoletz, and D. R. Engstrom. 2008 Climate-Driven Ecosystem Succession in the Sahara: The Past 6000 Years. Science: 320:765- 768.

Kull, O., A.Sober, M.D. Coleman, R.E. Dickson, J.G. Isebrands, Z. Gagnon and D.F. Karnosky. 1996. Photosynthetic responses of aspen clones to simultaneous exposure of ozone and CO2. Can. Jour. For. Res. 26: 639-648.

Kurz, W.A., G. Stinson and G. Rampley. 2008. Could increased boreal forest ecosystem productivity offset carbon losses from increased disturbances. Phil. Trans. Roy. Soc. B 363: 2285-2299.

Lamb, D., P.D. Erskine and J.A. Parrotta. 2005. Restoration of degraded tropical landscapes. Science 310: 1628-1632.

Laurance, W.F. and G.B. Williamson. 2001. Positive feedbacks among forest fragmentation, drought, and climate change in the Amazon. Conserv. Biol. 15: 1529–1535.

Laurance, W.F. 1998. A crisis in the making: responses of Amazonian forests to land use and climate change. Trends in Ecol. Evol. 13: 411-415.

Law, B.E. Falge, E.; Gu, L.; Baldocchi, D. D.; Bakwin, P.; Berbigier, P.; Davis, K.; Dolman, A. J.; Falk, M.; Fuentes, J. D.; Goldstein, A.; Granier, A.; Grelle, A.; Hollinger, D.; Janssens, I. A.; Jarvis, P.; Jensen, N. O.; Katul, G.; Mahli, Y.; Matteucci, G.; Meyers, T.; Monson, R.; Munger, W.; Oechel, W.; Olson, R.; Pilegaard, K. (et al). 2002. Environmental controls over carbon dioxide and water vapour exchange of terrestrial vegetation. Agric For Meteor 113: 97-120.

Ledig, F.T. and J.H. Kitzmiller. 1992. Genetic strategies for reforestation in the face of global climate change. For. Ecol. Manage. 50: 153-169.

Lehman, C.L. and D. Tilman. 2000. Biodiversity, stability, and productivity in competitive communities. Amer. Natur. 156: 534-552.

Leigh, E.G., P. Davidar, C.W. Dick, J.P. Puyravaud, J. Terborgh, H. Ter Steege and S.J. Wright. 2004. Why do some tropical forests have so many species of trees? Biotropica 36: 447–473.

Levine, J.M. 2000. Species diversity and biological invasions: relating local processes to communities. Science 288: 852-854.

Levine, J.M., T. Kennedy and S. Naeem. 2002. Neighbourhood effects of species diversity on biological invasions and their relationship to community patterns. Pages 114-125 in M. Loreau, S. Naeem and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Pres, Oxford, UK.

Lewis, S.L. 2006. Tropical forests and the changing earth system. Phil. Trans. Roy. Soc. Lond. B Biol. Sci.. 36: 195–210.

Lewis, S. L., G. Lopez-Gonzalez, B. Sonké, K. Affum-Baffoe, T.R. Baker, L.O. Ojo, O.L. Phillips, J.M. Reitsma, L. White, J.A. Comiskey, K. Djuikouo, C.E.N. Ewango T.R. Feldpausch, A.C. Hamilton, M. Gloor, T. Hart, A. Hladik, J. Lloyd, J.C. Lovett, J.R. Makana, Y. Malhi, F.M. Mbago, H.J. Ndangalasi, J. Peacock, K.S.H. Peh, K. D. Sheil, T. Sunderland, M.D. Swaine, J. Taplin, D. Taylor, S.C. Thomas, R. Votere and W. Hannsjorg. 2009. Increasing carbon storage in intact African tropical forests. Nature 457: 1003-1006.

Li, C. 2000. Fire regimes and their simulation with reference to Ontario. Pages 115-140 in A. Perera, D. Euler and I. Thompson (eds.), Ecology of a managed terrestrial landscape: patterns and processes of forest landscapes in Ontario. UBC Press, Vancouver, Canada.

Liao ChengZhang, Peng, Rong Hao, Luo Yiqi, Zhou, X. H., Wu, X. W., Fang ChangMing, Chen JiaKuan, and Li Bo. 2008. Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. New Phytologist 177: 706-714.

Liiri, M., H. Setala, J. Haimi, T. Pennanen and H. Fritze. 2002. Relationship between soil microarthropod species diversity and plant growth does not change when the system is disturbed. Oikos 96: 137-149.

Lindroth, A., F. Lagergren, A. Grelle, L. Klemedtsson, O. Langvall, P. Weslien and J. Tuulik. 2009. Storms can cause Europe-wide reduction in forest carbon sink. Glob. Change Biol. 15: 346-355.

Little, R.L., D.L. Peterson and L.L. Conquest. 1994. Regeneration of subalpine fir (Abies lasiocarpa) following fire: effects of climate and other factors. Can. Jour. For. Res. 24: 934-944.

Liu, K.-B. 1990. Holocene paleoecology of the boreal forest and the Great-Lakes St. Lawrence forest in northern Ontario. Ecol. Monogr. 60: 179-212.

Longpré, M.H., Y. Bergeron, D Paré and M. Béland. 1994. Effect of companion species on the growth of jack pine. Can. Jour. For. Res. 24: 1846-1853.

Lonsdale, W.M. 1999. Global patterns of plant invasions. Ecology 80: 1522-1536.

Loreau, M. 2000. Biodiversity and ecosystem function: recent theoretical advances. Oikos 91: 3-17.

Loreau, M., A. Downing, M. Emmerson, A. Gonzalez, J. Hughes, P. Inchausti, J. Joshi, J. Norberg and O. Sala. 2002. A new look at the relationship between diversity and stability. Pages 79-91 in M. Loreau, S. Naeem and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Pres, Oxford, UK.

Loreau, M, S. Naeem, P. Inchausti, J. Bengtsson, J.P. Grime, A. Hector, D.U. Hooper, M.A. Huston, D. Raffaelli, B. Schmid, D. Tilman and D.A. Wardle. 2001. Biodiversity and ecosystem functioning: current knowledge and future challenges. Science 294: 804-808.

Lu, J., G. Sun, D.M. Amatya and S.G. McNulty. 2005. A Comparison of Six Potential Evapotranspiration methods for regional use in the Southeastern United States. Jour. Amer. Water Resourc. Assoc. 41: 621-633.

Lukac, M., A. Lagomarsino, M.C. Moscatelli, P. De Angelis, M.F. Cotrufo and D.L. Godbold. 2009. Forest soil carbon cycle under elevated CO2 – a case of increased throughput? Forestry 82: 75-86.

Luyssaert, S., E.-D. Schulze, A. Börner, A. Knohl, D. Hessenmöller, B.E. Law, P. Ciais and J. Grace. 2008. Old-growth forests as global carbon sinks. Nature 455: 213-215.

Lynch, M. and R. Lande. 1993. Evolution and extinction in response to environmental change. Pages 234-250 in P.M. Kareiva, J.G. Kingsolver and R.B. Huey (eds.), Biotic interactions and global change. Sinauer Assoc., Sunderland, MA, USA.

Macdonald, I.A., L.L. Loope, M.B. Usher and O. Hamann. 1989. Wildlife conservation and the invasion of nature reserves by introduced species: a global perspective. Pages 215-255 in J.A. Drake, H.A. Mooney, F. di Castro, F. J. Kruger, M. Rejmanek and M. Williamson (eds.), Biological invasion: a global perspective. J. Wiley and Sons, Hoboken, NJ, USA.

Mackey, B.G. 1994. Predicting the spatial distribution of rainforest structural characteristics. Jour. Vege. Sci. 5: 43-54.

Mackey, B.G., D.B. Lindenmayer, A.M. Gill, A.M. McCarthy and J.A. Lindesay. 2002. Wildlife, fire and future climate: a forest ecosystem analysis. CSIRO Publishing.

Mackey, G.B., J.E.M. Watson G and Hope. 2008. Climate change, biodiversity conservation, and the role of protected areas: an Australian perspective. Biodiversity 9: 11-18.

Malcolm, J.R., A. Markham, R.P. Neilson, and M. Garaci. 2002. Estimated migration rates under scenarios of global climate change. Jour. Biogeogr. 29: 835-849.

Malhi, Y., L.E.O.C. Aragão, D. Galbraith, C. Huntingford, R. Fisher, P. Zelazowski, S. Sitch, C. McSweeney and P. Meir. 2009. Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. Proc. Nat. Acad. Sci. USA: online at: http://www.pnas.org/content/early/2009/02/12/0804619106.full.pdf+html?sid=3978dfb7-646f-4d85-a9b8-e373ca183a9c

Malhi, Y., J.T. Roberts, R.A. Betts, T.J. Killeen, W.H. Li and C.A. Nobre. 2008. Climate change, deforestation, and the fate of the Amazon. Science 319: 169-172.

Margules, C. R. and R.L. Pressey. 2000. Systematic conservation planning. Nature 405: 243–253.

Marks, P.L. and F.H. Bormann. 1972. Revegetation following forest cutting: mechanisms for return to steady-state nutrient cycling. Science 176: 914-915.

Mayer, A.L. and M. Reitkerk. 2004. The dynamic regime concept for ecosystem management and restoration. Bioscience 54: 1013-1020.

McCann, K.S. 2000. The diversity-stability debate. Nature 405: 228-233.

McCullough, D.G., R.A. Werner and D. Neumann. 1998. Fire and insects in northern and boreal forest ecosystems of North America. Ann. Rev. Entomol. 43: 107-127.

McLaughlin, J.A. 2001. Impact of Armillaria root disease on succession in red pine plantations in southern Ontario. For. Chron. 77: 519-524.

McNulty S.G. and W.T. Swank. 1995. Relationships between wood carbon isotope discrimination, annual basal area growth, and growing season soil water potential in a mature Pinus strobus forest. Ecology 76:1581-1586.

McNulty, S.G. and J. Boggs. 2009. A conceptual framework: redefining forest soil's critical acid loads under a changing climate. Environ. Pollution. In Press.

Melillo, J.M., J.D. Aber and J.F. Muratore. 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. Ecology 63:621-626.

Millar, C.I., N.L. Stephenson and S.L. Stephens. 2007. Climate change and forests of the future: Managing in the face of uncertainty. Ecol. Applic. 17: 2145-2151.

Miles, L., A. Grainger and O. Phillips. 2004. The impact of global climate change on tropical forest biodiversity in Amazonia. Global Ecol. Biogeogr. 13: 553–565.

Milne, R and M. Van Oijen. 2005. A comparison of two modeling studies of environmental effects on forest carbon stocks across Europe. Annals For. Sci. 62: 911-923.

Mitton, J. B. and M.C. Grant. 1996. Genetic variation and the natural history of quaking aspen. BioScience 46: 25-31.

Moffat, A.S. 1996. Biodiversity as a boon to ecosystems, not species. Science 271: 1497.

Montagnini, F. 2000. Accumulation in above-ground biomass and soil storage of mineral nutrients in pure and mixed plantations in a humid tropical lowland. For. Ecol. Manage. 134: 257-270.

Morales, P., T. Hickler, D.P. Rowell, B. Smith and M.T. Sykes. 2007. Changes in European ecosystem productivity and carbon balance driven by regional climate model output. Glob. Change Biol. 13: 108–122.

Mosseler, A., J.E. Major, O.P. Rajora, and K.H. Kim. 2004. Reproductive and genetic characteristics of rare, disjunct pitch pine populations at the northern limits of its range in Canada. Conserv. Genetics 5: 571-583.

Mosseler, A., K.N. Egger and G.A. Hughes. 1992. Low levels of genetic diversity in red pine confirmed by random amplified polymorphic DNA markers. Can. Jour. For. Res. 22: 1332 1337.

Mosseler, A., D. Innes and B. Roberts. 1991. Lack of allozymic variation in disjunct Newfoundland populations of red pine (Pinus resinosa Ait.). Can. Jour. For. Res. 21: 525 528.

Muller-Starck, G., Ziehe, M., and Schubert, R. 2005. Genetic diversity parameters associated with viability selection , reproductive efficiency, and growth in forest tree species. Pages.87-108 in M. Scherer-Lorenzen, C. Korner and E.-D. Schulze, (eds), Forest diversity and function: temperate boreal systems. Springer-Verlag, Berlin.

Munger J.W., W.C. Oechel, U.K.T. Paw, H.P. Schmid, R.L.Scott, G. Sun, A.E. Suyker and M.S. Torn. 2008. Estimation of net ecosystem carbon exchange for the conterminous United States by combining MODIS and AmeriFlux data. Agricultural and Forest Meteorology 148: 1827-1847.

Murphy, M., T. Balser, N. Buchmann, V. Hahn and C. Potvin. 2008. Linking tree biodiversity to belowground process in a young tropical plantation: Impacts on soil CO2 flux. For. Ecol. Manage. 255: 2577-2588.

Naeem, S. 1998. Species redundancy and ecosystem reliability. Conserv. Biol. 12: 39-45.

Naeem, S., M. Loreau and P. Inchausti. 2002. Biodiversity and ecosystem functioning: the emergence of a synthetic ecological framework. Pages 3-11 in M. Loreau, S. Naeem and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Pres, Oxford, UK.

Naeem, S., I.J. Thompson, S.P. Lawler, J.H. Lawton and R.M. Woodfin. 1995. Empirical evidence that declining species diversity may alter the performance of terrestrial ecosystems. Trans. Roy. Soc. Lond. B.: 347: 249-262.

Nason, J.D. and J.L. Hamrick. 1997. Reproductive and genetic consequences of forest fragmentation: two case studies of neotropical canopy trees. Jour. Heredity 88: 264-276.

Nemani, R., M. White, P. Thortone, K. Nishida, S. Reddy, J. Jenkins and S. Running. 2002. Recent trends in hydrologic balance have enhanced the terrestrial carbon sink in the United States. Geophys. Res. Lett. 29: 10.1029/2002GL014867.

Ni, J. 2002. Effects of climate change on carbon storage in boreal forests of China: a local perspective. Climatic Change 55: 61-75.

Norden, N., R.L. Chazdon, A. Chao, Y.-H. Jiang and B. Vilchez-Alvarado. 2009. Resilience of tropical rainforests: tree community reassembly in secondary forests. Ecol. Letters 12: 385-394.

Nussey, D.H., E. Postma, P. Gienapp and M.E. Visser. 2005. Selection on heritable phenotypic plasticity in a wild bird population. Science 310: 304-306.

O'Connell, L.M., A. Mosseler and O.P. Rajora. 2007. Extensive long-distance pollen dispersal in a fragmented landscape maintains genetic diversity in white spruce. Jour. Heredity 98: 640-645.

