Full Descriptions of all Shortleaf Pine-Oak Woodland Metrics

Carl Nordman, Don Faber-Langendoen, and Joanne Baggs

NatureServe and the USDA Forest Service

November 2021

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[1] NatureServe, Data and Methods Division, Arlington, VA

[2] USDA Forest Service, Atlanta, GA

Acknowledgements

The NatureServe project team would like to thank the effort of Joanne Baggs and the many other US Forest Service staff who have helped improve the rapid assessment metrics for shortleaf and Appalachian pine ecosystems. We also appreciate the work of researchers and land managers whose cooperation has advanced our understanding of southern open pine ecosystems. In particular, these efforts have improved our understanding of shortleaf and Appalachian pine ecosystems and their restoration. The scientists of the US Forest Service, Southern Research Station and scientists at Land-Grant Universities have helped greatly improve our understanding of southern open pine ecosystems. NatureServe is a network organization, and our strength comes from our many network partners. These partner Natural Heritage Programs have worked with NatureServe in recent years to advance the ecological integrity assessment methods, so that regionally appropriate and science-based assessment methods are available to land managers.

Suggested Citation:
Nordman, C., D. Faber-Langendoen, J. Baggs. 2021. Full Descriptions of all Shortleaf Pine-Oak Woodland Metrics. NatureServe and the USDA Forest Service. Available online: https://www.natureserve.org https://www.natureserve.org/projects/developing-rapid-assessment-metrics-measuring-open-pine-ecosystem-health-southeastern-0

Cover Photo: Shortleaf Pine image from the USDA Forest Service, SRS (in the public domain and shared on Wikipedia).

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INTRODUCTION

Open woodlands dominated by southern yellow pines were historically a large component of the landscape across the southeastern United States. These include longleaf, slash, shortleaf, loblolly, pitch, and Table Mountain pines. As human populations increased, and land management practices and land use patterns changed, these once dominant open pine ecosystems were cleared for agriculture and/or development, resulting in significant declines in both extent and quality of pine systems across the southeast (Oswald 2012). In fact, longleaf and shortleaf pine dominated systems have declined to the point where only a small fraction of their original historic acreage remains today (Anderson et al. 2016, Oswald 2012). This project facilitates the identification, prioritization, and enhancement of sites to advance the conservation and management of these precious open pine ecosystems and wildlife.

NatureServe has worked over the past decade with the USDA Forest Service, US Fish & Wildlife Service, Florida Natural Areas Inventory, Alabama Natural Heritage Program, the Shortleaf Pine Initiative, and other partners to advance rapid assessment field methods for southern open pine ecosystems. These methods should be easy to apply in the field, repeatable, scalable, ecologically meaningful, relevant to ecological integrity, and complementary (not redundant). A few metrics for each stratum (canopy, midstory, shrub, and ground layer) should constitute a good rapid assessment method for field data collection for southern open pine ecosystems.

Rapid assessment metrics are presented here for southern open pine ecosystems, dominated by shortleaf pine, pitch pine, and Table Mountain Pine. This document contains the rapid assessment metrics for the five Shortleaf Pine – Oak and Southern Appalachian Pine - Oak Woodland Groups (Table 1). The overview of the project (Nordman et al. 2021) is described in:

Nordman, Carl, Don Faber-Langendoen, and Joanne Baggs. 2021. Rapid Ecological Assessment Metrics to Restore Wildlife Habitat and Biodiversity for Shortleaf Pine-Oak Ecosystems. Forests 12. https://doi.org/10.3390/xxx

The rapid assessment metrics follow NatureServe's Ecological Integrity Assessment approach, which has been implemented for a variety of ecosystems across the United States. Details on this approach are available online at:

https://www.natureserve.org/products/ecological-integrity-assessment

Details on NatureServe's recent application of the Ecological Integrity Approach to rapid assessment metrics for southern open pine ecosystems are available in online at:

https://www.natureserve.org/projects/developing-rapid-assessment-metrics-measuring-open-pine-ecosystem-health-southeastern-0

Shortleaf Pine – Oak Woodland Classification

Table 1. Shortleaf Pine - Oak and Southern Appalachian Pine - Oak woodland groups. The 1st column shows the project Southern Open Pine Groups, and the 2nd column the shows the US National Vegetation Classification Alliance names and codes, followed by the Group code (in bold).

Southern Open Pine Groups	USNVC Group Name	USNVC Alliance Name
A.1. Interior Highlands Shortleaf Pine – Oak Forest and Woodlands	Interior Highlands Oak - Pine Forest & Woodland (G012a)	Ozark-Ouachita Shortleaf Pine - Oak Forest & Woodland (A2083)
A.2. Interior Highlands Shortleaf Pine – Bluestem Woodlands	Interior Highlands Oak - Pine Forest & Woodland (G012a)	Ozark-Ouachita Shortleaf Pine - Bluestem Woodland (A2082)
B. Montane Longleaf Pine – Shortleaf Pine Woodlands	Interior Highlands Oak - Pine Forest & Woodland (G012c)	Montane Longleaf Pine - Shortleaf Pine Woodland (A3272)
C. Southern Appalachian Pine-Oak	Southern Appalachian Virginia Pine - Table Mountain Pine Woodland (G905)	Appalachian Table Mountain Pine - Pitch Pine - Chestnut Oak Woodland (A0677)
		Appalachian Shortleaf Pine - Oak Woodland (A3269)
D. West Gulf Coastal Plain Pine – Oak Woodlands	Western Gulf Coastal Plain Pine – Oak Forest & Woodland (G013)	West Gulf Coastal Plain Scrub Oak - Shortleaf Pine Sandhill Woodland (A0386)
		West Gulf Coastal Plain Shortleaf Pine - Post Oak Forest (A3129)
		West Gulf Coastal Plain Loblolly Pine - White Oak Forest (A3130)
E. Southeast Coastal Plain & Piedmont Shortleaf Pine – Oak Woodlands	Interior Highlands Oak - Pine Forest & Woodland (G012b)	Upper Coastal Plain Shortleaf Pine – Oak Woodland (A3270)
	Piedmont- Coastal Plain Oak- (Pine) Forest & Woodland (G165)	Piedmont Post Oak - Hickory - Pine Woodland (A3294)*

*former A3268 largely merged into A3294

Shortleaf Pine – Oak Woodland Metrics by Group

Rapid assessment metrics for Shortleaf Pine - Oak and Southern Appalachian Pine - Oak Woodlands are included here. The metrics are in subsets representing the canopy, midstory, and ground layer, and the larger landscape setting. This approach of grouping metrics by strata allows users to assess the condition of the canopy (trees >5” DBH), midstory (trees 10 feet tall to base of the tree canopy), tall shrubs (3-10 feet tall), short shrubs (<3 feet tall), and ground layer separately (Longleaf Partnership Council 2014), and to also include an evaluation of the broader landscape setting of the area assessed.

Interior Highlands Shortleaf Pine-Oak Woodlands **(Dry & Mesic Highlands Pine Woodlands)**				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine	<10 or >110 ft^2/acre basal area of shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of shortleaf pine	20-25% or >70 to 80% canopy cover of shortleaf pine	10 to <20% or >80 to 90% canopy cover of shortleaf pine	<10% or >90% canopy cover of shortleaf pine
Southern Yellow Pine Stand Size Structure	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14” DBH class	Basal area ≥10 to <20 ft^2/acre of shortleaf pine trees ≥14” DBH class	Shortleaf pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees	No shortleaf pine trees ≥14” DBH are present
Canopy Fire Tolerant Hardwood Basal Area	≤50 ft^2/acre BA of fire tolerant hardwood trees	>50 to 60 ft^2/acre BA of fire tolerant hardwood trees	>60 to 70 ft^2/acre BA of fire tolerant hardwood trees	>70 ft^2/acre BA of fire tolerant hardwood trees
Canopy Fire Intolerant Tree Basal Area	≤10 ft^2/acre BA of fire intolerant trees	>10 to 20 ft^2/acre BA of fire intolerant trees	>20 to 30 ft^2/acre BA of fire intolerant trees	>30 ft^2/acre BA of fire intolerant trees
Stand Density Index (Optional, applies to shortleaf pine)	SDI = 65 – 135 (14 - 30% of Maximum SDI of 450)	SDI = 45 – 65 or 135 - 180 (10-14% or 30-40% of Maximum SDI of 450)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	2 to <20% cover of midstory fire tolerant hardwoods	20-40%cover of midstory fire tolerant hardwoods	>40 to 50%, or <2% cover of midstory fire tolerant hardwoods	>50% cover of midstory fire tolerant hardwoods
Midstory Fire Intolerant Tree Cover	<10% cover of fire intolerant tree midstory	10 to 20% cover of fire intolerant tree midstory	>20 to 30% cover of fire intolerant tree midstory	>30% cover of fire intolerant tree midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <30% cover	Tall shrubs average 30 - 40% cover	Tall shrubs average >40 to 50% cover	Tall shrubs average >50% cover
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 30% cover	Short shrubs average >30 to 50% cover	Short shrubs average >50% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover
Native Graminoid Cover	>25 to 85% cover of all native graminoids	>15 to 25% or >85% cover of native graminoids	10-15% cover of all native graminoids	<10% cover of all native graminoids
Floristic Quality Index, Mean C (Optional)	Mean C >4.00	Mean C is 3.01 to 4.00	Mean C is 2.01 to 3.00	Mean C <2.00
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent	Invasive nonnative plant species present in any stratum but sporadic (<1 % cover)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)	Invasive nonnative plant species in any stratum common (>5% cover)
Soil Metric				
Forest Soil Disturbance	Soil Disturbance Class 0	Soil Disturbance Class 1	Soil Disturbance Class 2	Soil Disturbance Class 3

Interior Highlands Shortleaf Pine-Bluestem Woodlands **(Dry & Mesic Highlands Pine Woodlands)**				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine	<10 or >110 ft^2/acre basal area of shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of shortleaf pine	20-25% or >70 to 80% canopy cover of shortleaf pine	10 to <20% or >80 to 90% canopy cover of shortleaf pine	<10% or >90% canopy cover of shortleaf pine
Southern Yellow Pine Stand Size Structure	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14" DBH class	Basal area ≥10 to <20 ft^2/acre of shortleaf pine trees ≥14" DBH class	Shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No shortleaf pine trees ≥14" DBH are present
Canopy Fire Tolerant Hardwood Basal Area	≤20 ft^2/acre BA of fire tolerant hardwood trees	>20 to 30 ft^2/acre BA of fire tolerant hardwood trees	>30 to 40 ft^2/acre BA of fire tolerant hardwood trees	>40 ft^2/acre BA of fire tolerant hardwood trees
Canopy Fire Intolerant Tree Basal Area	≤10 ft^2/acre BA of fire intolerant trees	>10 to 20 ft^2/acre BA of fire intolerant trees	>20 to 30 ft^2/acre BA of fire intolerant trees	>30 ft^2/acre BA of fire intolerant trees
Stand Density Index (Optional, applies to shortleaf pine)	SDI = 65 – 135 (14 - 30% of Maximum SDI of 450)	SDI = 45 – 65 or 135 - 180 (10-14% or 30-40% of Maximum SDI of 450)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	2 to 10% cover of midstory fire tolerant hardwoods	10-30%, or <2% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Fire Intolerant Tree Cover	<5% cover of fire intolerant tree midstory	5-10% cover of fire intolerant tree midstory	>10 to 20% cover of fire intolerant tree midstory	>20% cover of fire intolerant tree midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <5% cover.	Tall shrubs average 5 - 10% cover.	Tall shrubs average >10 to 25% cover.	Tall shrubs average >25% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover
Native Graminoid Cover	>25 to 85% cover of all native graminoids	20 to 25% or >85% cover of native graminoids	10 to <20% cover of all native graminoids	<10% cover of all native graminoids
Floristic Quality Index, Mean C (Optional)	Mean C >4.00	Mean C is 3.01 to 4.00	Mean C is 2.01 to 3.00	Mean C <2.00
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent	Invasive nonnative plant species present in any stratum but sporadic (<1 % cover)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)	Invasive nonnative plant species in any stratum common (>5% cover)
Soil Metric				
Forest Soil Disturbance	Soil Disturbance Class 0	Soil Disturbance Class 1	Soil Disturbance Class 2	Soil Disturbance Class 3

Montane Longleaf Pine - Shortleaf Pine Woodlands				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of longleaf and/or shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of longleaf and/or shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of longleaf and/or shortleaf pine	<10 or >110 ft^2/acre basal area of longleaf and/or shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of longleaf and/or shortleaf pine	20-25% or >70 to 80% canopy cover of longleaf and/or shortleaf pine	10 to <20% or >80 to 90% canopy cover of longleaf and/or shortleaf pine	<10% or >90% canopy cover of longleaf and/or shortleaf pine
Southern Yellow Pine Stand Size Structure	Basal area ≥20 ft^2/acre of longleaf pine and/or shortleaf pine trees ≥14" DBH class or flat-top longleaf pine is present	BA ≥10 to <20 ft^2/acre of longleaf and/or shortleaf pine trees ≥14" DBH class. No flat-top longleaf pine is present.	Longleaf and/or shortleaf pine trees ≥14" DBH class are present, but at <10 ft^2/acre BA. No flat-top longleaf pine is present.	No longleaf and/or shortleaf pine trees ≥14" DBH or flat-top longleaf pine are present
Canopy Fire Tolerant Hardwood Basal Area	≤20 ft^2/acre BA of fire tolerant hardwood trees	>20 to 40 ft^2/acre BA of fire tolerant hardwood trees	>40 to 50 ft^2/acre BA of fire tolerant hardwood trees	>50 ft^2/acre BA of fire tolerant hardwood trees
Canopy Fire Intolerant Tree Basal Area	≤10 ft^2/acre BA of fire intolerant trees	>10 to 20 ft^2/acre BA of fire intolerant trees	>20 to 30 ft^2/acre BA of fire intolerant trees	>30 ft^2/acre BA of fire intolerant trees
Stand Density Index (Optional, applies to longleaf pine)	SDI = 55 – 120 (14 - 30% of Maximum SDI of 400)	SDI = 40 – 55 or 120 -160 (10-14% or 30-40% of Maximum SDI of 400)	SDI = 15 – 40 or 160 - 200 (4-10% or 40-50% of maximum SDI)	SDI <15 or >200 (<4% or >50%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	2 to 10% cover of midstory fire tolerant hardwoods	10-30%, or <2% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Fire Intolerant Tree Cover	<5% cover of fire intolerant tree midstory	5 to 10% cover of fire intolerant tree midstory	>10 to 20% cover of fire intolerant tree midstory	>20% cover of fire intolerant tree midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20-25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover
Native Graminoid Cover	>25 to 85% cover of all native graminoids	20-25% or >85% cover of all native graminoids	10 to <20% cover of all native graminoids	<10% cover of all native graminoids
Floristic Quality Index, Mean C (Optional)	Mean C >4.00	Mean C is 3.01 to 4.00	Mean C is 2.01 to 3.00	Mean C <2.00
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent	Invasive nonnative plant species present in any stratum but sporadic (<1 % cover)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)	Invasive nonnative plant species in any stratum common (>5% cover)
Soil Metric				
Forest Soil Disturbance	Soil Disturbance Class 0	Soil Disturbance Class 1	Soil Disturbance Class 2	Soil Disturbance Class 3

Southern Appalachian Pine - Oak Woodlands				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of pitch pine, Table Mountain pine and/or shortleaf pine	20 to 35 or >75 to 90 ft^2/acre basal area of pitch pine, Table Mountain pine and/or shortleaf pine	10 to <20 or >90 to 110 ft^2/acre basal area of pitch pine, Table Mountain pine and/or shortleaf pine	<10 or >110 ft^2/acre basal area of pitch pine, Table Mountain pine and/or shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of pitch pine, Table Mountain pine and/or shortleaf pine	20-25% or >70 to 80% canopy cover of pitch pine, Table Mountain pine and/or shortleaf pine	10 to <20% or >80 to 90% canopy cover of pitch pine, Table Mountain pine and/or shortleaf pine	<10% or >90% canopy cover of pitch pine, Table Mountain pine and/or shortleaf pine
Southern Yellow Pine Stand Size Structure	BA ≥20 ft^2/acre of pitch pine, Table Mountain pine and/or shortleaf pines ≥12" DBH class	BA ≥10 to <20 ft^2/acre of pitch pine, Table Mountain pine and/or shortleaf pines ≥12" DBH class	Pitch pine, Table Mountain pine and/or shortleaf pines ≥12" DBH class are present, but at <10 ft^2/acre BA	No pitch pine, Table Mountain pine or shortleaf pines ≥12" DBH
Canopy Fire Tolerant Hardwood Basal Area	≤20 ft^2/acre BA of fire tolerant hardwood trees	>20 to 30 ft^2/acre BA of fire tolerant hardwood trees	>30 to 40 ft^2/acre BA of fire tolerant hardwood trees	>40 ft^2/acre BA of fire tolerant hardwood trees
Canopy Fire Intolerant Tree Basal Area	≤10 ft^2/acre BA of fire intolerant trees	>10 to 20 ft^2/acre BA of fire intolerant trees	>20 to 30 ft^2/acre BA of fire intolerant trees	>30 ft^2/acre BA of fire intolerant trees
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	2 to 10% cover of midstory fire tolerant hardwoods	10-30%, or <2% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Fire Intolerant Tree Cover	<10% cover of fire intolerant tree midstory	10 to 20% cover of fire intolerant tree midstory	>20 to 30% cover of fire intolerant tree midstory	>30% cover of fire intolerant tree midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <50% cover	Short shrubs average 50- <70% cover	Short shrubs average 70 to 80% cover	Short shrubs average >80% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>15% herbaceous cover	5 to 15% herbaceous cover	<5% herbaceous cover	Herbaceous cover absent
Native Graminoid Cover	>10% cover of all native graminoids	5 to 10% cover of all native graminoids	Native graminoids present, but with <5% cover	Native graminoids absent
Floristic Quality Index, Mean C (Optional)	Mean C >4.00	Mean C is 3.01 to 4.00	Mean C is 2.01 to 3.00	Mean C <2.00
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent	Invasive nonnative plant species present in any stratum but sporadic (<1 % cover)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)	Invasive nonnative plant species in any stratum common (>5% cover)
Soil Metric				
Forest Soil Disturbance	Soil Disturbance Class 0	Soil Disturbance Class 1	Soil Disturbance Class 2	Soil Disturbance Class 3

West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands (Dry & Mesic Hilly Pine Woodlands)				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-85 ft^2/acre basal area of shortleaf, loblolly, and/or longleaf pine	20 to <30 or >85 to 100 ft^2/acre basal area of shortleaf, loblolly, and/or longleaf pine	10 to <20 or >100 to 115 ft^2/acre basal area of shortleaf, loblolly, and/or longleaf pine	<10 or >115 ft^2/acre basal area of shortleaf, loblolly, and/or longleaf pine
Southern Yellow Pine Canopy Cover	>25 to 75% canopy cover of shortleaf, loblolly, and/or longleaf pine	>15 to 25% canopy cover or >75 to 85% canopy cover of shortleaf, loblolly, and/or longleaf pine	10-15% canopy cover or >85 to 95% canopy cover of shortleaf, loblolly, and/or longleaf pine	<10% cover or >95% cover of shortleaf, loblolly, and/or longleaf pine
Southern Yellow Pine Stand Size Structure	BA ≥20 ft^2/acre of shortleaf, loblolly, and/or longleaf pine trees ≥14" DBH class	BA ≥10 to <20 ft^2/acre of shortleaf, loblolly, and/or longleaf pine trees ≥14" DBH class	Shortleaf, loblolly, and/or longleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No shortleaf, longleaf, or loblolly pine trees ≥14" DBH are present
Canopy Fire Tolerant Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 30 ft^2/acre BA of hardwood trees	>30 to 40 ft^2/acre BA of hardwood trees	>40 ft^2/acre BA of hardwood trees
Canopy Fire Intolerant Tree Basal Area	≤10 ft^2/acre BA of fire intolerant trees	>10 to 20 ft^2/acre BA of fire intolerant trees	>20 to 30 ft^2/acre BA of fire intolerant trees	>30 ft^2/acre BA of fire intolerant trees
Stand Density Index (Optional, for shortleaf and loblolly pine)	SDI = 55 – 155 (12 - 34% of Maximum SDI of 450)	SDI = 35 – 55 or 155 -205 (8-12% or 34-45% of Maximum SDI of 450)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	2 to 10% cover of midstory fire tolerant hardwoods	10-20%, or <2% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods
Midstory Fire Intolerant Tree Cover	<10% cover of fire intolerant tree midstory	10 to 20% cover of fire intolerant tree midstory	>20 to 30% cover of fire intolerant tree midstory	>30% cover of fire intolerant tree midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover
Native Graminoid Cover	25-100% cover of all native graminoids	>15 to <25% cover of all native graminoids	10-15% cover of all native graminoids	<10% cover of all native graminoids
Floristic Quality Index, Mean C (Optional)	Mean C >4.00	Mean C is 3.01 to 4.00	Mean C is 2.01 to 3.00	Mean C <2.00
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent	Invasive nonnative plant species in any stratum present but sporadic (<1 % cover)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)	Invasive nonnative plant species in any stratum common (>5% cover)
Soil Metric				
Forest Soil Disturbance	Soil Disturbance Class 0	Soil Disturbance Class 1	Soil Disturbance Class 2	Soil Disturbance Class 3

Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands (Dry & Mesic Hilly Pine Woodlands)				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-85 ft²/acre basal area of shortleaf and/or longleaf pine	20 to <30 or >85 to 100 ft²/acre basal area of shortleaf and/or longleaf pine	10 to <20 or >100 to 115 ft²/acre basal area of shortleaf and/or longleaf pine	<10 or >115 ft²/acre basal area of shortleaf and/or longleaf pine
Southern Yellow Pine Canopy Cover	>25 to 75% canopy cover of shortleaf and/or longleaf pine	>15 to 25% canopy cover or >75 to 85% canopy cover of shortleaf and/or longleaf pine	10-15% canopy cover or >85 to 95% canopy cover of shortleaf and/or longleaf pine	<10% cover or >95% cover of shortleaf and/or longleaf pine
Southern Yellow Pine Stand Size Structure	BA ≥20 ft²/acre of shortleaf and/or longleaf pine trees ≥14" DBH class	BA ≥10 to <20 ft²/acre of shortleaf and/or longleaf pine trees ≥14" DBH class	Shortleaf and/or longleaf pine trees ≥14" DBH class are present, but <10 ft²/acre basal area of those large trees	No shortleaf or longleaf pine trees ≥14" DBH are present
Canopy Fire Tolerant Hardwood Basal Area	≤20 ft²/acre BA of hardwood trees	>20 to 30 ft²/acre BA of hardwood trees	>30 to 40 ft²/acre BA of hardwood trees	>40 ft²/acre BA of hardwood trees
Canopy Fire Intolerant Tree Basal Area	≤10 ft²/acre BA of fire intolerant trees	>10 to 20 ft²/acre BA of fire intolerant trees	>20 to 30 ft²/acre BA of fire intolerant trees	>30 ft²/acre BA of fire intolerant trees
Stand Density Index (Optional, applies to shortleaf pine)	SDI = 55 – 155 (12 - 34% of Maximum SDI of 450)	SDI = 35 – 55 or 155 -205 (8-12% or 34-45% of Maximum SDI of 450)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	2 to 10% cover of midstory fire tolerant hardwoods	10-20%, or <2% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods
Midstory Fire Intolerant Tree Cover	<10% cover of fire intolerant tree midstory	10 to 20% cover of fire intolerant tree midstory	>20 to 30% cover of fire intolerant tree midstory	>30% cover of fire intolerant tree midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover
Native Graminoid Cover	25-100% cover of all native graminoids	>15 to <25% cover of all native graminoids	10-15% cover of all native graminoids	<10% cover of all native graminoids
Floristic Quality Index, Mean C (Optional)	Mean C >4.00	Mean C is 3.01 to 4.00	Mean C is 2.01 to 3.00	Mean C <2.00
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent	Invasive nonnative plant species in any stratum present but sporadic (<1 % cover)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)	Invasive nonnative plant species in any stratum common (>5% cover)
Soil Metric				
Forest Soil Disturbance	Soil Disturbance Class 0	Soil Disturbance Class 1	Soil Disturbance Class 2	Soil Disturbance Class 3

METRIC DESCRIPTIONS: STAND CONDITION

RANK FACTOR: CANOPY

VEGETATION

Metric Name: Canopy Southern Yellow Pine Basal Area

Definition: Combined basal area of southern yellow pine species appropriate to the Southern Open Pine Group (broad ecosystems used in this document) of the site, primarily shortleaf pine, with pitch pine or Table Mountain pine in the Appalachians. Loblolly pine is often mixed with shortleaf pine, especially in the Coastal Plain and Piedmont. The cross-section area of shortleaf pine, pitch pine, Table Mountain pine, and/or loblolly pine tree stems (defined here as square feet /acre) for trees 5 inches DBH or greater, and measured using a 10x basal area prism or gauge at four (4) locations near the rapid assessment area center and (optionally) also at the center point of the rapid assessment area, or by measuring each of these pine trees 5 inches DBH or greater within the defined area plot or assessment area.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Basal area is a widely used measure quantifying the dominance of tree species in forests and woodlands, and it is repeatable with several averaged measures at various locations within an assessment area using a 10x basal area prism or gauge. Fixed area plots may need to be used on mountain slopes or in areas with dense shrub cover. Since many stands of shortleaf pine (or other southern yellow pines) have uneven tree sizes and spacing, measures of basal area need to be collected at multiple locations to get an estimate of basal area.

An open canopy of southern yellow pine is important for the functioning of southern open pine ecosystems, and it is especially important for management with fire and promoting the grassy herbaceous understory and associated focal wildlife. This metric emphasizes shortleaf pine basal area. Shortleaf pine has a large natural range, it has declined dramatically during the 20^{th} century, and it naturally grows in open stands which support characteristic wildlife species. Basal area of trees by species is data very commonly collected as part of forestry inventory.

In Southern Appalachian Pine – Oak Woodlands, the canopy pine was found to be bimodal, generally two aged in the Great Smoky Mountains, in Table Mountain pine stands the average basal area was 24.4 ft^2/acre (Murphy & Nowacki 1997, Whittaker 1956). At Linville Gorge, pine woodlands ranged from 30 to 90 ft^2/acre basal area (Newell and Peet 1998), but this includes all tree stems, not just canopy trees. It may not be necessary for the sparse pine overstory to be eliminated for pine reproduction to develop, particularly with understory burning (Murphy & Nowacki 1997).

Certain ranges of southern yellow pine basal area have been identified as characteristic of optimal habitat for southern open pine wildlife species. For red-cockaded woodpecker, open pine with large trees and less than 90 ft^2/acre of pine is optimal (Lower Mississippi Valley Joint Venture WGCPO Landbird Working Group 2011, USFWS 2003). For brown-headed nuthatch, 20-70 ft^2/acre of pine is optimal, and for Bachman's sparrow less than 60 ft^2/acre of pine (Richardson 2014a). The prairie warbler prefers low canopy basal area, which includes open pine woodlands, thinned pine stands, and cut over areas (NatureServe 2015, Thompson et al. 1992). However, for the pine warbler, habitat quality increases with higher southern yellow pine basal area (Schroeder 1985). The prairie warbler and pine warbler occur in sites which are on the low and high ends, respectively, of the range of southern yellow pine basal area which is best suited to the other open pine dependent wildlife species.

For Southern Appalachian Pine – Oak Woodlands, basal area of pitch pine, Table Mountain pine, and shortleaf pine are together measured. Shortleaf pine basal area is measured in stands of Interior Highlands Shortleaf Pine - Oak Woodlands and Interior Highlands Shortleaf Pine - Bluestem Woodlands. However, in Montane Longleaf – Shortleaf Pine Woodlands, longleaf pine and shortleaf pine basal area should be measured. In Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands, shortleaf pine and longleaf pine basal area should be measured, and in West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands, shortleaf pine, longleaf pine, and loblolly pine should be measured (Bragg 2002). This metric is applied to Upper Coastal Plain Pine Flatwoods based on the basal area of shortleaf pine and loblolly pine (Bragg et al. 2014).

Virginia pine (*Pinus virginiana*) is not desirable in southern open pine woodlands, and is not included as a southern yellow pine. The natural range of Virginia pine (*Pinus virginiana*) is broadly Appalachian, not including the Coastal Plain or areas west of the Mississippi River, such as the Ozarks or Ouachita Mountains. On open sites where both shortleaf pine and Virginia pine occur, and in the absence of fire, shortleaf pine is badly out-competed by Virginia pine (*Pinus virginiana*) due to several factors. Shortleaf pines generally bear seeds at a much later age than Virginia pine (Carter and Snow 1990, Lawson 1990). Although mature shortleaf pine produces some seed almost every year, abundant crops occur only sporadically (Haney 1957), and these seeds may not be disseminated far from the original seed source (Stephenson 1963). This example points to the special conditions which are needed to sustain open woodlands dominated by shortleaf pine, throughout its natural range.

The values for canopy tree basal area, tree stems per acre, and canopy cover are interrelated, and can be shown in a Gingrich table (Gingrich 1967). A Gingrich table for shortleaf pine stands was developed as part of the Interior Highlands Shortleaf Pine Restoration Initiative, Desired Future Conditions effort (Blaney et al. 2016), shown below.

	Percent Canopy Closure for Forest Grown Shortleaf Pine Stands											
	10%		20%		25%		30%		40%		50%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	30	16	59	32	74	40	89	49	119	65	148	81
12	14	11	28	22	35	28	42	33	57	44	71	56
14	10	11	21	22	26	27	31	33	41	44	51	55
16	9	12	17	24	22	30	26	36	35	49	44	61
18	7	12	14	25	17	31	21	37	28	49	35	62
20	7	15	14	30	17	37	20	45	27	59	34	74
22	6	17	13	34	16	42	19	51	26	68	32	84
24	4	14	9	28	11	35	13	42	18	57	22	71

	Percent Canopy Closure for Forest Grown Shortleaf Pine Stands									
	60%		70%		80%		90%		100%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	178	97	208	113	237	129	267	146	297	162
12	85	67	99	78	113	89	127	100	142	111
14	62	66	72	77	82	88	92	99	103	110
16	52	73	61	85	70	97	78	109	87	122
18	42	74	49	86	56	99	63	111	70	123
20	41	89	48	104	55	119	61	134	68	149
22	38	101	45	118	51	135	58	152	64	169
24	27	85	31	99	36	113	40	127	45	141

These Gingrich tables show average tree diameter at breast height (DBH) as rows, and in columns show percent tree canopy cover, number of trees per acre (#/ac), and basal area (BA). By using Gingrich tables, the relationships between these measures can be seen, and the measures can be applied to southern open pine wildlife habitat in a more informed way. Also, the canopy cover of 1 sq. foot BA of hardwood equals the canopy cover of 2 sq. feet of BA of shortleaf pine. Keep this in mind when assigning canopy cover metric values.

Measurement Protocol: Basal area is measured for the appropriate southern yellow pine species (primarily shortleaf pine) 5" diameter or greater at 4.5 feet (54”), diameter at breast height (DBH). For details on collecting these data, see Appendix A: Basal Area Methods.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor. The values below represent results in ft^2/acre. Calculated values other than multiples of 10 are accommodated, using the tables below. The appropriate southern yellow pine species are listed in each table. For details on collecting these data, see Appendix A: Basal Area Methods.

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
EXCELLENT (A)	>35-75 ft^2/acre basal area of shortleaf pine
GOOD (B)	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine
FAIR (C)	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine
POOR (D)	<10 or >110 ft^2/acre basal area of shortleaf pine

Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	>35-75 ft^2/acre basal area of longleaf pine and/or shortleaf pine
GOOD (B)	30 to 35 or >75 to 90 ft^2/acre basal area of longleaf pine and/or shortleaf pine
FAIR (C)	10 to <30 or >90 to 110 ft^2/acre basal area of longleaf pine and/or shortleaf pine
POOR (D)	<10 or >110 ft^2/acre basal area of longleaf pine and/or shortleaf pine

Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
EXCELLENT (A)	>35-75 ft^2/acre basal area of pitch pine, Table Mountain pine, and/or shortleaf pine
GOOD (B)	20 to 35 or >75 to 90 ft^2/acre basal area of pitch pine, Table Mountain pine, and/or shortleaf pine
FAIR (C)	10 to <20 or >90 to 110 ft^2/acre basal area of pitch pine, Table Mountain pine, and/or shortleaf pine
POOR (D)	<10 or >110 ft^2/acre basal area of pitch pine, Table Mountain pine, and/or shortleaf pine

Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	30-85 ft^2/acre basal area of shortleaf pine, longleaf pine and/or loblolly pine
GOOD (B)	20 to <30 or >85 to 100 ft^2/acre basal area of shortleaf pine, longleaf pine and/or loblolly pine
FAIR (C)	10 to <20 or >100 to 115 ft^2/acre basal area of shortleaf pine, longleaf pine and/or loblolly pine
POOR (D)	<10 or >115 ft^2/acre basal area of shortleaf pine, longleaf pine and/or loblolly pine

Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	30-85 ft^2/acre basal area of shortleaf pine and/or longleaf pine
GOOD (B)	20 to <30 or >85 to 100 ft^2/acre basal area of shortleaf pine and/or longleaf pine
FAIR (C)	10 to <20 or >100 to 115 ft^2/acre basal area of shortleaf pine and/or longleaf pine
POOR (D)	<10 or >115 ft^2/acre basal area of shortleaf pine and/or longleaf pine

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

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Lower Mississippi Valley Joint Venture WGCPO Landbird Working Group. 2011. West Gulf Coastal Plain/Ouachitas Open Pine Landbird Plan. A Report to the Lower Mississippi Valley Joint Venture Management Board. <http://www.lmvjv.org/library/WGCPO_Landbird_Open_Pine_Plan_Oct_2011.pdf>

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NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (*Peucaea aestivalis*). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

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Thompson, F. R., III, W. D. Dijak, T. G. Kulowiec, and D. A. Hamilton. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. Journal of Wildlife Management 56(1): 23-29. <http://www.nrs.fs.fed.us/pubs/jrnl/1992/nc_1992_thompson_001.pdf>

U.S. Fish and Wildlife Service. 2003. Recovery plan for the red-cockaded woodpecker (*Picoides borealis*): second revision. U.S. Fish and Wildlife Service, Atlanta, GA. 296 pp.

Scaling Rationale: Two options for data collection are provided, the first is using the 10x basal area prism or gauge in ft^2/acre. The second option uses calculated basal area values from the measured diameters of all southern yellow pines of the appropriate species. A 5x basal area prism or gauge could also be used, at multiple locations within the assessment are, as described in Option 1.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Southern Yellow Pine Canopy Cover

Definition: Percentage of the ground within the plot covered by the general extent of southern yellow pine canopy trees, as determined by visual (ocular) estimate. Southern yellow pine canopy is defined as the canopy trees primarily of shortleaf pine, or with mixed loblolly pine or (mountain) longleaf pine with stems 5" diameter or greater at 4.5 feet (54"), diameter at breast height (DBH).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: The measure of canopy cover by ocular estimate (by eye), is repeatable to the precision of the ranges of percent cover used here. This is a fast and easy metric which complements the measure of basal area of southern yellow pine.

A variety of characteristic wildlife species occur in open canopy shortleaf pine dominated woodlands. While the pine warbler does well in dense pine stands (Schroeder 1985), several birds, which are species of concern occur in open canopy pine stands (NatureServe 2015, Richardson 2014a, Tucker 2006). Higher plant diversity in pine woodlands is associated with open pine canopies (Platt et al. 2006).

The values for canopy tree basal area, tree stems per acre, and canopy cover are interrelated, and can be shown in a Gingrich table (Gingrich 1967). A Gingrich table for shortleaf pine stands was developed as part of the Interior Highlands Shortleaf Pine Restoration Initiative, Desired Future Conditions effort (Blaney et al. 2016), shown below.

	Percent Canopy Closure for Forest Grown Shortleaf Pine Stands											
	10%		20%		25%		30%		40%		50%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	30	16	59	32	74	40	89	49	119	65	148	81
12	14	11	28	22	35	28	42	33	57	44	71	56
14	10	11	21	22	26	27	31	33	41	44	51	55
16	9	12	17	24	22	30	26	36	35	49	44	61
18	7	12	14	25	17	31	21	37	28	49	35	62
20	7	15	14	30	17	37	20	45	27	59	34	74
22	6	17	13	34	16	42	19	51	26	68	32	84
24	4	14	9	28	11	35	13	42	18	57	22	71

	Percent Canopy Closure for Forest Grown Shortleaf Pine Stands									
	60%		70%		80%		90%		100%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	178	97	208	113	237	129	267	146	297	162
12	85	67	99	78	113	89	127	100	142	111
14	62	66	72	77	82	88	92	99	103	110
16	52	73	61	85	70	97	78	109	87	122
18	42	74	49	86	56	99	63	111	70	123
20	41	89	48	104	55	119	61	134	68	149
22	38	101	45	118	51	135	58	152	64	169
24	27	85	31	99	36	113	40	127	45	141

These Gingrich tables show average tree diameter at breast height (DBH) as rows, and in columns show percent tree canopy cover, number of trees per acre (#/ac), and basal area (BA). By using Gingrich tables, the relationships between these measures can be seen, and the measures can be applied to southern open pine wildlife habitat in a more informed way. Also, the canopy cover of 1 sq. foot BA of hardwood equals the canopy cover of 2 sq. feet of BA of shortleaf pine. Keep this in mind when assigning canopy cover metric values.

This metric emphasizes shortleaf pine canopy cover. Shortleaf pine has a large natural range. It declined dramatically during the 20th century. It naturally grows in open stands which support focal wildlife species. Other southern yellow pines are also included. Shortleaf pine canopy cover is measured in stands of Interior Highlands Shortleaf Pine - Oak Woodlands and Interior Highlands Shortleaf Pine - Bluestem Woodlands. However, in Montane Longleaf Pine – Shortleaf Pine Woodlands, longleaf pine and shortleaf pine canopy cover should be measured. In Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands, shortleaf pine and longleaf pine canopy cover should be measured, but in West Gulf Coastal Plain Shortleaf Pine – Oak Woodlands, canopy cover of shortleaf pine, longleaf pine, and loblolly pine is measured (Bragg 2002). This metric is applied to Upper Coastal Plain Pine Flatwoods based on the canopy cover of shortleaf pine and loblolly pine (Bragg et al. 2014).

Measurement Protocol: For assessment area, the percentage of the ground within the plot covered by the general extent of shortleaf pine and other southern yellow pine canopy trees, as determined by visual (ocular) estimate. Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface, estimated visually by the field researcher (Peet et al. 1998). Spaces between leaves and stems also count as cover. Southern yellow pine canopy is defined as the canopy trees primarily of shortleaf pine, or with mixed loblolly pine or (mountain) longleaf pine with stems 5" diameter or greater at 4.5 feet (54”), diameter at breast height (DBH).

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.
Format table as done for Canopy Fire Tolerant Hardwood Basal Area and use the new ordering of Groups.

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
EXCELLENT (A)	>25 to 70% canopy cover of shortleaf pine
GOOD (B)	20-25% canopy cover or >70 to 80% canopy cover of shortleaf pine
FAIR (C)	10 to <20% canopy cover or >80 to 90% canopy cover of shortleaf pine
POOR (D)	<10% canopy cover or >90% canopy cover of shortleaf pine

Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	>25 to 70% canopy cover of longleaf pine and/or shortleaf pine
GOOD (B)	20-25% canopy cover or >70 to 80% canopy cover of longleaf pine and/or shortleaf pine
FAIR (C)	10 to <20% canopy cover or >80 to 90% canopy cover of longleaf pine and/or shortleaf pine
POOR (D)	<10% canopy cover or >90% canopy cover of longleaf pine and/or shortleaf pine

Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
EXCELLENT (A)	>25 to 70% canopy cover of pitch pine, Table Mountain pine, and/or shortleaf pine
GOOD (B)	20-25% canopy cover or >70 to 80% canopy cover and shortleaf pine
FAIR (C)	10 to <20% canopy cover or >80 to 90% canopy cover of pitch pine, Table Mountain pine, and/or shortleaf pine
POOR (D)	<10% canopy cover or >90% canopy cover of pitch pine, Table Mountain pine, and/or shortleaf pine

Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	>25 to 75% canopy cover of shortleaf pine, longleaf pine and/or loblolly pine
GOOD (B)	>15 to 25% canopy cover or >75 to 85% canopy cover of shortleaf pine, longleaf pine and/or loblolly pine
FAIR (C)	10-15% canopy cover or >85 to 95% canopy cover of shortleaf pine, longleaf pine and/or loblolly pine
POOR (D)	<10% canopy cover or >95% canopy cover of shortleaf pine, longleaf pine and/or loblolly pine

Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	>25 to 75% canopy cover of shortleaf pine and/or longleaf pine
GOOD (B)	>15 to 25% canopy cover or >75 to 85% canopy cover of shortleaf pine and/or longleaf pine
FAIR (C)	10-15% canopy cover or >85 to 95% canopy cover of shortleaf pine and/or longleaf pine
POOR (D)	<10% canopy cover or >95% canopy cover of shortleaf pine and/or longleaf pine

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

Bragg, D. C. 2002. Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. Jour. Torrey Botanical Society 129(4):261-288.

