Introduction to Upland Hardwood Woodlands and Forest of the Ozark Highlands

The Ozark Highlands have historically been dominated by a matrix of oak-hickory upland hardwood and mixed pine-hardwood systems, with upland hardwoods found in both open woodland and closed-canopy forest conditions. Large tracts of public and private forest lands render the upland hardwood system in this geography unique and critical to many wildlife species, particularly those requiring large forest patches to carry out their life history. The GCPO LCC Integrated Science Agenda (ISA) identifies the upland hardwoods system in the Ozark Highlands as one of the nine initial priority systems of focus for LCC science efforts. The upland hardwood priority system in the ISA was loosely derived from the Upland Hardwoods and Montane Conifers class in the NatureServe/U.S. Fish and Wildlife Service series of "Broadly Defined Habitats", which includes general ecological systems of oak-hickory woodlands, loess bluff hardwoods, mixed mesic hardwoods, and other classes crosswalked to NatureServe Ecological Classifications.

The desired ecological state for Ozark Highlands upland hardwoods is described in the ISA as "*large blocks of oak forest and woodland in appropriately distributed successional stages in predominately forested landscapes. Woodlands are characterized by moderate canopy cover and tree densities that allow ample light to reach the ground, supporting a variety of grasses and forbs. Forests are characterized by nearly closed overstory canopy with well-developed subcanopy, shrub, and understory strata comprised of shade-tolerant species*". To meet these desired ecological states, the ISA targets landscape endpoints of upland hardwood forests and woodlands found in large and connected forest patches in primarily forested landscapes, with specific conditions of overstory and midstory cover, basal area, tree density and diameter, snags and dead/down wood, and disturbance/succession, with defined thresholds provided below in the relevant section from Appendix 1 of the GCPO LCC ISA.

Amount:

- 1.9 million acres of woodland
- 0.7 million acres of forest

Configuration:

- Large blocks of oak forest and woodland in predominantly forested landscapes
- Forest patch size ≥5,000 acres of interdigitated forest types
- Landscape composition (woodland and forest in 10-km radius) >70%
- Adequate connectivity

Condition: Structure

- Canopy cover:
  - 20 – 80% for woodlands
  - ≥80% for forests
- Average dbh ≥14"
- Tree density:
  - ≈40 trees/ac for woodlands
  - ≈80 trees/ac for forests

- Snag density: 1 large (≥16” dbh) snag/5 acres
- Dead/downed wood: One 6’ log (≥8” dbh)/acre
- Midstory density ≤20%

Composition

- Oak and hickory basal area:
    - >90% for woodlands
    - >70% for forests

Temporal considerations:

- An appropriate distribution of successional stages; ≤10% of the landscape
- Fire return interval:
    - 3 years for woodland
    - 10 years for forest

The ISA also identifies a suite of species hypothesized to reflect these landscape endpoints in upland hardwood systems. Priority species for Ozark Highlands upland hardwoods system identified in the GCPO ISA include 8 avian species/species groups (cerulean warbler [*Dendroica cerulea*], Kentucky warbler [*Oporornis formosus*], yellow-billed cuckoo [*Coccyzus americanus*],nightjars [eg., *Caprimulgus* spp.], prairie warbler [*Dendroica discolor*], wood thrush [*Hylocichla mustelina*], wild turkey [*Meleagris gallopavo*],American woodcock [*Scolopax minor*]); 5 mammalian species (black bear [*Ursus americanus*], elk [*Cervus canadensis*], silver-haired bat [*Lasionycteris noctivagans*], Indiana bat [*Myotis sodalis*], Eastern spotted skunk [*Spilogale putorius*]); and one amphibian species (southern red-backed salamander [*Plethodon serratus*]). In the draft ISA, each of these species is hypothesized to be limited by ecological conditions of patch size, landscape composition, connectivity, canopy cover, tree, midstory, snag and woody debris density, tree diameter and basal area, and other factors. Phase II of the GCPO ecological assessment will evaluate these hypothesized species-habitat relationships.

The purpose of this Assessment is to understand how much habitat is available and what condition that habitat is currently in relative to habitat targets, or endpoints, defined in the ISA. To assess the ISA endpoints for upland hardwood systems, it was necessary that the most consistent, comprehensive, current and accurate data be used in summary and analysis. For the best possible assessment product we cross-checked geospatial datasets spanning variable time periods and data sources in the Ozark Highlands subgeography and remainder of the GCPO geography.

Chapter 1: Amount

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attributes: Amount

Desired Landscape Endpoints: 1.9 million acres of woodland, 0.7 million acres of forest

Delineating potential upland hardwood woodlands and forests in the GCPO geography

Successfully assessing upland hardwood woodlands and forests separately at a regional scale presents a formidable data challenge. Remote-sensing based land cover classifications are typically either too general for differentiation between woodland and forest (e.g., NLCD), or are specific enough to separate woodland classes in some cases, but not others (e.g., GAP and Landfire). Other techniques, such as using forest canopy cover or basal area to determine woodland vs. forest in hardwood systems is also challenged by availability of reliable data at the landscape scale. After several iterations to determine the best possible means to differentiate woodlands from forests, members from the LCC Adaptation Science Management Team suggested that distinct, undisputable land cover classes that specify woodland should be used, but for classes where the description allows for forest and woodland (e.g., Crosstimbers Oak Forest and Woodland) we would only characterize pixels as woodland if they were located in areas with site potential for woodland (typically drier, south and west facing slopes in the Ozark Highlands). To do this we first had to characterize potential upland hardwood woodland and forest pixels, through which we could delineate present woodland and forest.

We derived potential upland hardwood pixels from a combination of potential classes in the Central Hardwoods Joint Venture Ecological Potential data layer, and the Landfire Biophysical Settings (BPS) layer (USGS EROS Center 2016). The Ecological Potential layer was developed by Central Hardwoods Joint Venture staff and partners and represents an expert-driven process for identifying where vegetative communities were once found and where management activities to restore natural vegetative communities have the greatest potential for success. The process used land-type associations and abiotic and biotic attributes to map 11 natural vegetative communities, which include classes of open oak woodlands (20-50% overstory canopy cover), closed oak woodlands (50-80% overstory canopy cover), and mesic closed canopy upland forests (>80% overstory canopy cover) in the Central Hardwoods Joint Venture geography (**Table UH.1**). The Landfire BPS layer provides a national dataset that maps the presumed pre-European settlement vegetative communities that dominated the landscape, and uses the present-day "biophysical environment" in combination with approximations of past disturbance regimes to map out pixels classified to NatureServe Ecological Systems.

We resampled 30 m resolution ecological potential and 30 m resolution BPS data to 250 m using a nearest neighbor algorithm for spatial consistency with other layers used in this assessment. For woodland we used the resampled open and closed canopy woodland ecological potential data in the GCPO Ozark Highlands subgeography and mosaicked the data with the resampled BPS woodland classes for the remaining GCPO subgeographies (**Table UH.1**). For forest we used the resampled mesic forest ecological potential data in the Ozark Highlands subgeography and mosaicked the data with the resampled BPS hardwood forest classes for the remaining subgeographies. Thus the potential upland hardwoods layers used in the ecological assessment reflect the ecological potential data in the Ozark Highlands, and BPS elsewhere in the GCPO.

Table UH.1. Potential upland hardwood woodland and forest classes selected from the Central Hardwoods Joint Venture Ecological Potential layer for the Ozark Highlands and from the Landfire Biophysical Settings layer in the remainder of the GCPO.

	Potential Woodland Classes	**Potential Forest Classes**
Ozark Highlands	CHJV Ecological Potential: • Open oak woodlands • Closed oak woodlands	CHJV Ecological Potential: • Mesic Forest
East & West Gulf Coastal Plain, Gulf Coast, Mississippi Alluvial Valley	Landfire Biophysical Settings: • East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland [*13060*] • East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland [*13070*] • Crosstimbers Oak Forest and Woodland [*13080*] • North-Central Interior Dry-Mesic Oak Forest and Woodland [*13100*] • North-Central Interior Dry Oak Forest and Woodland [*13110*] • Ouachita Montane Oak Forest [*13120*] • Allegheny-Cumberland Dry Oak Forest and Woodland [*13170*] • South-Central Interior/Upper Coastal Plain Flatwoods [*13260*] • Central and South Texas Coastal Fringe Forest and Woodland [*13380*] • Central Interior Highlands Dry Acidic Glade and Barrens [*13630*] • Ozark-Ouachita Dry Oak Woodland [*13640*] • Southern Ridge and Valley/Cumberland Dry Calcareous Forest [*13760*] • Lower Mississippi River Dune Woodland and Forest [*13810*] • Edwards Plateau Limestone Savanna and Woodland [*13830*] • North-Central Interior Oak Savanna [*13940*] • Alabama Ketona Glade and Woodland [*14080*] • South-Central Interior/Upper Coastal Plain Wet Flatwoods [*14570*] • East-Central Texas Plains Post Oak Savanna and Woodland [*15190*]	Landfire Biophysical Settings: • Ozark-Ouachita Dry-Mesic Oak Forest [*13040*] • Southern Interior Low Plateau Dry-Mesic Oak Forest [*13050*] • North-Central Interior Maple-Basswood Forest [*13140*] • Southern Appalachian Oak Forest [*13150*] • Southern Piedmont Mesic Forest [*13160*] • Central and Southern Appalachian Montane Oak Forest [*13200*] • South-Central Interior Mesophytic Forest [*13210*] • Southern Crowley`s Ridge Mesic Loess Slope Forest [*13220*] • West Gulf Coastal Plain Mesic Hardwood Forest [*13230*] • East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest [*13250*] • South-Central Interior/Upper Coastal Plain Flatwoods [*13260*] • East Gulf Coastal Plain Northern Loess Bluff Forest [*13270*] • East Gulf Coastal Plain Southern Loess Bluff Forest [*13290*] • Ozark-Ouachita Mesic Hardwood Forest [*13340*] • West Gulf Coastal Plain Chenier and Upper Texas Coastal Fringe Forest and Woodland [*13390*] • Atlantic Coastal Plain Mesic Hardwood Forest [*13430*] • Southern Coastal Plain Mesic Slope Forest [*13570*] • South-Central Interior/Upper Coastal Plain Wet Flatwoods [*14570*] • Mississippi River Alluvial Plain Dry-Mesic Loess Slope Forest [*15090*]