Olesen, J.E., T.R. Carter, C.H. Az-Ambrona, S. Fronzek, T. Heidmann, T. Hickler, T. Holt, M. Quemeda, M. Ruiz-Ramos, G.H. Rubeak, F. Sau, B. Smith and M.T. Sykes. 2007. Uncertainties in projected impacts of climate change on European agriculture and terrestrial ecosystems. Climatic Change 81: 123-143.

Ough, K. 2001. Regeneration of wet forest flora a decade after clear-felling or wildfire - is there a difference? Aust. Jour. Bot. 49: 645-664.

Parrotta, J.A. 1999. Productivity, nutrient cycling, and succession in single- and mixed-species plantations of Casuarina equisetifolia, Eucalyptus robusta, and Leucaena leucocephala in Puerto Rico. For. Ecol. Manage. 124: 45-77.

Pautasso, M., O. Holdenreider and J. Stenlid. 2005. Susceptibility to fungal pathogens of forests differing in tree diversity. Pages 263-290 in M. Scherer-Lorenzen, C. Körner and E.-D. Schulze (eds.), Forest diversity and function: temperate and boreal systems. Springer, Berlin.

Payette, S. 1992. Fire as a controlling process in North American boreal forest. Pages 144-169 in H.H. Shugart, R. Leemans and G.B. Bonan, (eds.), A systems analysis of the global boreal forest. Cambridge Univ. Press, Cambridge, UK.

Pearce, D. and D. Moran. 1994. The economic value of biodiversity. Earthscan, London.

Pease, C.M., R. Lande and J.J. Bull. 1989. A model of population growth, dispersal and evolution in a changing environment. Ecology 70: 1657-1664.

Perera, A.H., L.J. Buse and M.G. Weber (eds.). 2004. Emulating natural forest landscape disturbances. Colombia Univ. Press, NY, USA.

Peterson, G., C.R. Allen and C.S. Holling. 1998. Ecological resilience, biodiversity and scale. Ecosystems 1: 6-18.

Petit, B. and F. Montagnini. 2004. Growth equations and rotation ages of ten native tree species in mixed and pure plantations in the humid neotropics. For. Ecol. Manage. 199: 243-257.

Petit, R.J., R. Bialozyt, P. Ganier-Géré and A. Hampe. 2004. Ecology and genetics of tree invasions: from recent introductions to Quaternary migrations. For. Ecol. Manage. 197: 117-137.

Phillips, O.L. et al. 2009. Drought sensitivity of the Amazon rainforest. Science 323: 1344-1347.

Phillips, O.L., S.L. Lewis, T.R. Baker, K.J. Chao and N. Higuchi. 2008. The changing Amazon forest. Phil. Trans. R. Soc. Lond. B 363: 1819–1827.

Phillips, O.L., S. Rose, A.M. Mendoza and P.N. Vargas. 2006. Resilience of southwestern Amazon forests to anthropogenic edge effects. Conserv. Biol. 20: 1698-1710.

Phillips, O.L., Y. Malhi, N. Higuchi, W.F. Laurance, P.V. Núñez, R.M. Vásquez, S.G. Laurance, L.V. Ferreira, M. Stern, S. Brown and J. Grace. 1998. Changes in the Carbon Balance of Tropical Forests: Evidence from Long-Term Plots. Science 282: 439-442.

Phillips, O.L. 1997. The changing ecology of tropical forests. Biodiversity and Cons. 6: 291-311.

Phillips, O. L. and A.H. Gentry. 1994. Increasing turnover through time in tropical forests.: Science 263:

954-958.

Phillips, O.L., A.H. Gentry, P. Hall, S.A. Sawyer and R. Vasquez. 1994. Dynamics and species richness of tropical rain forests. Proc. Nat. Acad. Sci. USA 91: 2805-2809.

Pimm, S.L. 1991. The balance of nature?: Ecological issues in the conservation of species and communities. Univ. Chicago Press, Chicago, USA.

Pimm,S.L. 1984. The complexity and stability of ecosystems. Nature 307:321–6.

Piotto, D. 2008. A meta-analysis comparing tree growth in monocultures and mixed plantations. For. Ecol. Manage. 255: 781-786.

Pitelka, L.F. 1988. Evolutionary responses of plants to anthropogenic pollutants. Trends Ecol. Evol. 3: 233-236.

Pitman, A.J., G.T. Narisma and J. McAneney. 2007. The impact of climate change on the risk of forest and grassland fires in Australia. Clim. Change 84: 383–401.

Porter, K.B., B. Hemens and D.A. MacLean. 2004. Using insect patterns of disturbance in northern New Brunswick to inform forest management. Pages 135-145 in A.H. Perera, L.J. Buse and M.G. Weber (eds.), Emulating natural forest landscape disturbances. Colombia Univ. Press, NY, USA.

Possingham, H.P. and K.A. Wilson. 2005. Turning up the heat on hotspots. Nature 436: 919–920.

Post, M.W. and S.L. Pimm. 1983. Community assembly and food web stability. Math. Biosciences 64: 169-192.

Pretzsch, H. 2005. Diversity and productivity in forests: evidence from long-term experimental plots. Pages 41-64 in M. Scherer-Lorenzen, C. Körner and E.-D. Schulze (eds.), Forest diversity and function: temperate and boreal systems. Springer, Berlin.

Price, D.T. and D. Scott. 2006. The Vincera project: vulnerability and impacts of North American forests to climate change: ecosystem responses and adaptation. Online: http://www.fes.uwaterloo.ca/research/vincera/ and ftp://ftp.nofc.cfs.nrcan.gc.ca/pub/climate/dprice/vincera_finrep_20060601.pdf

Price, D.T., C.H. Peng, M.J. Apps and D.H. Halliwell. 1999. Simulating effects of climate change on boreal ecosystem carbon pools in central Canada. Jour. Biogeogr. 26: 1237-1248.

Prokopev, M.N. 1976. Mixed plantings of pine and spruce. Lesnoe Khozyaistvo 5: 37-41 (Engl. Transl.)

Rajora, O.P., A. Mosseler and J.E. Major. 2002. Mating system and reproductive fitness traits of eastern white pine (Pinus strobus) in large, central versus small, isolated, marginal populations. Can. Jour. Bot. 80: 1173-1184.

Ravindranath, N.H. and M. Ostwald. 2008. Carbon inventory methods handbook for greenhouse gas inventory, carbon mitigation and roundwood production projects. Advances in Global Change Research. Springer-Verlag, Berlin.

Reinhart, K.O., E. Greene and R.M. Callaway, R. M. 2005. Effects of Acer platanoides invasion on understory plant communities and tree regeneration in the northern Rocky Mountains: A review. Ecography: 573-582.

Reusch, T.B.H., A. Ehler, A. Hammerli and B. Worm. 2005. Ecosystem recovery after climatic extremes enhanced by genetic diversity. Proc. Natl. Acad. Sci., USA 102: 2826-2831.

Richardson, D.M. 1998. Forestry trees as invasive aliens. Cons. Biol.12: 18-26.

Ricklefs R.E. 2001. The Economy of Nature (5th ed). W.H. Freeman Publisher 500 p.

Reuveny, R. and C.S. Decker. 2000. Easter Island: historical anecdote or warning for the future? Ecol. Econ. 35: 271-287.

Ritchie, J.C. and G.M. MacDonald. 1986. The patterns of post-glacial spread of white spruce. Jour. Biogeography 13: 527-540.

Richardson, D.M. and B.W. van Wilgen. 2000. Invasive alien plants in South Africa: how well do we understand the ecological impacts? South African Jour. Sci.. 100: 45-52.

Root, R.B. 1973. Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards. Ecol. Monogr. 43: 94-125.

Roukolainen, K., H. Tuomisto and R. Kalliola. 2005. Landscape heterogeneity and species diversity in Amazonia. Pages 251-270 in E. Bermingham, C.W. Dick and C. Moritz (eds.), Tropical Forests: past, present and future. The University of Chicago Press, Chicago, IL, USA.

Roxburgh, S.H., B.G. Mackey, C. Dean, L. Randall, A. Lee and J. Austin. 2006. Organic carbon partitioning in soil and litter in subtropical woodlands and open forests: a case study from the Brigalow Belt, Queensland. The Rangeland Jour. 28: 115–125.

Roxburgh, S.H., S.W. Wood, B.G. Mackey, G. Woldendorp and P. Gibbons. 2006. Assessing the carbon sequestration potential of managed forests: A case study from temperate Australia. Jour. Appl. Ecol. 43: 1149-1159

Rull, V. and T. Vegas-Vilarrubia. 2006. Unexpected biodiversity loss under global warming in the neotropical Guayana highlands: a preliminary appraisal. Global Change Biol. 12: 1-9

Sakai, A. F.W. Allendorf, J.S. Holt, D.M. Lodge, J. Molofsky, K.A. With, S. Baughman, R.J. Cabin, J.E. Cohen, N.C. Ellstrand, D.E. McCauley, P. O'Neil, I.M. Parker, J.N. Thompson and S.G. Weller. 2001. The population biology of invasive species. Ann. Rev. Ecol. Syst. 32: 305-332.

Schaberg, P.G., D.H. DeHayes, G.J., Hawley and S.E. Nijensohn. 2008. Anthropogenic alterations of genetic diversity within tree populations: Implications for forest ecosystem resilience. For. Ecol. Manage. 256: 855-862.

Scheffer, M. and S.R. Carpenter. 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. Trends Ecol. Evol. 18: 648-656.

Schelhaas, M. J., G.J. Nabuurs and A. Schuck. 2003. Natural disturbances in the European forests in the 19th and 20th centuries. Global Change Biology 9: 1620-1633.

Scherer-Lorenzen, M., C. Körner and E.-D. Schulze (eds.). 2005. Forest diversity and function: temperate and boreal systems. Springer, Berlin.

Schläpfer, F. and B. Schmid. 1999. Ecosystem effects of biodiversity: a classification of hypotheses and cross-system exploration of empirical results. Ecol. Appl. 9: 893-912.

Schneider, C.J. and Williams, S.E. 2005. Effects of Quaternary climate change on rainforest diversity: insights fro spatial analyses of species and genes in Australia's Wet Tropics. Pages 401-424 in E. Bermingham, C.W. Dick and C. Moritz (eds.), Tropical Forests: past, present and future. The University of

Chicago Press, Chicago, IL, USA.

Schmid, B., A. Hector, M.A. Huston, P.Inchausti, I. Nijs, P.W. Leadley and D. Tilman. 2002. The design and analysis of biodiversity experiments. Pages 61-77 in M. Loreau, S. Naeem and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Pres, Oxford, UK.

Schmid, J. and M. Kazda. 2001. Vertical distribution and radial growth of coarse roots in pure and mixed stands. Can. Jour. For. Res. 31: 539-548.

Scholtz, F., H.R. Gregorius and D. Rudin. (eds.). 1989. Genetic effects of air pollutants in forest tree populations. Springer, Berlin.

Scholze, M., W. Knorr, N.W. Arnell and I.C. Prentice. 2006. A climate change risk analysis for world ecosystems. Proc. Nat. Acad. Sci.103: 13116–13120.

Schroder, A., L. Persson and A.M. de Roos. 2005. Direct experimental evidence for alternative stable states: a review. Oikos 110: 3-19.

Schroth, G., S.A. D'Angelo, W.G. Teixeira, D. Haag and R.Lieberei. 2002. Conversion of secondary forest into agroforestry and monoculture plantations in Amazonia: consequences for biomass, litter and soil carbon stocks after 7 years. For. Ecol. Manage. 163: 131-150.

Schulze, E.-D., F.A. Bazzaz, K.J. Nadelhoffer, T. Koike and S. Takatsuki. 1996. Biodiversity and ecosystem function of temperate deciduous broad-leaved forests. Pages 120-150 in H.A. Mooney, J.H. Cushman, E. Medina, O. Sala and E.-D. Schultze (eds.), Functional roles of biodiversity: a global perspective. Wiley, Chichester, UK.

Schwartz, M.W., C.A. Brigham, J.D. Hoeksema, K.G. Lyons, M.H. Mills and P.J. van Mantgem. 2000. Linking biodiversity to ecosystem function: implications for conservation ecology. Oecologia 122: 297-305.

Shore, T., L. Safranyik, B.C. Hawkes and S.W. Taylor. 2006. Effects of the mountain pine beetle on lodgepole pine stand structure and dynamics. Pages 94-114 in L. Safranyik and B. Wilson (eds.), The mountain pine beetle: a synthesis of biology, management and impacts on lodgepole pine. Can. For. Serv., Victoria.

Simberloff, D.M.A. Relva and M. Nuñez. 2002. Gringos en el bosque: introduced tree invasion in a native Nothofagus/Austrocedrus forest. Biol. Invas. 4: 35-53.

Sitch, S., B. Smith, I.C. Prentice, A.Arneth, A. Bondeau, W. Cramer, J.O. Kaplan, S. Levis, W. Lucht, M.T. Sykes, K. Thonicke and S.Venevsky, 2003: Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Global Change Biol. 9: 161-185.

Skellam, J.G. 1951. Random dispersal in theoretical populations. Biometrika 38:196-218.

Smithwick, E.A.H., M.G. Ryan, D.M. Kashian, W.H. Rommel, D.B. Tinker and M.G. Turner. 2009. Modeling the effects of fire and climate change on carbon and nitrogen storage in lodgepole pine stands. Global Change Biol. 15: 535-548.

Soares-Filho, B.S., D.C. Nepstad, L.M. Curran, G.C. Cerqueira, R.A.. Garcia, C.A. Ramos, E. Voll, A. McDonald, P. Lefebvre and P. Schlesinger. 2006. Modelling conservation in the Amazon basin. Nature 440: 520-523.

Soja, A.J., N.M. Tchebakova, N.H.F. French, M.D. Falnnigan, H.H. Shugart, B.J. Stocks, A.I. Sukhinin, E.I. Parfenova, F.S. Chapin and P.W. Stackhouse. 2007. Climate-induced boreal forest change: predictions vs. current observations. Glob. and Planetary Change 56: 274-296.

Srivastava, D.S. and M. Velland. 2005. Biodiversity-ecosystem function research: is it relevant to conservation? Ann. Rev. Ecol. Syst. 36: 267-294.

Stone, L., A. Gabric and T. Berman. 1996. Ecosystem resilience, stability, and productivity: Seeking a relationship. Amer. Natur. 148: 892-903.

Sun, G., S.G. McNulty, J. Lu, D.M. Amatya, Y. Liang and R.K. Kolka. 2005. Regional annual water yield from forest lands and its response to potential deforestation across the Southeastern United States. Jour. Hydrology 308: 258-268.

Symstad, A.J., D. Tilman, J. Wilson and J.M.H. Knops. 1998. Species loss and ecosystem functioning: effects of species identity and community composition. Oikos 81: 389-397.