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

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Schroeder, R. L. 1985. Habitat suitability index models: Pine Warbler. Biol. Rep. 82(10.28). U.S. Fish and Wildlife Service. 8 pp.

Tucker, J. W., W. D. Robinson, and J. B. Grand. 2006. Breeding productivity of Bachman's sparrows in fire-managed longleaf pine forests. The Wilson Journal of Ornithology 118(2):131–137. <http://www.nwtf.org/NAWTMP/downloads/Literature/Breeding_Productivity_Bachman_Sparrows.pdf>

U.S. Fish and Wildlife Service. 2003. Recovery plan for the red-cockaded woodpecker (Picoides borealis): second revision. U.S. Fish and Wildlife Service, Atlanta, GA. 296 pp.

Scaling Rationale: Scaling of this metric is informed by the cited literature, and by expert input from a project experts meeting held in March 2015.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Southern Yellow Pine Stand Size Structure

Definition: Southern yellow pine, especially shortleaf pine (*Pinus echinata*) stand size structure, including the presence of large (greater than or equal to 14" DBH) southern yellow pines characteristic of the assessed ecosystem.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Woodlands of shortleaf pine (*Pinus echinata*) which have large trees have higher ecological integrity. The presence of large shortleaf pine trees (greater than or equal to 14" DBH) indicates potential seedling recruitment and provides for a variety of wildlife in mixed shortleaf pine (*Pinus echinata*) stands (Bragg 2002, NatureServe 2006). These large, old trees are important for pine regeneration in natural stands, near natural stands, and stands that will be naturally regenerated rather than clearcut and replanted. Large old southern yellow pines also provide benefits for focal wildlife species. This metric is applied to Upper Coastal Plain Pine Flatwoods based on the size structure of shortleaf pine or loblolly pine (Bragg et al. 2014). Presence of large (basal area at least 20 ft^2/acre of trees ≥ 14" DBH or greater) southern yellow pine is evidence of mature characteristics in a southern open pine stand (Longleaf Partnership Council 2014). However, an additional note says, "Represents presence of mature wildlife habitat associations – tree size may be smaller, and therefore, basal area slightly lower in some community types" (Longleaf Partnership Council 2014). Data on basal area of trees by species is very commonly collected as part of forestry inventory. It is a widely used measure quantifying the dominance of tree species, and it is repeatable by using several measures with a 10x basal area prism or gauge. It can be measured using a 10x basal area prism or gauge at four (4) locations within the rapid assessment area, and (optionally) also at the center, or by measuring all southern yellow pine trees 14" DBH or greater within the defined rapid assessment area. DBH can be deceiving in xeric or low site indices – basing tree size on ability to employ RCW inserts is an artificial condition; in natural conditions with low site index (LLP or SLP) can be quite small and still be used for cavity nesters like RCW.

In Southern Appalachian Pine - Oak Woodlands in the Great Smoky Mountains, canopy stems pitch pine heath were 12" – 15" diameter, and in Table Mountain pine heath are usually 10" – 15" diameter (Murphy & Nowacki 1997, Whittaker 1956). These trees in Appalachian pine stands are not as large as shortleaf pines in lower elevation stands in the Piedmont or Interior Highlands (Murphy & Nowacki 1997). Even-aged pine stands, especially with low amounts of hardwood are more susceptible to outbreaks of southern pine beetle (*Dendroctonus fontalis*) than multi-aged stands or mixed pine – hardwood stands (Lafon et al. 2017).

Measurement Protocol: Measure the basal area of southern yellow pine trees 14" DBH or greater. In addition to shortleaf pine, in West Gulf Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands, loblolly pine is included. In the Montane Longleaf Pine - Shortleaf Pine

Woodlands, longleaf pine is included. A 10x factor basal area prism or gauge is used at four (4) locations 33 feet (10 meters) from the outer edge of the assessment area, such as along the north, east, south, and west tapes, and (optionally) also at the center of the data collection area. If assessment area is smaller than 1/8 acre (500 square meters), then four (4) basal area points should be 10 feet (3.0 meters) from the assessment area center to the north, east, south, and west. Large pine trees are tallied by size class. At each basal area point, the tallied count of 14" DBH or greater southern yellow pine is multiplied by the basal area factor of 10 to get the basal area values for southern yellow pines of 14" DBH or greater in ft^2/acre.

Format table as done for Canopy Fire Tolerant Hardwood Basal Area

Metric Rating: Large trees defined as the appropriate southern yellow pine species ≥ 14" DBH.

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
Metric Rating	***Interior Highlands Shortleaf Pine – Bluestem Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14" DBH class
GOOD (B)	Basal area ≥10 to <20 ft^2/acre of shortleaf pine trees ≥14" DBH class
FAIR (C)	Shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No shortleaf pine trees ≥14" DBH are present

Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of longleaf pine and/or shortleaf pine trees ≥14" DBH class or flat-top longleaf pine is present
GOOD (B)	Basal area ≥10 to <20 ft^2/acre of longleaf pine and/or shortleaf pine trees ≥14" DBH class. No flat-top longleaf pine is present.
FAIR (C)	Longleaf pine and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees. No flat-top longleaf pine is present.
POOR (D)	No longleaf pine or shortleaf pine trees ≥14" DBH nor flat-top longleaf pine are present

Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of pitch pine, Table Mountain pine, and/or shortleaf pine trees ≥12" DBH class
GOOD (B)	Basal area ≥10 to <20 ft^2/acre of pitch pine, Table Mountain pine, and/or shortleaf pine ≥12" DBH class
FAIR (C)	Pitch pine, Table Mountain pine, and/or shortleaf pine ≥12" DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No shortleaf pine, pitch pine, or Table Mountain pine trees ≥12" DBH are present

Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of loblolly pine, longleaf pine and/or shortleaf pine trees ≥14" DBH class
GOOD (B)	Basal area ≥10 to <20 ft^2/acre of loblolly pine, longleaf pine and/or shortleaf pine trees ≥14" DBH class
FAIR (C)	Loblolly pine, longleaf pine and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No loblolly pine, longleaf pine or shortleaf pine trees ≥14" DBH are present

Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre shortleaf pine and/or longleaf pine trees ≥14" DBH class
GOOD (B)	Basal area ≥10 to <20 ft^2/acre of shortleaf pine and/or longleaf pine trees ≥14" DBH class
FAIR (C)	Shortleaf pine and/or longleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No shortleaf pine or longleaf pine trees ≥14" DBH are present

Data for Metric Rating: Published data that support the basis for the metric rating

Bragg, D. C. 2002. Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. Jour. Torrey Botanical Society 129(4):261-288.

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

NatureServe. 2006. International Ecological Classification Standard: Terrestrial Ecological Classifications. Classification and Integrity Indicators for Selected Forest Types of Office Depot's Sourcing Areas of the Southeastern United States. NatureServe Central Databases. Arlington, VA. Data current as of 29 March 2006.

NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

White, D. L. and F. T. Lloyd. 1998. An Old-Growth Definition for Dry and Dry-Mesic Oak Pine Forests. USDA Forest Service - Southern Research Station. Gen. Tech. Rept. SRS-23.

Scaling Rationale: Scaling is consistent and based on recent literature, for nearly all ecosystems the presence of large pine 14" DBH or greater is used. Due to the slow growth of longleaf pine in the Xeric Longleaf Pine Barrens, the presence of large longleaf pine 12” DBH or greater is used rather than 14” DBH or greater.

Confidence that reasonable logic and/or data support the index: Moderate to high.

RANK FACTOR: VEGETATION

Metric Name: Canopy Fire Tolerant Hardwood Basal Area

Definition: Combined basal area of all fire tolerant canopy hardwood trees. Basal area is collected separately for both fire tolerant hardwood (this metric) and fire intolerant trees (the following metric). The basal area of fire intolerant trees is the most meaningful of these two metrics. The basal area is the cross-section area of fire tolerant hardwood tree stems (defined here as square feet /acre) for canopy trees 5 inches DBH or greater, measured using a 10x basal area prism or gauge at four (4) locations near the rapid assessment area center and (optionally) also at the center point of the rapid assessment area, or by measuring the DBH of all hardwood trees 5 inches DBH or greater within an assessment area plot of a defined area. Refer to Appendix A: Basal Area Methods for guidance on collecting basal area values.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Basal area is a widely used measure quantifying the dominance of tree species. Basal area is repeatable with several averaged measures from various locations within an assessment area using a 10x basal area prism or gauge. Measures of basal area need to be collected at multiple locations within a stand to get a stand level estimate of basal area. Refer to Appendix A: Basal Area Methods for guidance on collecting basal area values. In southern open pine ecosystems, increasing hardwood dominance or codominance, especially of fire intolerant hardwoods is associated with declines of southern open pine wildlife.

A small amount of hardwood tree basal area naturally occurs in many upland southern open pine ecosystems, especially fire tolerant (pyrophytic) oaks such as turkey oak *(Quercus laevis),* sand post oak (*Quercus margarettae),* bluejack oak (*Quercus incana*), blackjack oak (*Quercus marilandica),* black oak (*Quercus velutina),* post oak (*Quercus stellata*)*,* southern red oak (*Quercus falcata),* white oak (*Quercus alba),* scarlet oak (*Quercus coccinea),* chestnut oak (*Quercus montana = Quercus prinus*), black hickory (*Carya texana*), mockernut hickory (*Carya tomentosa*), pignut hickory (*Carya glabra*), sand hickory (*Carya pallida*), and blackgum (*Nyssa sylvatica*) (Albrecht & McCarthy 2006, Bragg 2002, Bragg 2014, Elliott et al. 1999, Hammond et al. 2015, Hiers et al. 2014, Hutchinson et al. 2005, Keyser et al. 2018, Kreye et al. 2013, LANDFIRE 2020, NatureServe 2015b, Signell et al. 2005, Thomas-Van Gundy & Nowacki 2013, Varner et al. 2003). Some hardwood trees are fire resilient, more than fire tolerant. These trees include blackgum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), and sourwood (*Oxydendrum arboreum*). There are various wildlife benefits to retention of some fire tolerant hardwoods, especially oaks, in southern open pine ecosystems (Hiers et al. 2014). Increasing hardwood dominance or codominance can result from lack of fire.

For brown-headed nuthatch and pine warbler, hardwood basal area less than 22 ft^2/acre is best, when deciduous hardwoods begin to reach the canopy of stands, these birds are rarely present (Richardson 2014). Bachman's sparrow and prairie warbler habitat should lack or have a low proportion of hardwood in the canopy (Richardson 2014a). In good red-cockaded woodpecker areas, the canopy lacks hardwood, or has low proportion of hardwoods, only 10 to 30% of the canopy trees (USFWS 2003). Maintenance condition for longleaf pine woodlands is considered, to be basal area 10 ft^2/acre or less of canopy hardwoods or off-site pines 5" DBH or greater. (Longleaf Partnership Council 2014).

Measurement Protocol: Basal area is measured for the appropriate hardwood trees 5" diameter or greater at 4.5 feet (54"), diameter at breast height (DBH). For details on collecting these data, see Appendix A: Basal Area Methods.

It is not necessary to tally hardwood trees by species, trees are separately tallied for canopy fire tolerant hardwoods (this metric) and fire intolerant trees (the following metric). **Fire tolerant hardwood tree species** include turkey oak, sand post oak, bluejack oak, blackjack oak, black oak, post oak, southern red oak, white oak, scarlet oak, black hickory, mockernut hickory, pignut hickory, sand hickory, chestnut oak, and blackgum. At each basal area point, the tallied count of hardwood tree species is multiplied by the basal area factor of 10 to get the basal area values in ft^2/acre. The final measure is the average of each of the data taken for each of the prism points in the assessment area.

Metric Rating: The set of tables below accommodate basal area taken with a 10x basal area prism, or from measuring all trees within a defined assessment area. For details on collecting these data, see Appendix A: Basal Area Methods.

Canopy Fire Tolerant Hardwood Basal Area

Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	≤20 ft^2/acre basal area of fire tolerant hardwood trees
GOOD (B)	>20 to 30 ft^2/acre basal area of fire tolerant hardwood trees
FAIR (C)	>30 to 40 ft^2/acre basal area of fire tolerant hardwood trees
POOR (D)	>40 ft^2/acre basal area of fire tolerant hardwood trees

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	≤50 ft2/acre basal area of fire tolerant hardwood trees
GOOD (B)	>50 to 60 ft2/acre basal area of fire tolerant hardwood trees
FAIR (C)	>60 to 70 ft2/acre basal area of fire tolerant hardwood trees
POOR (D)	>70 ft2/acre basal area of fire tolerant hardwood trees

Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	≤20 ft2/acre basal area of fire tolerant hardwood trees
GOOD (B)	>20 to 40 ft2/acre basal area of fire tolerant hardwood trees
FAIR (C)	>40 to 50 ft2/acre basal area of fire tolerant hardwood trees
POOR (D)	>50 ft2/acre basal area of fire tolerant hardwood trees

Data for Metric Rating: Published data that support the basis for the metric rating

Abrams, M.D. 2007. Tales from the blackgum, a consummate subordinate tree. BioScience 57(4): 347–359.

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Hammond, D. H., J. M. Varner, J. S. Kush, and Z. Fan. 2015. Contrasting sapling bark allocation of five southeastern USA hardwood tree species in a fire prone ecosystem. Ecosphere 6(7):112. http://dx.doi.org/10.1890/ ES15-00065.1

Hiers, J. K., J. R. Walters, R. J. Mitchell, J. M. Varner, L. M. Conner, L. A. Blanc, and J. Stowe. 2014. Commentary: Ecological Value of Retaining Pyrophytic Oaks in Longleaf Pine Ecosystems. The Journal of Wildlife Management 78(3):383–393.

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Keyser, T.L., V.L. McDaniel, R.N. Klein, D.G. Drees, J.A. Burton, and M.M. Forder. 2018. Short-term stem mortality of 10 deciduous broadleaved species following prescribed burning in upland forests of the Southern US. International Journal of Wildland Fire 27: 42–51.

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Elledge, J. and B. Barlow. 2012. Basal Area: A Measure Made for Management. ANR-1371. Alabama Cooperative Extension System (Alabama A&M University and Auburn University). <http://www.aces.edu/pubs/docs/A/ANR-1371/ANR-1371.pdf>

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NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

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Oakman, E.C., Hagan, D.L., Waldrop, T.A., & Barret, K. 2019. Understory vegetation responses to 15 years of repeated fuel reduction treatments in the southern Appalachian Mountains, USA. Forests, 10(350), 21 p. DOI: 10.3390/f10040350. <https://www.mdpi.com/1999-4907/10/4/350/htm>

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Signell, S.A., M.D.Abrams, J.C. Hovis, S.W. Henry. 2005. Impact of multiple fires on stand structure and tree regeneration in central Appalachian oak forests. Forest Ecology and Management. 218: 146-158.

Thomas-Van Gundy, M., and G.J. Nowacki. 2013. The use of witness trees as pyro-indicators for mapping past fire conditions. Forest Ecology and Management 304: 333-344.

Varner, J.M., III, Kush, J.S., and Meldahl, R.S. 2003. Vegetation of frequently burned old-growth longleaf pine (*Pinus palustris* Mill.) savannas on Choccolocco Mountain, Alabama, USA. Natural Areas Journal 23:43–52.

Scaling Rationale: The scaling here for stands with less than 10 basal area of hardwood may need more work. It might be worth clarifying in the metric scoring, the differences between hardwoods which may be a natural component of dry site southern open pine woodlands, and those which are ruderal or indicative of lack of fire.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Canopy Fire Intolerant Tree Basal Area

Definition: Basal area of all fire intolerant canopy trees. Basal area is collected separately for fire intolerant trees (this metric) and fire tolerant hardwood trees (previous metric). Basal area of fire intolerant trees is the most meaningful of these two metrics. Basal area is the cross section area of fire intolerant tree stems (defined here as square feet /acre) for canopy trees 5 inches DBH or greater, measured using a 10x basal area prism or gauge at four (4) locations near the rapid assessment area center and (optionally) also at the center point of the rapid assessment area, or by measuring the DBH of all fire intolerant trees 5 inches DBH or greater within an assessment area plot of a defined area. Refer to Appendix A: Basal Area Methods for guidance on collecting basal area values.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Basal area is a widely used measure quantifying the dominance of tree species. Basal area is repeatable with several averaged measures from various locations within an assessment area using a 10x basal area prism or gauge. Measures of basal area need to be collected at multiple locations within a stand to get a stand level estimate of basal area. Refer to Appendix A: Basal Area Methods for guidance on collecting basal area values. In southern open pine ecosystems, increasing hardwood dominance or codominance, especially of fire intolerant hardwoods is associated with declines of southern open pine wildlife. Increases of fire intolerant conifers, such as Virginia pine (*Pinus virginiana*), white pine (*Pinus strobus*), and Eastern red-cedar (*Juniperus virginiana*) also indicate degradation in southern open pine ecosystems.

Hardwood trees in southern open pine can include ruderal and fire-intolerant hardwood trees, red maple (*Acer rubrum),* serviceberry *(Amelanchier sp.),* sweet birch *(Betula lenta),* beech (*Fagus grandifolia),* American holly (*Ilex opaca*), sweetgum (*Liquidambar styraciflua),* tulip-tree (*Liriodendron tulipifera),* flowering dogwood (*Cornus florida*), black cherry (*Prunus serotina*), laurel oak (*Quercus hemisphaerica*), water oak (*Quercus nigra),* live oak *(Quercus virginiana),* and especially in wet flatwoods and savannas, the exotic Chinese tallow tree (*Triadica sebifera)* (Bragg 2014, Kreye et al. 2013, NatureServe 2011, Oakman et al. 2019, Signell et al. 2005). Fire intolerant conifers include Virginia pine (*Pinus virginiana*), white pine (*Pinus strobus*), and Eastern red-cedar (*Juniperus virginiana*). A small amount of hardwood tree basal area naturally occurs in many upland southern open pine ecosystems, especially fire tolerant (pyrophytic) oaks. There are various wildlife benefits to retention of some fire tolerant hardwoods, especially oaks, in southern open pine ecosystems (Hiers et al. 2014). Increasing hardwood dominance or codominance can result from lack of fire, or lack of other disturbances.

For brown-headed nuthatch and pine warbler, hardwood basal area less than 22 ft^2/acre is best, when deciduous hardwoods begin to reach the canopy of stands, these birds are rarely present (Richardson 2014). Bachman's sparrow and prairie warbler habitat should lack or have a low proportion of hardwood in the canopy (Richardson 2014a). In good red-cockaded woodpecker areas, the canopy lacks hardwood, or has low proportion of hardwoods, only 10 to 30% of the canopy trees (USFWS 2003). Maintenance condition for longleaf pine woodlands is considered, to be basal area 10 ft^2/acre or less of canopy hardwoods or off-site pines 5" DBH or greater. (Longleaf Partnership Council 2014).

Measurement Protocol: Basal area is measured for the appropriate fire intolerant trees 5" diameter or greater at 4.5 feet (54"), diameter at breast height (DBH). For details on collecting these data, see Appendix A: Basal Area Methods.

It is not necessary to tally fire intolerant trees by species. **Fire intolerant tree species include Virginia pine, white pine, Eastern red-cedar, red maple, serviceberry, sweet birch, beech, American holly, sweetgum, tulip-tree, flowering dogwood, black cherry, laurel oak, water oak, live oak, and Chinese tallow tree.** At each basal area point, the tallied count of fire intolerant hardwood tree species is multiplied by the basal area factor of 10 to get the basal area values in ft^2/acre. The final measure is the average of each of the data taken for each of the prism points in the assessment area.