We also sought to remove pixels from the potential layer that were presently developed (open space, and low, medium, and high intensity development), as well as pixels currently considered open water as these pixels have low probability of converting back to upland hardwood systems in the future. Developed and open water pixels were reclassified out of the 2011 National Land Cover Database (NLCD) (Homer et al. 2015) and used as a mask to indicate that areas currently under development or open water were not expected to be converted to forest over time. We used a series of map algebra calculations to extract out developed (NLCD classes, 21, 22, 23, 24) and open water (NLCD class 11) from potential hardwood pixels. The product identified where upland hardwood woodlands and forest could potentially be on the landscape based on edaphic, geographic and local site conditions. The layers of "potential" upland hardwood woodlands and forest were calculated at 250 m resolution, and then reclassified to a binary 1 or 0 (**Figure UH.1).**

Table UH.2. Acres of potential upland hardwood woodland and forest habitat by GCPO geography, derived in the Ozark Highlands from the Central Hardwoods Joint Venture Ecological Potential layer and from the Landfire Biophysical Settings layer in the remaining GCPO. The table reflects acres of site potential only on all pixels that are currently not developed and not in an open water classification, and does not account for pixels that are currently in a woodland or forest state.

	Acres site potential upland hardwood woodland	Acres potential upland hardwood forest
Ozark Highlands	17,214,240	4,791,184
West Gulf Coastal Plain	3,906,980	4,012,988
East Gulf Coastal Plain	5,399,480	9,641,626
Mississippi Alluvial Valley	443,029	461,037
Gulf Coast	0	25,653
GCPO LCC	26,963,730	18,932,487

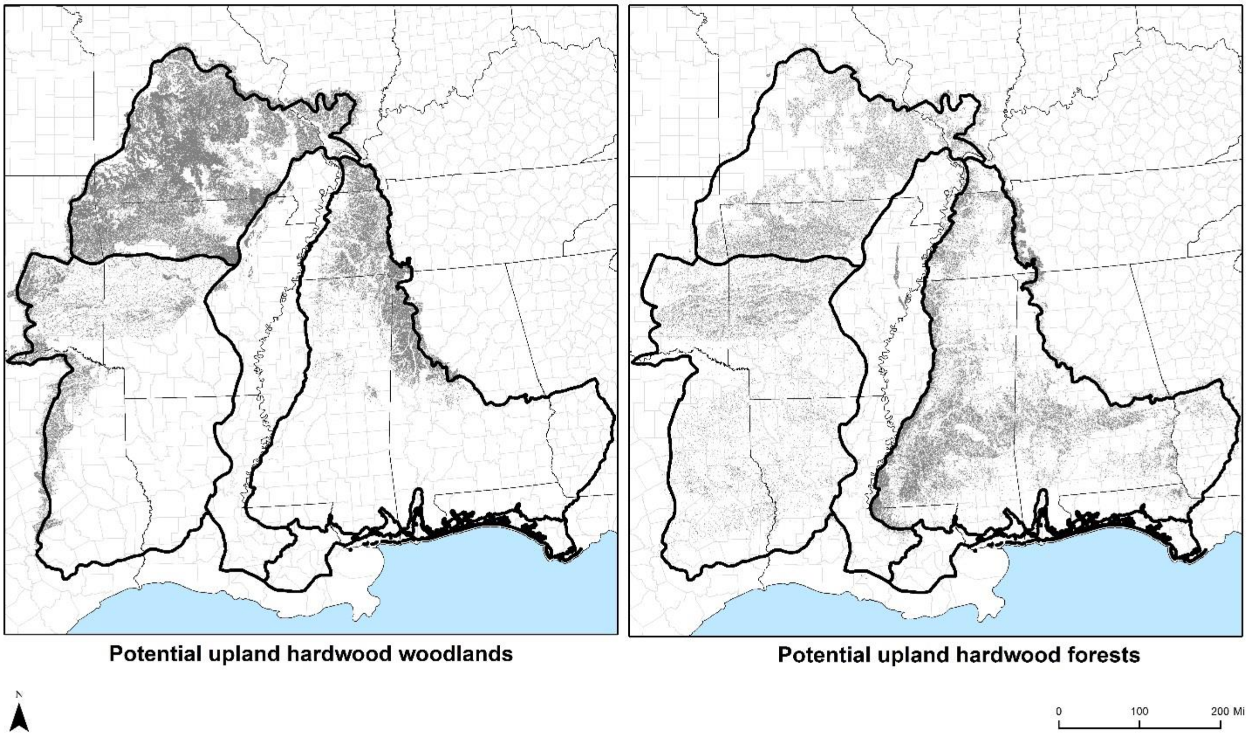

Figure UH.1. Potential upland hardwood woodland (left) and hardwood forest (right) at 250 m resolution developed from the Central Hardwoods Joint Venture Ecological Potential data layer in the Ozark Highlands and Landfire Biophysical Settings data layer in the remaining GCPO geography. These reflect pixels that are currently not developed or classified as open water.

Delineating current upland hardwood woodlands and forests in the GCPO geography

We used a composite approach that incorporated state-level land cover data from Florida, Oklahoma and Texas in combination with 2011 GAP land cover update data in the remaining GCPO states for development of an upland hardwood "mask" to delineate where pixels of upland hardwood woodlands and forest currently exist on the landscape. We relied heavily on the description for each land cover class provided with the layer documentation for Florida (Kawula 2014), Oklahoma (Diamond and Elliott 2015), and Texas (Elliott et al. 2014) land cover datasets and on the NatureServe Ecological Descriptions (NatureServe 2009) document for the GAP layer when selecting woodland and forest classes. This approach allows for the most current available data to be used as a basis for woodland and forest delineation, but represents a tradeoff in consistency. We outline input data sources for the composite hardwood dataset below.

GAP/Landfire

The National Gap Analysis Program (GAP) is designed to provide foundational data for assessments of vertebrate species by creating and combining maps of detailed land cover, species distribution, and land stewardship. Once created these data layers are analyzed to identify areas of vertebrate biodiversity, conservation gaps, and assess vertebrate species status in the U.S. Land cover products created through the GAP program are mapped to multi-season 1999-2001 Landsat ETM+ satellite imagery and include a crosswalk to NLCD land cover, and tiered land cover based on the top 5 National Vegetation Classification System (NVCS) levels and 538 classes provided in the NatureServe Ecological Systems Classification (NESC) (Comer et al. 2003). Comer et al. (2003) defines terrestrial ecological systems as a “group of plant community types (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients” and takes into account upland and wetland areas and prominent environmental features into classification. Datasets used in mapping GAP land cover analysis included landscape layers derived from numerous physiographic, community, and disturbance models (e.g., elevation, slope, aspect, landform, geology, soils, hydrology, rare plant communities, fire, tree harvest, agriculture, developed) in addition to Landsat derived products such as Normalized Difference Vegetation Index. Therefore GAP land cover products incorporate both dominant vegetation and physical elements of the environment in classification. GAP land cover is provided as a national layer and combines data from four regional GAP analysis projects (California, Northwest, Southeast, Southwest) supplemented with crosswalked Landfire Existing Vegetation Type data in other areas without GAP classification (i.e., states west of the Mississippi River in the GCPO geography).

We used of the recently-released 2011 national GAP land cover dataset, with relevant level 3 GAP ecological classifications for delineation of upland hardwood woodland and forest systems in the GCPO listed in **Table UH.3** below. For the woodland system we selected only six classes that were distinctly defined as woodland and left the remaining classes that reflected “forest and woodland” in the definition to be extracted through the layer of potential woodland and forest described below. This guaranteed that what we determined to be woodland truly exhibited woodland character, such that classes that were combined forest and woodland classes were only considered woodland if they were found on a site that was woodland-appropriate. All distinct woodland classes from **Table UH.3** were mosaicked with pixels determined to be woodland via extracting the data through the layer for woodland site potential. Similarly, we extracted all indeterminate forest and woodland classes as well as classes that were clearly identified as forest through the layer of forest site potential. This data was used to define the upland hardwood woodland and forest mask components in Alabama, Arkansas, Georgia, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee portions of the GCPO.

Table UH.3. Upland hardwood classes defined in the 2011 national GAP land cover data that were used in concert with information on site potential to delineate woodlands and forests in the GCPO. Codes reflect GAP level 3 classification codes, Landfire EVT Fuel classification codes, and NatureServe ESLF/CES code.