Taylor, S. W., A.L. Carroll, R.I. Alfaro and L. Safranyik. 2006. Forest, climate and mountain pine beetle outbreak dynamics in Western Canada. Pages 67-94 in L. Safranyik, L. and B. Wilson (eds.), The mountain pine beetle: a synthesis of biology, management and impacts on lodgepole pine. Can. For. Serv, Victoria, Can.

Thompson, I.D., G. Patterson, S. Leiner, R. Nasi, C.Pola, P. Sigaud, J.-P. LeDanff, K.J. Mulongoy and H. Toivonen. 2002. Review of the status and trends of, and threats to, forest biological diversity. Convention Biological Diversity Tech. Series No. 7. Montreal, Canada.

Thompson, I.D., M.D. Flannigan, B.M. Wotton and R. Suffling. 1998. The effects of climate change on landscape diversity: an example in Ontario forests. Envir. Assess. Monitoring 49: 213-233.

Thompson, I.D. and D.A. Welsh. 1993. Integrated resource management in boreal forest ecosystems – impediments and solutions. Forestry Chronicle 69: 32-39.

Tilman, D. 1996. Biodiversity: population vs. ecosystem stability. Ecology 77: 350-363.

Tilman, D., J. Knops, D. Wedin and P. Reich. 2002. Plant diversity and composition: effects on productivity and nutrient dynamics of experimental grasslands. Pages 21-35 in M. Loreau, S. Naeem, and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Oxford University Press, Oxford, UK.

Tilman, D. and C. Lehman. 2001. Biodiversity, composition, and ecosystem processes: theory and concepts. Pages 9-41 in A.P. Kinzig, S.W. Pacala and D. Tilman (eds.), The functional consequences of biodiversity: empirical progress and theoretical extensions. Princeton Univ. Press, Princeton, NJ, USA.

Tilman, D., D. Wedin, and J. Knops. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379: 718-720.

Tilman, D. and J.A. Downing. 1994. Biodiversity and stability in grasslands. Nature 367: 363-365.

Uhl, C. and J.B. Kauffman. 1999. Deforestation, fire susceptibility, and potential tree responses to fire in the eastern Amazon. Ecology 71: 437-449.

UNEP/CBD/SBSTA. (2001). Main Theme: Forest Biological Diversity. Report of the Ad Hoc Technical Expert Group on Forest Biological Diversity. Subsidiary Body for Scientific, Technical and Technological Advice, Seventh Meeting, Montreal, 12-16 November 2001.

USDA (2007) Valuing Ecosystem Services: Capturing the true value of nature's capital. US Department of Agriculture. Available from URL: http://www.fs.fed.us/ecosystemservices

Vilà, M. P. Inchausti, J. Vayreda, O. Barrantes, C. Gracia, J.J. Ibanez and T. Mata. 2005. Confounding factors in the observational productivity-diversity relationship in forests. Pages 87-108 in M. Sherer-Lorenzen, C. Körner, and E.D. Schulze (eds.), Forest diversity and function: temperate and boreal systems. Ecol. Stud. 176. Springer-Verlag, Berlin.

Vitousek, P.M., H.A. Mooney, J. Luchenko and J.M. Melillo. 1997. Human domination of the Earth's ecosystems. Science 277: 494-499.

Waide, R.B., M.R. Willig, C.F. Steiner, G. Mittlebach, L. Gough, S.I. Dodson, G.P. Juday, and R. Parmenter. 1999. The relationship between productivity and species richness. Ann. Rev. Ecol. Syst. 30: 257-300.

Walker, B.H., C.S. Holling, S.R. Carpenter and A.P. Kinzig. 2004. Resilience, adaptability and transformability in socio-ecological systems. Ecol and Society 9: art. 5. Online at: http:www.ecology and society.org/vol9/iss2/art5

Walker, B. 1995. Conserving biological diversity through ecosystem resilience. Cons. Biol. 9: 747-752.

Walker, B.H. 1992. Biological diversity and ecological redundancy. Cons. Biol. 6: 18-23.

Walker, B. and D. Salt. 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Island Press, Washington, DC., USA.

Wardle, D.A., K.I. Boner and K.S. Nicholson. 1997. Biodiversity and plant litter: experimental evidence which does not support the view that enhanced species richness improves ecosystem function. Oikos 79: 247-258.

Wardle, D.A., K.I. Bonner, G.M. Barker, G.W. Yeates, K.S. Nicholson, R.D. Bardgett, R.N. Watson and A. Ghani. 1999. Plant removals in perennial grassland: vegetation dynamics, decomposers, soil biodiversity, and ecosystem properties. Ecol. Monogr. 69: 535-568.

Watt, A.D. 1992. Insect pest population dynamics: effects of tree species diversity. Pages 267-275 in M.G.R Cannell, D.C. Malcolm and P.A. Robertson (eds.), The ecology of mixed species stands of trees. Blackwell, Oxford, UK.

Webb, S.L., M. Dwyer, C.K. Kaunzinger and P.H. Wyckoff. 2004. The myth of the resilient forest: case study of the invasive Norway maple (Acer platanoides). Rhodora 102: 332-354.

Whittaker, R.H. 1970. Communities and ecosystems. Collier-Macmillan Ltd., London. 158 p

Williams, M. C. and G.M. Wardle.. 2007. Pinus radiata invasion in Australia: identifying key knowledge gaps and research directions. Austral. Ecol. 32: 721-73.

Williamson, M. 1996. Biological invasions, Chapman and Hall, UK

Wilkinson, D.M. 1997. Plant colonization: Are wind dispersed seeds really dispersed by birds at large spatial and temporal scales? Jour. Biogeogr. 24: 61-65.

Wilson J.B. and A.D.Q. Agnew. 1992. Positive feedback switches in plant communities. Adv. Ecol. Res. 23: 263-336.

Xiao J, Q. Zhuang, D.D. Baldocchi, B.E. Law, A.D. Richardson, J. Chen, R. Oren, G. Starr, A. Noormets, S. Ma, S.B. Verma, S. Wharton, S.C. Wofsy, P.V. Bolstad, S.P. Burns, D.R. Cook,P.S. Curtis, B.G. Drake, M. Falk, M.L. Fischer, D.R. Foster, L. Gu, J.L. Hadley, D.Y. Hollinger, G.G. Katul, M. Litvak, T.A. Martin, R. Matamala, S.G. McNulty, T.P. Meyers, R.K. Monson, J.W. Munger, A. Noormets, W.C. Oechel, A.D. Richardson, H.P. Schmid, R.L. Scott, G. Starr, G. Sun, A.E. Suyker, M.S. Torn, P.U. Kyaw, B.V. Shashi, S.Wharton and S.C. Wofsy. 2008. Estimation of net ecosystem carbon exchange for the conterminous

United States by combining MODIS and AmeriFlux data. Agric. For. Meteorology 148: 1827-1847.

Yachi, S. and M. Loreau. 1999. Biodiversity and ecosystem productivity in a fluctuating environment: the insurance hypothesis. Proc. Nat. Acad. Sci. USA 96: 1463-1468.

Yarie, J. and B. Parton. 2005. Potential changes in carbon dynamics due to climate change measured in the past two decades. Can. Jour. For. Res. 35: 2258-2267

Young, A., T. Boyle, and T. Brown. 1996. The population genetic consequences of habitat fragmentation for plants. Trends Ecol. Evol. 11: 413-418.

Zhang, Q.H., G.T. Liu, F. Schlyter, G. Birgersson, P. Anderson and P. Valeur. 2001. Olfactory responses of Ips duplicatus from Inner Mongolia, China, to non-host leaf and bark volatiles. Jour. Chem. Ecol. 27: 995-1009.

Zhang, X., F. Swiers, G. Hergel, F.H. Lambert, N.P. Gillet, S. Solomon, P.A. Stott and T. Nozwa. 2007. Detection of human influence on twentieth-century precipitation trends. Nature 448: 461-465.

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PRIMARY RESEARCH ARTICLE

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The climate sensitivity of carbon, timber, and species richness covaries with forest age in boreal–temperate North America

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Abstract

Climate change threatens the provisioning of forest ecosystem services and biodiversity (ESB). The climate sensitivity of ESB may vary with forest development from young to old-growth conditions as structure and composition shift over time and space. This study addresses knowledge gaps hindering implementation of adaptive forest management strategies to sustain ESB. We focused on a number of ESB indicators to (a) analyze associations among carbon storage, timber growth rate, and species richness along a forest development gradient; (b) test the sensitivity of these associations to climatic changes; and (c) identify hotspots of climate sensitivity across the boreal–temperate forests of eastern North America. From pre-existing databases and literature, we compiled a unique dataset of 18,507 forest plots. We used a full Bayesian framework to quantify responses of nine ESB indicators. The Bayesian models were used to assess the sensitivity of these indicators and their associations to projected increases in temperature and precipitation. We found the strongest association among the investigated ESB indicators in old forests (>170 years). These forests simultaneously support high levels of carbon storage, timber growth, and species richness. Older forests also exhibit low climate sensitivity of associations among ESB indicators as compared to younger forests. While regions with a currently low combined ESB performance benefitted from climate change, regions with a high ESB performance were particularly vulnerable to climate change. In particular, climate sensitivity was highest east and southeast of the Great Lakes, signaling potential priority areas for adaptive management. Our findings suggest that strategies aimed at enhancing the representation of older forest conditions at landscape scales will help sustain ESB in a changing world.

KEYWORDS
adaptive management, biodiversity, boreal–temperate ecotone, carbon, climate change, ecosystem services, forest age, forest growth, species richness, timber production

William S. Keeton is senior author.

1 | INTRODUCTION

Climate change constitutes one of the greatest threats to forest ecosystem services and biodiversity (ESB) (Sala, 2000; Schröter et al., 2005; Thomas et al., 2004). Broad-scale scenario analyses have predicted negative effects of climate change on a number of services and biodiversity indicators (Sala, 2000; Schröter et al., 2005; Seidl, Schelhaas, Rammer, & Verkerk, 2014; Thomas et al., 2004; Thuiller et al., 2011). Yet, few studies have simultaneously estimated climate change impacts on multiple ESB indicators and quantified their associations (Creutzburg, Scheller, Lucash, LeDuc, & Johnson, 2017; Irauschek, Rammer, & Lexer, 2017). Moreover, the climate sensitivity of ESB may vary with structural and compositional changes induced by forest aging (Boulanger, Taylor, Price, Cyr, & Sainte-Marie, 2018; Pan et al., 2011). For instance, older forests, being more structurally and functionally complex (Becknell & Powers, 2014; Martin, Fenton, & Morin, 2018; Tyrrell & Crow, 1994), are potentially better at buffering against undesired climate change effects on ESB than younger forests of lower complexity (Lindner et al., 2010; Urbano & Keeton, 2017). Large uncertainties about the effects of aging forests on ESB associations and their climate sensitivities hinder the design of the robust adaptive forest management strategies needed to sustain a broad range of species and ecosystem services under a changing climate. Our study addresses these research gaps and, thus, helps guiding forest management to better sustain ESB into the future.

Forest age class distributions, disturbance dynamics, and stand development pathways (i.e., trajectories of structural and compositional development) have been profoundly altered by land-use history and forest management over large portions of the boreal and temperate biomes (Bürgi, Östlund, & Mladenoff, 2017; Collins, Fry, Lydersen, Everett, & Stephens, 2017; Foster et al., 2003; Thom, Rammer, Garstenauer, & Seidl, 2018). For instance, the majority of forests in the US Northeast are still recovering from 19th century clearing and are younger and structurally more simple compared to pre-European settlement conditions (Foster, Motzkin, & Slater, 1998). As forests age, their species composition and structure change (Tyrrell & Crow, 1994; Urbano & Keeton, 2017), which has consequences for ESB (Díaz, Armesto, Reid, Sieving, & Willson, 2005; Fuhr, Bourrier, & Cordonnier, 2015; Seedre, Taylor, Brassard, Chen, & Jõgiste, 2014; Seidl, Rammer, & Spies, 2014). These changes complicate joint management for ESB. Previous studies have quantified the relationships between various indicators of ESB at the end of rotation periods (Lutz et al., 2016; Pukkala, 2016; Triviño et al., 2017), however, stand development likely changes these associations (Bradford & D'Amato, 2012). How associations vary with forest development (i.e., development of complex stand structures and changes in the diversity of plant species) is poorly understood, limiting our ability to optimize the outcome of multiple management objectives, particularly in the face of climate change.

Climate change is a major source of uncertainty when predicting the individual and combined future dynamics of ESB indicators. Boreal–temperate ecotones constitute the transition zone between boreal and temperate biomes and harbor characteristic species of both systems. Ecotones of eastern North America may face exceptionally strong climate forcing in the future (Hayhoe et al., 2017). This may cause severe consequences for ecosystems because ecotones are expected to be particularly sensitive to climate change as many species are currently at the peripheries of their geographic distributions or environmental tolerance ranges (Taylor et al., 2017). Moreover, it is likely that climate change impacts will be spatially heterogeneous and nonlinear due to differences in climate, edaphic conditions, and competitive interactions among other factors (Creutzburg et al., 2017; Frey et al., 2016). The climate sensitivity of ESB may also covary with forest age and development. For instance, older forests might have greater capacity to sustain favorable microclimates for species sensitive to climatic changes than younger forests (Fritz, Niklasson, & Churski, 2009). As a result of spatial heterogeneity, we can expect hotspots in the sensitivity of ESB to climate (Seddon, Macias-Fauria, Long, Benz, & Willis, 2016). The identification of such hotspots would help land managers and policy makers prioritize areas where reallocation of resources for climate adaptation could be concentrated (Thom et al., 2017).

This study quantifies the individual and combined performance of multiple ESB indicators in the context of climate sensitivity and forest development within the boreal–temperate transitional forest region of eastern North America. We compiled an extensive and highly unique dataset of indicators related to carbon storage, timber growth rate (i.e., periodic annual increment which indicates potential wood production), and species richness from various sources. Our objectives were to (a) analyze associations between carbon storage, timber growth rate, and species richness along a forest development gradient; (b) test the sensitivity of these associations to increases in annual average temperature and total precipitation; and (c) identify hotspots of climate sensitivity across the study region. Based on previous studies in the temperate and boreal biomes, we expected a logarithmic trend for carbon storage (Keeton, Whitman, Mcgee, & Goodale, 2011; Weng et al., 2012), an early optimum for timber growth rate (Ward, Pothier, & Paré, 2014), and a U-shaped curve for biodiversity (Hilmers et al., 2018) in relation to forest age, which was employed as a proxy for stand development (Franklin et al., 2002; Taylor & Chen, 2011). As mesic temperate and boreal forests age, they develop greater structural complexity in both vertical (e.g., vertically differentiated canopies, range of tree sizes) and horizontal (e.g., patch mosaics, variation in stem densities) dimensions, which may also increase niche availability (Crow, Buckley, Nauertz, & Zasada, 2002; McGee, Leopold, & Nyland, 1999; Urbano & Keeton, 2017). Ultimately, age-related changes are likely to increase both the resistance and resilience of forests to climatic alterations (Lindner et al., 2010), although there remains uncertainty around this question (D'Amato, Bradford, Fraver, & Palik, 2011). We thus expected a lower climate sensitivity of indicator associations with increasing forest age. Moreover, we anticipated distinct variation in climate sensitivity of the indicators across the study region due to nonlinear responses to increases in temperature and precipitation as well as differences in site and stand conditions. In gaining novel insights into ESB associations and their sensitivities to climate, our study highlights opportunities to improve forest management strategies and identifies priority regions for adaptation measures.