Metric Rating: The set of tables below accommodate basal area taken with a 10x basal area prism, or from measuring all trees within a defined assessment area. For details on collecting these data, see Appendix A: Basal Area Methods.

Canopy Fire Intolerant Tree Basal Area

Metric Rating	***Interior Highlands Shortleaf Pine-Oak Woodlands***
Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	≤10 ft^2/acre basal area of fire intolerant trees
GOOD (B)	>10 to 20 ft^2/acre basal area of fire intolerant trees
FAIR (C)	>20 to 30 ft^2/acre basal area of fire intolerant trees
POOR (D)	>30 ft^2/acre basal area of fire intolerant trees

Data for Metric Rating: Published data that support the basis for the metric rating

Albrecht, M.A., and B.C. McCarthy. 2006. Effects of prescribed fire and thinning on tree recruitment patterns in central hardwood forests. Forest Ecology and Management 226: 88-103.

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

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Elliott, K.J., R.L. Hendrick, A.E. Major, J.M. Vose, W.T. Swank. 1999. Vegetation dynamics after a prescribed fire in the southern Appalachians. Forest Ecology and Management 114 (2-3): 199-213.

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Hutchinson, T.F., E.K. Sutherland, and D.A. Yaussy. 2005. Effects of repeated prescribed fires on the structure, composition, and regeneration of mixed-oak forests in Ohio. Forest Ecology and Management 218: 210-228.

Keyser, T.L., V.L. McDaniel, R.N. Klein, D.G. Drees, J.A. Burton, and M.M. Forder. 2018. Short-term stem mortality of 10 deciduous broadleaved species following prescribed burning in upland forests of the Southern US. International Journal of Wildland Fire 27: 42–51.

Kreye, Jesse K., J. Morgan Varner, J. Kevin Hiers, and John Mola. 2013. Toward a mechanism for eastern North American forest mesophication: differential litter drying across 17 species. Ecological Applications 23(8): 1976-1986.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

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NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

NatureServe. 2015b. International Ecological Classification Standard: Terrestrial Ecological Classifications. U.S. National Vegetation Classification. Southern Open Pine Groupings. NatureServe Central Databases. Arlington, VA. Data current as of 10 March 2015.

Oakman, E.C., Hagan, D.L., Waldrop, T.A., & Barret, K. 2019. Understory vegetation responses to 15 years of repeated fuel reduction treatments in the southern Appalachian Mountains, USA. Forests, 10(350), 21 p. DOI: 10.3390/f10040350. <https://www.mdpi.com/1999-4907/10/4/350/htm>

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Signell, S.A., M.D.Abrams, J.C. Hovis, S.W. Henry. 2005. Impact of multiple fires on stand structure and tree regeneration in central Appalachian oak forests. Forest Ecology and Management. 218: 146-158.

Thomas-Van Gundy, M., and G.J. Nowacki. 2013. The use of witness trees as pyro-indicators for mapping past fire conditions. Forest Ecology and Management 304: 333-344.

Varner, J.M., III, Kush, J.S., and Meldahl, R.S. 2003. Vegetation of frequently burned old-growth longleaf pine (*Pinus palustris* Mill.) savannas on Choccolocco Mountain, Alabama, USA. Natural Areas Journal 23:43–52.

Scaling Rationale: The scaling here for stands with less than 10 basal area of hardwood may need more work. It might be worth clarifying in the metric scoring, the differences between hardwoods which may be a natural component of dry site southern open pine woodlands, and those which are ruderal or indicative of lack of fire.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Stand Density Index (Optional)

Definition: Stand Density Index (SDI) is an index of tree density which incorporates the size (quadratic mean diameter) and density (trees per acre) of trees in a stand. Trees per acre (TPA) alone is not as useful a measure of stand density since it does not account for differences in tree diameter (Ziede 2005). The tree count must incorporate some measure of tree size to have meaning in forest management. SDI has two significant advantages over basal area (BA): 1) BA varies in equally dense stands (stands of equal BA can have differing amounts of competition for resources since TPA may vary), and 2) BA is not independent of site and age (BA values that indicate a need for thinning vary with stand age and site quality). A primary benefit to SDI is its independence of stand age and site quality (Harrington 2001, Ziede 2005).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Forest managers who have been managing southern open pine for wildlife have found that Stand Density Index (Shaw and Long 2007) has many advantages over basal area, or measures of canopy cover (such as visual estimates, or spherical densiometer). Research indicates that Stand Density Index has a predicable relationship to grassy herbaceous groundcover conditions in open pine stands (Moore and Deiter 1992, Mulligan et al. 2002).

Stand Density Index (SDI) was first developed in the 1930s (Reineke 1933), and it has been used more in forestry during recent years (Ducey and Valentine 2008, Shaw and Long 2010). SDI has been used in the assessment and management of goshawk nesting habitat (Lilieholm et al. 1993, Lilieholm et al. 1994) and elk thermal cover, in both ponderosa pine (McTague and Patton 1989) and lodgepole pine (Smith and Long 1987). More recently, SDI has been shown to be useful in managing longleaf pine for the recovery of red-cockaded woodpecker (Shaw and Long 2007) and as a measure of canopy trees in relation to functioning herbaceous groundcover in longleaf pine woodlands in Georgia (Mulligan et al. 2002). Commercial forestry uses SDI for scheduling thinning in intensively managed southern pine stands (Doruska and Nolan 1999, Harrington 2001, Williams 1996).

Stand Density Index (SDI) is calculated:

$$SDI = TPA * (Dq/10)^{1.6}$$

where TPA is the density, in trees per acre
Dq is quadratic mean stand diameter in inches at breast height
10 is the reference diameter in inches
1.6 is the slope factor

Quadratic mean diameter is different from the common arithmetic mean diameter. Quadratic mean diameter is the diameter of a tree of average basal area, and is calculated:

$$Dq = \sqrt{BA/(0.005454 * n)}$$

Where *BA* is the basal area in square feet per acre
n is the corresponding number of trees

Quadratic mean diameter is also simply calculated as the square root of the average of the squared diameters of the tallied trees, calculated:

$$Dq = \sqrt{(\sum d_i^2)/n}$$

Where *d* is the diameter of each tree
n is the number of trees

Stand Density Index is grounded in the "-3/2 self-thinning law", which describes the inverse relationship between the average mass of plants, and their density (Shaw and Long 2010). For use in forestry, the quadratic mean diameter (*Dq*) is substituted for average mass of trees.

For many kinds of trees, maximum SDI values have been calculated. The maximum SDI values for longleaf pine and slash pine are 400 (Harrington 2001, Reineke 1933, Shaw and Long 2007), and the maximum SDI values for shortleaf pine and loblolly pine are 450 (Harrington 2001, Reineke 1933). Various percentages of the maximum SDI values relate to levels of canopy closure, effects of canopy trees on understory plants, and density dependent mortality in forest stands. For instance:

- 25% SDI is where the overstory begins to have significant negative effects on the understory (Mulligan et al. 2002, Shaw and Long 2007), and is associated with the transition from open-grown to competing trees (Long 1985, Shaw and Long 2007)
- 35% SDI is the lower limit of full site occupancy, i.e. stand growth continues to increase with increasing relative density above this point, but at a decreasing rate (Long 1985)
- 35 – 40% SDI is the range of maximum stand tree growth (Long 1985, Shaw and Long 2007)
- 60% SDI is the onset of self-thinning, i.e. density dependent tree mortality (Long 1985, Shaw and Long 2007)

In practice, larger diameter stands of southern pines do not follow the maximum SDI, but follow a lower curve called mature stand boundary (Shaw and Long 2007, Shaw and Long 2010). This relates to higher mortality of large trees which is not density dependent, and perhaps is due to the inability of tree growth to quickly recapture the canopy gaps were large pines have died (Shaw and Long 2010).

Measurement Protocol: Stand Density Index is calculated from the density in trees per acre (TPA) and the quadratic mean diameters (*Dq*) at breast height of the pine trees in sample plots. Within a stand, SDI can be calculated from either a set of fixed area plots or variable area plots (i.e. prism sampling), where trees are tallied, and the diameters of each tree is measured. Both are easy to apply. Simple calculations in the office can average values across the stand, spreadsheets make this easier. Silvicultural treatments occur at the scale of the stand, not a specific point within a stand, so the stand level data is most useful for informing management.

Metric Rating: Values are calculated and averaged from sample plots within a stand.

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands*** applies to shortleaf pine (*Pinus echinata)*
Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands*** applies to shortleaf pine (*Pinus echinata)*
EXCELLENT (A)	SDI = 65 – 135 (14-30% of Maximum SDI of 450)
GOOD (B)	SDI = 45 – 65 or 135 -180 (10-14% or 30-40% of Maximum SDI of 450, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of Maximum SDI, 270 is 60% of Maximum SD of 450, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >225 (<4% or > 50%, 270 is 60% of Maximum SD of 450, *the onset of self-thinning*)

Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands*** applies to mountain longleaf pine (*Pinus palustris*)
EXCELLENT (A)	SDI = 55 – 120 (14-30% of Maximum SDI of 400)
GOOD (B)	SDI = 40 – 55 or 120 -160 (10-14% or 30-40% of Maximum SDI of 400, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 15 – 40 or 160 - 200 (4-10% or 40-50% of Maximum SDI, 240 is 60% of Maximum SD of 400, *which is the onset of self-thinning*)
POOR (D)	SDI <15 or >200 (<4% or > 50%, 240 is 60% of Maximum SD of 400, *the onset of self-thinning*)

Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands*** applies to shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands*** applies to shortleaf pine (*Pinus echinata)*
EXCELLENT (A)	SDI = 55 – 155 (12-34% of Maximum SDI of 450)
GOOD (B)	SDI = 35 – 55 or 155 -205 (8-12% or 34-45% of Maximum SDI of 450, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of Maximum SDI, 270 is 60% of Maximum SD of 450, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >225 (<4% or > 50%, 270 is 60% of Maximum SD of 450, *the onset of self-thinning*)

Data for Metric Rating: Published data that support the basis for the metric rating

Doruska, P.F. and Nolen, W.R., Jr. 1999. Use of stand density index to schedule thinnings in loblolly pine plantations: a spreadsheet approach. Southern Journal of Applied Forestry. 23(1): 21-29.

Ducey, M. J. and H. T. Valentine. 2007. Direct Sampling for Stand Density Index. Western Journal of Applied Forestry 23(2): 78-82.

Lilieholm, R. J., W. B. Kessler, and K. Merrill. 1993. Stand density index applied to timber and goshawk habitat objectives in Douglas-fir. Environmental Management 17(6): 773-779.

Lilieholm, R. J., J. N. Long, and S. Patla. 1994. Assessment of goshawk nest area habitat using stand density index. Pp. 18-23 *In* Block, W.M., M.L. Morrison, and M.H. Rieser, eds. The northern goshawk: ecology and management. Proceedings of a Symposium of the Cooper Ornithological Society. Studies in Avian Biology No. 16.

Long, J. N. 1985. A practical approach to density management. The Forestry Chronicle 61(1):23-27.

Harrington, T. B. 2001. Silvicultural approaches for thinning southern pines: method, intensity and timing. Warnell School of Forest Resources and Georgia Forestry Commission. Publication No. FSP002. <http://www.gfc.state.ga.us/resources/publications/SilviculturalApproaches.pdf>

McTague, J. P. and D. R. Patton. 1989. Stand density index and its application in describing wildlife habitat. Wildlife Society Bulletin 17(1):58-62.

Moore, M. M. and D. A. Deiter. 1992. Stand Density Index as a predictor of forage production in northern Arizona pine forests. Journal of Range Management 45:267-271.

Mulligan, M. K., L. K. Kirkman, and R. J. Mitchell. 2002. *Aristida beyrichiana* (wiregrass) establishment and recruitment: implications for restoration. Restoration Ecology 10(1): 68-76.

Reineke, L. H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46(7): 627–637.

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Shaw, J. D., and Long, J. N. 2010. Consistent definition and application of Reineke's stand density index in silviculture and stand projection. In Integrated Management of Carbon Sequestration and Biomass Utilization Opportunities in a Changing Climate. Proceedings of the 2009 National Silviculture Workshop, 15–18 June 2009, Boise, Idaho. Jain, T. B., R. T. Graham, and J. Sandquist (eds.). RMRS-P-61. pp. 199–209.

Smith, F. W. and J. N. Long. 1987. Elk hiding and thermal cover guidelines in the context of lodgepole pine stand density. Western Journal of Applied Forestry 2(1):6-10.

Williams, R. A. 1996. Stand density index for loblolly pine plantations in North Louisiana. Southern Journal of Applied Forestry 20(2): 110-113.

Zeide. B. 2005. How to measure stand density. Trees 19(1):1-14.

Scaling Rationale: Scaling is informed by the research pertaining to SDI in open pine stands which have a grass dominated ground cover (Moore and Deiter 1992, Mulligan et al. 2002, Shaw and Long 2007). The range of 15–30 % of maximum SDI correlates well with the ranges of basal area considered to indicate excellent condition by external expert reviewers. Values below 25% of maximum SDI are best for the functioning of native wiregrass (Mulligan et al. 2002), but in longleaf pine ecosystems adequate basal area is needed to provide needle drop which is necessary as fuel for frequent prescribed fire.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: MIDSTORY and SHRUB

RANK FACTOR: VEGETATION

Metric Name: Midstory Fire Tolerant Hardwood Cover

Definition: Midstory Fire Tolerant Hardwood Cover. Percentage of the ground within the plot or assessment area covered by fire tolerant hardwood midstory foliage, branches, and stems as determined by ocular (visual) estimate. Fire tolerant hardwoods include numerous oaks and several hickories. Midstory is defined as woody stems (including tall shrubs, small trees, and vines) that are > 10 feet tall, up to the height of the bottom of the tree canopy. **Fire tolerant hardwood tree species include turkey oak, sand post oak, bluejack oak, blackjack oak, black oak, post oak, southern red oak, white oak, scarlet oak, black hickory, mockernut hickory, pignut hickory, sand hickory, chestnut oak, and blackgum.** Individuals that reach canopy size are included in the canopy basal area metrics.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: **Fire tolerant hardwood species (especially oaks and hickories) naturally occur in upland southern open pine ecosystems, and include turkey oak, sand post oak, bluejack oak, blackjack oak, black oak, post oak, southern red oak, white oak, scarlet oak, black hickory, mockernut hickory, pignut hickory, sand hickory, chestnut oak, and blackgum** (Elliott et al. 1999, Hutchinson et al. 2005, Keyser et al. 2018, Kreye et al. 2013, Signell et al. 2005, Varner et al. 2003)**.** Hardwood species are listed as fire tolerant based on multiple factors such as regular occurrence in stands which have been frequently burned over a long time, bark resistance to fire, ability to resprout after fire, how well downed leaves burn in fuel beds, and how fire influences recruitment. Some hardwood trees are fire resilient, more than fire tolerant. These trees include blackgum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), and sourwood (*Oxydendrum arboreum*). There are various wildlife benefits to retention of some fire tolerant hardwoods in southern open pine ecosystems (Hiers et al. 2014). However, the presence of a dense midstory of hardwoods may be associated with the decline in herbaceous groundcover.

Southern open pine ecosystems with an open midstory provide habitat for many focal wildlife species, including birds and reptiles. Metrics similar to this have been used successfully on other southern open pine projects (FNAI and FFS 2014, NatureServe 2011). Many of these wildlife species rely on grassy herbaceous groundcover with some dwarf shrubs, often associated with open midstory and open canopy of southern yellow pine. While also preferring an open midstory, the northern bobwhite and Bachman's sparrow both use scattered tall shrubs and saplings for perching, including oaks, sassafras, black cherry and persimmon (NatureServe 2015, Richardson 2014a).

For longleaf pine woodlands, maintenance conditions are considered to be 20% or less mid-story cover, with most of this composed of fire tolerant species and less than 5% cover of fire-intolerant hardwood or off-site pine trees over 16 feet tall (Longleaf Partnership Council 2014). To recover the biodiversity associated with shortleaf pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for cover of the midstory layer were determined to be less than 10% for Shortleaf Pine-Bluestem, less than 30% for Dry Mesic Shortleaf Pine-Oak Woodland, and 15% for Dry Shortleaf Pine-Oak. Midstory was defined as greater than 10 feet (3 m) tall and below the bottom of the canopy (Blaney et al. 2016), which is followed here. Most of the midstory would be composed of fire tolerant or fire-resistant trees and tall shrubs.

In Appalachian Pine Woodlands, dense understories might prevent establishment of seedlings of overstory species (Murphy & Nowacki 1997). Fire can reduce the amount of midstory hardwoods, however oaks (*Quercus)* have higher resistance to fire-related mortality than other hardwoods, such as *Acer rubrum*, red maple (Lafon et al. 2017).

Measurement Protocol: For assessment area, separately estimate percentage within the plot covered by fire intolerant hardwood and fire tolerant hardwood midstory foliage, branches, and stems as determined by ocular (visual) estimate. Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface, estimated visually by the field researcher (Peet et al. 1998). Spaces between leaves and stems also count as cover. Midstory is defined to include any woody stems (including tall shrubs, small trees and vines) which are greater than 10 feet tall, up to the height of the bottom of the tree canopy (Blaney et al. 2016). Measure fire tolerant hardwood cover (cover of turkey oak, sand post oak, bluejack oak, blackjack oak, black oak, post oak, southern red oak, white oak, scarlet oak, black hickory, mockernut hickory, pignut hickory, sand hickory, chestnut oak, and blackgum, (Albrecht & McCarthy 2006, Elliott et al. 1999, Hammond et al. 2015, Hutchinson et al. 2005, Kreye et al. 2013, Signell et al. 2005, Varner et al. 2003). Ocular (visual) estimate of the percent of ground within the plot covered by all aboveground parts of the midstory fire tolerant hardwoods.

Metric Rating:

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	2 to 20% cover of midstory fire tolerant hardwoods
GOOD (B)	20 to 40% cover of midstory fire tolerant hardwoods
FAIR (C)	>40 to 50%, or <2% cover of midstory fire tolerant hardwoods
POOR (D)	>50% cover of midstory fire tolerant hardwoods

Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
EXCELLENT (A)	2 to 10% cover of midstory fire tolerant hardwoods
GOOD (B)	10-30%, or <2% cover of midstory fire tolerant hardwoods
FAIR (C)	>30 to 40% cover of midstory fire tolerant hardwoods
POOR (D)	>40% cover of midstory fire tolerant hardwoods

Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	2 to 10% cover of midstory fire tolerant hardwoods
GOOD (B)	10-20%, or <2% cover of midstory fire tolerant hardwoods
FAIR (C)	>20 to 35% cover of midstory fire tolerant hardwoods
POOR (D)	>35% cover of midstory fire tolerant hardwoods

Data for Metric Rating: Published data that support the basis for the metric rating

Abrams, M.D. 2007. Tales from the blackgum, a consummate subordinate tree. BioScience 57(4): 347–359.

Albrecht, M.A., and B.C. McCarthy. 2006. Effects of prescribed fire and thinning on tree recruitment patterns in central hardwood forests. Forest Ecology and Management 226: 88-103.

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

Elliott, K.J., R.L. Hendrick, A.E. Major, J.M. Vose, W.T. Swank. 1999. Vegetation dynamics after a prescribed fire in the southern Appalachians. Forest Ecology and Management 114 (2-3): 199

FNAI and FFS. 2014. Longleaf Pine Ecosystem Geodatabase v.1 Final Report. A cooperative project between Florida Natural Areas Inventory and the Florida Forest Service. <http://www.fnai.org/LongleafGDB.cfm>

Hammond, D. H., J. M. Varner, J. S. Kush, and Z. Fan. 2015. Contrasting sapling bark allocation of five southeastern USA hardwood tree species in a fire prone ecosystem. Ecosphere 6(7):112. http://dx.doi.org/10.1890/ ES15-00065.1

Hiers, J. K., J. R. Walters, R. J. Mitchell, J. M. Varner, L. M. Conner, L. A. Blanc, and J. Stowe. 2014. Commentary: Ecological Value of Retaining Pyrophytic Oaks in Longleaf Pine Ecosystems. The Journal of Wildlife Management 78(3):383–393.

Hutchinson, T.F., E.K. Sutherland, and D.A. Yaussy. 2005. Effects of repeated prescribed fires on the structure, composition, and regeneration of mixed-oak forests in Ohio. Forest Ecology and Management 218: 210-228.