	System/Class	GAP	Landfire	NatureServe
Upland hardwood woodlands (definitively)	East-Central Texas Plains Post Oak Savanna and Woodland	4140	2519	4158/CES205.679
	Edwards Plateau Limestone Savanna and Woodland	4152	2383	4326/CES303.660
	North-Central Interior Oak Savanna	5506	2394	5410/CES202.698
	North-Central Oak Barrens Woodland	5507	2395	5411/CES202.727
	Ozark-Ouachita Dry Oak Woodland	4149	2364	4306/CES202.707
	Western Great Plains Mesquite Woodland and Shrubland	5801	2111	5317/CES303.668

Upland hardwood forests or woodlands (determined by site potential)	Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	4126	2317	4123/CES202.359
	Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	4133	2335	4141/CES203.241
	Central and South Texas Coastal Fringe Forest and Woodland	4136	2338	4144/CES203.464
	Crosstimbers Oak Forest and Woodland	4118	2308	4114/CES205.682
	Crowley's Ridge Mesic Loess Slope Forest	4203	2321	4128/CES203.079
	Deciduous Plantations	8201	N/A	N/A
	East Gulf Coastal Plain Limestone Forest	4102	2328	4134/CES203.502
	East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	4117	2307	4113/CES203.483
	East Gulf Coastal Plain Northern Loess Bluff Forest	4128	2327	4133/CES203.481
	East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland – Hardwood Modifier	4103	2306	4112/CES203.482
	East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest	4205	2325	4131/CES203.477
	East Gulf Coastal Plain Southern Loess Bluff Forest	4129	2329	4135/CES203.556
	East Gulf Coastal Plain Southern Mesic Slope Forest	4209	N/A	N/A
	Lower Mississippi River Dune Woodland and Forest	4151	2381	4324/CES203.531
	Mississippi River Alluvial Plain Dry-Mesic Loess Slope Forest	4139	2509	4155/CES203.071
	North-Central Interior Beech-Maple Forest	4123	2313	4119/CES202.693
	North-Central Interior Dry-Mesic Oak Forest and Woodland	4120	2310	4116/CES202.046
	North-Central Interior Dry Oak Forest and Woodland	4121	2311	4117/CES202.047
	North-Central Interior Maple-Basswood Forest	4124	2314	4210/CES202.696
	Northeastern Interior Dry-Mesic Oak Forest	4106	2303	4109/CES202.592
	Northern Atlantic Coastal Plain Hardwood Forest	4313	2324	4130/CES203.475
	Ouachita Montane Oak Forest	4122	2312	4118/CES202.306
	Ozark-Ouachita Dry-Mesic Oak Forest	4115	2304	4110/CES202.708
	Ozark-Ouachita Mesic Hardwood Forest	4207	2334	4140/CES202.043
	South-Central Interior Mesophytic Forest	4402	2321	4127/CES202.887
	Southern and Central Appalachian Oak Forest	4125	N/A	N/A
	Southern Atlantic Coastal Plain Mesic Hardwood Forest	4403	2343	4150/CES203.242
	Southern Coastal Plain Dry Upland Hardwood Forest	4130	2330	4136/CES203.560
	Southern Coastal Plain Oak Dome and Hammock	4146	N/A	4275/CES203.494
	Southern Interior Low Plateau Dry-Mesic Oak Forest	4116	2305	4111/CES202.898
	Southern Piedmont Mesic Forest	4202	2316	4122/CES202.342
	Southern Ridge and Valley / Cumberland Dry Calcareous Forest	4334	2376	4319/CES202.457
	West Gulf Coastal Plain Chenier and Upper Texas Coastal Fringe Forest and Woodland	4137	2339	4145CES203.466.2
	West Gulf Coastal Plain Mesic Hardwood Forest	4204	2323	4129/CES203.280

Texas, Oklahoma, and Florida land cover classification

In 2014, the Texas Parks and Wildlife Department working in concert with the Texas Natural Resources Information System, and Missouri Resource Assessment Partnership (MoRAP) finalized development of the Texas Ecological Systems Data (Elliott et al. 2014). The data was delineated state-wide as part of a six phase effort that mapped 398 unique classes at 10 m spatial resolution to standards of the NatureServe Ecological Systems Classification. The approached used 30 m multi-season Landsat satellite imagery, soil and elevation data, and high resolution NAIP aerial imagery in an expert ruleset and in combination with >12,000 field-based vegetation plots to map ecological systems. Using the associated ecological descriptions document (Elliott 2014) we found nine relevant woodland classes and eight relevant forest classes for use in the upland hardwood ecological assessment (**Table UH.4**).

Table UH.4. Land cover classification code and description for upland hardwood woodland and forest classes used to delineate the forest mask in Texas, derived from the Texas Ecological Systems Data (Elliott et al. 2014).

System	Class code	State-level classification
Upland hardwood woodland	1	Post Oak Savanna: Post Oak Motte and Woodland
	18	Native Invasive: Deciduous Woodland
	29	Post Oak Savanna: Sandyland Woodland and Shrubland
	42	Pineywoods: Sandhill Oak Woodland
	82	Post Oak Savanna: Live Oak Motte and Woodland
	103	Crosstimbers: Post Oak Woodland
	109	Edwards Plateau: Live Oak Motte and Woodland
	120	Edwards Plateau: Oak / Hardwood Motte and Woodland
	125	Edwards Plateau: Oak - Hardwood Motte and Woodland
Upland hardwood forest	11	Pineywoods: Upland Hardwood Forest
	12	Pineywoods: Dry Upland Hardwood Forest
	28	Post Oak Savanna: Oak - Hardwood Slope Forest
	46	Pineywoods: Southern Mesic Hardwood Forest
	92	Chenier Plain: Live Oak Fringe Forest
	93	Chenier Plain: Mixed Live Oak - Deciduous Hardwood Fringe Forest
	108	Post Oak Savanna: Oak / Hardwood Slope Forest
	117	Edwards Plateau: Oak / Hardwood Slope Forest

Working under a similar premise the Oklahoma Department of Wildlife Conservation partnered in 2012 with MoRAP, University of Oklahoma Biological Survey, and the Gulf Coast Prairie and Great Plains Landscape Conservation Cooperatives to produce the state-wide Oklahoma Ecological Systems Mapping dataset in 2015 (Diamond and Elliott 2015). The state-wide dataset was completed in two phases (east-west), and aimed to map to both National Vegetation Classification System and the NatureServe Ecological Systems Classification targets to the subsystem level. The project used a similar mapping strategy as was done in the state of Texas, and incorporated >3,000 field-based vegetation plots in combination with satellite and aerial imagery and abiotic factors to map >175 land cover classes land cover at 10 m spatial resolution. Using the ecological descriptions provided in Diamond and Elliott (2015) we found twelve relevant woodland classes and three relevant forest classes for use in the upland hardwood ecological assessment (**Table UH.5**).

Table UH.5. Land cover classification code and description for upland hardwood woodland and forest classes used to delineate the forest mask in Oklahoma, derived from the Oklahoma Ecological Systems Mapping data (Diamond and Elliott 2015).

System	Class code	State-level classification
Upland hardwood woodland	504	Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
	506	Crosstimbers: Young Post Oak - Blackjack Oak Woodland
	534	Crosstimbers: Sandyland Post Oak - Blackjack Oak Forest and Woodland
	604	Post Oak Savanna: Post Oak Woodland
	614	Post Oak Savanna: Post Oak Sandyland Woodland
	1114	Arbuckle: Oak Woodland
	3006	West Gulf Coastal Plains: Young Upland Hardwood Woodland Regrowth
	3204	West Gulf Coastal Plain: Sandhill Oak Woodland
	9104	Ruderal Deciduous Woodland
	9206	Ruderal Deciduous Shrubland and Young Woodland
	13104	Ozark-Ouachita: Dry Oak Woodland
	13706	Ozark-Ouachita: Montane Stunted Oak Woodland
Upland hardwood forest	524	Crosstimbers: Post Oak - Blackjack Oak Slope Forest
	3014	West Gulf Coastal Plain: Dry Upland Hardwood Forest
	13004	Ozark-Ouachita: Dry-Mesic Oak Forest

In October 2015 the cooperative Florida Fish and Wildlife Commission and Florida Natural Areas Inventory (FNAI) partnership released version 3.1 of the Florida Cooperative Land Cover Map (CLC). CLC provides a compilation of 37 land cover and vegetation data products collected into a state-wide land cover classified hierarchically to the Florida Land Cover Classification System, a unified combination of the natural community classification of FNAI and the Florida Land Use and Forms Classification System of the Florida Department of Environmental Protection (Knight et al. 2010). The Florida CLC maps land cover classification in vector and 30 m raster format at two levels of confidence, including state-level (classifications mapped with confidence at the state-level) and site-level (detailed, site-based information that may not be available at the state-level). State-level classifications were of greater relevance to this assessment as we desired to delineate upland hardwood woodland and forest classes for the entirety of the western Florida panhandle. We found no relevant upland hardwood woodland classes in this geography, and eight upland hardwood forest classes described in **Table UH.6** below. Advantages to use of Florida CLC in the ecological assessment reflect the variety of detailed product inputs used to produce the compiled maps, often reflecting extensive local knowledge of Florida land cover. However, CLC data is only valuable in the Florida portion of the GCPO LCC geography and therefore prohibits assessment beyond state boundaries. Variation in input data sources (in time and in mapping methodology) also adds inherent uncertainty to map products.

Table UH.6. State-level classification code and description for upland hardwood forest classes used to delineate the forest mask in Florida, derived from the Florida Cooperative Land Cover version 3.1 data.

State-level code	State-level classification	Site-level code	Site-level classification
1110	Upland hardwood forest	1110	Upland hardwood forest
		1112	Mixed hardwoods
1120	Mesic hammock	1120	Mesic hammock
		1123	Live oak
1140	Slope forest	1140	Slope forest
1210	Scrub	1211	Oak scrub
1830	Rural	18311	Rural open forested
18333	Tree plantations	183331	Hardwood plantations

Advantages to use of each state-level dataset for Florida, Oklahoma, and Texas in the ecological assessment include the variety of detailed field-based data, reflecting extensive local knowledge of state-level land cover. However, a tradeoff is that each dataset is only valuable in the state portion of the GCPO LCC geography and therefore prohibits consistency in assessment across state boundaries. Variation in input data sources (in time and in mapping methodology) also adds inherent uncertainty to map products. However, in various stakeholder meetings throughout the GCPO in 2016, it was clear that states prefer state-generated products over national and regional land cover layers for conservation assessment and planning purposes.