2 | METHODS

2.1 | Study area

Our study area spans eastern temperate and northern forests of three ecoregions: "Mixed Wood Shield," "Atlantic Highlands," and "Mixed Wood Plains" (Figure 1; EPA, 2016). These ecoregions roughly encompass the boreal–temperate ecotone of eastern North America. The distinct gradient in environmental conditions and the high competition among species makes ecotones ideal regions to investigate the climate sensitivity of ESB (Boulanger et al., 2017; Evans & Brown, 2017). The forests of these ecoregions span oak-hickory communities in the south over maple-beech-birch to spruce–fir communities in the north.

2.2 | Database and literature review

We performed a database and literature search collecting individual plot records on carbon stocks and timber growth rate (an indicator of wood commodity production), two of the most frequently discussed ecosystem services in forest management and policy (Schwenk, Donovan, Keeton, & Nunery, 2012), and species richness (see Section S1 in the supporting information for more details). We omitted observations with missing values for forest age (i.e., the average age of dominant and codominant overstory trees), conifer share, or geographic coordinates. In total, we collected 74,777 observations from 18,507 plots within the focal ecoregions (Table S1; Figure S1). Most of the plot data were derived from the USDA Forest Inventory and Analysis (FIA) Program. Other sources complemented FIA data, in particular by providing additional information on underrepresented old-growth plots (Anderson-Teixeira et al., 2018; Keeton et al., 2011), rarely measured variables (Kurth, D'Amato, Palik, & Bradford, 2014), or by extending the environmental gradient (e.g., Canada's National Forest Inventory [NFI]). Each observation includes information about carbon pools (aboveground live carbon [ALC]; dead standing carbon [DSC]; dead downed carbon [DDC]; soil organic carbon [SOC]; forest floor carbon [FFC]), timber growth rate (current annual volume increment), or biodiversity within three taxonomic groups (species richness of trees, lichens, or vascular plants). Additionally, for each plot, we collected data on seasonal and annual average temperature and total precipitation (resolution: 1 km; reference period: 1970–2000) (WorldClim, 2016), soil type (resolution: 1 km) (Fischer et al., 2008), management designation/protection status (resolution: 2 km) (CEC, 2010), and elevation (resolution: 1 km) (EROS, 2018).

2.3 | Carbon, growth, and species richness models

We used Bayesian generalized linear models (GLMs) to analyze the performance of carbon storage, timber growth rate, and species richness (described above). To do this, we first scaled and zero-centered all continuous predictor variables. Next, we used a combination of statistical techniques to determine candidate models for each of the nine response variables (ALC, DSC, DDC, SOC, FFC, timber growth rate, and tree, lichen, and vascular plant species richness; see Table S2 for details on statistical methods and variables). For continuous response variables (i.e., carbon storage and timber growth rate indicators), we assumed a Gaussian error distribution. For count response variables (i.e., species richness

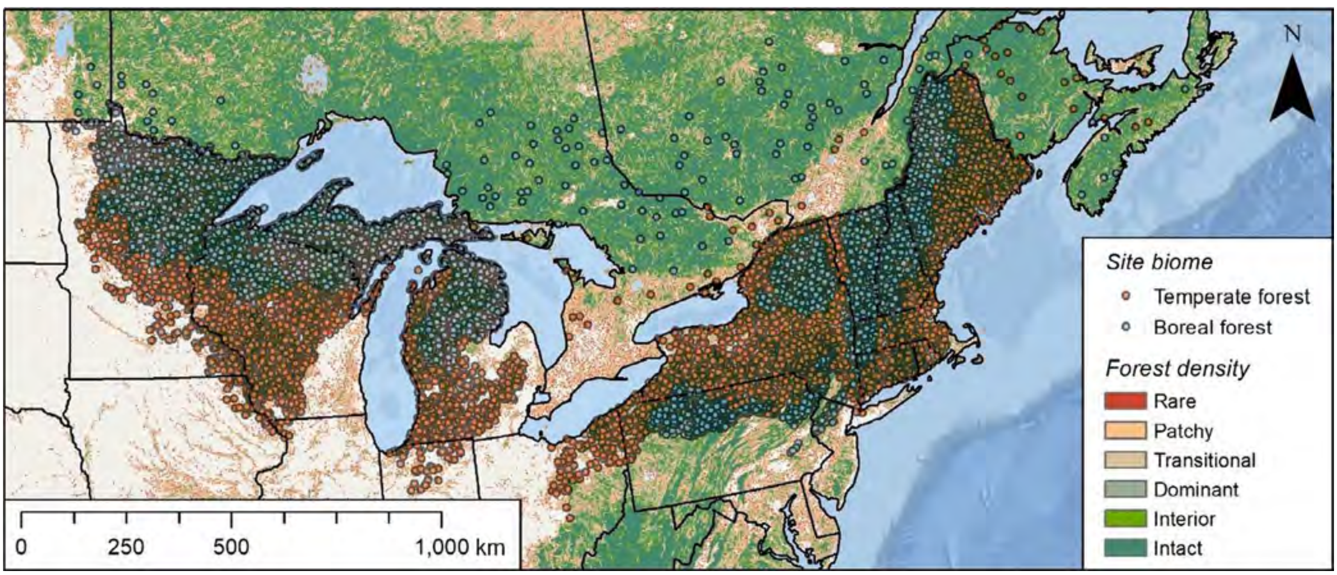

FIGURE 1 Spatial distribution of plots across the study region. We collected 18,507 plots in three ecoregions spanning the eastern temperate and northern forests of the boreal–temperate ecotone in the northeastern United States and southeastern Canada [Colour figure can be viewed at wileyonlinelibrary.com]

indicators), we tested two different error distributions across all candidate models: a negative binomial error distribution and a Gaussian error distribution after log transformation (Ives, 2015). On average, we derived nine candidate models for each response variable, while the number varied between 5 and 14 models depending on interaction terms considered in candidate models and data type (Table S2). A Gaussian field of longitude and latitude was included in all models to control for residual spatial autocorrelation. Based on the partial effect plots derived for all candidate predictor variables using random forest models (Breiman, 2001) and ecological theory (e.g., for the hypothesized covariation of total ecosystem carbon (TEC), timber growth rate, and species richness with forest age), we included smoothing terms for predictors for which we expected nonlinear relationships with the respective response variable.

All models were parametrized within a full Bayesian framework (Bürkner, 2018) at the Vermont Advanced Computing Core (VACC). In a Bayesian framework, all parameters are modeled with uncertainty, and direct probability statements about quantities of interest can be made. We selected the most parsimonious models using the Watanabe–Akaike information criterion (WAIC) (Vehtari, Gelman, & Gabry, 2017). We assessed the predictive accuracy of the final models with posterior predictive checks, and compared the Bayesian R^2, Generalized variance inflation factor (GVIF), partial effects plots, and Moran's I for residual spatial autocorrelation among models. Based on these tests, we maintained the log-transformed count data models, and in four cases (DDC, growth rate, as well as specie richness of trees and lichens), we rejected the model with the lowest WAIC in favor of another model (e.g., if GVIF was >10, see Dormann et al. (2013)). Finally, we used WAIC for backwards elimination of variables with the highest uncertainty in the selected candidate models. The final models (used to predict ESB) performed with moderate rigor, with Bayesian R^2 explaining on average 31.1% of the variance, with the minimum being 8.8% (DSC) and the maximum 66.4% (lichen species richness) (see Table S3 for details). No model showed evidence of strong residual spatial autocorrelation (Moran's I ranged between −0.102 and 0.069).

2.4 | Trends and associations

We used forest age as a proxy for forest stand developmental condition across the study region in a space-for-time substitution approach (Franklin et al., 2002; Taylor & Chen, 2011). Hence, final models were employed to predict the responses of each indicator related to carbon storage, timber growth rate, and species richness to forest age. Specifically, we set all continuous variables except forest age to their mean values and categorical variables to their most frequent levels in the dataset. TEC was derived by summing all carbon pools, whereas total species richness was the sum of individual taxa richness scaled by dividing by the maximum value to ensure their comparability. Subsequently, TEC, timber growth rate, and total species richness were divided by their respective maximums to derive a measure of relative performance as a function of forest age. As our data were limited by a relatively low number of observations for old-growth forests (Figure 2), and as the concept of forest age has limitations in uneven-aged old-growth forests (Keeton et al., 2011), we restricted the interpretation of individual indicators' responses to changes in climate variables to the first 200 years of forest development.

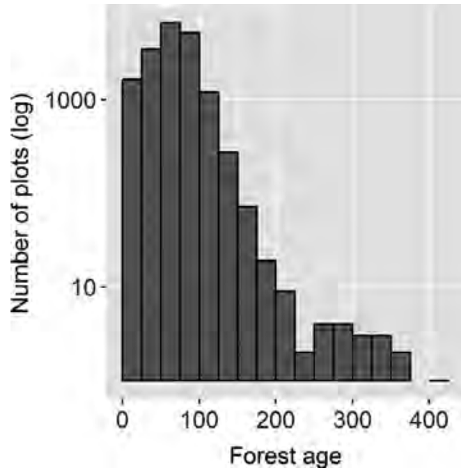

FIGURE 2 Distribution of forest age classes across the 18,507 plots recorded in this study. Forest age is based on the average age of dominant and codominant overstory trees. Note that the *y*-axis is log transformed

Next, we used the Bayesian models to map and identify regional variations in ESB indicators. Using the complete dataset with the original information about stand and site conditions, we predicted the performance of individual response variables for each plot. Subsequently, we derived and mapped TEC and species richness following the same approach as described above. The combined indicator performance was derived by averaging across TEC, timber growth rate, and species richness outcomes. Subsequently, we used inverse distance weighting to derive wall-to-wall (i.e. spatial inter- and extrapolation) estimates for the entire study region.

Central to our analysis was an assessment of similarities in trends (performance change along the entire forest age gradient) and associations (performance at a specific forest age) between TEC, timber growth rate, and species richness. We performed Gleichläufigkeit (GLK) tests (Bunn et al., 2018) for all pairwise combinations of indicators (e.g., TEC and timber growth rate) to assess synchrony in trends within the first 200 years of forest development. A GLK value of 0.5 indicates no mutual pattern of two variables (no covariation), a value of 1 indicates that all values of the variables always increase or decrease in the same years (positive covariation), and a value of 0 means that variables compared pairwise never increase or decrease in the same years (negative covariation). Associations between TEC, timber growth rate, and species richness along the forest development gradient were assessed following the approach described in Bradford and D'Amato (2012). Briefly, we computed the root mean squared error of the performance of two indicators at a given forest age. The resulting curves were averaged to derive the mean divergence (D_{base}) among all indicators.

2.5 | Climate sensitivity

Finally, we assessed the climate sensitivity of TEC, timber growth rate, and species richness, and their associations by increasing all temperature variables by 4°C, annual precipitation by 200 mm, and seasonal precipitation variables by 50 mm in the statistical prediction. These values roughly correspond with the RCP6.0 emission scenarios projected for the study region by the end of the 21st century (Hayhoe et al, 2017; Nazarenko et al., 2015). The predictions were divided by the respective maximum values under baseline climate to make indicator performance comparable between climate regimes. Relative performances under baseline climate were then subtracted from the relative performance under changed conditions to derive the absolute percent change for each indicator (i.e., the change in percentage points; hereafter "% points").

Following the approach described above, we derived wall-to-wall maps of changes in indicator performance. We also compared the results for GLK under baseline and changed climatic conditions. Moreover, we derived the divergence (D_{cc}) (i.e., the degree of association) between indicators under elevated temperature and precipitation regimes and subtracted the results from the outcome under baseline climate conditions. For example, an increase in divergence indicates a weaker association between TEC, timber growth rate, and species richness at a particular forest age in a warmer and wetter environment. Further, we investigated the sensitivity of all indicators to individual changes in temperature and precipitation. To that end, we predicted the region-wide performance of the nine response variables first toward an increase in all temperature variables of +4°C and subsequently toward an increase in annual precipitation of 200 mm and seasonal precipitation of 50 mm.

All analyses were performed using the R language and statistical computing environment (R Development Core Team, 2018) using the packages dplyr (Wickham, Francois, Henry, & Müller, 2018) and reshape2 (Wickham, 2017) for data organization; foreign (R Development Core Team, 2017) for loading external data sources; pedometrics (Samuel-Rosa, 2015) and randomForest (Liaw & Wiener, 2018) for variable selection of candidate models; brms (Bürkner, 2018) for Bayesian models; usdm (Naimi, 2017) for multicollinearity tests; dplR (Bunn et al., 2018) for GLK tests; fmsb (Nakazawa, 2018) and ggplot2 (Wickham, 2009) for data visualization; and gstat (Pebesma, 2018), raster (Hijmans, 2018), rgdal (Bivand, Keitt, & Rowlingson, 2018), sp (Pebesma & Bivand, 2018), and spdep (Bivand et al., 2019) for spatial analyses.