Kreye, Jesse K., J. Morgan Varner, J. Kevin Hiers, and John Mola. 2013. Toward a mechanism for eastern North American forest mesophication: differential litter drying across 17 species. Ecological Applications 23(8): 1976-1986.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

Peet, R. K., T. R. Wentworth and P. S. White. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262-274. <http://cvs.bio.unc.edu/methods.htm>

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (Peucaea aestivalis). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Signell, S.A., M.D.Abrams, J.C. Hovis, S.W. Henry. 2005. Impact of multiple fires on stand structure and tree regeneration in central Appalachian oak forests. Forest Ecology and Management. 218: 146-158.

Thomas-Van Gundy, M., and G.J. Nowacki. 2013. The use of witness trees as pyro-indicators for mapping past fire conditions. Forest Ecology and Management 304: 333-344.

Varner, J.M., III, Kush, J.S., and Meldahl, R.S. 2003. Vegetation of frequently burned old-growth longleaf pine (*Pinus palustris* Mill.) savannas on Choccolocco Mountain, Alabama, USA. Natural Areas Journal 23:43–52.

Scaling Rationale: This metric has been used extensively in open pine woodlands in the Interior Highlands, especially in Arkansas (Blaney et al. 2016).

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Midstory Fire Intolerant Tree Cover

Definition: Midstory Fire Intolerant Tree Cover. Fire intolerant trees, include the conifers Virginia pine (*Pinus virginiana*), white pine (*Pinus strobus*), and Eastern red-cedar (*Juniperus virginiana*), and hardwoods red maple (*Acer rubrum),* serviceberry *(Amelanchier sp.),* sweet birch *(Betula lenta),* beech (*Fagus grandifolia),* American holly (*Ilex opaca*), sweetgum (*Liquidambar styraciflua),* tulip-tree (*Liriodendron tulipifera),* flowering dogwood (*Cornus florida*), black cherry (*Prunus serotina*), laurel oak (*Quercus hemisphaerica*), water oak (*Quercus nigra),* live oak *(Quercus virginiana),* and especially in wet flatwoods and savannas, the exotic Chinese tallow tree (*Triadica sebifera)* (Bragg 2014, Kreye et al. 2013, NatureServe 2011, Oakman et al. 2019, Signell et al. 2005). Other trees which are not naturally part of the fire maintained open pine ecosystem are also included. The metric is the percentage of the ground within the plot covered by midstory foliage, branches, and stems as determined by ocular (visual) estimate. Spaces between leaves and stems count as cover. Midstory is defined to include any fire intolerant woody stem (including tall shrubs, trees and vines) that are greater than 10 feet tall, up to the height of the bottom of the tree canopy.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Southern open pine ecosystems with an open midstory can provide better habitat for many of the characteristic wildlife. The presence of a midstory greater than 25% cover is associated with the decline in habitat quality for many wildlife species of southern open pine ecosystems. Generally, there is a decline in herbaceous groundcover with an increase in midstory cover to greater than 25%. Metrics similar to this have been used successfully on other southern open pine projects (FNAI and FFS 2014, NatureServe 2011). Many of these wildlife species rely on grassy herbaceous groundcover with some dwarf shrubs, often associated with open midstory and open canopy of southern yellow pine. While also preferring an open midstory, the northern bobwhite and Bachman’s sparrow both use scattered tall shrubs and saplings for perching, including oaks, sassafras, black cherry and persimmon (NatureServe 2015, Richardson 2014a). To recover the biodiversity associated with Shortleaf Pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for cover of the midstory layer were determined to be less than 10% for Shortleaf Pine-Bluestem, less than 30% for Dry Mesic Shortleaf Pine-Oak Woodland, and 15% for Dry Shortleaf Pine-Oak. Midstory was defined as greater than 10 feet (>3 m) tall and below the bottom of the canopy (Blaney et al. 2016). For longleaf pine woodlands, maintenance conditions are considered to be 20% or less mid-story cover, with less than 5% cover of fire-intolerant hardwood or off-site pine trees over 16 feet tall (Longleaf Partnership Council 2014). Fire intolerant trees generally don’t occur or are sparse in stands which have been frequently burned over a long time, may have bark which is not resistant to fire, and tend to have downed leaves which don’t burn well in fuel beds. In these ways, they can disrupt the function of southern open pine ecosystems. Fire intolerant trees, include the conifers Virginia pine (*Pinus* *virginiana*), white pine (*Pinus strobus*), and Eastern red-cedar (*Juniperus virginiana*), and hardwoods red maple (*Acer rubrum),* serviceberry *(Amelanchier sp.),* sweet birch *(Betula lenta),* beech (*Fagus grandifolia),* American holly (*Ilex opaca*), sweetgum (*Liquidambar styraciflua),* tulip-tree (*Liriodendron tulipifera),* flowering dogwood (*Cornus florida*), black cherry (*Prunus serotina*), laurel oak (*Quercus hemisphaerica*), water oak (*Quercus nigra),* live oak *(Quercus virginiana),* and especially in wet flatwoods and savannas, the exotic Chinese tallow tree (*Triadica sebifera)* (Bragg 2014, Kreye et al. 2013, NatureServe 2011, Signell et al. 2005)*.* Other trees which are not naturally part of the fire-maintained open pine ecosystem, are also included.

Measurement Protocol: For the assessment area, estimate the percent of the ground within the plot covered by fire intolerant midstory tree foliage, branches, and stems as determined by ocular (visual) estimate. Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface, estimated visually by the field researcher (Peet et al. 1998). Spaces between leaves and stems also count as cover. Midstory is defined to include any fire intolerant woody stem (including tall shrubs, trees and woody vines) that are greater than 10 feet tall, up to the height of the bottom of the tree canopy (Blaney et al. 2016). Ocular (visual) estimate of the percent of ground within the plot covered by all above ground parts of the midstory woody plants. Because forest vegetation layers can overlap, total percent cover of the canopy, midstory and shrub layers may exceed 100%.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	<10% cover of fire intolerant tree midstory
GOOD (B)	10 to 20% cover of fire intolerant tree midstory
FAIR (C)	>20 to 30% cover of fire intolerant tree midstory
POOR (D)	>30% cover of fire intolerant tree midstory

Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
Metric Rating	***Montane Longleaf Pine – Shortleaf Pine Woodlands***
EXCELLENT (A)	<5% cover of fire intolerant tree midstory
GOOD (B)	5 – 10% cover of fire intolerant tree midstory
FAIR (C)	>10 to 20% cover of fire intolerant tree midstory
POOR (D)	>20% cover of fire intolerant tree midstory

Data for Metric Rating: Published data that support the basis for the metric rating.

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

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Scaling Rationale: Scaling includes a definition of excellent which has a low amount of midstory, such as might provide perching sites for Bachman's sparrow and northern bobwhite.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Short Shrub (<3 feet tall) Cover and Tall Shrub (3-10 feet tall) Cover

Definition: An assessment of amount of cover of shrubs and small broad-leaved trees less than 10 feet tall. Percentage of the ground within the plot covered by the general extent of woody plants including small broad-leaved trees and short shrubs (less than 3 feet tall) and tall shrubs (3-10 feet tall).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: This metric is drafted to accommodate shortleaf pine-bluestem vegetation and other Southern Open Pine Groups. Information is incorporated from Southern Open Pine workshops held at the Jones Center in March 2015 and Knoxville, TN in September 2015. Maintenance condition class for shrub cover in longleaf pine woodlands exists when shrubs average 30% cover or less and average 3 feet tall or less (Longleaf Partnership Council 2014).

Shortleaf pine (*Pinus echinata*) is a shade-intolerant species, and a canopy dominant in fire-maintained southern open pine ecosystems. Shortleaf pine thrives with low intensity surface fires which provide for open structure and adequate regeneration of the overstory trees. In addition, fire exposes mineral soil which is necessary for seed germination and seedling recruitment.

A dense tall shrub layer shades the ground, inhibiting both the regeneration of shortleaf pine seedlings as well as the vigor and reproduction of native warm season grasses and forbs that constitute the fuels needed to carry fire in the stand. Competition from woody plants (including shrubs) is highly detrimental to the growth and development of these pine seedlings and saplings (Lawson 1986, Lowery 1986). To recover the biodiversity associated with shortleaf pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for shrubs of the understory (1-3 m tall) were determined to be less than 10% for Shortleaf Pine-Bluestem, less than 30% for Dry Mesic Shortleaf Pine-Oak Woodland, and less than 30% for Dry Shortleaf Pine-Oak in the Ouachita and Boston Mountains, and 20-80% shrub cover in the Ozarks, further north (Blaney et al. 2016).

With the absence of fire (or other disturbance), the less fire-adapted shrubs can spread into the understory, competing for site resources, nutrients, and light and hindering the growth and regeneration of shortleaf pine seedlings, as well as inhibiting and suppressing the vigor and growth of grasses and forbs in the ground layer (LMJV WGCPO Landbird Working Group 2011).

Mature shortleaf pine-bluestem stands with abundant herbaceous ground cover and little to no hardwood midstory, managed with late-dormant season fire at 3-year intervals, show dramatic increases in both richness and density of small mammals and songbirds (Wilson et al. 1995, Masters et al. 1998, 2001, 2002; cited in Masters 2007). Periodic fire can control the size of understory hardwoods, but only annual summer burning (for decades) is likely to completely remove hardwood sprouts (Waldrop et al., 1992, cited in Van Lear et al. 2005).

Shrub coverage in Table Mountain pine heath is 60 – 90%, in pitch pine heath is 40 – 70% and in most cases >50% (Whittaker 1956). Mountain laurel (*Kalmia latifolia*) is often dominant, with other Ericaceous (heath) shrubs especially blueberries (*Vaccinium*), and Huckleberries (*Gaylussacia*) (Lafon et al. 2017, Whittaker 1956). Mountain laurel (*Kalmia latifolia*) cover and height is reduced by fire, but it can respond with new growth following fire (Dumas, Neufeld, and Fisk 2007).

Measurement Protocol: This metric consists of a visual evaluation of the cover and height of shrubs and small broad-leaved trees (less than 10 feet tall) within a delimited assessment area, including small broad-leaved trees and short shrubs (less than 3 feet tall) and small trees and tall shrubs (3-10 feet tall). This assessment area should be at least 0.1 acre or 400 m^2 and can be delimited either with tapes, by pacing distances, or with a range finder. Within this area, a visual assessment is made of the cover of shrubs, including small individuals of broad-leaved trees. Visually assess the percentage of the ground within the plot covered by the general extent of woody plants including small broad-leaved trees and short shrubs (less than 3 feet tall) and tall shrubs (3-10 feet tall). This should not include shortleaf pine regeneration. For assessment area, estimate percentage of the ground within the plot covered by the general extent of the foliage, branches, and stems from all shrubs (all woody plants, single- or multi-stemmed, including woody seedlings, tree saplings, short shrubs, saw palmetto, scrub palmetto and woody vining plants). Spaces between leaves and stems count as cover. Because forest vegetation layers can overlap, the total of short shrub percent cover and tall shrub percent cover may exceed 100%.

Shrub Cover Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor. Variants are provided.

Tall Shrubs (3-10 feet tall)

Metric Rating	***Interior Highlands Shortleaf Pine-Oak Woodlands***
EXCELLENT (A)	Shrubs 3-10 feet in height average <30% cover.
GOOD (B)	Shrubs 3-10 feet in height average 30 to 40% cover.
FAIR (C)	Shrubs 3-10 feet in height average >40 to 50% cover.
POOR (D)	Shrubs 3-10 feet in height average >50% cover.

Metric Rating	*Interior Highlands Shortleaf Pine - Bluestem Woodlands*
EXCELLENT (A)	Shrubs 3-10 feet in height average <5% cover.
GOOD (B)	Shrubs 3-10 feet in height average 5 to 10% cover.
FAIR (C)	Shrubs 3-10 feet in height average >10 to 25% cover.
POOR (D)	Shrubs 3-10 feet in height average >25% cover.

Metric Rating	*Montane Longleaf Pine - Shortleaf Pine Woodlands*
Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain and Piedmont Shortleaf Pine Woodlands***
EXCELLENT (A)	Shrubs 3-10 feet in height average <15% cover.
GOOD (B)	Shrubs 3-10 feet in height average 15 to 20% cover.
FAIR (C)	Shrubs 3-10 feet in height average >20 to 30% cover.
POOR (D)	Shrubs 3-10 feet in height average >30% cover.

Short Shrubs (<3 feet tall)

Metric Rating	*Interior Highlands Shortleaf Pine-Oak Woodlands*
Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	Shrubs < 3 feet in height average <20% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 20 to 30% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >30 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Metric Rating	*Interior Highlands Shortleaf Pine - Bluestem Woodlands*
Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	Shrubs < 3 feet in height average <20% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 20 to 25% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >25 to 40% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >40% cover in the assessment area

Metric Rating	*Southern Appalachian Pine - Oak Woodlands*
EXCELLENT (A)	Shrubs < 3 feet in height average <50% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 50 to <70% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average 70 to 80% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >80% cover in the assessment area

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

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Scaling Rationale: This metric has been scaled based on scientific judgment of NatureServe ecologists and other expert ecologists and wildlife biologists. The metric is scaled based on the similarity between the observed vegetation structure and what is expected based on reference (or appropriately managed natural disturbance) conditions. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources. The basis for assigning the ratings should be documented on the field forms.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: GROUND COVER

RANK FACTOR: VEGETATION

Metric Name: Overall Native Herbaceous Ground Cover

Definition: Percentage cover of all (native) herbaceous species in the ground layer.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Native herbaceous groundcover provides fine fuel which can allow frequent low intensity fires. The amount of native herbaceous groundcover is an important for the habitat needs of many wildlife species which depend on southern open pine ecosystems. Some southern open pine woodlands have many species of herbaceous legumes. These legumes provide food for wildlife and fix nitrogen which helps maintain site productivity. Maintenance condition class for herbaceous cover in longleaf pine woodlands is considered to have herbaceous cover greater than 35% with native pyrogenic species present in stand (Longleaf Partnership Council 2014). Birds of southern open pine ecosystems that benefit from native herbaceous ground cover include northern bobwhite (McIntyre 2012), Bachman's sparrow (Richardson 2014a), prairie warbler (NatureServe 2015), and red-cockaded woodpecker (James et al. 2001). To promote the biodiversity associated with shortleaf pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for cover of the ground layer were determined to be 80-100% for Shortleaf Pine-Bluestem, 50-80% for Dry Mesic Shortleaf Pine-Oak Woodland, and 40-60% for Dry Shortleaf Pine-Oak (Blaney et al. 2016).

In Appalachian open pine woodlands, the most frequent native grasses are *Danthonia spicata, Piptochaetium avenaceum*, and *Schizachyrium scoparium.* Typical forbs include *Antennaria plantaginifolia, Coreopsis major, Helianthus microcephalus, Pityopsis graminifolia var. latifolia, Symphyotrichum concolor*, and *Symphyotrichum patens* (NatureServe 2020). In the Great Smoky Mountains, the total herbaceous cover in Southern Appalachian Pine - Oak Woodlands was usually 5 – 20% cover, including grasses, forbs, and ferns (Whitaker 1956).

Measurement Protocol: For assessment area, estimate the cover of all native herbaceous ground cover (FNAI and FFS 2014). This includes all native non-woody, soft-tissue plants regardless of height, including non-woody vines, legumes, composites, graminoids (grasses, sedges, and rushes, including beaked rushes), and other herbaceous plants. Visually assess the percentage of the ground within the plot covered by the general extent of native herbaceous plants. Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface, estimated visually by the field researcher (Peet et al. 1998). Spaces between leaves and stems count as cover.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	*Interior Highlands Shortleaf Pine - Oak Woodlands*
Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	35-80% herbaceous cover
GOOD (B)	20 to <35% or >80% herbaceous cover
FAIR (C)	10 to <20% herbaceous cover
POOR (D)	<10% herbaceous cover

Metric Rating	*Interior Highlands Shortleaf Pine - Bluestem Woodlands*
Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	>45 to 80% herbaceous cover
GOOD (B)	30-45% or >80% herbaceous cover
FAIR (C)	15 to <30% herbaceous cover
POOR (D)	<15% herbaceous cover

Metric Rating	*Southern Appalachian Pine - Oak Woodlands*
EXCELLENT (A)	>15% herbaceous cover
GOOD (B)	5 to 15% herbaceous cover
FAIR (C)	<5% herbaceous cover
POOR (D)	Herbaceous cover absent

Data for Metric Rating: Published data that support the basis for the metric rating.

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

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Peet, R. K., T. R. Wentworth and P. S. White. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262-274. <http://cvs.bio.unc.edu/methods.htm>

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (*Peucaea aestivalis*). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale:

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Native Graminoid Cover

Definition: Native graminoid cover may also be called cover of pyrophytic graminoids which include grasses and grass-like plants (grasses, sedges, and rushes, including beaked rushes). This metric is the percent cover of native warm season grasses and other perennial graminoids that are maintained by, or thrive with, periodic fire. These native grasses and grass-like plants (mostly native warm season grasses) are the natural groundcover in southern open pine stands. For a list of example species to include and which to exclude, see the Measurement Protocol below.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Grasses and grass-like plants provide much of the fine fuels which allow frequent low intensity fire to occur in southern open pine ecosystems (Kirkman et al. 2004). This metric has been useful in other assessments (FNAI and FFS 2014, NatureServe 2011).

Fire is a natural disturbance process which helps maintain southern open pine ecosystems. Native grasses and grass-like plants which provide the fine fuels in southern open pine are called pyrophytic graminoids. These are mostly native perennial warm season grasses, which can resprout fairly quickly following fire during the growing season. Native warm season grasses use the four Carbon, C_4 pathway in photosynthesis (not the more common three Carbon C_3 pathway used by cool season grasses) and generally are associated with prairies and open woodlands. The C_4 pathway is more efficient for photosynthesis in warmer temperatures (Edwards et al. 2010). For most southern open pine ecosystems, there is broad overlap between native warm season grasses (using the C_4 pathway), and the plants measured in this metric, which have been called pyrophytic graminoids. Areas with good cover of native warm season grasses can be nesting and feeding areas for Bachman's sparrow, and bobwhite quail (McIntyre 2012, Richardson 2014a. Maintenance condition class for herbaceous cover in longleaf pine woodlands is herbaceous cover greater than 35% with native pyrogenic species present in stand (Longleaf Partnership Council 2014).

Native warm season grasses are a minor component of the vegetation in many examples of Southern Appalachian Pine - Oak Woodlands (Newell & Peet 1998). Sites that have been burned and had mechanical removal of midstory, have increased graminoids, but their cover may still be below 5% (Oakman et al. 2019). In the Ozarks, poverty oakgrass (*Danthonia spicata*) is an important native grass and Pennsylvania sedge (*Carex pensylvanica*) is an important native graminoid in open woodlands.

In the Great Smoky Mountains, the total herbaceous cover in Southern Appalachian Pine - Oak Woodlands was usually 5 – 20% cover (including grasses, forbs, and ferns), the important grasses were little bluestem (*Schizachyrium scoparium*), broomsedge (*Andropogon virginicus*), and panic grasses (*Panicum* sp.) (Whitaker 1956). Other important grasses include poverty oatgrass (*Danthonia spicata*), forked panicgrass (*Dichanthelium dichotomum*), muhly (*Muhlenbergia* sp.), switchgrass (*Panicum virgatum*), blackseed speargrass (*Piptochaetium avenaceum*), and Indiangrass (*Sorghastrum nutans*) (NatureServe 2020). Chinese silvergrass (*Miscanthus sinensis*) is an invasive exotic grass spreading in Appalachian pine ecosystems (Black et al. 2018), it should not be confused with native warm season grasses when assessing cover.

Measurement Protocol: For the assessment area, estimate total cover of all native graminoids (FNAI and FFS 2014, NatureServe 2011). Visually assess the percentage of the ground within the plot covered by the general extent of native grasses and grass-like plants. Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface, estimated visually by the field researcher (Peet et al. 1998). Spaces between leaves and stems also count as cover.