A note on 2011 NLCD Deciduous Forest

The National Land Cover Database (NLCD) is a periodic national 30-m resolution geospatial data product derived from the Landsat Thematic Mapper satellite imagery that provides land cover data and change information for the U.S. in 5-year intervals (Homer et al. 2015). NLCD products are produced by the Multi-Resolution Land Characteristics Consortium (MRLC) with NLCD component led by the U.S. Geological Survey. The 2011 NLCD product maps to 2011 Landsat 5 TM imagery data from NLCD 2001 and 2006, derived elevation data products, soils, cropland, and wetland data and other data layers to classify land cover (Homer et al. 2015). We considered use of NLCD class 41, deciduous forest for assessment of the upland hardwoods system, which is defined loosely following Anderson et al. (1976) as land cover dominated by trees >5 m tall, with >20% of total vegetation cover and with >75% of the tree species shedding foliage seasonally (MRLC). NLCD is one of the most current and comprehensive datasets available at this time, however it does not provide the specificity necessary to differentiate hardwood woodlands from hardwood forests, nor does it align with the Broadly Defined Habitat classes used in the initial definition for these systems.

Composite approach

To develop the composite approach for use in the remainder of the ecological assessment of upland hardwoods we first resampled the 30 m GAP and Florida CLC and 10 m Texas and Oklahoma land cover data to 250 m using a nearest neighbor algorithm. The assessment was conducted at a 250 m spatial resolution to allow for use of U.S. Forest Service Forest Inventory and Analysis Program (FIA) imputed data to assess several landscape endpoints related to forest structure. To proceed with the mask we reclassified each 250 m land cover layer to extract the selected woodland and forest classes, and created a binary (1,0) layer for each woodland and forest layer. These data were clipped to a 10 km buffer around the GCPO boundary. For upland hardwood woodlands, we then mosaicked three binary datasets together, taking the Oklahoma and Texas data as primary over the remaining GAP data for the rest of the GCPO geography. The result was a binary layer of upland hardwood woodland that represented state-derived woodland classes for Oklahoma and Texas, and GAP woodland cover for the remaining states in the GCPO. For upland hardwood forests, we mosaicked four binary datasets together, taking the Florida, Oklahoma, and Texas data as primary over the remaining GAP data for the GCPO. This resulted in a separate binary layer for upland hardwood forest similar to that of woodland (**Figure UH.2**). These became the woodland and forests "masks" summarized below and used in the remainder of the assessment. We summarized woodland and forest data by GCPO subgeography, as proportion of area within a HUC 12 watershed, and by area currently considered protected under the Protected Areas Database (PAD-US, GAP Status 1-3).

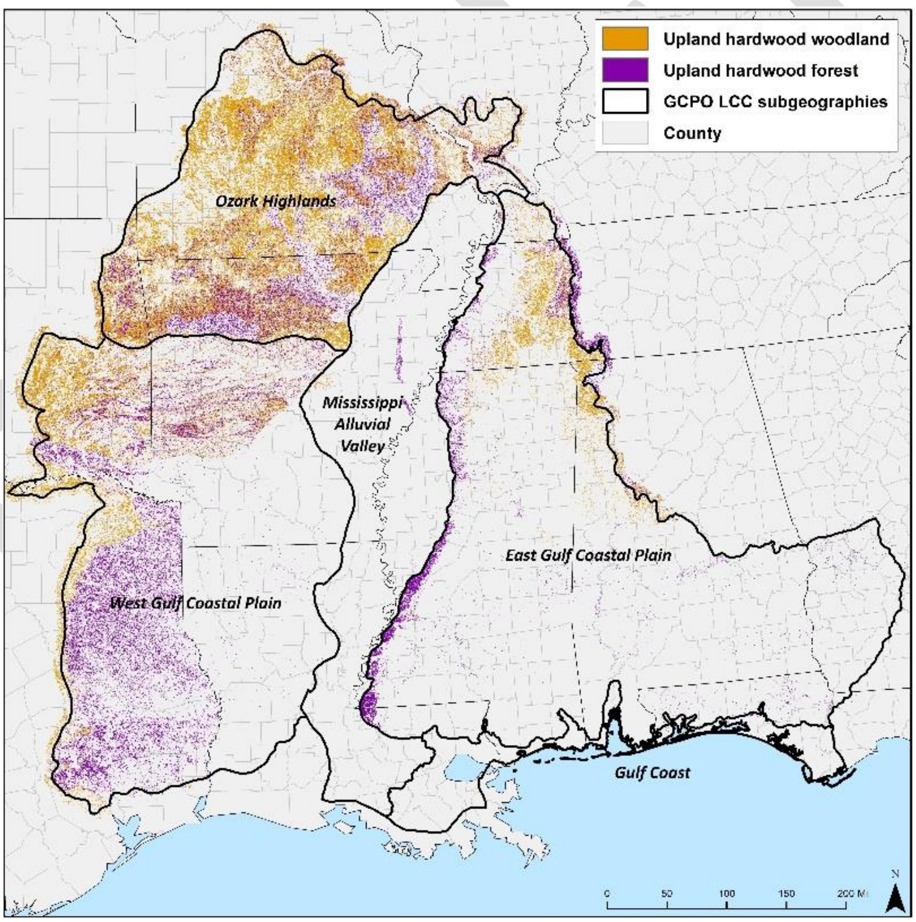

Figure UH.2. Upland hardwood woodland and forest systems within the GCPO LCC at 250 m resolution (generated from composite 2011 GAP, 2014 Florida Cooperative Land Cover, 2014 Texas Ecological Systems Data, and 2015 Oklahoma Ecological Systems Mapping data).

The landscape endpoint for upland hardwood amount specified 1.9 million acres of woodland and 0.7 million acres of forest meet the desired ecological condition in the Ozark Highlands subgeography. Those targets are yet to be defined for the remaining GCPO geography, though there are areas of high apparent woodland and forest density in the West Gulf Coastal Plain and East Gulf Coastal Plain (**Figure UH.2**). Through summary of the upland hardwood masks we estimate nearly 9.8 million acres of upland hardwood woodland and nearly 3.8 million acres of upland hardwood forest exist in any condition in the Ozarks Highlands subgeography, with over 14.3 million acres of woodland and 9.8 million acres of forest across the entire GCPO (**Table UH.7**). **Figure UH.3** summarizes woodland and forest proportionally by HUC12 watershed and demonstrates several high-density woodland watersheds throughout the Ozark Highlands, as well as in parts of western Oklahoma in the West Gulf Coastal Plain, and western Tennessee/northwestern Alabama in the East Gulf Coastal Plain. It also shows very distinct watersheds of upland hardwood forest along the Loess Hills area of southwestern Mississippi, as well as in the Boston Mountains of northern Arkansas, along the GCPO boundary in western Tennessee, as well as in parts of east Texas. We estimate nearly 11% of upland hardwood woodlands and nearly 24% of upland hardwood forests are currently considered protected in the Ozark Highlands subgeography, with 10% of woodlands and 15% of forests protected across the GCPO geography (**Table UH.7**).

Table UH.7. Acres of upland hardwood woodland and forest in any condition by GCPO LCC subgeography (generated from 250 m resolution composite "mask" of 2011 GAP, 2014 Florida Cooperative Land Cover, 2014 Texas Ecological Systems Data, and 2015 Oklahoma Ecological Systems Mapping data).

	Upland hardwood woodland acres	**Proportion woodland acres protected**	**Upland hardwood forest acres**	**Proportion forest acres protected**
Ozark Highlands	9,796,824	1,058,846	3,786,254	899,710
West Gulf Coastal Plain	3,048,737	358,874	4,459,275	468,017
East Gulf Coastal Plain	1,425,673	40,819	1,418,260	47,398
Mississippi Alluvial Valley	59,012	4,973	137,499	19,413
Gulf Coast	0	0	11,413	587
GCPO LCC	14,330,246	1,463,511	9,812,700	1,435,125