3 | RESULTS

3.1 | Old forests exhibit highest combined performance of ESB

The combined performance of multiple ecosystem indicators peaked in 200 year old forests as a result of simultaneously high

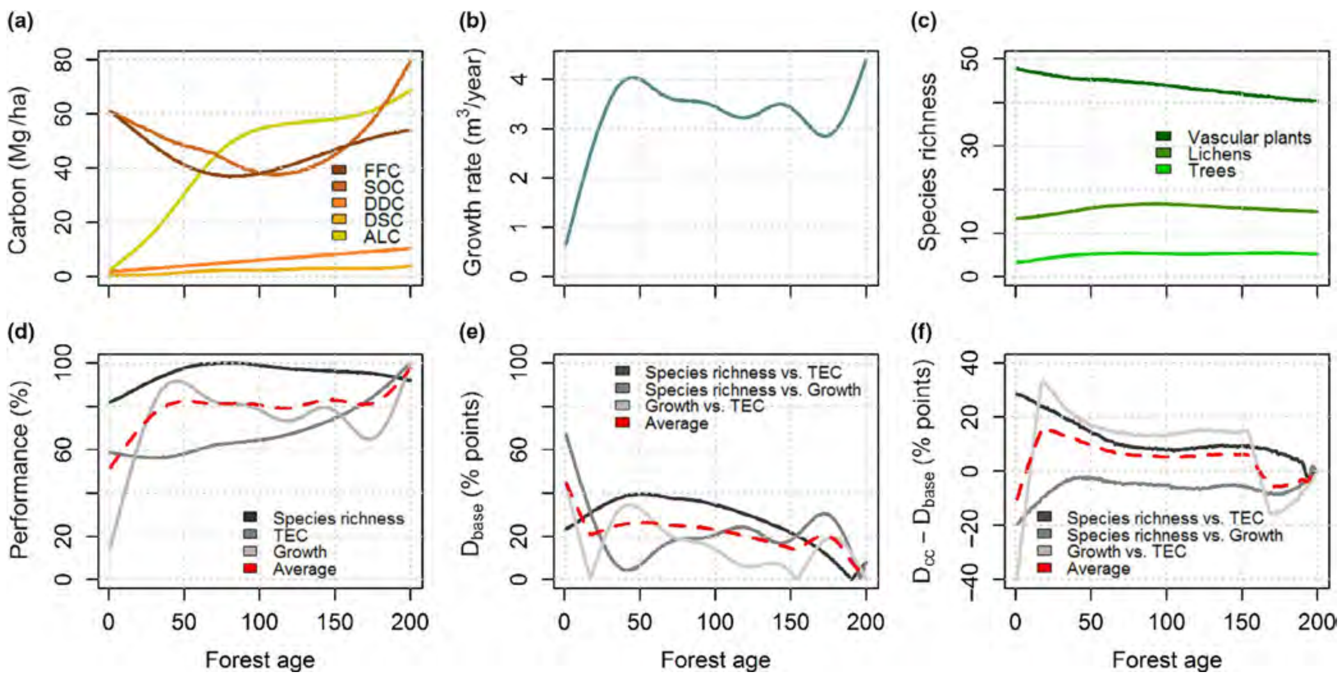

FIGURE 3 Ecosystem services and biodiversity (ESB) performance, associations, and climate sensitivity of associations along a forest age gradient. (a) Carbon pools (aboveground live carbon [ALC]; dead standing carbon [DSC]; dead downed carbon [DDC]; soil organic carbon [SOC]; forest floor carbon [FFC]); (b) timber growth rate; (c) species richness indicators (trees, lichen, and vascular plant species richness); (d) relative combined performance (i.e., ESB outcomes) of total ecosystem carbon (TEC), timber growth rate, and species richness; (e) their associations under baseline climate conditions (i.e., D_{base}, the divergence in performance between indicators); and (f) changes in associations in a warmer and wetter world (i.e., $D_{cc} - D_{base}$, change in the divergence). D_{cc} denotes an increase in temperature by 4°C and precipitation by 200 mm. Note that the *y*-axes in (a)–(c) are in original units, while (d) presents percentages (indicator performance relative to the observed maximum value), and *y*-axes in (e) and (f) are in percentage points (absolute difference of percentages) [Colour figure can be viewed at wileyonlinelibrary.com]

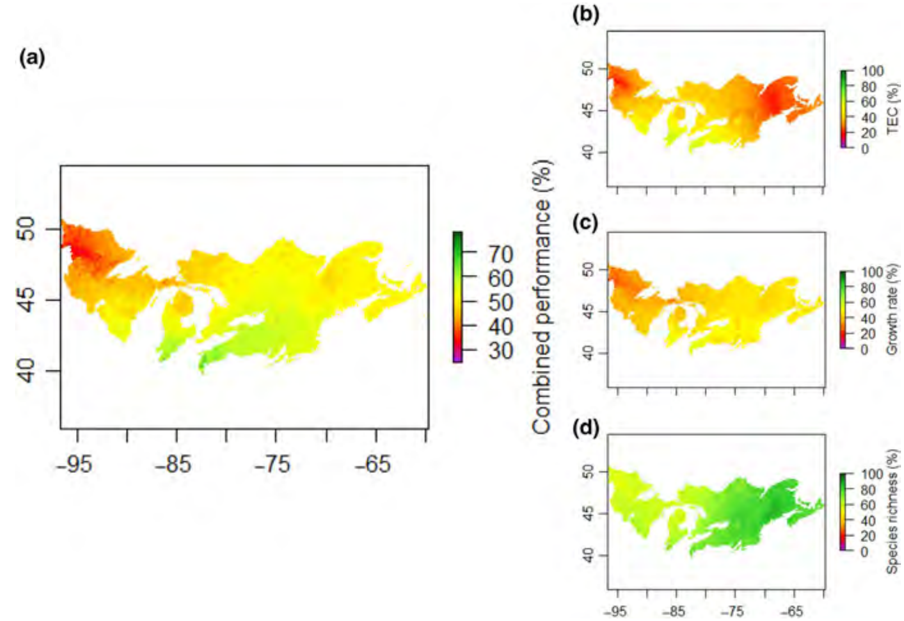

FIGURE 4 Ecosystem services and biodiversity (ESB) performance across the study region. Values were predicted for each inventory plot using final Bayesian generalized linear models, standardized, and spatially interpolated (see text for details). Left panel: (a) Joint average relative combined performance (i.e., ESB outcomes) of total ecosystem carbon (TEC), timber growth rate, and species richness. Right panel: Relative performance of (b) TEC, (c) timber growth rate, and (d) species richness. Note that scales differ between panels [Colour figure can be viewed at wileyonlinelibrary.com]

levels of carbon storage and timber growth rate, coupled with relatively stable species richness along the forest development gradient (Figure 3d). TEC increased with forest age, due to carbon accumulation in all pools (Figure 3a; Figure S2a–e), particularly in forests older than 130 years. SOC and FFC declined during the first 80–120 years, after which both pools increased (Figure 3a; Figure S2d,e). Timber growth rate peaked twice, first between years 40 and 50, and again after year 170 (Figure 3b; Figure S2f). Individual components of species richness were only moderately associated with forest age (Figure 3c; Figure S2g–i). While lichen species richness was highest between years 90 and 100, vascular plant richness slightly decreased with forest age, and tree species richness first increased slightly but leveled off at year 50. As a result, total species richness was quite stable over the 200 years of forest stand development (Figure 3d).

We did not detect common trends in the trajectories of TEC and timber growth rate (GLK = 0.44), timber growth rate and species richness (GLK = 0.56), and TEC and species richness (GLK = 0.44) as related to forest age (Figure 3d). However, ESB associations covaried with forest age. The divergence (D_{base}) among all indicators was highest during the first decade of forest development, constituting on average 37.7% points (Figure 3e). D_{base} decreased with increasing forest age in two distinctive dips within the first and last two decades of the predicted period (ultimately reaching <5% points), indicating the strongest association among TEC, growth rate, and species richness in old forests.

3.2 | Variation in climate sensitivity across boreal–temperate forests

The combined ESB performance varied spatially across the region, being lowest in the northwestern portions (parts of Manitoba, Ontario, and Minnesota) and highest in the central-southern portions (parts of Indiana, Ohio, Michigan, Pennsylvania, and New York) of the region (Figure 4a). The central-south was a hotspot for TEC (Figure 4b) and timber growth rate (Figure 4c), while species richness was positively correlated with proximity to the Atlantic Ocean (Figure 4d).

Ecosystem services and biodiversity indicators were highly sensitive to changes in temperature and precipitation (Figure 5a). On average over the study region, increasing temperature and precipitation together altered the combined indicator performance only marginally (+0.7% points). However, the spatial variability of this effect was high (Figure 5a). The western and northeastern parts of the region, which had low-to-moderate combined indicator performance under current climate conditions (Figure 4a), benefitted from climatic changes. In contrast, large areas in the east and south decreased in performance (Figure 5a). As the decrease in TEC (on average −9.0% points; Figure 5b) and the increase in timber growth rate (on average +13.0% points; Figure 5c) cancelled each other out in many locations, the differences in combined indicator performance were strongly determined by changes in species richness, despite its low magnitude of change on average across the region (−2.1% points; Figure 5d).

3.3 | High climate sensitivity of young forests

Climate sensitivity varied markedly among the investigated indicators (Figure 6; Figure S4). Changes in TEC were primarily driven by decreases in SOC (−8.2% and −4.4% points) and FFC (−13.7% and −2.4% points), which were highly sensitive to both increases in temperature and precipitation. DSC and DDC were only moderately sensitive and responded negatively to temperature (−0.1% and −3.3% points) and positively to precipitation (+0.9% and +1.8% points). In congruence with the change in ALC (+9.1% points), an increase in temperature and precipitation improved timber growth rate by 12.9% points, while precipitation had only a small effect on both (+2.4% and −0.4% points, respectively).

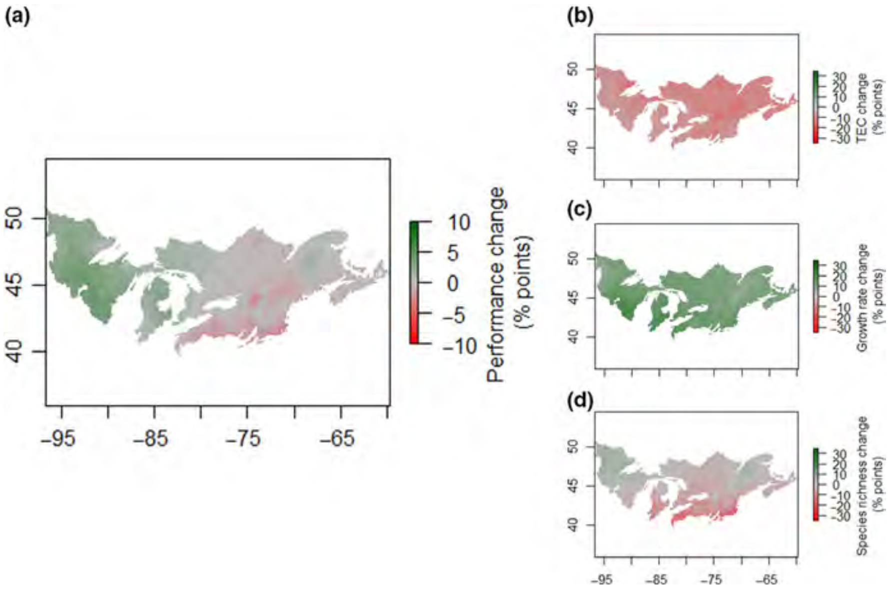

FIGURE 5 Climate-induced changes in ecosystem services and biodiversity (ESB) across the study region. Predictions represent an increase in temperature by 4°C and precipitation by 200 mm. Left panel: (a) Change in the relative combined performance (i.e., ESB outcomes) of total ecosystem carbon (TEC), timber growth rate, and species richness (in % points). Right panel: change in performance (in % points) of (b) TEC, (c) timber growth rate, and (d) species richness. Note that scales differ between panels [Colour figure can be viewed at wileyonlinelibrary.com]

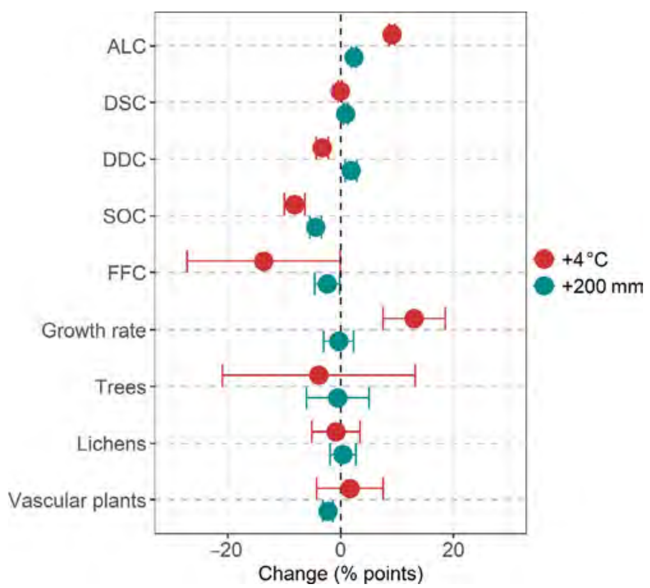

FIGURE 6 Sensitivity of ecosystem services and biodiversity toward increased temperature and precipitation. Presented are mean changes (dots) and confidence intervals (whiskers) for individual carbon storage, timber growth rate, and species richness indicators across the study region. ALC, aboveground live carbon; DSC, dead standing carbon; DDC, dead downed carbon; SOC, soil organic carbon; FFC, forest floor carbon; timber growth rate; trees, lichen and vascular plant species richness [Colour figure can be viewed at wileyonlinelibrary.com]

Changes in species richness components were diverse, of lower magnitude, and exhibited higher uncertainty compared to carbon pools and timber growth rate. Specifically, tree species richness was negatively affected by changes in temperature and precipitation (−3.9% and −0.5% points), lichen species richness showed a weak negative response to altered temperature and a weak positive response to altered precipitation (−0.8% and +0.4% points), and vascular plant species richness was positively affected by changes in temperature and negatively by changes in precipitation (+1.6% and −2.3% points). Spatial variation in climate sensitivity was low for all carbon pools and for timber growth rate (Figure S4). In contrast, species richness components varied in their response to temperature across the region. In particular, tree species richness strongly decreased in the central-southern reaches, while the northwest and northeast of the region benefitted from higher temperatures (Figure S4).

Changes in climate moderately altered the correlation between TEC and growth (GLK = 0.55), between TEC and species richness (GLK = 0.53), and between growth and species richness (GLK = 0.59) along the forest age gradient. Associations between TEC, growth rate, and species richness were more divergent (D_{cc}) than in the baseline scenario (D_{base}) during the first 160 years of forest development (max. increase in divergence: 15.9% points) (Figure 3f). Afterwards, the change in divergence became negative, indicating a stronger ESB association under climate change compared to baseline conditions. Between year 190 and 200, D_{cc} and D_{base} were very similar (on average −1.9% points), demonstrating a stable and strong association among ESB in old forests independent of climatic conditions.

4 | DISCUSSION

4.1 | Variation of carbon, growth, and species richness across forest age

Ecosystem services and biodiversity change over time as boreal–temperate forests undergo processes of stand development. Although there were no common trends in the trajectories of TEC, timber growth, and species richness in relation to forest age, their combined performance was highest in older forests. Our results only partly support the expected response curves relating these indicators to forest age (Figure 3d). Specifically, TEC continued to increase in older forests and did not follow a logarithmic curve to an asymptote as predicted. This increase was driven by both above- and belowground carbon pools. As forests develop toward late-seral stages, mortality of canopy trees increases through both density-dependent and density-independent processes (Franklin et al., 2002), leading to dead tree recruitment and deadwood accumulation (Garbarino, Marzano, Shaw, & Long, 2015) (Figure 3a). However, our data suggest that the increase in deadwood occurs concurrently with increases in ALC (Figure 3a), which is a much larger carbon pool than deadwood in our study system (e.g., up to an order of magnitude larger in 200 year old forests). Temporal dynamics of ALC are likely due to increases in the structural complexity of temperate and boreal forests (Lorimer & Halpin, 2014), which has been related to carbon accumulation in previous studies (McGarvey, Thompson, Epstein, & Shugart, 2015; Thom & Keeton, 2019; Urbano & Keeton, 2017) (see also discussion about growth rate below). Although decomposition gradually releases carbon to the atmosphere via respiration, the large accumulations of deadwood and litter in old forests also contribute to organic matter and free carbon incorporation into the humus layer and soil profile, thereby increasing belowground carbon pools (Manzoni & Porporato, 2009) (Figure 3a). The initial decrease of FFC and SOC in young forests is likely a legacy of carbon carried over from predisturbance stands, which slowly releases from redeveloping stands through decomposition (Franklin et al., 2000; Harmon, 2001).