In wet pinelands various narrow leaved graminoids such as rushes (*Juncus spp.*), and beaked rushes (*Rhynchospora spp.*) are included here as they have similar functions as the native warm season grasses. However, switchgrass (*Panicum virgatum*) and broomsedge (*Andropogon virginicus*) are not included. Switchgrass (*Panicum virgatum*) can become so dominant that other grasses, legumes and small bare ground areas are crowded out. Broomsedge (*Andropogon virginicus*) is excluded, because it is weedy and ruderal, commonly found in old fields, pastures and in recently logged pine stands. Some typical wide ranging southern native warm season grasses of open pine woodlands include splitbeard bluestem (*Andropogon ternarius*), Elliott's bluestem (*Andropogon gyrans var. gyrans*), pineywoods dropseed (*Sporobolus junceus*), rough dropseed (*Sporobolus clandestinus*), little bluestem (*Schizachyrium scoparium*), slender little bluestem (*Schizachyrium tenerum*), Indiangrass (*Sorghastrum nutans*), slender Indiangrass (*Sorghastrum elliottii*), and lopsided Indiangrass (*Sorghastrum secundum*). In the Ozarks and Ouachitas (Interior Highlands), native warm season grasses include little bluestem (*Schizachyrum scoparium*), big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), bearded shorthusk (*Brachyelytrum erectum*), Elliott's bluestem (*Andropogon gyrans*), blackseed speargrass (*Piptochaetium avenaceum*), composite dropseed (*Sporobolus compositus*), and other grasses (Blaney et al. 2016, Farrington 2010, Nelson 1985). In open shortleaf pine woodlands in northern Mississippi, native warm season grasses include little bluestem (*Schizachyrum scoparium*) and broomsedge (*Andropogon virginicus*), but broomsedge is excluded here due to its weediness (Brewer et al. 2015, Maynard and Brewer 2013).

A summary of species in two tables:

🚫 **Always exclude**	
switchgrass	*Panicum virgatum*
broomsedge	*Andropogon virginicus*

☑ **Examples of typical warm season grasses, not an exhaustive list**	
big bluestem	*Andropogon gerardii*
Elliott's bluestem	*Andropogon gyrans*
other bluestems	*Andropogon* spp.
splitbeard bluestem	*Andropogon ternarius*
bearded shorthusk	*Brachyelytrum erectum*
hairawn muhly	*Muhlenbergia capillaris*
blackseed speargrass	*Piptochaetium avenaceum*
little bluestem	*Schizachyrium scoparium*
slender little bluestem	*Schizachyrium tenerum*
slender Indiangrass	*Sorghastrum elliottii*
Indiangrass	*Sorghastrum nutans*
rough dropseed	*Sporobolus clandestinus*
composite dropseed	*Sporobolus compositus*
pineywoods dropseed	*Sporobolus junceus*

There are many other native warm season grasses in these genera: *Andropogon, Aristida, Muhlenbergia, Panicum, Paspalum, Saccharum, Schizachyrium, Sorghastrum, Sporobolus, Steinchisma, Tridens, Triplasis,* and *Tripsacum* (Osborne et al. 2014).

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***Interior Highlands Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	>25 to 85% cover of all native graminoids
GOOD (B)	>15 to 25% or >85% cover of all native graminoids
FAIR (C)	10 -15% cover of all native graminoids
POOR (D)	<10% cover of all native graminoids

Metric Rating	***Interior Highlands Shortleaf Pine - Bluestem Woodlands***
Metric Rating	***Montane Longleaf Pine - Shortleaf Pine Woodlands***
EXCELLENT (A)	>25 to 85% cover of all native graminoids
GOOD (B)	20 to 25% or >85% cover of all native graminoids
FAIR (C)	10 to <20% cover of all native graminoids
POOR (D)	<10% cover of all native graminoids

Metric Rating	***Southern Appalachian Pine - Oak Woodlands***
EXCELLENT (A)	>10% cover of all native graminoids
GOOD (B)	5 to 10% cover of all native graminoids
FAIR (C)	Native graminoids present, but with <5% cover
POOR (D)	Native graminoids absent

Metric Rating	***West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands***
Metric Rating	***Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands***
EXCELLENT (A)	25- 100% cover of all native graminoids
GOOD (B)	>15 to <25% cover of all native graminoids
FAIR (C)	10-15% cover of all native graminoids
POOR (D)	<10% cover of all native graminoids

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2016. Appendix G. Desired Future Conditions for Restored Shortleaf Pine Ecosystem in the Interior Highlands of Arkansas and Missouri. Appendix G in Anderson, M., L. Hayes, P.D. Keyser, C.M. Lituma, R.D. Sutter, and D. Zollner. 2016. Shortleaf Pine Restoration Plan: Restoring an American Forest Legacy. Shortleaf Pine Initiative. <http://shortleafpine.net/shortleaf-pine-initiative/shortleaf-pine-restoration-plan>

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

Brewer, J. S., M.J. Abbott, and S. Moyer. 2015. Effects of oak-hickory woodland restoration treatments on native groundcover vegetation and the invasive grass Microstegium vimineum. Ecological Restoration 33(3): 256-265.

Edwards, E.J., C.P. Osborne, C.A.E. Strömberg, S.A. Smith, and the C_4 Grasses Consortium. 2010. The origins of C_4 grasslands: integrating evolutionary and ecosystem science. Science 328: 587–591.

Farrington, S. 2010. Common indicator plants of Missouri Upland Woodlands. <http://www.forestandwoodland.org/uploads/1/2/8/8/12885556/common_indicator_plants_of_missouri_upland_woodlands.pdf>

FNAI and FFS. 2014. Longleaf Pine Ecosystem Geodatabase v.1 Final Report. A cooperative project between Florida Natural Areas Inventory and the Florida Forest Service. <http://www.fnai.org/LongleafGDB.cfm>

Kirkman, L. K., K. L. Coffey, R. J. Mitchell and E. B. Moser. 2004. Ground cover recovery patterns and life-history traits: implications for restoration obstacles and opportunities in a species-rich savanna. Journal of Ecology 92:409-421.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

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NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

Nelson, P. W. 1985. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City. 197 pp. Revised edition, 1987.

Nelson, P. 2010. The terrestrial natural communities of Missouri. Revised edition. Missouri Natural Areas Committee, Department of Natural Resources and the Department of Conservation, Jefferson City.

Osborne, C. P., A. Salomaa, T. A. Kluyver, V. Visser, E. A. Kellogg, O. Morrone, M. S. Vorontsova, W. D. Clayton, and D. A. Simpson. 2014. A global database of C4 photosynthesis in grasses. New Phytologist 204(3): 441-446.

Peet, R. K., T. R. Wentworth and P. S. White. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262-274. <http://cvs.bio.unc.edu/methods.htm>

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (*Peucaea aestivalis*). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale: The scaling of this metric is based on literature and the input of experts in the southern open pine ecosystems and the wildlife using these ecosystems.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Floristic Quality Index, Mean C (Optional)

Definition: The Floristic Quality Index is a widely used vegetation-based index of ecological integrity. The metric requires a list of the plant species within the assessment area. The Floristic Quality Index is based on the plant species which are present in an assessment area, and their Coefficients of Conservatism, or C values. The C values are integers from 0 to 10 and have been assigned by working groups of botanists who are very familiar with the plants of their states or regions. High C values indicate a native plant's fidelity to natural areas with natural processes. Low C values indicate weedy plants which commonly occur in ruderal habitats, such as old fields or vacant lots. Weedy native plants have C values of 0-3, many native plants which are not weedy have C values of 4-6, and those native plants which usually do not occur outside of natural areas or very special habitats have C values of 7-10. Mean C is a simple metric which is the average C value of all the native plants recorded in the rapid assessment area. References for C values for plants are available for some states and regions within the range of shortleaf pine.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: The Floristic Quality Index is a widely used vegetation-based index of ecological integrity (Rocchio and Crawford 2013, Swink and Wilhelm 1994). There are several values that can be calculated as part of the Floristic Quality Index, but Mean C is basic, easy to interpret and the most straightforward. For a full discussion, see section *4.3.3 Which Metric to Use?* in Rocchio and Crawford 2013.

The Floristic Quality Index requires a list of the plant species within the assessment area, so it is an optional metric for those rapid assessments which are listing the plant species as part of their field data collection. The Floristic Quality Index is based on the plant species which are present in an assessment area, and their Coefficients of Conservatism, or C values (Ladd and Thomas 2015, Swink and Wilhelm 1994). The C values are integers from 0 to 10 and have been assigned by working groups of botanists who are very familiar with the plants of their states or regions (Chamberlain and Ingram 2012, Herman et al. 1997, Ladd and Thomas 2015, Zomlefer et al. 2013). High C values indicate a native plant's fidelity to natural areas with natural processes, and low C values indicate plants which commonly occur in ruderal habitats, such as old fields or vacant lots (Ladd and Thomas 2015, Swink and Wilhelm 1994). Weedy native plants have C values of 0-3, many native plants which are not weedy have C values of 4-6, and those native plants which usually do not occur outside of natural areas or very special habitats have C values of 7-10. C values have been found to be informative, robust ecological indicators with significant predictive ability (Matthews et al. 2015). Mean C is a simple metric which is the average C value of all the native plants recorded in the rapid assessment area. References for C values for plants are available for some states and regions within the range of shortleaf pine (Ladd and Thomas 2015).

The Floristic Quality Assessment has been effectively used in open conifer woodland restoration projects in Missouri (Maginel et al. 2016, Maginel et al. 2019, Reid et al. 2020).

The Universal FQA Calculator is an online tool for calculating Floristic Quality Assessment metrics and managing data. There are many projects which have imported their data to the Universal FQA website:

https://universalfqa.org/

The tool can be used on a tablet in the field to calculate Mean C.

Measurement Protocol: List all the plant species encountered within the assessment area. The plant list should be fairly complete, but every single species within the assessment area does not need to be found and recorded. A field worker who knows the plants of the open pine woodlands can keep a species list as the assessment area is examined and the other metrics are completed. Since Mean C is an average, its value will stabilize as more plants are included, and then each additional plant encountered will have a smaller influence on the value of Mean C. For instance, a good Mean C value can be obtained from a list of all plants with more than 1% cover. Mean C does not need to be calculated in the field, it could be calculated as part of the metrics data management process. Here are some example data, using the Missouri C values (Ladd and Thomas 2015):

Assessment Area #1	C value
Pinus echinata	*5*
Quercus stellata	*4*
Vaccinium arboreum	*6*
Vaccinium stamineum	*6*
Schizachyrium scoparium	*5*
Andropogon ternarius	*5*
Carex pensylvanica	*6*

Mean C = 37/7 = 5.29
Metric rating of Assessment Area #1 is Excellent (A)

Assessment Area #2	C value
Pinus echinata	*5*
Prunus serotina	*2*
Sassafras albidum	*2*
Rhus glabra	*1*
Rhus coppalinum	*2*
Andropogon virginicus	*2*
Eupatorium serotinum	*1*
Pteridium aquilinum	*4*
Pyrus calleryana	** (exotic plants should be recorded, but aren't used for Mean C)*

Mean C = 19/8 = 2.375
Metric Rating of Assessment Area #2 is FAIR (C)

Exotic or non-native plant species encountered should be recorded, but they are not included in the Mean C calculation, which is based on the native plants and their C values only. Invasive exotic plants are assigned total percent cover in the Invasive Plant Presence/Distribution metric.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Mean C >4.00
GOOD (B)	Mean C is 3.01 to 4.00
FAIR (C)	Mean C is 2.01 to 3.00
POOR (D)	Mean C <2.00

Data for Metric Rating: Published data that support the basis for the metric rating

Chamberlain, S.J. and H.M. Ingram. 2012. Developing coefficients of conservatism to advance floristic quality assessment in the Mid-Atlantic region. Journal of the Torrey Botanical Society 139(4): 416-427.

Freyman, W.A., L.A. Masters, and S. Packard. 2016. The Universal Floristic Quality Assessment (FQA) Calculator: an online tool for ecological assessment and monitoring. Methods in Ecology and Evolution 7(3): 380–383. <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.12491>

Herman, K.D., L.A. Masters, M.R. Penskar, A.A. Reznicek, G.S. Wilhelm, and W.W. Brodowicz. 1997. Floristic quality assessment: Development and application in the state of Michigan (USA). Natural Areas Journal 17: 265–279.

Ladd, D. and J.R. Thomas. 2015. Ecological checklist of the Missouri flora for Floristic Quality Assessment. Phytoneuron 2015-12: 1–274. <https://conservationresearchinstitute.org/files/missouri_fqa.pdf>

Maginel, C.J., B.O. Knapp, J.M. Kabrick, E.K. Olson, R. Muzika. 2016. Floristic Quality Index for woodland ground flora restoration: Utility and effectiveness in a fire-managed landscape. Ecological Indicators 67: 58-67.

Maginel, C.J., B.O. Knapp, J.M. Kabrick, and R-M. Muzika. 2019. Landscape- and site-level responses of woody structure and ground flora to repeated prescribed fire in the Missouri Ozarks. Canadian Journal of Forest Research 49:1004-1014.

Matthews, J.W., G. Spyreas, and C.M. Long. 2015. A null model test of Floristic Quality Assessment: Are plant species' coefficients of conservatism valid? Ecological Indicators 52: 1–7.

Reid, J.L., N.J. Holmberg, M. Albrecht, S. Arango-Caro, O. Hajek, Q. Long, and J. Trager. 2020. Annual understory plant recover dynamics in a temperate woodland mosaic during a decade of ecological restoration. Natural Areas Journal 40 (1): 23-34.

Rocchio, F.J. and R.C. Crawford. 2013. Floristic Quality Assessment for Washington Vegetation. Natural Heritage Report 2013-10. Washington Natural Heritage Program, Washington Department of Natural Resources. Olympia, WA. <https://www.dnr.wa.gov/publications/amp_nh_fqa_washington.pdf>

Swink, F. and G. Wilhelm. 1994. Plants of the Chicago Region (ed. 4). The Morton Arboretum, Lisle, Illinois.

Zomlefer, W., L. Chafin, J. Carter, D. Giannasi. 2013. Coefficient of conservatism rankings for the flora of Georgia: wetland indicator species. Southeastern Naturalist 12 (4): 790-808.

Scaling Rationale: The scaling is based on the application of Mean C to a variety of ecosystems by a variety of users of the Floristic Quality Assessment, including NatureServe partners. The scaling is not specific to certain open pine woodlands. The metric can be applied to small assessment areas (fixed radius areas around points) or larger stands or conservation sites.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name: Invasive Plant Presence/Distribution

Definition: Invasive plant presence and distribution. Describes the extent and distribution of invasive nonnative (exotic) plants within or along the perimeter of the polygon; references of invasive plants are available for most southern states.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Invasive exotic species are a major threat to biological integrity in a wide variety of ecosystems (Miller 2003). These species can out compete the native species, alter ecological functions (Bryson and Carter 1993, Lippincott 2000) and contribute to decline in biological integrity. The metric and scaling are based on the detection likely on a cursory or rapid field visit to a site. For wetlands, NatureServe has used cover of invasive nonnative plants for rapid ecological integrity assessment (Faber-Langendoen et al. 2015). NatureServe's categories are excellent if absent or less than 1% cover, good if sporadic or 1-3% cover, fair if somewhat abundant with 4-10% cover, between fair and poor if abundant with 11-30% cover, and poor if very abundant with greater than 30% cover of invasive nonnative plants (Faber-Langendoen et al. 2015). Less than or equal to 1% cover of invasive exotic plant species (here, Excellent or Good) or ongoing progress towards this indicates maintenance condition for longleaf pine woodlands (Longleaf Partnership Council 2014). Most examples of southern open pine ecosystems have low amounts of invasive exotic plants, this metric has been scaled as a rapid assessment indicator for these ecosystems, based on expert input. For example, invasive nonnative plant species cover >5% in any stratum indicates a Poor (D) rating for this metric for southern open pine ecosystems. In South Carolina, use the Invasive Plant Species of South Carolina booklet from Clemson (Lund et al. 2015), and the Terrestrial Exotic Invasive Species List (South Carolina Exotic Pest Plant Council 2014). There are similar lists available for other states in the region (Georgia Exotic Pest Plant Council 2018, Kentucky Exotic Pest Plant Council 2013, NC Invasive Plant Council 2020, Tennessee Invasive Plant Council 2018), and for the southern region (Miller 2003). Exotic subtropical grasses, including rose cogongrass (*Imperata cylindrica*), Natal grass (*Melinis repens*) and small carpetgrass (*Arthraxon hispidus*) are a particular threat to longleaf pine ecosystems (FLEPPC 2019). Tallow tree (*Triadica sebifera*) and cogongrass (*Imperata cylindrica*) are threats to Wet Longleaf & Slash Pine Flatwoods & Savannas (Brewer 2008, Wang et al. 2011). Cogongrass is also a threat to other southern open pine ecosystems, especially as it becomes more common in Alabama and Mississippi. Japanese stiltgrass (*Microstegium vimineum*) and Japanese honeysuckle (*Lonicera japonica*) are threats during restoration of open woodlands in northern Mississippi, such as the Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands (Brewer, Abbott and Moyer 2015).

Increasing fire severity in Southern Appalachian Pine – Oak Woodlands heightened the likelihood of invasion by non-native species (Black et al. 2018, Neel 2012), specifically princess tree (*Paulownia tomentosa*) and Chinese silvergrass (*Miscanthus sinensis*). This was found after a wildfire (Black et al. 2018).

After wildfires in Southern Appalachian Pine – Oak Woodlands in Linville Gorge (North Carolina), there were multiple large-scale invasions of princess tree (*Paulownia tomentosa*), due to increased post-fire recruitment (Dumas, Neufeld, and Fisk 2007, Kuppinger 2008, Kuppinger, Jenkins & White 2010, Lovenshimer & Madritch 2017). The tree of heaven (*Ailanthus altissima*) is also common in the Appalachian region and benefits from fire (Crandall & Knight 2018, Rebbeck 2012). Other invasive exotic plants of management concern *include Dioscorea oppositifolia, Eleagnus, Ligustrum japonicum, Ligustrum sinense*, and *Lonicera japonica* (NatureServe 2020).

Measurement Protocol: Describe the extent and distribution of invasive exotic plants within the site and/or along the perimeter of the site. Estimate a percent cover value of invasive plant species for your assessment area. Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface, estimated visually by the field researcher (Peet et al. 1998). Spaces between leaves and stems also count as cover. There also are references of invasive plants available for most southern states (Georgia Exotic Pest Plant Council 2018, Kentucky Exotic Pest Plant Council 2013, Lund et al. 2015, NC Invasive Plant Council 2020, Tennessee Invasive Plant Council 2018), and for the southern region (Miller 2003), and for the southern region (Miller 2003).

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Invasive nonnative plant species absent
GOOD (B)	Invasive nonnative plant species present in any stratum but sporadic (<1 % cover)
FAIR (C)	Invasive nonnative plant species in any stratum uncommon (1-5% cover)
POOR (D)	Invasive nonnative plant species in any stratum common (>5% cover)

Data for Metric Rating: Published data that support the basis for the metric rating

Brewer, S. 2008. Declines in plant species richness and endemic plant species in longleaf pine savannas invaded by *Imperata cylindrica*. Biological Invasions 10:1257–1264.

Brewer, J. S., M. J. Abbott, and S. Moyer. 2015. Effects of oak-hickory woodland restoration treatments on native groundcover vegetation and the invasive grass *Microstegium vimineum*. Ecological Restoration 33(3): 256-265.

Bryson, C. T. and R. Carter. 1993. Cogongrass *Imperata cylindrica,* in the United States. Weed Technology 7:1005-1009.

Faber-Langendoen, D., W. Nichols, K. Strakosch Walz, J. Rocchio, J. Lemly, L. Gilligan, and G. Kittel. 2015. NatureServe Ecological Integrity Assessment Protocols: Wetland Rapid Assessment Method [revisions in progress]. NatureServe. Arlington, VA.

FLEPPC. 2019. List of Invasive Plant Species. Florida Exotic Pest Plant Council. http://www.fleppc.org/list/list.htm

Georgia Exotic Pest Plant Council. 2018. List of Non-native Invasive Plants in Georgia. https://www.gaeppc.org/list/

Kentucky Exotic Pest Plant Council. 2013. Exotic Invasive Plants of Kentucky (3rd Edition). https://www.se-eppc.org/ky/KYEPPC_2013list.pdf

Lippincott, C. L. 2000. Effects of *Imperata cylindrica* (L.) Beauv. (Cogongrass) Invasion on Fire Regime in Florida Sandhill (USA). Natural Areas Journal 20:140-149.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

Lund, M., D. Soriano, L. S. Pile, S. D. Thomas, and G. G. Wang. 2015. Invasive Plant Species of South Carolina. Clemson, SC. 76 pages. <https://www.se-eppc.org/southcarolina/Publications/InvasivePlantsBooklet.pdf>

Miller J. H. 2003. Nonnative invasive plants of southern forests: a field guide for identification and control. Asheville, NC. Southern Research Station, USDA Forest Service. Revised General Technical Report SRS-62.