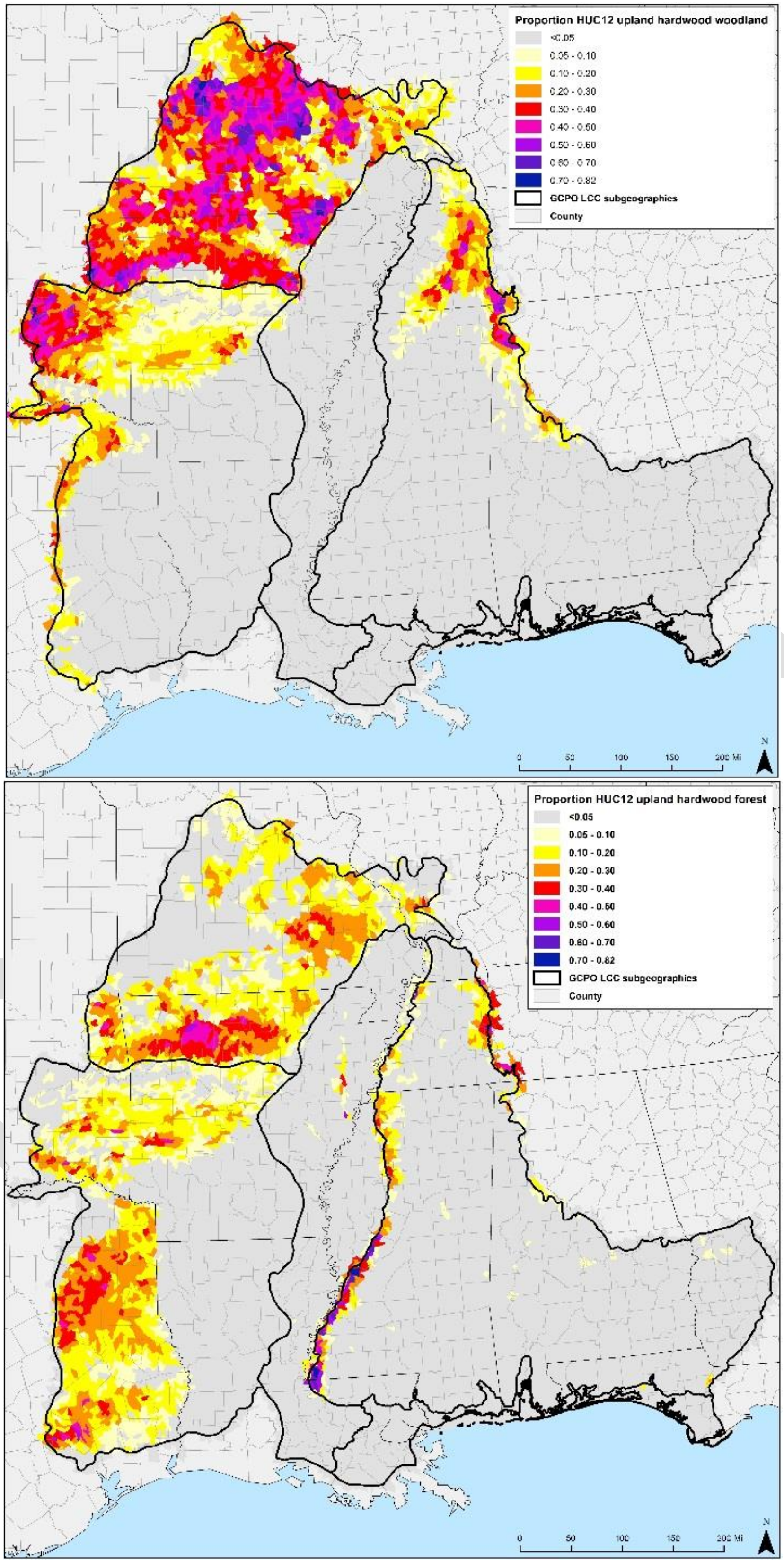

Figure UH.3. Upland hardwood woodland (top) and forest (bottom) systems within the GCPO LCC assessed by proportion of pixels in each HUC12 watershed.

Future Directions and Limitations

Assessment of the upland hardwood system via the composite land cover approach reveals that there are ample amounts of woodland and forest available on the landscape to be managed toward the desired ecological state outlined in the GCPO Integrated Science Agenda. The purpose of the assessment is to examine acreage of woodland and forest in this "mask" that meet the landscape endpoint criteria defined by the ISA. The assessment then overlays that information to determine how much and where the acreage of woodland and forest can be found in the desired ecological state. This also defines how much more as well as where and how to potentially target management to help meet those desired endpoints. We evaluate acreage falling within the desired ecological state at the end of the synopsis where we calculate condition index values for upland hardwood woodland and forest systems

One obvious limitation associated with development of the upland hardwood mask relates to thematic and scale mismatches associated with the composite land cover approach. It is clear from the assessment that state-level thematic classes may not align well with GAP classification, as exemplified along the state of Texas boundary in the assessment of upland hardwood forests. These issues in land cover must be resolved in future iterations of the ecological assessment of hardwood systems. A consistent and temporally current classification like that currently being developed for the GCPO LCC east of Texas and Oklahoma will help offset these issues, as will the forthcoming GAP/Landfire remap efforts that commenced in 2016.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- GCPO LCC Upland Hardwood Woodland and Forest (All condition) (raster and vector – polygon: proportion HUC 12 acres)

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Chapter 2: Configuration, large blocks of hardwood forest, forest landscape composition

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attributes: Configuration

Desired Landscape Endpoints: Forest patch size ≥5,000 ac of interdigitated forest habitat types, landscape composition (woodland and forest in 10-km radius) >70%

Delineating forest cover in the GCPO geography

Much like we see in other forested systems, ecological function of upland hardwood system is presumed to be positively related to the amount and configuration of all forest habitat in the surrounding landscape, such that interspersion of upland hardwood systems with mixed pine-hardwood, pine-dominated, and forested wetland will better support the holistic ecological integrity of the system. The breadth of targeted priority species in the ISA are also presumed to exhibit more sustainable populations in upland hardwood forests and woodlands that consist of large and connected forest patches (≥5,000 ac) (consisting of all forest types), with >70% forest cover in the surrounding landscape in the Ozark Highlands. This is particularly relevant for ISA priority species like the black bear (*Ursus americanus*) in the Ozarks, which exhibit very large home ranges and are thought to be influenced by forest composition and patch size. For the upland hardwood woodland and forest systems the ISA suggests configuration endpoints related to multiple forest types for patch size and forest composition as important. We therefore approached the assessment of upland hardwood woodlands and forests by first examining <u>all</u> forest cover in the landscape. For assessment of forest cover we used a combination of remote sensing products including 2011 National Land Cover Database (NLCD) forest classes (Homer et al. 2015) and the [2011 MAV forest characterization layer] produced by the Lower Mississippi Valley Joint Venture (LMVJV; Mitchell et al. 2016). We used NLCD as the primary data source when assessing forests outside the GCPO LCC MAV subgeography, and the LMVJV forest characterization as the primary data source for forest assessment within the MAV.

NLCD was developed using 2011 Landsat TM imagery, with forest classes including only areas with trees exceeding 5 m (16 ft) in height and where trees compose at least 20% of the total vegetation cover (Homer et al. 2015). We first clipped the 2011 NLCD to a 10 km buffer around the GCPO LCC geographic boundary, then resampled the data from 30 m resolution to 250 m resolution using a nearest neighbor algorithm. We resampled to 250 m to allow the forest classification to be assessed with other forested wetland condition data developed at a 250 m resolution from MODIS satellite imagery (see sections below). Once data were at 250 m resolution we then reclassified the data to extract NLCD Deciduous Forest (41), Evergreen Forest (42), Mixed Forest (43), and Woody Wetlands (90) classes as a single forest value.

We next assessed the LMVJV forest characterization data for the MAV, using 2011 Landsat-based classification supplemented with known reforestation patches and aggregated across 90 m breaks (Mitchell et al. 2016). To produce this product Mitchell et al. used 11 cloud free Landsat 5 TM scenes from Oct-Nov 2011 in combination with ancillary data, then used object-based image analysis to segment out classify forests and other land cover features. This analysis was supplemented with spatial data on regenerating forest planted under the U.S. Department of Agriculture Wetland Reserve Program (now part of the Agricultural Conservation

Enhancement Program), Conservation Reserve Program, and other conservation easement lands, which is often misclassified in national mapping products. We converted vector polygon data to a 30 m resolution raster layer, then resampled up to 250 m resolution using a nearest neighbor algorithm. We clipped this layer to the GCPO LCC MAV subgeography boundary. We then mosaicked the LMVJV forest classification to 2011 NLCD forest classes using LMVJV forest as the primary operator, resulting in a 250 m resolution forest "mask" that combined the two datasets within the GCPO (**Table UH.8**).

Table UH.8. Estimated acreage per GCPO subgeography of forest derived from National Land Cover Dataset forest classes (deciduous forest, mixed forest, evergreen forest, forested wetlands) mosaicked with the Lower Mississippi Valley Joint Venture forest classification for the Mississippi Alluvial Valley.

	Acres forest mask per GCPO subgeography
Ozark Highlands	**19,448,550**
East Gulf Coastal Plain	34,365,330
West Gulf Coastal Plain	30,480,610
Mississippi Alluvial Valley	9,185,486
Gulf Coast	2,917,463
Gulf Coastal Plains and Ozarks (full extent)	96,397,439

Forest patch size

During the ecological assessment process, staff from the GCPO LCC consulted with upland hardwood system experts, including staff at the Central Hardwoods Joint Venture in concert with upland hardwood specialists on the LCC Adaptation Science Management Team, to revise select ISA endpoints. The group felt strongly that the forest patch size endpoint of >5,000 ac was too restrictive for use in the assessment given evidence of species-habitat relationships in the Ozark Highlands. Evidence from existing literature supports the ASMT's recommendation and suggests patches smaller than the ISA target may be appropriate in the Ozark Highlands subgeography. In Appendix A of the 2005 Forest Plan for the Mark Twain National Forest (USFS 2005), Nelson indicated targeting of patch sizes 10-100 acres for open woodlands, 100->1,000 ac for closed woodland, and 10-100 ac for upland forest would be appropriate targets for natural community management within the National Forest. Dickson et al. (1993) suggested somewhat greater forest patch sizes between 3,400 and 6,200 acres would promote neotropical migratory bird diversity, including ISA target species such as Kentucky warbler, prairie warbler, and wood thrush, though his estimates focused on mixed oak-pine forests. Greenburg et al. (2014) also suggested a patch size of 3,294 ac would maximize breeding birds in upland hardwood oak regeneration treatments. In contrast, Herbeck and Larsen (1999) suggest red-backed salamanders were found within a study area approximately 16,000 ac in size.

Given the literature and input from the ASMT we therefore reduced the forest patch size threshold to >3,000 ac and completed the ecological assessment following this revised target. To assess forest patch size we first clipped the forest classification raster layer to a 10 km buffer around the GCPO geography, then converted pixels to non-simplified polygons. We then ran an aggregate polygon function in ArcGIS, aggregating all polygons within 250 m (i.e., grouping adjacent and diagonal pixels into a single polygon). We then selected out contiguous forest patches within the GCPO >3,000 acres in size (**Figure UH.4**). We then extracted the forest patch layer through the upland hardwood woodland and forest mask pixels to produce a layer that indicated which woodland and forest pixels fell in forest patches >3,000 ac. This was used as part of the compiled assessment to calculate a hardwood condition index, described in later sections.

When assessed for contiguity across 250 m pixels we estimate there are 834 unique forest patches >3,000 acres in the GCPO geography, ranging up to 30 million acres in size. We estimate over 6.6 million acres of upland hardwood woodland and nearly 3.2 million acres of upland hardwood forest are found in forest patches >3,000 acres in the Ozarks Highlands (**Table UH.9).** This suggests nearly 68% of woodlands and over 84% of forests in the Ozark Highlands are found in forest patches >3,000 acres. We estimate nearly 9.2 million acres, or 64% of upland hardwood woodlands and over 6.7 million acres, or 69% of upland hardwood forests are found in forest patches >30,000 acres across the entire GCPO geography. Pixels of woodland and hardwood associated with large forest patches were found throughout the Ozark Highlands, often associated with large public protected lands like National Forests. Upland hardwood woodlands and forest across the West Gulf Coastal Plain, as well as the Mississippi Loess Hills, parts of western Tennessee and northern Alabama in the East Gulf Coastal Plain, and Crowley's Ridge in Arkansas were also found in large forest patches (**Figure UH.5**).