Timber growth rate peaked after the first four to five decades in our study (Figure 3b). This finding is consistent with previous models in which growth rate was highest in relatively young and even-aged, secondary forests (Bormann & Likens, 1979; Halpin & Lorimer, 2016). However, we did not anticipate an acceleration of the growth rate after forests reached about 170 years in age. Uncertainty clearly increased, as indicated by the credibility interval in our results (Figure S2f), which reflects variability in the sample size across ages. However, the variance in the credibility intervals was not sufficient to override the general trend. In addition, we only calculated timber growth rate from the FIA data, thereby avoiding any confounding age-related trends that otherwise might have been attributed to multiple data sources. Thus, our finding of an acceleration in timber growth rate in older forests appears robust. This acceleration might be explained by tree growth releases at multiple canopy positions as forests age, experience gap dynamics, and interact with partial disturbances that free up growing space and increase light availability for mixtures of shade-tolerant and shade-intolerant species (Gough, Curtis, Hardiman, Scheuermann, & Bond-Lamberty, 2016; Hanson & Lorimer, 2007; Hardiman, Bohrer, Gough, Vogel, & Curtis, 2011). This inference is partially supported by previous research showing that renewed growth and physiological function in mature and old forests sometimes leads to an increase in growth rate (Keeton, 2018). Further research is needed to resolve whether and why the growth rate increases late in forest stand development.

Total species richness was insensitive to forest age overall but followed a unimodal hump-shaped curve instead of the expected U-shaped curve (Figure 3d). The pattern was driven by the increase in the number of tree and lichen species during the first decades, while vascular plant species richness decreased with forest age (Figure 3c). On the one hand, this finding supports the notion that biodiversity change during forest development strongly depends on the species or taxonomic groups studied (Thom et al., 2017; Thorn et al., 2017). For instance, rare lichen species are often associated with old-growth forest conditions (Selva, 1994) and are used as indicators of forest health (McCune, 2000). The overall species richness derived here may thus represent only one aspect of biodiversity within forest landscapes and conservation strategies. Moreover, a mix of different age classes implying various seral habitat conditions is needed to support a high beta-diversity on forest landscapes (Franklin, 1993). On the other hand, our analysis might exclude some important variables to estimate the effects of forest structure on species richness. In particular, the R^2 of vascular plant species was low (0.112, see Table S3). A more detailed analysis incorporating a higher number of variables related to forest structure and composition represents an important area for future research building on our analyses (see e.g., Zilliox & Gosselin, 2014). For instance, we used conifer share as key variable to describe forest vegetation. While this simplification limits details, for instance, on the dominant species in each plot, it increased computational efficiency (computational time of the Bayesian models was several weeks on the VACC) and data availability.

4.2 | Carbon, timber growth, and species richness associations are sensitive to climate

Our study has shown that associations between TEC, timber growth, and species richness vary with forest age and are sensitive to climatic changes. However, TEC, timber growth rate, and species richness did not follow similar trajectories with forest age based on the results of the GLK tests. Rather, we found strong variations in divergence and congruence between the investigated indicators throughout the 200 year forest development gradient. Despite this variation, their combined performance peaked and the deviance in performance of the investigated indicators was lowest in old forests. This indicates neither a trade-off nor a synergistic behavior among these indicators; rather, forest age and associated stand development drive each indicator's performance independently.

While the strong association between indicators was stable in old forests, our findings suggest that the mix of ESB provided in younger forests may shift into the future as a result of climate change. For example, our analysis suggests a decrease in TEC while, congruent with changes in ALC, timber growth rate increases. However, we acknowledge that the responses to climate change are likely more complex and will be influenced by multiple interacting factors, including stressors such as drought frequency, spread of invasive pests and pathogens, altered disturbance dynamics, and airborne pollutants (Ollinger, Aber, Reich, & Freuder, 2002; Seidl et al., 2017). As tree species migration is unlikely to keep pace with climate change (Thom et al., 2017; Thom, Rammer, & Seidl, 2017a), ecosystems may become increasingly maladapted with negative consequences for ESB. For instance, an increase in water shortage caused by higher evapotranspiration and longer dry periods in the study region (Allen et al., 2010) will likely reduce the growth rate and cause mortality of tree species with low drought tolerance (Eilmann & Rigling, 2012). Species currently predominating on dry sites may have to migrate long distances to occupy similar newly available niches under climate change. Mechanistic models enable the simulation of natural processes and emergence from interactions among vegetation, climate change, other anthropogenic stressors, and natural disturbances, and can thus improve the simultaneous predictions of future ESB outcomes in the study region (Boulanger et al., 2017).

4.3 | Climate sensitivity of boreal–temperate forests

Our results indicate differences in the climate sensitivity across indicators and among geographic regions arising from the heterogeneity in climate, soil, and forest conditions within the boreal–temperate transition zone (Figure 5; Figure S4). While TEC and timber growth rate was highly sensitive to changes in climatic conditions across the entire study region, the sensitivity of species richness was less pronounced overall yet varied spatially more strongly. TEC decreases were mainly driven by reductions in SOC and FFC (Figure 6; Figure S4d–n). Elevated temperature and precipitation increase decomposition rates of organic material stored in soils and on the forest floor, which leads to release of carbon into the atmosphere (Barraclough, Smith, Worrall, Black, & Bhogal, 2015; Jansson & Berg, 1985). However, it has to be noted that the comparably low number of observations for SOC and FFC (119 and 130) in our analysis induced a wide credibility interval (Figure 2e,f), and temperature extrapolations of our models were outside the observed value range for most parts across the study region (Figures S4a–r). Uncertainty about the effects of future changes in plant and soil communities ultimately altering SOC and FFC warrants further investigation (Rouifed, Handa, David, & Hättenschwiler, 2010).

The predicted increase in timber growth with temperature is congruent with other studies reporting enhanced productivity in a warmer world (Boisvenue & Running, 2006; D'Orangeville et al., 2018). However, recent research has shown that reduced winter snowpack and increased soil freezing are negatively affecting the growth rate of sugar maple (*Acer saccharum*), one of the study region's most important tree species (Reinmann, Susser, Demaria, & Templer, 2019). This example demonstrates the high degree of uncertainty in overly general predictions regarding growth responses due to the potential for complex interactions and process feedbacks. Moreover, negative effects from altered disturbances regimes (Kang, Kimball, & Running, 2006), other stressors like invasive species and airborne pollution (Dukes et al., 2009; Ollinger et al., 2002), and changes in tree species composition (Morin et al., 2018) may neutralize the positive direct effects of climate change on timber growth. Thermal conditions in parts of the northern reaches of the study region may become more suitable to support species from temperate biomes (Hamann & Wang, 2006). In contrast, the southern reaches will likely lose boreal species, which face strong competition from temperate species even under current climatic conditions (Murray et al., 2017). As changes in the mix of species and ecosystem services are likely to be nonuniform across the region, challenges will vary for forest management intended to maintain high levels of multiple ESB outcomes simultaneously.

4.4 | Managing forests in the face of climate change

Although our analysis suggests that old forests exhibit the highest combined ESB performance, less than 0.2% of the investigated sites are currently occupied by forests older than 200 years (Figure 2). This suggests a large potential to improve joint ESB outcomes in temperate and boreal forests of eastern North America by enhancing the representation of late-successional and older forest stand structures. For example, our results suggest that increased application of longer rotations as a component of multifunctional forest management would help achieve a broader range of ESB objectives.

Climate change is predicted to have overall negative impacts on the future provisioning of ecosystem services (D'Orangeville et al., 2018; Schröter et al., 2005; Thom et al., 2017; Thom, Rammer, & Seidl, 2017b) and biodiversity (Bellard, Bertelsmeier, Leadley, Thuiller, & Courchamp, 2012; Thomas et al., 2004; Thuiller, Lavorel, Araujo, Sykes, & Prentice, 2005). The slow adaptation process of forests implies that adaptive forest management strategies require long lead-in times (Maciver & Wheaton, 2005). Our study indicates that management aimed at increasing representation of older stand structures on forest landscapes could partly offset the negative effects of climate change on carbon storage (Figure 3f). Moreover, our study indicates how such adaptive efforts could be concentrated in areas most sensitive to climate effects on ESB. In particular, regions east and southeast of the Great Lakes constitute priority areas for adaptive measures as these were identified as potential hotspots of decreasing ESB outcomes under increasing temperature and precipitation regimes (Figure 5a). However, we recognize that our results are dependent on the specific response variables, which do not represent the full spectrum of ESB attributes of forests in the region. Nevertheless, the available variables are directly applicable to key objectives of contemporary forest management.

The slow development of forests on the one hand and the worldwide increasing demand for timber on the other hand (FAO, 2016) creates a challenge for forest managers that is further heightened by the impacts of climate change. Altering age-class distributions at the landscape scale is one strategy to mitigate climate change impacts that would specifically address currently overrepresented mature forests in the study region (Figure 2), while a mix of all development stages needs to be retained to support ESB indicators associated with different forest conditions (see e.g., Swanson et al., 2011). Moreover, increasing the relative abundance of older forests may result in less harvested timber in the transition phase until the desired development stage is reached. However, this initial decrease may be mitigated in the intermediate to long term as the mean annual increment increases in older forests (Figure 3b). This transition phase could be shortened through the use of silvicultural practices designed to increase rates of late-successional forest development and structural complexity in managed forests (Fahey et al., 2018; Felipe-Lucia et al., 2018; Keeton, 2006,2018). Case studies in mixed-northern hardwood conifer forests have demonstrated positive impacts of these measures on carbon storage (Ford & Keeton, 2017; Urbano & Keeton, 2017), timber growth rate (Arseneault, Saunders, Seymour, & Wagner, 2011; Schuler, 2004), and late-successional biodiversity (Kern, Montgomery, Reich, & Strong, 2014; McKenny, Keeton, & Donovan, 2006; Smith, Keeton, Twery, & Tobi, 2008). Field experiments coupled with mechanistic modeling may improve our understanding of the underlying processes determining the dynamics of ESB across forest development stages. In particular, a better understanding of the variation in nutrient and water cycling, photosynthesis rates, and habitat structures supporting high species diversity along forest development gradients may help to optimize landscape-oriented management strategies. Addressing these processes in adaptive forest management frameworks will help sustain ecosystem services and multiple elements of biodiversity in a rapidly changing world.

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REFERENCES

Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., … Cobb, N. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management*, *259*(4), 660–684. https://doi.org/10.1016/j.foreco.2009.09.001

Anderson-Teixeira, K. J., Wang, M. M. H., McGarvey, J. C., Herrmann, V., Tepley, A. J., Bond-Lamberty, B., & LeBauer, D. S. (2018). ForC: A global database of forest carbon stocks and fluxes. *Ecology*, *99*(6), 1507. https://doi.org/10.1002/ecy.2229

Arseneault, J. E., Saunders, M. R., Seymour, R. S., & Wagner, R. G. (2011). First decadal response to treatment in a disturbance-based silviculture experiment in Maine. *Forest Ecology and Management*, *262*, 404–412. https://doi.org/10.1016/j.foreco.2011.04.006

Barraclough, D., Smith, P., Worrall, F., Black, H. I. J., & Bhogal, A. (2015). Is there an impact of climate change on soil carbon contents in England and Wales? *European Journal of Soil Science*, *66*(3), 451–462. https://doi.org/10.1111/ejss.12253

Becknell, J. M., & Powers, J. S. (2014). Stand age and soils as drivers of plant functional traits and aboveground biomass in secondary tropical dry forest. *Canadian Journal of Forest Research*, *44*(6), 604–613. https://doi.org/10.1139/cjfr-2013-0331

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology Letters*, *15*(4), 365–377. https://doi.org/10.1111/j.1461-0248.2011.01736.x

Bivand, R., Altman, M., Anselin, L., Assunção, R., Berke, O., Bernat, A., …Yu, D. (2019). Package "spdep". Retrieved from https://cran.r-project.org/web/packages/spdep/spdep.pdf

Bivand, R., Keitt, T., & Rowlingson, B. (2018). Package "rgdal". Retrieved from https://cran.r-project.org/web/packages/rgdal/rgdal.pdf

Boisvenue, C., & Running, S. W. (2006). Impacts of climate change on natural forest productivity—Evidence since the middle of the 20th century. *Global Change Biology*, *12*(5), 862–882. https://doi.org/10.1111/j.1365-2486.2006.01134.x

Bormann, F. H., & Likens, G. E. (1979). Catastrophic disturbance and the steady-state in northern hardwood forests. *American Scientist*, *67*(6), 660–669.

Boulanger, Y., Taylor, A. R., Price, D. T., Cyr, D., McGarrigle, E., Rammer, W., … Mansuy, N. (2017). Climate change impacts on forest landscapes along the Canadian southern boreal forest transition zone. *Landscape Ecology*, *32*(7), 1415–1431. https://doi.org/10.1007/s10980-016-0421-7

Boulanger, Y., Taylor, A. R., Price, D. T., Cyr, D., & Sainte-Marie, G. (2018). Stand-level drivers most important in determining boreal forest response to climate change. *Journal of Ecology*, *106*(3), 977–990. https://doi.org/10.1111/1365-2745.12892

Bradford, J. B., & D'Amato, A. W. (2012). Recognizing trade-offs in multi-objective land management. *Frontiers in Ecology and the Environment*, *10*(4), 210–216. https://doi.org/10.1890/110031

Breiman, L. (2001). Random forests. *Machine Learning*, *45*(1), 5–32. https://doi.org/10.1023/A:1010933404324

Bunn, A., Korpela, M., Biondi, F., Campelo, F., Mérian, P., Qeadan, F., …Wernicke, J. (2018). Package 'dplR'. Retrieved from https://cran.r-project.org/web/packages/dplR/dplR.pdf

Bürgi, M., Östlund, L., & Mladenoff, D. J. (2017). Legacy effects of human land use: Ecosystems as time-lagged systems. *Ecosystems*, *20*(1), 94–103. https://doi.org/10.1007/s10021-016-0051-6

Bürkner, P.-C. (2018). Package "brms". Retrieved from https://cran.r-project.org/web/packages/brms/brms.pdf

CEC. (2010). Terrestrial protected areas of North America, 2010. Retrieved from https://www.sciencebase.gov/catalog/item/4fb68c04e4b03ad19d64b3dc

Collins, B. M., Fry, D. L., Lydersen, J. M., Everett, R., & Stephens, S. L. (2017). Impacts of different land management histories on forest change. *Ecological Applications*, 1–12. https://doi.org/10.1002/eap.1622

Creutzburg, M. K., Scheller, R. M., Lucash, M. S., LeDuc, S. D., & Johnson, M. G. (2017). Forest management scenarios in a changing climate: Trade-offs between carbon, timber, and old forest. *Ecological Applications*, *27*(2), 503–518. https://doi.org/10.1002/eap.1460

Crow, T. R., Buckley, D. S., Nauertz, E. A., & Zasada, J. C. (2002). Effects of management on the composition and structure of northern hardwood forests in Upper Michigan. *Forest Science*, *48*(1), 129–145.