Miller, S. J. and D. H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. Ecological Indicators 6(2): 313–326.

NC Invasive Plant Council. 2020. NC Invasive Plants. http://nc-ipc.weebly.com/nc-invasive-plants.html

Rejmánek, M., D. M. Richardson, S. I. Higgins, M. J. Pitcairn, and E. Grotkopp. 2005. Ecology of invasive plants: State of the art. Pp 104–161 In H. Mooney, R. N. Mack, J. A. McNeely, L. E. Neville, P. J. Schei, and J. K. Waage. Invasive alien species: A new synthesis. SCOPE 63. Island Press, Washington, DC.

Richardson, D. M., P. Pysek, M. Rejmánek, M. G. Barbour, F. D. Panetta, and C. J. West. 2000. Naturalization and invasion of alien plants: Concepts and definitions. Diversity and Distributions 6: 93–107.

Tennessee Invasive Plant Council. 2018. 2018 TN-IPC Invasive Plant List. https://www.tnipc.org/invasive-plants/

Tierney, G. L., D. Faber-Langendoen, B. R. Mitchell, W. G. Shriver, and J. P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7: 308–316.

South Carolina Exotic Pest Plant Council. 2014. Terrestrial Exotic Invasive Species List. https://www.se-eppc.org/southcarolina/invasivePlants.cfm

Wang, H., W. E. Grant, T. M. Swannack, J. Gan, W. E. Rogers, T. E. Koralewski, J. H. Miller and J.W. Taylor, Jr. 2011. Predicted range expansion of Chinese tallow tree (*Triadica sebifera*) in forestlands of the southern United States. Diversity and Distributions 17: 552–565.

Scaling Rationale: The scaling is based on the type of detection likely on a cursory or rapid field visit to a site. In order to detect invasive exotic plants, it is important to be familiar with those plants, and how to differentiate them from native plants. The metric can be applied to small assessment areas (fixed radius areas around points) or larger stands or conservation sites.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: SOIL

Metric Name: Forest Soil Disturbance

Definition: This metric describes surface conditions that affect site sustainability, hydrologic function, and site productivity. It is a rapid assessment tool for monitoring forest soils using standardized visual disturbance classes. It can be applied either through visual assessment of soil conditions in the stand or as a statistical assessment method to asses effects of forest management activity.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Forest soil disturbance classes can be assigned using visual indicators, following the US Forest Service's Forest Soil Disturbance Monitoring Protocol. The method is designed to be repeatable, and statistically sound, where needed. Further details of this metric are available in the Forest Soil Disturbance Monitoring Protocol documentation (Napper et al. 2009, Page-Dumroese et al. 2009a, (Page-Dumroese et al. 2009b), including use of a random sampling method before collecting data in the field.

Measurement Protocol: For an overall one-time assessment, the stand can be surveyed visually, and a soil disturbance class (0,1,2,3) assigned. For statistical sampling, the point location is a 15 cm (6 inch) diameter circle where soil disturbance class data is collected, the point locations need to be randomized within the assessment area, using a minimum of 30 point locations need to be assessed. Three randomization methods are suggested by Page-Dumroese et al. (2009a): Option 1: Randomly Oriented Transects, Option 2: Systematic Grid Points, Option 3: A Random Transect.

At each point location, a soil disturbance class (0, 1, 2, or 3) is assigned, based on visual indicators. Some visual indicators are in Table 1, from Page-Dumroese et al 2009b (below).

Table 1.—*Visual indicators and their definitions.*

Forest floor impacted	Forest floor material includes all organic horizons above the mineral soil surface.
Topsoil displacement	The surface mineral soil primarily includes the A horizons, but if the A horizon is shallow or undeveloped, it may include other horizons. This disturbance is usually due to machinery but does not include "rutting" described below.
Rutting	Ruts vary in depth but are primarily the result of equipment movement. Ruts are defined as machine-generated soil displacement or compression. Often soil puddling is also present within the rut.
Burning (light, moderate, severe)	Burn severity includes only effects on the forest floor and mineral soil, not on above-ground vegetation.
Compaction	Compaction by equipment results in either a compression of the soil profile or increased resistance to penetration.
Platy structure/ massive/puddled	Platy or tabular structure in the mineral soil. Massive soil indicates no structural units are present and soil material is a coherent mass. Puddled soil is often found after wet weather harvest operations. Soil pores are usually smeared and prevent water infiltration.

Soil disturbance classes are summarized in Table 2, from Page-Dumroese et al. 2009a (below). Details and pictures of the soil disturbance classes are in the Soil-disturbance field guide (Napper et al. 2009). The documents can be downloaded and kept on a tablet for reference while in the field.

Table 2.—*Soil disturbance classes used in the Forest Soil Disturbance Monitoring Protocol. Soil disturbance classes increase in severity of impact from class 0 to class 3. (1 of 2)*

Soil disturbance class 0	Soil disturbance class 1
Soil surface: • No evidence of compaction; i.e., past equipment operation, ruts, skid trails. • No depressions or wheel tracks evident. • Forest floor layers present and intact. • No soil displacement evident. • No management-generated soil erosion. • Litter and duff layers not burned. No soil char. Water repellency may be present.	Soil surface: • Faint wheel tracks or slight depressions evident and are <5 cm deep. • Forest floor layers present and intact. • Surface soil has not been displaced and shows minimal mixing with subsoil. • Burning light: Depth of char <1 cm. *Accessory**: Litter charred or consumed. Duff largely intact. Water repellency is similar to preburn conditions. Soil compaction: • Compaction in the surface soil is slightly greater than observed under natural conditions. • Concentrated from 0 to 10 cm deep. Observations of soil physical conditions: • Change in soil structure from crumb or granular structure to massive or platy structure; restricted to the surface 0 to 10 cm. • Platy structure is noncontinuous. • Fine, medium, and large roots can penetrate or grow around the platy structure. No "J" rooting observed. • Erosion is slight.

Table 2.—*Soil disturbance classes used in the Forest Soil Disturbance Monitoring Protocol. Soil disturbance classes increase in severity of impact from class 0 to class 3. (2 of 2)*

Soil disturbance class 2	Soil disturbance class 3
Soil surface: • Wheel tracks or depressions are 5 to 10 cm deep. • *Accessory**: Forest floor layers partially intact or missing. • Surface soil partially intact and may be mixed with subsoil. • Burning moderate: Depth of char is 1 to 5 cm. *Accessory**: Duff deeply charred or consumed. Surface soil water repellency increased compared with the preburn condition. Soil compaction: • Increased compaction is present from 10 to 30 cm deep. Observation of soil physical condition: • Change in soil structure from crumb or granular structure to massive or platy structure; restricted to the surface, 10 to 30 cm. • Platy structure is generally continuous. • *Accessory**: Large roots may penetrate the platy structure, but fine and medium roots may not. • Erosion is moderate.	Soil surface: • Wheel tracks and depressions highly evident with depth >10 cm. • *Accessory**: Forest floor layers missing. • Evidence of surface soil removal, gouging, and piling. • Most surface soil displaced. Surface soil may be mixed with subsoil. Subsoil partially or totally exposed. • Burning severe: Depth of char is >5 cm. *Accessory**: Duff and litter layer completely consumed. Surface soil is water repellent. Surface is reddish or orange in places. Soil compaction: • Increased compaction is deep in the soil profile (>30 cm deep). Observations of soil physical conditions: • Change in soil structure from granular structure to massive or platy structure extends beyond 30 cm deep. • Platy structure is continuous. • *Accessory**: Roots do not penetrate the platy structure. • Erosion is severe and has produced deep gullies or rills.

**Accessory items are those descriptors that may help identify individual severity classes.*

Soil visual indicators are used to assign soil disturbance classes at point locations. Details and pictures of the soil visual indicators are in the Soil-disturbance field guide (Napper et al. 2009). Examples of soil visual indicators are in Table 3 from Page-Dumroese et al 2009b (below).

Table 3.—*Examples of soil visual indicators and management activities. (1 of 2)*

Disturbance type	Severity class 0	1	2	3
Equipment impacts				
Past operation	None.	Dispersed.	Faint.	Obvious.
Wheel tracks or depressions	None.	Faint wheel tracks or slight depressions evident (<5 cm deep).	Wheel tracks or depressions are >5 cm deep.	Wheel tracks or depressions highly evident with a depth being >10 cm.

Table 3.—*Examples of soil visual indicators and management activities. (2 of 2)*

Disturbance type	Severity class			
	0	1	2	3
Equipment trails from more than two passes	None.	Faintly evident.	Evident, but not heavily trafficked.	Main trails that are heavily used.
Excavated and bladed trails[1]	None.	None.	None.	Present.
Penetration and resistance[2]	Natural conditions.	Resistance of surface soils may be slightly greater than observed under natural conditions. Increased resistance is concentrated in the surface (10 cm).	Increased resistance is present throughout the top 30 cm of soil.	Increased resistance is deep into the soil profile (>30 cm).
Soil structure	Natural conditions.	Change in soil structure from crumb or granular structure to massive or platy structure in the surface (10 cm).	Change in soil structure in the surface (30 cm). Platy (or massive) structure is generally continuous. On older sites, large roots may penetrate the platy structure, but fine and medium roots may not.	Change in soil structure extends beyond the top 30 cm. Platy (or massive) structure is continuous. On older sites, roots do not penetrate the platy structure.
Displacement				
Forest floor	None.	Forest floor layers present and intact.	Forest floor layers partially intact or missing.	Forest floor layers missing.
Mineral soil	None.	Soil surface has not been displaced and shows minimal mixing with subsoil.	Mineral topsoil partially intact and may be mixed with subsoil.	Evidence of topsoil removal, gouging, and piling. Soil displacement has removed most of the surface soil. Surface soil may be mixed with subsoil or subsoil may be partially or totally exposed.
Erosion	None.	Slight erosion evident (i.e., sheet erosion[3]).	Moderate amount of erosion evident (i.e., sheet and rill erosion[3]).	Substantial amount of erosion evident. Gullies, pedestals, and rills noticeable.
Burning	None.	Fire impacts are light. Forest floor is charred but intact. Gray ash becomes inconspicuous and surface appears lightly charred to black. Soil surface structure intact.	Fire impacts are moderate. Litter layer is consumed and humus layer is charred or consumed. Mineral soil not visibly altered, but soil organic matter (OM) has been partially charred.	Fire impacts are deep. The entire forest floor is consumed and top layer of mineral soil is visibly altered. Surface mineral structure and texture are altered. Mineral soil is black due to charred or deposited OM or is orange from burning.

[1] *Evaluate on main trails but not necessarily for wheel tracks or depressions.*

[2] *Soil resistance to penetration with a tile spade or probe is best done when the soil is not moist or wet.*

[3] *USDA NRCS (1993).*

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Soil Disturbance Class 0
GOOD (B)	Soil Disturbance Class 1
FAIR (C)	Soil Disturbance Class 2
POOR (D)	Soil Disturbance Class 3

Data for Metric Rating: Published data that support the basis for the metric rating

Bergstrom, Robert M.; Page-Dumroese, Deborah S. 2019. How much soil disturbance can be expected as a result of southern pine beetle suppression activities? Gen. Tech. Rep. RMRS-GTR-399. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 11 p. <https://www.fs.usda.gov/treesearch/pubs/58507>

Napper, Carolyn; Howes, Steven; Page-Dumroese, Deborah. 2009. Soil-disturbance field guide. 0819 1815-SDTDC. San Dimas, CA: U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center. 103 p. <https://www.fs.usda.gov/treesearch/pubs/40599>

Page-Dumroese, Deborah S.; Abbott, Ann M.; Rice, Thomas M. 2009a. Forest Soil Disturbance Monitoring Protocol: Volume I: Rapid assessment. Gen. Tech. Rep. WO-GTR-82a. Washington, DC: U.S. Department of Agriculture, Forest Service. 31 p. <https://www.fs.usda.gov/treesearch/pubs/34427>

Page-Dumroese, Deborah S.; Abbott, Ann M.; Rice, Thomas M. 2009b. Forest Soil Disturbance Monitoring Protocol: Volume II: Supplementary methods, statistics, and data collection. Gen. Tech. Rep. WO-GTR-82b. Washington, DC: U.S. Department of Agriculture, Forest Service. 64 p. <https://www.fs.usda.gov/treesearch/pubs/34426>

Faber-Langendoen, D., W. Nichols, K. Strakosch Walz, J. Rocchio, J. Lemly, L. Gilligan, and G. Kittel. 2015. NatureServe Ecological Integrity Assessment Protocols: Wetland Rapid Assessment Method [revisions in progress]. NatureServe. Arlington, VA.

Scaling Rationale: The scaling is based on extensive research by Page-Dumroese et al. (2009a, 2009b) on the degree of alteration of the soil surface and soil profile, as well as its effect on hydrology. It is suitable either for detection likely on a cursory or rapid field visit to a site, as well as for statistically based assessments. There are few data on the relationship of disturbance class to the potential loss in long-term productivity, but Bergstrom et al. (2019) labeled the soil disturbance class of 3 as “detrimental soil disturbance” (DSD), based on discussions with Forest Service soil scientists.

Confidence that reasonable logic and/or data support the metric: High

METRIC DESCRIPTIONS: LANDSCAPE CONTEXT

RANK FACTOR: LANDSCAPE

Metric Name: Contiguous Natural Land Cover

Definition: This metric measures the percent of the landscape within 500 meters of the assessment area that is contiguous with (and thus forms an unfragmented connection to) the assessment area itself. Fragmentation can dramatically impact natural processes such as seed dispersal, animal movement, and genetic diversity (Lindenmayer and Fischer 2006).

Metric Type: Condition

Tier: Level 1 (remote sensing)

Rationale for Selection of the Variable: The intensity of human activity on the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of cultural land use (e.g., agricultural and developed urban/suburban patches) within the surrounding landscape provides an indirect estimate of connectivity among natural ecological systems. Landscapes that retain more connectivity among patches of otherwise isolated vegetation types, and therefore have higher levels of connectivity, are assumed to be more likely to maintain populations of various species that inhabit the natural patch. Studies have shown that lack of landscape connectivity reduces pollination and seed dispersal, animal movements, ecological processes, and ultimately genetic diversity (Lindenmayer and Fischer 2006).

The integrity of the landscape context can be critically important to certain biota. Amphibians and reptiles are especially sensitive to the matrix of habitats surrounding a wetland because they spend the majority of their lives foraging, resting, and hibernating in the adjacent terrestrial habitat (Semlitsch 1998). Upland habitats immediately surrounding wetlands serve as important dispersal corridors and are also used as foraging and aestivation areas for many amphibian species (Semlitsch 1998). Total unaltered area around the wetland also seems to be an important landscape component in the maintenance of wetland fauna. Guerry and Hunter (2002) found that wood frogs, green frogs, eastern newts, spotted salamanders, and salamanders of the blue-spotted/Jefferson's complex (*Ambystoma laterale/A. jeffersonianum*) were more likely to occupy ponds in unaltered landscapes (i.e., intact forested areas).

Measurement Protocol: To assess this metric, examine land use patterns within a 500 m envelope of the assessment area. This is best done using the most recent aerial photography available. GIS layers of land use or land cover can also be used, but may not be as accurate as interpretation of aerial photography. When possible, walk through portions of the 500 m envelop to ground truth the photo. Identify the largest unfragmented block that contains the assessment area and estimate its percentage of the total area within the 500 m envelope. This percent of unfragmented landscape can have small fragmentation inclusions (e.g., individual houses in a forested landscape, etc.), but roads that bisect the landscape form a hard boundary to the unfragmented block. Well-traveled dirt roads and major canals count as fragmentation, but hiking paths, non-tilled hayfields, open fences, and small lateral ditches can be included in unfragmented blocks. For larger roads, such as highways where road fill and trash borders the road, the zone of the road's influence should also be considered as fragmentation.

Metric Rating: Assign the metric rating and associated score based on the thresholds below.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Intact: embedded in 90–100% contiguous natural landscape.
GOOD (B)	Variegated: embedded in 60–90% contiguous natural landscape
FAIR (C)	Fragmented: embedded in 20–60% contiguous natural landscape
POOR (D)	Relictual: embedded in <20% contiguous natural landscape.

Data for Metric Rating: See McIntyre and Hobbs (1999); also see Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Metric concept and thresholds adapted from Rondeau (2001), Rocchio (2006a-g), and Faber-Langendoen et al. (2008). The categorical ratings are based on McIntyre and Hobbs (1999) and Heinz Center (2002).

Faber-Langendoen,D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation based on Ecological Integrity Assessments. NatureServe, Arlington, VA. + Appendices.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2011. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. NatureServe, Arlington VA.+ Appendices.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Strakosch Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach Part B. Ecological Integrity Assessment Protocols for Rapid Field Methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Guerry, A. D. and M. L. Hunter. 2002. Amphibian Distributions in a Landscape of Forests and Agriculture: An Examination of Landscape Composition and Configuration. Conservation Biology 16:745–754.

Heinz Center. 2002. The State of the Nation's Ecosystems: Measuring the Lands, Waters and Living Resources of the United States. Cambridge University Press, NY.

Lemly, J.M. and Rocchio, J.R. 2009. Field Testing and Validation of the Subalpine-Montane Riparian Shrublands Ecological Integrity Assessment (EIA) Scorecard in the Blue River Watershed, Colorado. Report prepared for the Colorado Division of Wildlife and US EPA

Region 8 by the Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/download/reports.asp

Lemly, J., L. Gilligan, and C. Wiechmann. 2016. Ecological Integrity Assessment (EIA) for Colorado Wetlands. Field Manual, Version 2.1. Colorado Natural Heritage Program. Accessed August 27, 2018. https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.

Lindenmayer, D. B. and Fischer, J. 2006. Habitat fragmentation and landscape change: an ecological and conservation synthesis. Island Press, Washington, DC

McIntyre S. and R. Hobbs. 1999. A framework for conceptualizing human effects on landscapes and its relevance to management and research models. ConservBiol 13:1282–1292.

Rocchio, J. (2006a) Intermountain Basin Playa ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rocchio, J. (2006b) North American Arid West Freshwater Marsh ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rocchio, J. (2006c) Rocky Mountain Alpine-Montane Wet Meadow ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rocchio, J. (2006d) Rocky Mountain Lower Montane Riparian Woodland and Shrubland ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rocchio, J. (2006e) Rocky Mountain Subalpine-Montane Fen ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rocchio, J. (2006f) Rocky Mountain Subalpine-Montane Riparian Shrubland ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rocchio, J. (2006g) Rocky Mountain Subalpine-Montane Riparian Woodland ecological system: Ecological Integrity Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Rondeau, R. 2001. Ecological system viability specifications for Southern Rocky Mountain ecoregion. First Edition. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. 181 pp.

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding amphibians. Conservation Biology 12:1113–1119.

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on McIntyre and Hobbs (1999).

Confidence that reasonable logic and/or data support the metric: Medium/High.

RANK FACTOR: LANDSCAPE

Metric Name: Land Use Index

Definition: This metric measures the intensity of human dominated land uses in the surrounding landscape and is based on Hauer et al. (2002) and Mack (2006).

Metric Type: Stressor

Tier: Level 1 (remote sensing)

Rationale for Selection of the Variable: The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural ecosystems. Assessing land use incorporates both the aspect of "habitat destruction" and "habitat modification" (sensu McIntyre and Hobbs 1999), at least for the non-natural habitats. That is, in addition to the effect of converting natural habitat to agricultural, urban and other land use modifications, there is the additional aspect of the intensity of that land use. Human land uses often directly or indirectly alter many natural ecological processes.

Tests of this metric in conjunction with the Landscape Connectivity metric found a high level of correlation (redundancy), suggesting that perhaps both are not needed (Faber-Langendoen et al. 2011). Landscape Connectivity is a simpler metric to apply. However, the tests were done in a fairly homogeneous region of land uses, and further tests should be conducted across a wider range of land use types.

Measurement Protocol: The Land Use Index is measured by documenting surrounding land uses within 500 m of the assessment area. The assessment should be completed in the office using remote sensing imagery, such as aerial photographs, satellite imagery, or landcover datasets. Where feasible, the rating should be verified in the field, using roads or transects to verify land use categories. Ideally, both field data as well as remote sensing tools are used to identify an accurate percent of each land use within the landscape area, but remote sensing data alone can be used. This metric can be calculated as an automated GIS process using the National Land Cover Dataset or the LANDFIRE Dataset, though both should be reviewed for accuracy.