Table UH.9. Acres of upland hardwood woodland and forest found in forest patches >3,000 ac by GCPO LCC subgeography.

	Upland hardwood woodland acres	**Upland hardwood forest acres**
Ozark Highlands	6,649,925	3,199,147
West Gulf Coastal Plain	1,680,763	2,487,561
East Gulf Coastal Plain	821,841	927,401
Mississippi Alluvial Valley	44,510	120,526
Gulf Coast	0	3,753
GCPO LCC	9,197,038	6,738,388

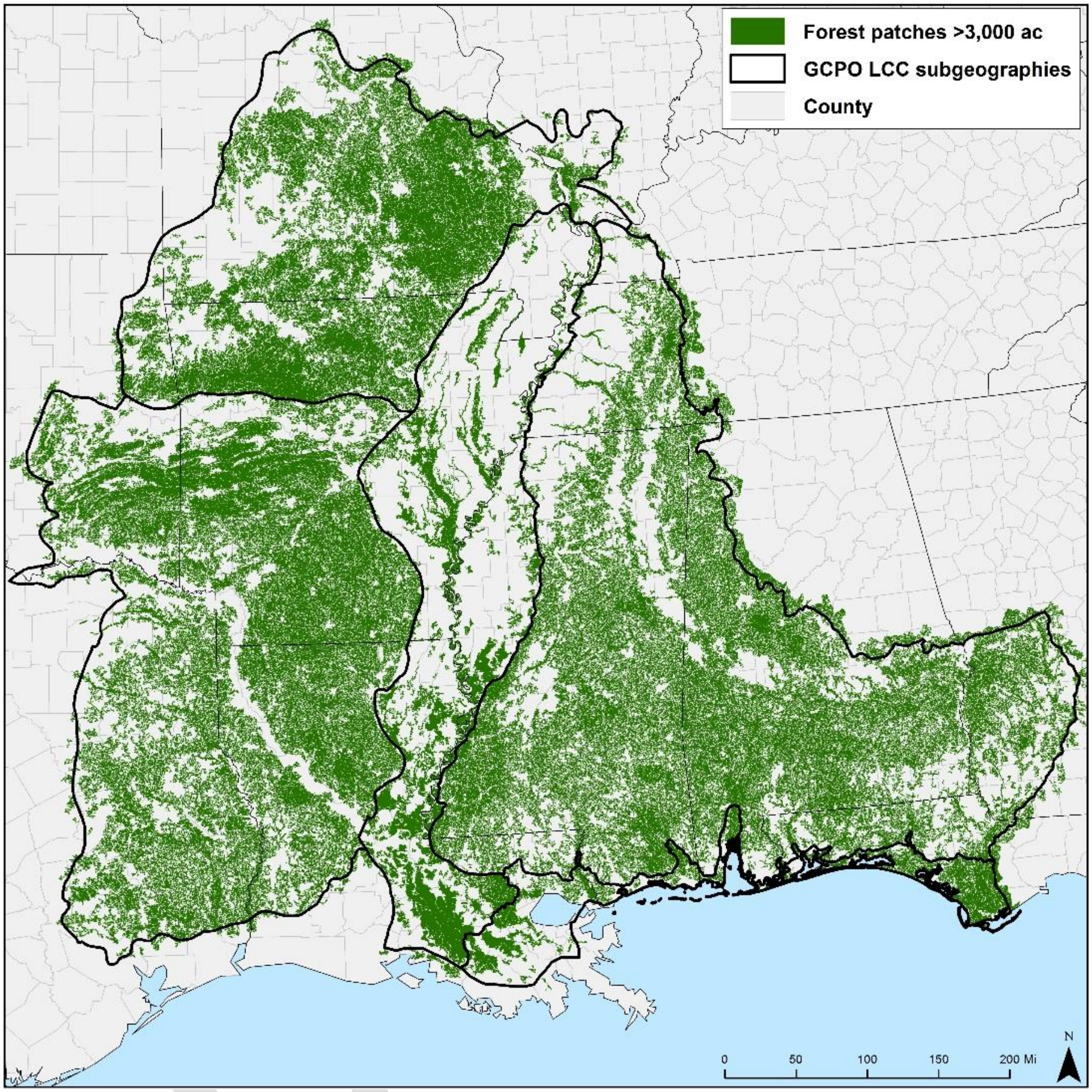

Figure UH.4. Composite patches of all forest types >3,000 ac in size in the GCPO LCC, generated from a combination of National Land Cover Data forest classes (Homer et al. 2015) and the Lower Mississippi Valley Joint Venture 2011 forest characterization (Mitchell et al. 2016).

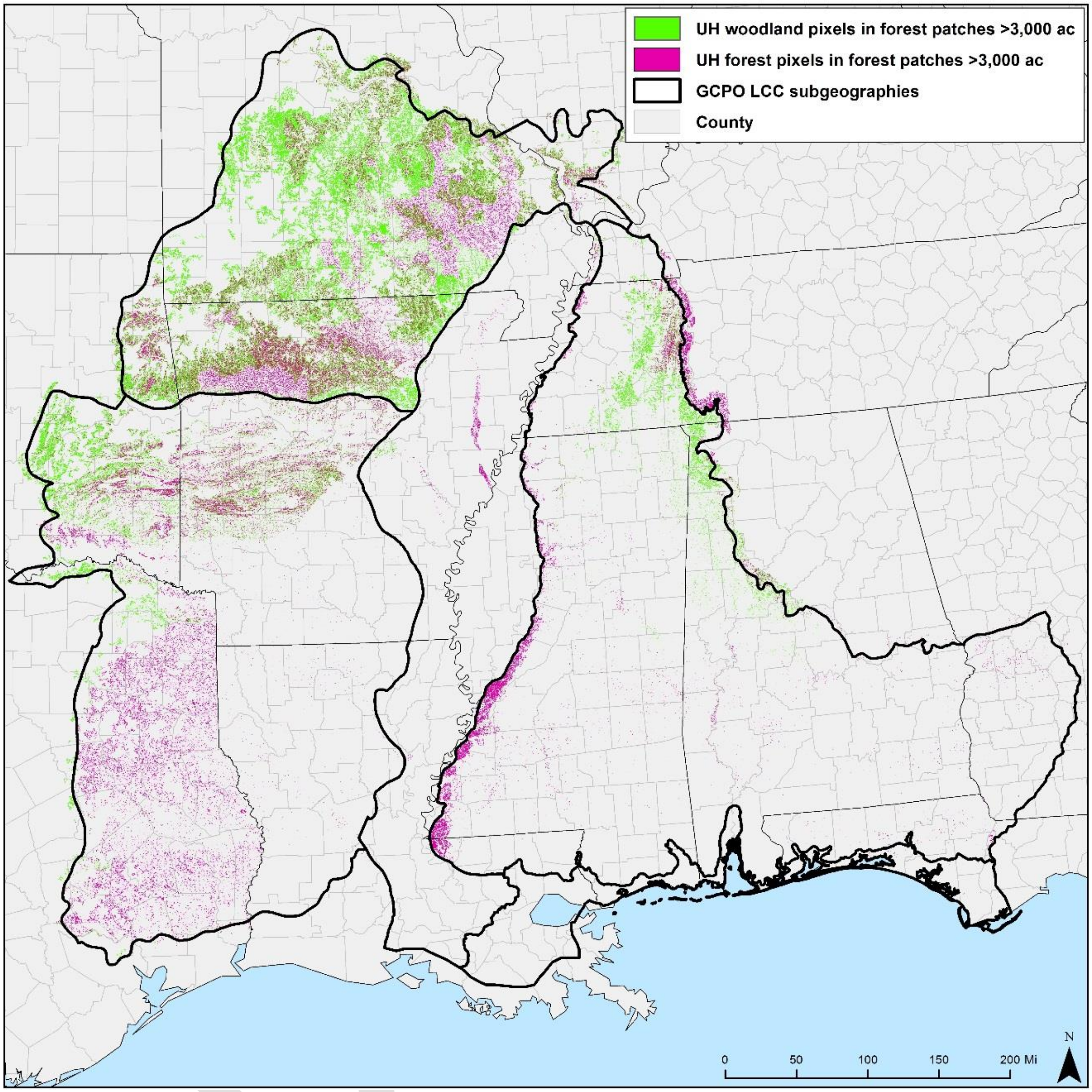

Figure UH.5. Pixels of upland hardwood woodland and forest that are found within patches of all forest types >3,000 ac in size in the GCPO LCC.

Forest landscape composition

Another configuration endpoint for the upland hardwoods system suggests targeting woodlands and forest in heavily (>70%) forested 10 km landscapes. This is related to forest patch size but suggests that the upland hardwood system is closer to the desired state when it falls within heavily forested surrounding landscapes. This is supported by evidence in the literature that indicated target bird species (e.g., Kentucky warbler, wood thrush) were found in areas with >54-65% forest composition (Thompson et al. 1992, Pagen et al. 2000). It has also been shown that priority bat species, including the ISA target Indiana bat were associated with >90% forest cover in the surrounding landscape (Yates and Muzika 2006).

To address this endpoint we used the same composite NLCD/LMVJV forest input data, but ran a focal statistics procedure in ArcGIS to assess the mean percent cover within a 71 cell circular neighborhood for analysis (approximating a window with a 10-km radius, or 77,630-ac landscape) throughout the GCPO. We then reclassified the mean forest cover output to >70% and extracted back through the hardwood woodland and forest masks to calculate acres on the pixels of each hardwood system that have >70% forest in surrounding10km^2 landscape.