D'Amato, A. W., Bradford, J. B., Fraver, S., & Palik, B. J. (2011). Forest management for mitigation and adaptation to climate change: Insights from long-term silviculture experiments. *Forest Ecology and Management*, *262*(5), 803–816. https://doi.org/10.1016/j.foreco.2011.05.014

D'Orangeville, L., Houle, D., Duchesne, L., Phillips, R. P., Bergeron, Y., & Kneeshaw, D. (2018). Beneficial effects of climate warming on boreal tree growth may be transitory. *Nature Communications*, *9*(1), 1–10. https://doi.org/10.1038/s41467-018-05705-4

Díaz, I., Armesto, J., Reid, S., Sieving, K., & Willson, M. (2005). Linking forest structure and composition: Avian diversity in successional forests of Chiloé Island, Chile. *Biological Conservation*, *123*(1), 91–101. https://doi.org/10.1016/j.biocon.2004.10.011

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., … Lautenbach, S. (2013). Collinearity: A review of methods to deal with it and a simulation study evaluating their performance. *Ecography*, *36*(1), 27–46. https://doi.org/10.1111/j.1600-0587.2012.07348.x

Dukes, J. S., Pontius, J., Orwig, D., Garnas, J. R., Rodgers, V. L., Brazee, N., … Ayres, M. (2009). Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? *Canadian Journal of Forest Research*, *39*(2), 231–248. https://doi.org/10.1139/X08-171

Eilmann, B., & Rigling, A. (2012). Tree-growth analyses to estimate tree species' drought tolerance. *Tree Physiology*, *32*(2), 178–187. https://doi.org/10.1093/treephys/tps004

EPA. (2016). Ecoregions of North America. Retrieved from https://www.epa.gov/eco-research/ecoregions-north-america

EROS. (2018). 30 arc-second DEM of North America. Retrieved from http://databasin.org/datasets/d2198be9d2264de19cb93fe6a380b69c

Evans, P., & Brown, C. D. (2017). The boreal–temperate forest ecotone response to climate change. *Environmental Reviews*, *25*(4), 423–431. https://doi.org/10.1139/er-2017-0009

Fahey, R. T., Alveshere, B. C., Burton, J. I., D'Amato, A. W., Dickinson, Y. L., Keeton, W. S., … Hardiman, B. S. (2018). Shifting conceptions of complexity in forest management and silviculture. *Forest Ecology and Management*, *421*, 59–71. https://doi.org/10.1016/j.foreco.2018.01.011

FAO. (2016). *State of the World's Forests 2016*. Rome, Italy: Food and Agriculture Organization of the United Nations. https://doi.org/10.1146/annurev-environ-102014-021358

Felipe-Lucia, M. R., Soliveres, S., Penone, C., Manning, P., van der Plas, F., Boch, S., … Allan, E. (2018). Multiple forest attributes underpin the supply of multiple ecosystem services. *Nature Communications*, *9*(1), 4839. https://doi.org/10.1038/s41467-018-07082-4

Fischer, G., Nachtergaele, F. O., Prieler, S., van Velthuizen, H., Verelst, L., & Wiberg, D. (2008). Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). Retrieved from http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/

Ford, S. E., & Keeton, W. S. (2017). Enhanced carbon storage through management for old-growth characteristics in northern hardwood-conifer forests. *Ecosphere*, *8*(4), e01721. https://doi.org/10.1002/ecs2.1721

Foster, D. R., Motzkin, G., & Slater, B. (1998). Land-use history as long-term broad-scale disturbance: Regional forest dynamics in central New England. *Ecosystems*, *1*(1), 96–119. https://doi.org/10.1007/s100219900008

Foster, D. R., Swanson, F., Aber, J. D., Burke, I., Brokaw, N., Tilman, D., & Knapp, A. (2003). The importance of land-use legacies to ecology and conservation. *BioScience*, *53*(1), 77. https://doi.org/10.1641/0006-3568(2003) 053

Franklin, J. F. (1993). Preserving biodiversity: Species, ecosystems, or landscapes? *Ecological Applications*, *3*(2), 202–205. https://doi.org/10.2307/1941820

Franklin, J. F., Lindenmayer, D., MacMahon, J. A., McKee, A., Magnuson, J., Perry, D. A., … Foster, D. (2000). Threads of continuity. *Conservation in Practice*, *1*(1), 8–17. https://doi.org/10.1111/j.1526-4629.2000.tb00155.x

Franklin, J. F., Spies, T. A., Van Pelt, R., Carey, A. B., Thornburgh, D. A., Berg, D. R., … Chen, J. (2002). Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. *Forest Ecology and Management*, *155*(1–3), 399–423. https://doi.org/10.1016/S0378-1127(01)00575-8

Frey, S. J. K., Hadley, A. S., Johnson, S. L., Schulze, M., Jones, J. A., & Betts, M. G. (2016). Spatial models reveal the microclimatic buffering capacity of old-growth forests. *Science Advances*, *2*(4), e1501392. https://doi.org/10.1126/sciadv.1501392

Fritz, Ö., Niklasson, M., & Churski, M. (2009). Tree age is a key factor for the conservation of epiphytic lichens and bryophytes in beech forests. *Applied Vegetation Science*, *12*, 93–106. https://doi.org/10.1111/j.1654-109x.2009.01007.x

Fuhr, M., Bourrier, F., & Cordonnier, T. (2015). Protection against rockfall along a maturity gradient in mountain forests. *Forest Ecology and Management*, *354*, 224–231. https://doi.org/10.1016/j.foreco.2015.06.012

Garbarino, M., Marzano, R., Shaw, J. D., & Long, J. N. (2015). Environmental drivers of deadwood dynamics in woodlands and forests. *Ecosphere*, *6*(3), art30. https://doi.org/10.1890/ES14-00342.1

Gough, C. M., Curtis, P. S., Hardiman, B. S., Scheuermann, C., & Bond-Lamberty, B. (2016). Disturbance, complexity, and succession of net ecosystem production in North America's temperate deciduous forests. *Ecosphere*, *7*(6), 1–15. https://doi.org/10.1002/ecs2.1375

Halpin, C. R., & Lorimer, C. G. (2016). Long-term trends in biomass and tree demography in northern hardwoods: An integrated field and simulation study. *Ecological Monographs*, *86*(1), 78–93. https://doi.org/10.1890/15-0392.1

Hamann, A., & Wang, T. (2006). Potential effects of climate change on ecosystem and tree species distribution in British Columbia. *Ecology*, *87*(11), 2773–2786. https://doi.org/10.1890/0012-9658(2006)87[2773:PEOCCO]2.0.CO;2

Hanson, J. J., & Lorimer, C. G. (2007). Forest structure and light regimes following moderate wind storms: Implications for multi-cohort management. *Ecological Applications*, *17*(5), 1325–1340. https://doi.org/10.1890/06-1067.1

Hardiman, B. S., Bohrer, G., Gough, C. M., Vogel, C. S., & Curtis, P. S. (2011). The role of canopy structural complexity in wood net primary production of a maturing northern deciduous forest. *Ecology*, *92*(9), 1818–1827. https://doi.org/10.1890/10-2192.1

Harmon, M. E. (2001). Carbon sequestration in forests: Addressing the scale question. *Journal of Forestry*, *99*, 24–29. https://doi.org/10.1093/jof/99.4.24

Hayhoe, K., Edmonds, J., Kopp, R. E., LeGrande, A. N., Sanderson, B. M., Wehner, M. F., & Wuebbles, D. J. (2017). Climate models, scenarios, and projections. In: D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, & T. K. May-cock (Eds.), *Climate science special report: Fourth national climate assessment* (Vol. *1*) (pp. 133–160). Washington, DC: U.S. Global Change Research Program.

Hijmans, R. J. (2018). Package "raster". Retrieved from https://cran.r-project.org/web/packages/raster/raster.pdf

Hilmers, T., Friess, N., Bässler, C., Heurich, M., Brandl, R., Pretzsch, H., … Müller, J. (2018). Biodiversity along temperate forest succession. *Journal of Applied Ecology*, *55*(6), 2756–2766. https://doi.org/10.1111/1365-2664.13238

Irauschek, F., Rammer, W., & Lexer, M. J. (2017). Evaluating multifunctionality and adaptive capacity of mountain forest management alternatives under climate change in the Eastern Alps. *European Journal of Forest Research*, *136*(5–6), 1051–1069. https://doi.org/10.1007/s10342-017-1051-6

Ives, A. R. (2015). For testing the significance of regression coefficients, go ahead and log-transform count data. *Methods in Ecology and Evolution*, *6*(7), 828–835. https://doi.org/10.1111/2041-210X.12386

Jansson, P. E., & Berg, B. (1985). Temporal variation of litter decomposition in relation to simulated soil climate: Long-term decomposition in a Scots pine forest. V. *Canadian Journal of Botany*, *63*(6), 1008–1016. https://doi.org/10.1139/b85-136

Kang, S., Kimball, J. S., & Running, S. W. (2006). Simulating effects of fire disturbance and climate change on boreal forest productivity and evapotranspiration. *Science of the Total Environment*, *362*(1–3), 85–102. https://doi.org/10.1016/j.scitotenv.2005.11.014

Keeton, W. S. (2006). Managing for late-successional/old-growth characteristics in northern hardwood-conifer forests. *Forest Ecology and Management*, *235*(1–3), 129–142. https://doi.org/10.1016/j.foreco.2006.08.005

Keeton, W. S. (2018). Source or sink? Carbon dynamics in old-growth forests and their role in climate change mitigation. In A. M. Barton & W. S. Keeton (Eds.), *Ecology and recovery of Eastern old-growth forests* (pp. 1–360). Washington, DC: Island Press.

Keeton, W. S., Whitman, A. A., Mcgee, G. C., & Goodale, C. L. (2011). Late-successional biomass development in northern hardwood-conifer forests of the northeastern United States. *Forest Science*, *57*(6), 489–505. https://doi.org/10.1093/forestscience/57.6.489

Kern, C. C., Montgomery, R. A., Reich, P. B., & Strong, T. F. (2014). Harvest-created canopy gaps increase species and functional trait diversity of the forest ground-layer community. *Forest Science*, *60*(2), 335–344. https://doi.org/10.5849/forsci.13-015

Kurth, V. J., D'Amato, A. W., Palik, B. J., & Bradford, J. B. (2014). Fifteen-year patterns of soil carbon and nitrogen following biomass harvesting. *Soil Science Society of America Journal*, *78*(2), 624. https://doi.org/10.2136/sssaj2013.08.0360

Liaw, A., & Wiener, M. (2018). Package "randomForest". Retrieved from https://cran.r-project.org/web/packages/randomForest/randomForest.pdf

Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., … Marchetti, M. (2010). Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management*, *259*(4), 698–709. https://doi.org/10.1016/j.foreco.2009.09.023

Lorimer, C. G., & Halpin, C. R. (2014). Classification and dynamics of developmental stages in late-successional temperate forests. *Forest Ecology and Management*, *334*, 344–357. https://doi.org/10.1016/j.foreco.2014.09.003

Lutz, D. A., Burakowski, E. A., Murphy, M. B., Borsuk, M. E., Niemiec, R. M., & Howarth, R. B. (2016). Trade-offs between three forest ecosystem services across the state of New Hampshire, USA: Timber, carbon, and albedo. *Ecological Applications*, *26*(1), 146–161. https://doi.org/10.1890/14-2207

Maciver, D. C., & Wheaton, E. (2005). Tomorrow's forests: Adapting to a changing climate. *Climatic Change*, *70*(1–2), 273–282. https://doi.org/10.1007/s10584-005-5950-z

Manzoni, S., & Porporato, A. (2009). Soil carbon and nitrogen mineralization: Theory and models across scales. *Soil Biology and Biochemistry*, *41*(7), 1355–1379. https://doi.org/10.1016/j.soilbio.2009.02.031

Martin, M., Fenton, N., & Morin, H. (2018). Structural diversity and dynamics of boreal old-growth forests case study in Eastern Canada. *Forest Ecology and Management*, *422*, 125–136. https://doi.org/10.1016/j.foreco.2018.04.007

McCune, B. (2000). Lichen communities as indicators of forest health. *The Bryologist*, *103*(2), 353–356. https://doi.org/10.1639/0007-2745(2000)103[0353:lcaiof]2.0.co;2

McGarvey, J. C., Thompson, J. R., Epstein, H. E., & Shugart, H. H. (2015). Carbon storage in old-growth forests of the Mid-Atlantic: Toward better understanding the eastern forest carbon sink. *Ecology*, *96*(2), 311–317. https://doi.org/10.1890/14-1154.1

McGee, G. G., Leopold, D. J., & Nyland, R. D. (1999). Structural characteristics of old-growth, maturing, and partially cut northern hardwood forests. *Ecological Applications*, *9*(4), 1316–1329. https://doi.org/10.1890/1051-0761(1999)009[1316:SCOOGM]2.0.CO;2

McKenny, H. C., Keeton, W. S., & Donovan, T. M. (2006). Effects of structural complexity enhancement on eastern red-backed salamander (*Plethodon cinereus*) populations in northern hardwood forests. *Forest Ecology and Management*, *230*(1–3), 186–196. https://doi.org/10.1016/j.foreco.2006.04.034

Morin, X., Fahse, L., Jactel, H., Scherer-Lorenzen, M., García-Valdés, R., & Bugmann, H. (2018). Long-term response of forest productivity to climate change is mostly driven by change in tree species composition. *Scientific Reports*, *8*(1), 5627. https://doi.org/10.1038/s41598-018-23763-y

Murray, D. L., Peers, M. J. L., Majchrzak, Y. N., Wehtje, M., Ferreira, C., Pickles, R. S. A., … Thornton, D. H. (2017). Continental divide: Predicting climate mediated fragmentation and biodiversity loss in the boreal forest. *PLoS ONE*, *12*(5), 1–20. https://doi.org/10.1371/journal.pone.0176706