To calculate a Land Use Index, estimate the percent of each land use category and calculate the corresponding category score based on land use coefficients and the following equation:
Land use category score = $\sum$ LU x PC/100

LU = Land use coefficient for each category
PC = % of adjacent area in each category

Do this for each land use category separately, then sum each category score to calculate the Total Land Use Score. If land uses overlap, use the more intensive land use for the calculation. For example, if 10% of the landscape contains unpaved roads (1 * 0.10 = 0.1), 30% is under moderate grazing (6 * 0.30 = 1.8), and 60% is natural vegetation (10 * 0.60 = 6.0), the Total Land Use Score would be 7.9 (0.1 + 1.8 + 6.0), for a rating of C.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Land Use Index = 9.5–10.0
GOOD (B)	Land Use Index = 8.0–9.49
FAIR (C)	Land Use Index = 4.0–7.99
POOR (D)	Land Use Index = <4.0

Data for Metric Rating: The National Land Cover Dataset 2011 and other years is available for download at: https://www.mrlc.gov/nlcd2011.php. The LANDFIRE Dataset is available for download at: https://www.landfire.gov.

Metric and thresholds adapted from Hauer et al. (2002) and Faber-Langendoen et al. (2012).

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2011. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. NatureServe, Arlington VA.+ Appendices.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Strakosch Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach Part B. Ecological Integrity Assessment Protocols for Rapid Field Methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Hauer, F.R., B.J. Cook, M.C. Gilbert, E.J. Clairain Jr., and R.D. Smith. 2002. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains. U.S. Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. ERDC/EL TR-02-21.

Lemly, J., L. Gilligan, and C. Wiechmann. 2016. Ecological Integrity Assessment (EIA) for Colorado Wetlands. Field Manual, Version 2.1. Colorado Natural Heritage Program. Accessed August 27, 2018. https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.

Mack, J.J. 2006. Landscape as a predictor of wetland condition: An evaluation of the Landscape Development Index (LDI) with a large reference wetland dataset from Ohio. Environmental Monitoring and Assessment 120: 221–241.

McIntyre S. and R. Hobbs. 1999. A framework for conceptualizing human effects on landscapes and its relevance to management and research models. ConservBiol 13:1282–1292.

Scaling Rationale: Land uses have differing degrees of potential impact on ecological patterns and processes. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and low intensity grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (e.g., urban development, roads, and mining) may completely destroy vegetation and drastically alter ecological processes (Hauer et al. 2002, Mack 2006).

Confidence that reasonable logic and/or data support the metric: Medium.

RANK FACTOR: BUFFER

RANK FACTOR: BUFFER

Metric Name: Perimeter with Natural Buffer

Definition: This metric measures the percent of the assessment area perimeter that is immediately surrounded by natural buffer land covers.

Metric Type: Condition

Tier: Level 1 (remote sensing)

Rationale for Selection of the Variable: Perimeter with Natural Buffer is one of three submetrics in NatureServe's Ecological Integrity Assessment Buffer Index metric; the other two submetrics are Average Buffer Width and Buffer Condition. The Buffer Index metric was developed for wetlands, and in applying the metrics to open pine and longleaf vegetation, the Perimeter with Natural Buffer seemed most practical to calculate and assess due to potential limitations of direct access to lands surrounding a site and to the geospatial calculation complexity of the other two submetrics.

The Environmental Law Institute (2008) summarizes extensive data on the rationale for the role of buffers in maintaining ecological integrity of wetlands. Many studies have looked at specific effects of buffers on water quality, birds and other attributes of ecosystems. For example, Semlitsch (1998) monitored terrestrial migrations for six Ambystomid salamander species and found that buffers were critical to permitting their passage into uplands. They found that buffer areas 164 m from wetland edges were needed to encompass 95% of population forays.

Measurement Protocol: Estimate the length of the assessment area perimeter contiguous with a natural buffer. Use a 5 m minimum buffer width. Perimeter includes open water. Metric is adapted from Collins et al. (2006) and US EPA (2011).

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Natural buffer surrounds 100% of the site perimeter
GOOD (B)	Natural buffer surrounds 75–99% of the site perimeter
FAIR (C)	Natural buffer surrounds 25–74% of the site perimeter
POOR (D)	Natural buffer surrounds <25% of the site perimeter

Data for Metric Rating: See Environmental Law Institute (2008); also see Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of a variant of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2006. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas. Version 4.2.3. 136 pp.

Environmental Law Institute. 2008. Planner's Guide to Wetland Buffers for Local Governments. Washington, DC. 25 pp.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2011. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. NatureServe, Arlington VA.+ Appendices.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Strakosch Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach Part B. Ecological Integrity Assessment Protocols for Rapid Field Methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Kennedy, C., Wilkinson, J., and Balch, J., 2003. Conservation thresholds for land use planners. Planning Guide. Washington, DC: Environmental Law Institute.

Lemly, J.M. and Rocchio, J.R. 2009. Field Testing and Validation of the Subalpine-Montane Riparian Shrublands Ecological Integrity Assessment (EIA) Scorecard in the Blue River Watershed, Colorado. Report prepared for the Colorado Division of Wildlife and US EPA Region 8 by the Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Lemly, J., L. Gilligan, and C. Wiechmann. 2016. Ecological Integrity Assessment (EIA) for Colorado Wetlands. Field Manual, Version 2.1. Colorado Natural Heritage Program. Accessed August 27, 2018. https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding amphibians. Conservation Biology 12:1113–1119.

U.S. EPA. 2011. USA RAM Manual, Version 11. (co-authors, J. Collins, S. Fennessy). U.S. Environmental Protection Agency, Washington, DC.

Scaling Rationale: There is abundant evidence on the value of even narrow buffers between 5 and 25 m (Environmental Law Institute 2008).

Confidence that reasonable logic and/or data support the metric: Medium/High

RANK FACTOR: SIZE

Metric Name: Absolute Patch Size [optional]

Definition: A measure of the current absolute size of the contiguous open pine-oak woodland polygon or patch, which may be larger than the assessment area. The metric is assessed with respect to expected patch sizes for the type across its range. This metric is one aspect of the size of specific occurrences of an open pine-oak woodland ecosystem type. The metric rating is taken from NatureServe's Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008). Assessors are sometimes hesitant of using absolute size as part of an EIA out of concern that a small, high-quality example will be down-ranked unnecessarily. We address these concerns to a degree by providing a landscape pattern-type scale, so that types that typically occur as large patches (e.g. Southern Appalachian Pine – Oak Woodlands) can use a different rating than types that may occur over large, extensive matrix areas (e.g. Interior Highlands Shortleaf Pine – Bluestem Woodlands) on the landscape (Faber-Langendoen et al. 2012).

Interior Highlands Shortleaf Pine-Oak Woodlands	***Matrix***
Interior Highlands Shortleaf Pine - Bluestem Woodlands	***Matrix***
Montane Longleaf Pine - Shortleaf Pine Woodlands	***Large Patch***
Southern Appalachian Pine - Oak Woodlands	***Large Patch***
West Gulf Coastal Plain Shortleaf Pine - Oak Woodlands	***Matrix***
Southeastern Coastal Plain & Piedmont Shortleaf Pine - Oak Woodlands	***Matrix***

Metric Type: Condition

Tier: 1 (remote sensing); 2 (rapid field measure)

Rationale for Selection of the Variable: The role of absolute size in assessing integrity is complex. First, higher ratings for size may not always indicate increased integrity. For some types, absolute size can vary widely for entirely natural reasons (e.g., a forest type may have very large occurrences on rolling landscapes and be restricted in other landscapes to small occurrences on north slopes or ravines).

Second, size overlaps with landscape context as a metric, depending on the scale of the vegetation type. Size and landscape context both address spatial aspects of an occurrence. Very large sized, matrix occurrences essentially define the landscape context. Standards for establishing the size metric ratings sometimes can be confounded with criteria for Landscape Context. For example, the use of Minimum Dynamic Area (MDA) as the basis for the Size criteria is misleading, at least at the system or natural community level, because MDA is really assessing the landscape area within which an occurrence is embedded and on which it depends for its persistence (Leroux et al. 2007). MDA is typically applied to types at very broad classification scales (e.g., northern hardwood and boreal forest landscapes).

Nonetheless, size can be an important aspect of integrity. For some types, diversity of animals or plants may be higher in larger occurrences than in small occurrences that are otherwise similar. For occurrences in mosaics, the larger occurrences often have more micro-habitat features. Larger areas are more resistant to stressors in general, and are more resistant to invasion by exotics specifically, since they buffer their own interior portions. Thus, size can serve as a readily measured proxy for some ecological processes and the diversity of interdependent assemblages of plants and animals.

Note that NatureServe's methodology for evaluation patches or polygons (the "Element Occurrence Rank") includes integrity and conservation values, so with respect to size, larger occurrences are generally presumed to be more value for conservation purposes, as they provide a better representation of the type being conserved. We keep the Size metrics separate within a Primary "Size Rank Factor" so that users can readily determine the role of these metrics in the overall EIA scores.

Measurement Protocol: The choice of patch type for the particular vegetation type being assessed is an important first step and should be based on knowledge of the typical sizes of mid to broad scale ecological types (Formations, Groups, Systems) found in excellent sites. Knowledgeable ecologists in the state or region should be consulted. Ecological System and Group types have all been assigned to a pattern type, so if the site is classified to Ecological System or Group, that information can be readily attained (www.natureserve.org/explorer).

Absolute Size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, or other data layers. Size can also be estimated in the field using 7.5 minute topographic quads, NPS Vegetation Mapping maps, National Wetland Inventory maps, or a global positioning system. Boundaries are not delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987); rather, they are delineated by ecological guidelines for delineating the boundaries of the vegetation type, based on the International Vegetation Classification, equivalent National Vegetation Classifications, National Wetland Inventory, or other classifications.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor for either matrix or large patch open pine ecosystems.

Metric Rating	***Matrix Southern Open Pine Ecosystems*** form extensive and contiguous cover, occur on the most extensive landforms, and typically have wide ecological tolerances.
EXCELLENT (A)	>6,000 acres
GOOD (B)	1,250-6,000 acres
FAIR (C)	125-1,250 acres
POOR (D)	<125 acres

Metric Rating	***Large Patch Southern Open Pine Ecosystems*** form large areas of interrupted cover and typically have narrower ranges of ecological tolerances than matrix types.
EXCELLENT (A)	>300 acres
GOOD (B)	60-300 acres
FAIR (C)	12-60 acres
POOR (D)	<12 acres

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation based on Ecological Integrity Assessments. NatureServe, Arlington, VA. + Appendices.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2011. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. NatureServe, Arlington VA.+ Appendices.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Strakosch Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach Part B. Ecological Integrity Assessment Protocols for Rapid Field Methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Lemly, J.M. and Rocchio, J.R. 2009. Field Testing and Validation of the Subalpine-Montane Riparian Shrublands Ecological Integrity Assessment (EIA) Scorecard in the Blue River Watershed, Colorado. Report prepared for the Colorado Division of Wildlife and US EPA Region 8 by the Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/download/reports.asp

Lemly, J., L. Gilligan, and C. Wiechmann. 2016. Ecological Integrity Assessment (EIA) for Colorado Wetlands. Field Manual, Version 2.1. Colorado Natural Heritage Program. Accessed August 27, 2018. https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.https://ecos.fws.gov/ServCat/DownloadFile/101684?Reference=61246.

Leroux, S.J., F.K.A. Schmiegelowa, R. B. Lessard, and S. G. Cumming. 2007. Minimum dynamic reserves: A framework for determining reserve size in ecosystems structured by large disturbances. Biological Conservation 138: 464–473.

U.S. Army Corps of Engineers. 1987. Corps of Engineers Wetlands Delineation Manual. Environmental Laboratory, U.S. Army Corps of Engineers Waterways Exp. Stn. Tech. Rep. Y-87-1.

Scaling Rationale: Scaling criteria are based on the NatureServe Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008). Our scaling has been informed by considerations of spatial pattern types, but no general guidelines have yet been established to assess wetland patch size.

Confidence that reasonable logic and/or data support the metric: Medium.

APPENDICES

APPENDIX A: BASAL AREA METHODS

Basal Area Methods

Measurement Protocol: Basal area is measured for the appropriate trees 5" diameter or greater at 4.5 feet (54"), diameter at breast height (DBH).

Option 1: A 10x factor basal area prism or gauge is used at four (4) locations 33 feet (10 meters) from the outer edge of the assessment area, such as along tapes going north, east, south, and west through the assessment area center, and (optionally) also at the center of the assessment area. If assessment area is smaller than 1/8 acre (500 square meters), then four (4) basal area points should be 10 feet (3.0 meters) from assessment area center, to the north, east, south, and west. Trees are tallied together for the appropriate southern yellow pines or hardwoods, according to the metric and ecosystem. At each basal area point, the tallied count of the appropriate trees is multiplied by the basal area factor of 10 (if using the 10x prism) to get the basal area values in ft^2/acre. The final value for the metric is the average of each of the basal areas from the 10x basal area prism points in the assessment area.

Option 2: Within the assessment area measure all appropriate southern yellow pine or hardwood species (according to the metric and ecosystem) which are 5" diameter or greater at 4.5 feet (54"), diameter at breast height (DBH) in inches, then convert diameter measurements to ft^2 using formula:

Basal area (in ft^2) = $0.005454 * DBH^2$

For the final value of basal area, the value for the plot area must be converted to a value of basal area in ft^2 / acre. The conversion math will depend on the assessment area and its units of measure. If basal area prism is not used, the appropriate southern yellow pine or hardwood tree (according to the metric and ecosystem) diameters can all be listed for the defined assessment area, and the basal area in ft^2/acre can be calculated later. Divide the basal area sum by the plot size in acres to get basal area in square feet per acre. Generally, there is no need to do the basal area calculations in the field.

APPENDIX B: LIST OF FIRE TOLERANT AND INTOLERANT HARDWOODS

A small amount of hardwood tree basal area naturally occurs in many upland southern open pine ecosystems, especially fire tolerant (pyrophytic) oaks (Albrecht & McCarthy 2006, Bragg 2002, Bragg 2014, Elliott et al. 1999, Hammond et al. 2015, Hiers et al. 2014, Hutchinson et al. 2005, Keyser et al. 2018, Kreye et al. 2013, LANDFIRE 2020, NatureServe 2015b, Signell et al. 2005, Thomas-Van Gundy & Nowacki 2013, Varner et al. 2003).

Fire tolerant hardwoods include:

turkey oak *(Quercus laevis),* sand post oak (*Quercus margarettae),* bluejack oak (*Quercus incana*), blackjack oak (*Quercus marilandica),* black oak (*Quercus velutina),* post oak (*Quercus stellata*)*,* southern red oak (*Quercus falcata),* white oak (*Quercus alba),* scarlet oak (*Quercus coccinea),* chestnut oak (*Quercus montana = Quercus prinus*), black hickory (*Carya texana*), mockernut hickory (*Carya tomentosa*), pignut hickory (*Carya glabra*), sand hickory (*Carya pallida*), and blackgum (*Nyssa sylvatica*)

Some hardwood trees are fire resilient, more than fire tolerant. These trees include:

blackgum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), and sourwood (*Oxydendrum arboreum*).

Fire intolerant trees, include:

the conifers Virginia pine (*Pinus virginiana*), white pine (*Pinus strobus*), and Eastern red-cedar (*Juniperus virginiana*), and hardwoods red maple (*Acer rubrum),* serviceberry *(Amelanchier sp.),* sweet birch *(Betula lenta),* beech (*Fagus grandifolia),* American holly (*Ilex opaca*), sweetgum (*Liquidambar styraciflua),* tulip-tree (*Liriodendron tulipifera),* flowering dogwood (*Cornus florida*), black cherry (*Prunus serotina*), laurel oak (*Quercus hemisphaerica*), water oak (*Quercus nigra),* live oak *(Quercus virginiana),* and especially in wet flatwoods and savannas, the exotic Chinese tallow tree (*Triadica sebifera*) (Bragg 2014, Keyser et al. 2018, Kreye et al. 2013, NatureServe 2011, Signell et al. 2005).

Other trees which are not naturally part of the fire-maintained open pine ecosystem, are also included as fire intolerant trees.

APPENDIX C: 2018 METRIC RATINGS.

METRIC RATINGS BY GROUP

Interior Highlands Shortleaf Pine – Oak (2018)				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine	<10 or >110 ft^2/acre basal area of shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of shortleaf pine	20-25% or >70 to 80% canopy cover of shortleaf pine	10 to <20% or >80 to 90% canopy cover of shortleaf pine	<10% or >90% canopy cover of shortleaf pine
Southern Yellow Pine Stand Age Structure	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14" DBH class	Basal area ≥10 ft^2/acre of shortleaf pine trees ≥14" DBH class	Shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No shortleaf pine trees ≥14" DBH are present
Canopy Hardwood Basal Area	<u><</u>20 ft^2/acre BA of hardwood trees	>20 to 40 ft^2/acre BA of hardwood trees	>40 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to shortleaf pine)	SDI = 65 – 135 (14 - 30% of Maximum SDI of 450)	SDI = 45 – 65 or 135 - 180 (10-14% or 30-40% of Maximum SDI of 450)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-30% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20-25% cover of woody midstory	>25 to 35% cover of woody midstory	>35% cover of woody midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover
Native Warm Season Grass Cover	>25 to 85% foliar cover of all native warm season grasses	>15 to 25% or >85% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (<u><</u>1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Mountain Longleaf-Shortleaf Pine (2018)				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of longleaf & shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of longleaf & shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of longleaf & shortleaf pine	<10 or >110 ft^2/acre basal area of longleaf & shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of longleaf & shortleaf pine	20-25% or >70 to 80% canopy cover of longleaf & shortleaf pine	10 to <20% or >80 to 90% canopy cover of longleaf & shortleaf pine	<10% or >90% canopy cover of longleaf & shortleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf pine of any diameter and/or longleaf or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf or shortleaf pine trees ≥14" DBH class	Longleaf or shortleaf pine trees ≥14" DBH class are present, but at<10 ft^2/acre BA	No longleaf or shortleaf pine trees ≥14" DBH or flat-top longleaf pine are present
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 40 ft^2/acre BA of hardwood trees	>40 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to longleaf pine)	SDI = 55 – 120 (14 - 30% of Maximum SDI of 400)	SDI = 40 – 55 or 120 -160 (10-14% or 30-40% of Maximum SDI of 400)	SDI = 15 – 40 or 160 - 200 (4-10% or 40-50% of maximum SDI)	SDI <15 or >200 (<4% or >50%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-30% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	≥20 to 25% cover of woody midstory	>25 to 35% cover of woody midstory	>35% cover of woody midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20-25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover
Longleaf Pine Regeneration	Longleaf pine regeneration cover is >1% of stand (Good and Excellent)	Longleaf pine regeneration cover is >1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand
Native Warm Season Grass Cover	>25 to 85% foliar cover of all native warm season grasses	20-25% or >85% foliar cover of all native warm season grasses	10 to <20% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Coastal Plain & Piedmont Shortleaf Pine-Oak (2018)				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-85 ft^2/acre basal area of loblolly or shortleaf pine	20 to <30 or >85 to 100 ft^2/acre basal area of loblolly or shortleaf pine	10 to <20 or >100 to 115 ft^2/acre basal area of loblolly or shortleaf pine	<10 or >115 ft^2/acre basal area of loblolly or shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 75% canopy cover of loblolly or shortleaf pine	>15 to 25% canopy cover or >75 to 85% canopy cover of loblolly or shortleaf pine	10-15% canopy cover or >85 to 95% canopy cover of loblolly or shortleaf pine	<10% cover or >95% cover of loblolly or shortleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	Loblolly and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No loblolly and/or shortleaf pine trees ≥14" DBH are present
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 30 ft^2/acre BA of hardwood trees	>30 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to shortleaf and loblolly pine)	SDI = 55 – 155 (12 - 34% of Maximum SDI of 450)	SDI = 35 – 55 or 155 - 205 (8-12% or 34-45% of Maximum SDI of 450)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-20% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	≥20 to 30% cover of woody midstory	>30 to 50% cover of woody midstory	>50% cover of woody midstory
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover
Native Warm Season Grass Cover	25-100% foliar cover of all native warm season grasses	>15 to <25% foliar cover of all native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)