The neighborhood analysis demonstrated that mean forest cover was greatest in the West Gulf Coastal Plain subgeography of the GCPO LCC, but upland hardwood woodland and forest acres that were found in heavily (>70%) forested landscapes were most prevalent in the Ozark Highlands (**Table UH.10**). Heavily forested areas were associated with the Boston Mountains/Ozark National Forest in Arkansas, and areas within and surrounding the Mark Twain National Forest in southern Missouri (**Figure UH.6**). There was also substantial forest cover in the Ouachita's and pineywoods areas of the West Gulf Coastal Plain, as well as in other pine and forested wetland-dominated areas in the Mississippi Alluvial Valley, Gulf Coast, and East Gulf Coastal Plain. Pockets of upland hardwood woodlands found in heavily forested landscapes were often associated with National Forest lands and private forest lands in the Ozarks, as well as along the Boston Mountains in Arkansas and Oklahoma, and in the vicinity of the Natchez Trace State Park in Tennessee. Upland hardwood forests in heavily forested areas were found in similar locations, but also found in the Mississippi Loess Hills region in southwestern Mississippi (**Figure UH.7**)

Table UH.10. Mean forest cover, acres of total forest cover >70%, and acres of upland hardwood woodland and forest found in forest-dominated landscapes where the 10 km radius is composed of >70% forest cover by GCPO subgeography.

	Mean forest cover	Acres total forest cover >70%	Upland hardwood woodland acres in >70% forested landscape	Upland hardwood forest acres in >70% forested landscape
Ozark Highlands	57%	9,977,273	3,002,343	2,177,599
West Gulf Coastal Plain	58%	13,398,770	669,084	767,725
East Gulf Coastal Plain	55%	8,864,512	80,819	410,195
Mississippi Alluvial Valley	36%	1,981,629	6,394	9,529
Gulf Coast	44%	1,131,525	0	1,483
GCPO LCC	50%	35,353,707	3,758,639	3,366,530

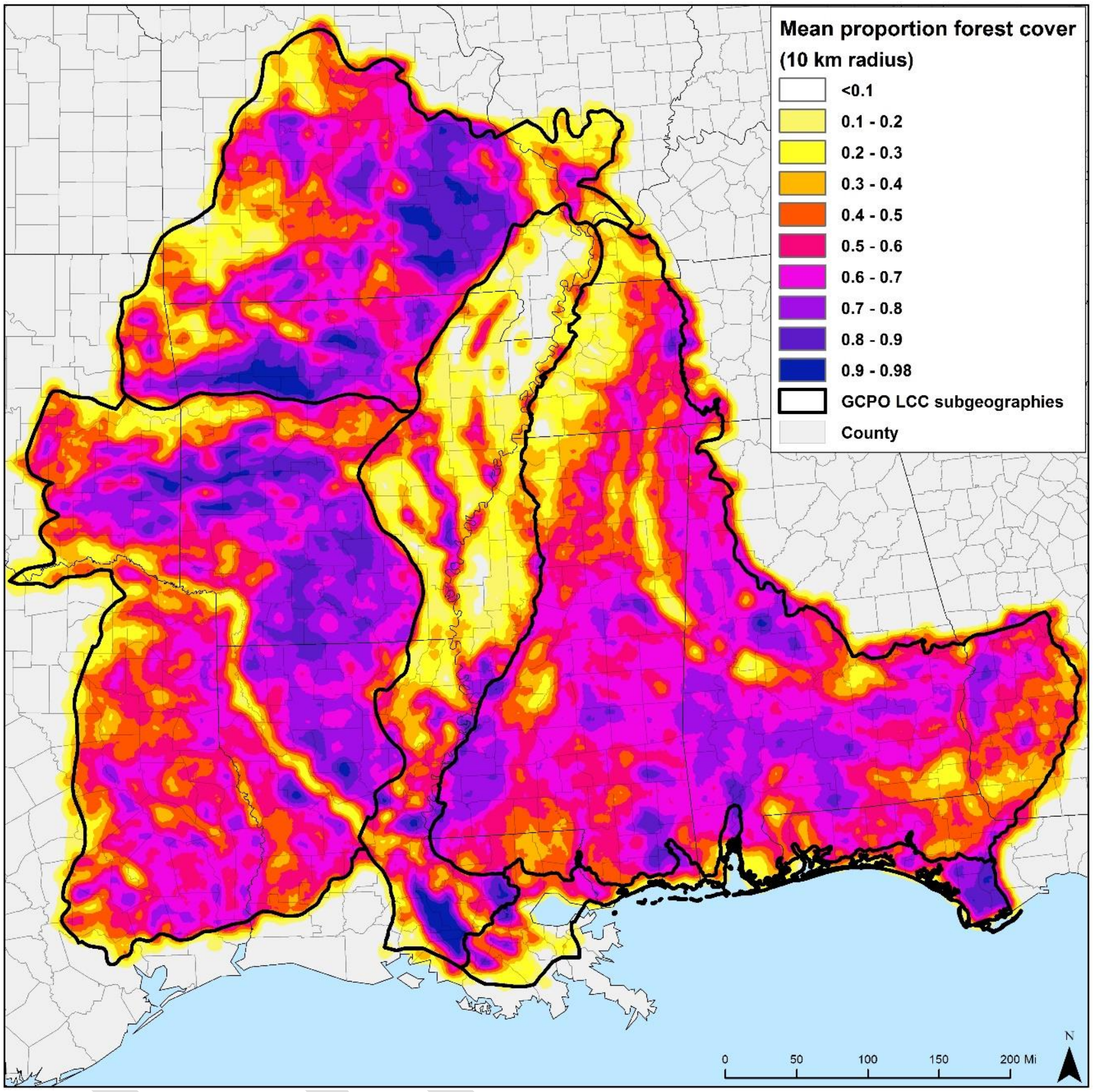

Figure UH.6. Mean percent forest cover within a 10 km linear radius of a 250m cell within the GCPO LCC.

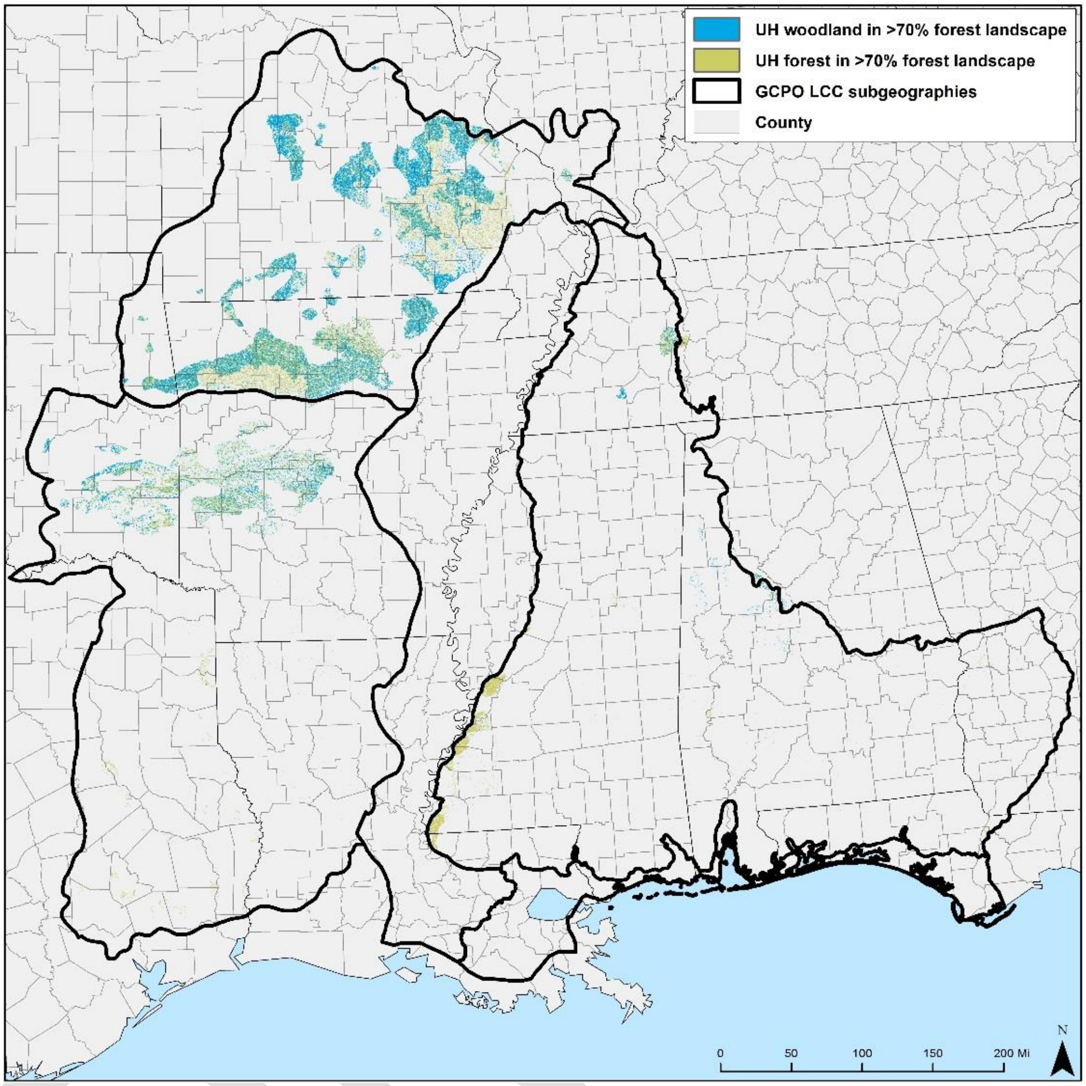

Figure UH.7. Pixels of upland hardwood woodland and forest that are found within >70% forested landscapes (derived at a 10km linear radius of a 250m cell) within the GCPO LCC.