Naimi, B. (2017). Package "usdm". Retrieved from https://cran.r-project.org/web/packages/usdm/usdm.pdf

Nakazawa, M. (2018). Package "fmsb". Retrieved from https://cran.r-project.org/web/packages/fmsb/fmsb.pdf

Nazarenko, L., Schmidt, G. A., Miller, R. L., Tausnev, N., Kelley, M., Ruedy, R., … Zhang, J. (2015). Future climate change under RCP emission scenarios with GISS ModelE2. *Journal of Advances in Modeling Earth Systems*, *7*(1), 244–267. https://doi.org/10.1002/2014MS000403

Ollinger, S. V., Aber, J. D., Reich, P. B., & Freuder, R. J. (2002). Interactive effects of nitrogen deposition, tropospheric ozone, elevated CO2 and land use history on the carbon dynamics of northern hardwood forests. *Global Change Biology*, *8*(6), 545–562. https://doi.org/10.1046/j.1365-2486.2002.00482.x

Pan, Y., Chen, J. M., Birdsey, R., McCullough, K., He, L., & Deng, F. (2011). Age structure and disturbance legacy of North American forests. *Biogeosciences*, *8*(3), 715–732. https://doi.org/10.5194/bg-8-715-2011

Pebesma, E. J. (2018). Package "gstat". Retrieved from https://cran.r-project.org/web/packages/gstat/gstat.pdf

Pebesma, E. J., & Bivand, R. S. (2018). Package "sp". Retrieved from https://cran.r-project.org/web/packages/sp/sp.pdf

Pukkala, T. (2016). Which type of forest management provides most ecosystem services? *Forest Ecosystems*, *3*(1), 9. https://doi.org/10.1186/s40663-016-0068-5

R Development Core Team. (2017). Package "foreign". Retrieved from https://cran.r-project.org/package=foreign

R Development Core Team. (2018). R: A language and environment for statistical computing. Retrieved from http://r-project.org

Reinmann, A. B., Susser, J. R., Demaria, E. M. C., & Templer, P. H. (2019). Declines in northern forest tree growth following snowpack decline and soil freezing. *Global Change Biology*, *25*(2), 420–430. https://doi.org/10.1111/gcb.14420

Rouifed, S., Handa, I. T., David, J. F., & Hättenschwiler, S. (2010). The importance of biotic factors in predicting global change effects on decomposition of temperate forest leaf litter. *Oecologia*, *163*(1), 247–256. https://doi.org/10.1007/s00442-009-1528-1

Sala, O. E. (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*(5459), 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Samuel-Rosa, A. (2015). Package "pedometrics". Retrieved from https://cran.rstudio.com/web/packages/pedometrics/pedometrics.pdf

Schröter, D., Cramer, W., Leemans, R., Prentice, I. C., Araújo, M. B., Arnell, N. W., … Zierl, B. (2005). Ecosystem service supply and vulnerability to global change in Europe. *Science*, *310*(5752), 1333–1337. https://doi.org/10.1126/science.1115233

Schuler, T. M. (2004). Fifty years of partial harvesting in a mixed mesophytic forest: Composition and productivity. *Canadian Journal of Forest Research*, *34*(5), 985–997. https://doi.org/10.1139/x03-262

Schwenk, W. S., Donovan, T. M., Keeton, W. S., & Nunery, J. S. (2012). Carbon storage, timber production, and biodiversity: Comparing ecosystem services with multi-criteria decision analysis. *Ecological Applications*, *22*(5), 1612–1627. https://doi.org/10.1890/11-0864.1

Seddon, A. W. R., Macias-Fauria, M., Long, P. R., Benz, D., & Willis, K. J. (2016). Sensitivity of global terrestrial ecosystems to climate variability. *Nature*, *531*(7593), 229–232. https://doi.org/10.1038/nature16986

Seedre, M., Taylor, A. R., Brassard, B. W., Chen, H. Y. H., & Jõgiste, K. (2014). Recovery of ecosystem carbon stocks in young boreal forests: A comparison of harvesting and wildfire disturbance. *Ecosystems*, *17*(5), 851–863. https://doi.org/10.1007/s10021-014-9763-7

Seidl, R., Rammer, W., & Spies, T. A. (2014). Disturbance legacies increase the resilience of forest ecosystem structure, composition, and functioning. *Ecological Applications*, *24*(8), 2063–2077. https://doi.org/10.1890/14-0255.1

Seidl, R., Schelhaas, M.-J., Rammer, W., & Verkerk, P. J. (2014). Increasing forest disturbances in Europe and their impact on carbon storage. *Nature Climate Change*, *4*(9), 806–810. https://doi.org/10.1038/nclimate2318

Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., … Reyer, C. P. O. (2017). Forest disturbances under climate change. *Nature Climate Change*, *7*(6), 395–402. https://doi.org/10.1038/nclimate3303

Selva, S. B. (1994). Lichen diversity and stand continuity in the northern hardwoods and spruce-fir forests of northern New England and western New Brunswick. *The Bryologist*, *97*(4), 424–429. https://doi.org/10.2307/3243911

Smith, K. J., Keeton, W. S., Twery, M. J., & Tobi, D. R. (2008). Understory plant responses to uneven-aged forestry alternatives in northern hardwood–conifer forests. *Canadian Journal of Forest Research*, *38*(6), 1303–1318. https://doi.org/10.1139/X07-236

Swanson, M. E., Franklin, J. F., Beschta, R. L., Crisafulli, C. M., DellaSala, D. A., Hutto, R. L., … Swanson, F. J. (2011). The forgotten stage of forest succession: Early-successional ecosystems on forest sites. *Frontiers in Ecology and the Environment*, *9*(2), 117–125. https://doi.org/10.1890/090157

Taylor, A. R., Boulanger, Y., Price, D. T., Cyr, D., McGarrigle, E., Rammer, W., & Kershaw, J. A. (2017). Rapid 21st century climate change projected to shift composition and growth of Canada's Acadian Forest Region. *Forest Ecology and Management*, *405*, 284–294. https://doi.org/10.1016/j.foreco.2017.07.033

Taylor, A. R., & Chen, H. Y. H. (2011). Multiple successional pathways of boreal forest stands in central Canada. *Ecography*, *34*(2), 208–219. https://doi.org/10.1111/j.1600-0587.2010.06455.x

Thom, D., & Keeton, W. S. (2019). Stand structure drives divergences in carbon storage in northern hardwood-conifer forests. *Forest Ecology and Management*, *442*, 10–20. https://doi.org/10.1016/j.foreco.2019.03.053

Thom, D., Rammer, W., Dirnböck, T., Müller, J., Kobler, J., Katzensteiner, K., … Seidl, R. (2017). The impacts of climate change and disturbance on spatio-temporal trajectories of biodiversity in a temperate forest landscape. *Journal of Applied Ecology*, *54*(1), 28–38. https://doi.org/10.1111/1365-2664.12644

Thom, D., Rammer, W., Garstenauer, R., & Seidl, R. (2018). Legacies of past land use have a stronger effect on forest carbon exchange than future climate change in a temperate forest landscape. *Biogeosciences*, *15*(18), 5699–5713. https://doi.org/10.5194/bg-15-5699-2018

Thom, D., Rammer, W., & Seidl, R. (2017a). Disturbances catalyze the adaptation of forest ecosystems to changing climate conditions. *Global Change Biology*, *23*(1), 269–282. https://doi.org/10.1111/gcb.13506

Thom, D., Rammer, W., & Seidl, R. (2017b). The impact of future forest dynamics on climate: Interactive effects of changing vegetation and disturbance regimes. *Ecological Monographs*, *87*(4), 665–684. https://doi.org/10.1002/ecm.1272

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., … Williams, S. E. (2004). Extinction risk from climate change. *Nature*, *427*(6970), 145–148. https://doi.org/10.1038/nature02121

Thorn, S., Bässler, C., Brandl, R., Burton, P. J., Cahall, R., Campbell, J. L., … Müller, J. (2017). Impacts of salvage logging on biodiversity: A meta-analysis. *Journal of Applied Ecology*, *55*, 279–289. https://doi.org/10.1111/1365-2664.12945

Thuiller, W., Lavergne, S., Roquet, C., Boulangeat, I., Lafourcade, B., & Araujo, M. B. (2011). Consequences of climate change on the tree of life in Europe. *Nature*, *470*(7335), 531–534. https://doi.org/10.1038/nature09705

Thuiller, W., Lavorel, S., Araujo, M. B., Sykes, M. T., & Prentice, I. C. (2005). Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences*, *102*(23), 8245–8250. https://doi.org/10.1073/pnas.0409902102

Triviño, M., Pohjanmies, T., Mazziotta, A., Juutinen, A., Podkopaev, D., Le Tortorec, E., & Mönkkönen, M. (2017). Optimizing management to enhance multifunctionality in a boreal forest landscape. *Journal of Applied Ecology*, *54*(1), 61–70. https://doi.org/10.1111/1365-2664.12790

Tyrrell, L. E., & Crow, T. R. (1994). Structural characteristics of old-growth hemlock-hardwood forests in relation to age. *Ecology*, *75*(2), 370–386. https://doi.org/10.2307/1939541

Urbano, A. R., & Keeton, W. S. (2017). Carbon dynamics and structural development in recovering secondary forests of the northeastern U.S. *Forest Ecology and Management*, *392*, 21–35. https://doi.org/10.1016/j.foreco.2017.02.037

Vehtari, A., Gelman, A., & Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing*, *27*(5), 1413–1432. https://doi.org/10.1007/s11222-016-9696-4

Ward, C., Pothier, D., & Paré, D. (2014). Do boreal forests need fire disturbance to maintain productivity? *Ecosystems*, *17*(6), 1053–1067. https://doi.org/10.1007/s10021-014-9782-4

Weng, E., Luo, Y., Wang, W., Wang, H., Hayes, D. J., McGuire, A. D., … Schimel, D. S. (2012). Ecosystem carbon storage capacity as affected by disturbance regimes: A general theoretical model. *Journal of Geophysical Research: Biogeosciences*, *117*(G3), 1–15. https://doi.org/10.1029/2012JG002040

Wickham, H. (2009). Package "ggplot2". Retrieved from https://cran.r-project.org/web/packages/ggplot2/ggplot2.pdf

Wickham, H. (2017). Package "reshape2". Retrieved from https://cran.r-project.org/web/packages/reshape2/reshape2.pdf

Wickham, H., Francois, R., Henry, L., & Müller, K. (2018). Package "dplyr". Retrieved from https://cran.r-project.org/web/packages/dplyr/dplyr.pdf

WorldClim. (2016). WorldClim 2.0 Beta version 1. Retrieved from http://worldclim.org

Zilliox, C., & Gosselin, F. (2014). Tree species diversity and abundance as indicators of understory diversity in French mountain forests: Variations of the relationship in geographical and ecological space. *Forest Ecology and Management*, *321*, 105–116. https://doi.org/10.1016/j.foreco.2013.07.049

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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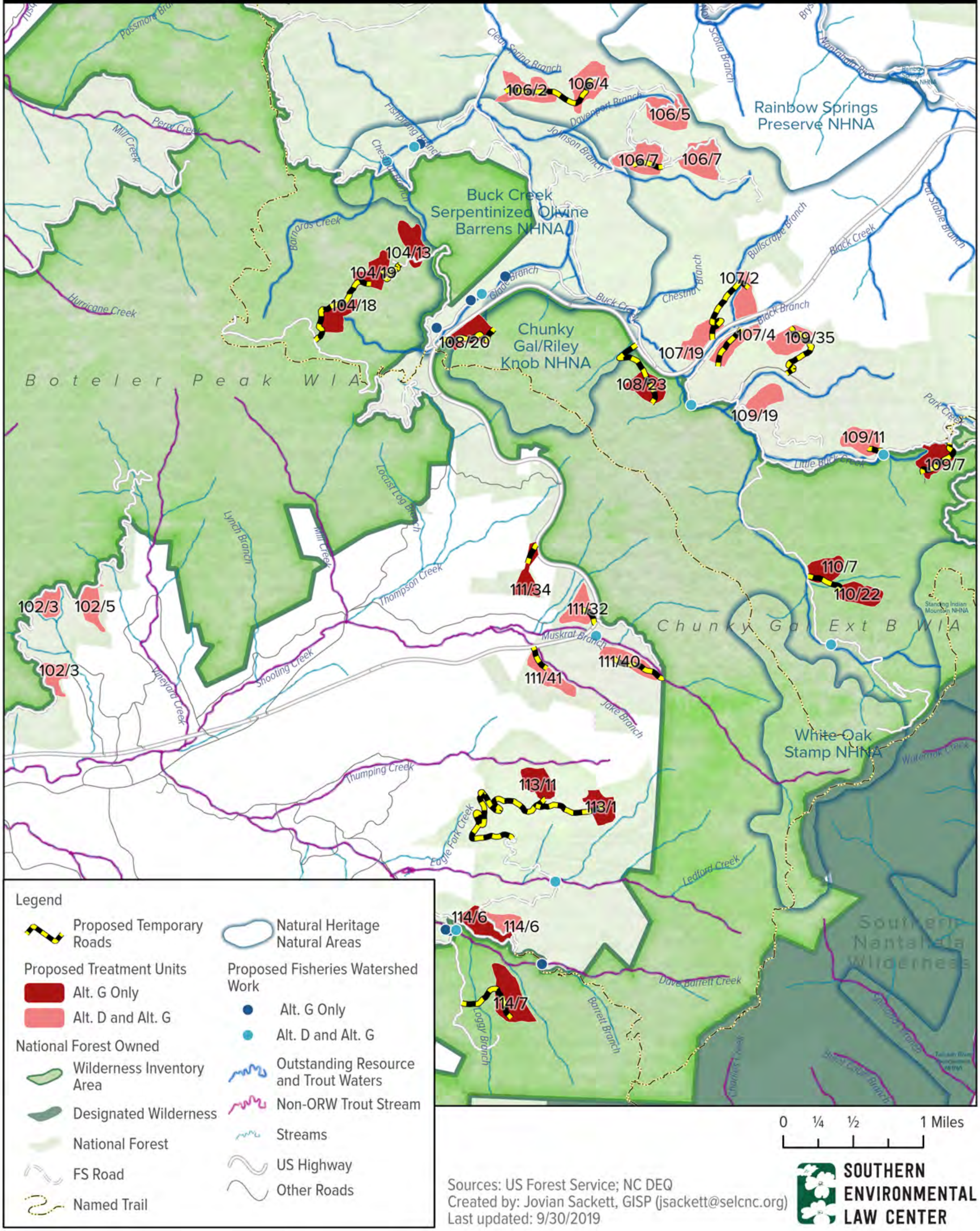
Attachment 12

Comparison of Alternatives D and G, Buck Project



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