Future Directions and Limitations:

Delineation of forest cover, and particularly forest patches in the GCPO, is challenging due to the contiguity of forest cover throughout much of the area. It is often difficult to delineate forest breaks, especially at a pixel size of 250 m. Further, breaks and forest patches are perceived differently by different LCC priority species and thresholds for species and patch size are not yet fully understood such that an arbitrary patch endpoint of 3,000 acres must be evaluated with empirical data. This assessment of forest patch size should therefore be approached with caution, and we recommend re-analysis of patch break thresholds for more local efforts, in addition to focused research on species relationships with patch configuration metrics. Likewise determination of mean forest cover in the landscape is driven by the size of the analysis window, which in this case reflected a 10 km radius landscape. It is still uncertain what proportion of forest across what size landscape is needed to maximize ecological integrity of upland hardwood systems. It is, however, undoubtedly true that forest patch size and forest composition in the landscape will be correlated, and it needs to be determined whether both or just one of these endpoints is relevant for future iterations of the ISA. Finally, though "adequate connectivity" was also a forest configuration endpoint for upland hardwood systems in the ISA, we have not yet directly addressed it in the ecological assessment. We expect further ISA iterations to specify thresholds of connectivity and will incorporate this data into the assessment at that time.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- GCPO LCC Forest Patches >3,000 ac (all forest types) (raster 250 m)
- Forested Landscape>70% (all forest types) (raster 250 m)

Technical References

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Chapter 3: Condition, structure, canopy

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Canopy cover:

- 20 – 80% for woodlands
- >80% for forests

Ecological conditions within forest stands are also important indicators of ecosystem integrity. Priority wildlife species are frequently shown to exhibit preference for a specific range of conditions of canopy cover and basal area, tree diameter, midstory cover, and other forest characteristics within a stand. Canopy cover is particularly important, with very specific ranges recommended for upland hardwood woodland and forest systems. The Missouri Department of Conservation recommends target forest canopy closure at 90-100% for dry-mesic and mesic forest, >80% for dry-mesic woodland, and 30-80% for dry open woodlands in the Ozark Highlands (Mike Leahy, MDC, personal communication). In the Mark Twain National Forest 2005, Nelson recommends 80-100% canopy closure for upland hardwoods systems in Arkansas (USFS 2005). In the ISA, the ASMT built upon these recommended ranges of canopy cover and then identifies a range of overstory canopy cover between 20-80% for upland hardwood woodlands and >80% for upland hardwood forests in the Ozark Highlands subgeography.

We used the 2011 National Land Cover Database (NLCD) U.S. Forest Service Tree Canopy (analytical) product (USDA Forest Service Remote Sensing Applications Center 2014) combined with the woodland and forest masks derived above for assessment of overstory canopy cover within upland hardwoods in the Ozark Highlands and other GCPO subgeographies. The USFS forest canopy layer contains values representing the unmasked proportion of each 30x30m pixel covered by tree canopy (0 to 100%) produced using random forest regression algorithms (Breiman 2001, Cutler et al. 2007). To align with resolution of the other hardwood forest condition data we sought to generate an average proportion of tree canopy cover across 30 m pixels within each 250 m upland hardwood pixel in the GCPO geography. To calculate average canopy cover we first aggregated 30 m canopy cover cells to 240 m using a mean function and a cell factor of 8 (the aggregate function in ArcGIS only allows for cell factor aggregation, not aggregation to a desired pixel size, whereas the resample function in ArcGIS does not allow for calculation of averages over the resampled cell size). We then resampled the 240 m cell aggregate to 250 m resolution using a nearest neighbor algorithm. This produced an approximation of the average tree canopy cover within each 250 m forested wetland pixel. We next extracted the average tree canopy layer through the upland hardwood woodland and forest masks, then reclassified to extract woodlands with 20-80% canopy cover and forests with >80% canopy cover. The NLCD tree canopy cover analytic product also provides pixel-level estimates of standard error associated with mean measures of canopy cover as a companion Band 2 in the data layer. We extracted the tree canopy product through the woodland and forest mask to assess measures of standard error associated with canopy cover in each system.

Mean canopy cover generally fell within the target range (20-80%) for upland hardwood woodlands in the Ozark Highlands and other LCC subgeographies (**Table UH.11**). However, mean canopy cover for upland hardwood forests fell below the target range of >80% in all subgeographies except the East Gulf Coastal Plain. We estimate 69% of upland hardwood woodlands and 43% of upland hardwood forests in the Ozark Highlands meet the desired canopy endpoints for each system. Similarly, 635 of woodlands and 49% of forests meet desired endpoints GCPO-wide. We estimate nearly 6.8 million acres of woodlands have between 20-80% canopy cover in the Ozarks, and over 1.6 million acres of forests have >80% canopy cover, which suggests much more prevalence of upland hardwood systems in desired canopy condition that expected. However, mean standard error on canopy cover estimates for both systems ranged from 10-14%. This is evidenced by the average canopy cover map in **Figure UH.8**, which clearly shows a prevalence of reduced canopy cover in the Ozark Highlands subgeography, reflecting woodland conditions. Areas of prevalent upland hardwood forest canopy conditions can also be found throughout the Ozarks and West/East Gulf Coastal Plains, but are of high density along the Mississippi Loess Hills (**Figure UH.9**).

***Table UH.11. Mean percent canopy cover and acres within target ranges for upland hardwood woodland and forest systems by GCPO LCC subgeography, as derived from the NLCD 2011 Tree Canopy Cover analytical layer*.**

LCC subgeography	Mean % canopy cover upland hardwood woodlands	Acres 20-80% canopy (woodland target)	Mean SE (woodland % canopy)	Mean % canopy cover upland hardwood forests	Acres >80% canopy (forest target)	Mean SE (forest % canopy)
Ozark Highlands	61%	6,774,867	14%	74%	1,612,809	14%
Mississippi Alluvial Valley	63%	34,394	14%	78%	81,869	11%
East Gulf Coastal Plain	72%	644,821	13%	80%	917,749	10%
West Gulf Coastal Plain	68%	1,560,778	14%	71%	2,169,244	12%
Gulf Coast	N/A	0	N/A	47%	2,209	15%
GCPO LCC	66%	9,014,860	14%	70%	4,783,879	13%

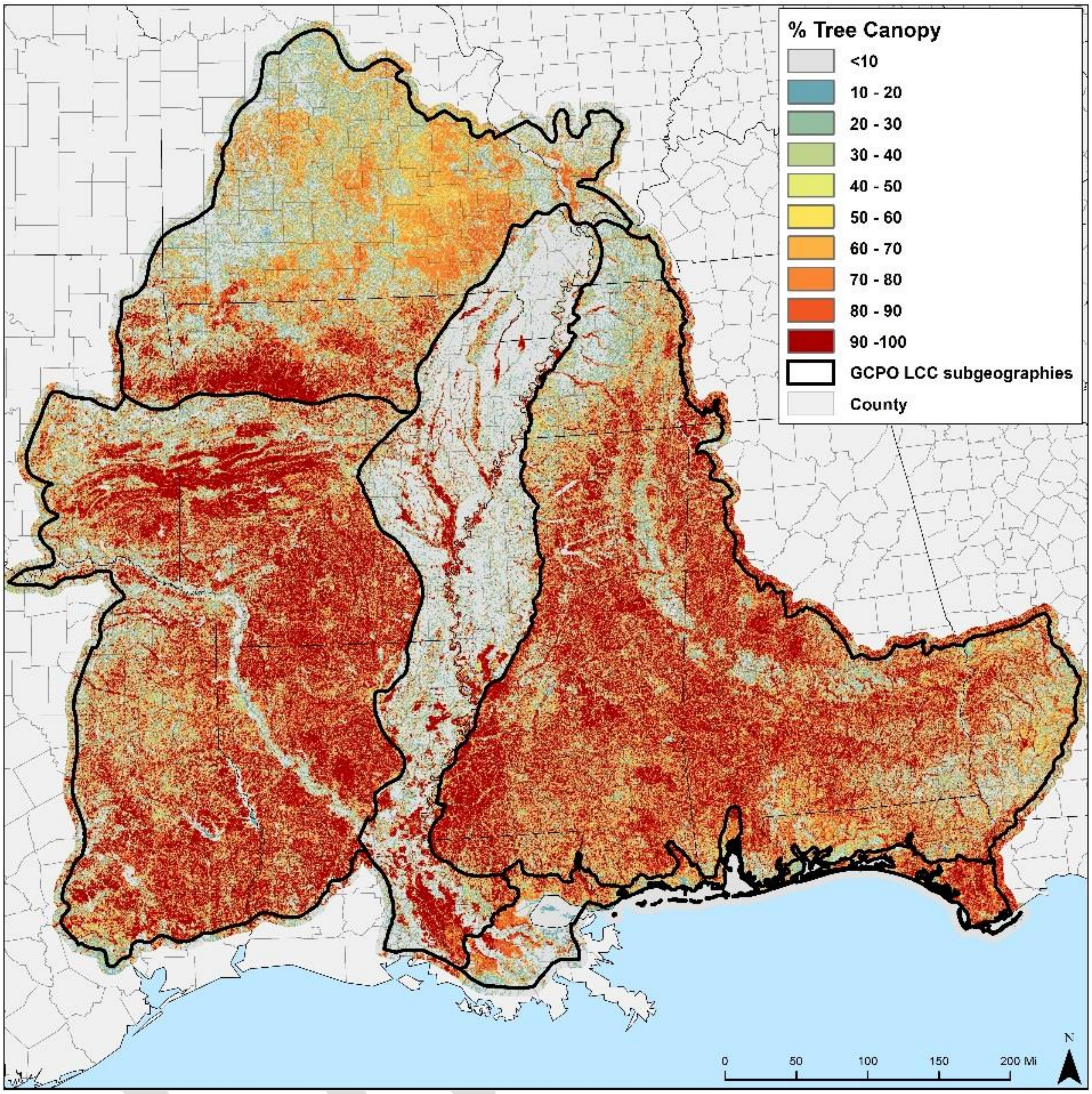

Figure UH.8. Mean percent tree canopy cover within the GCPO LCC geography, derived from the 2011 NLCD Tree Canopy Cover layer.

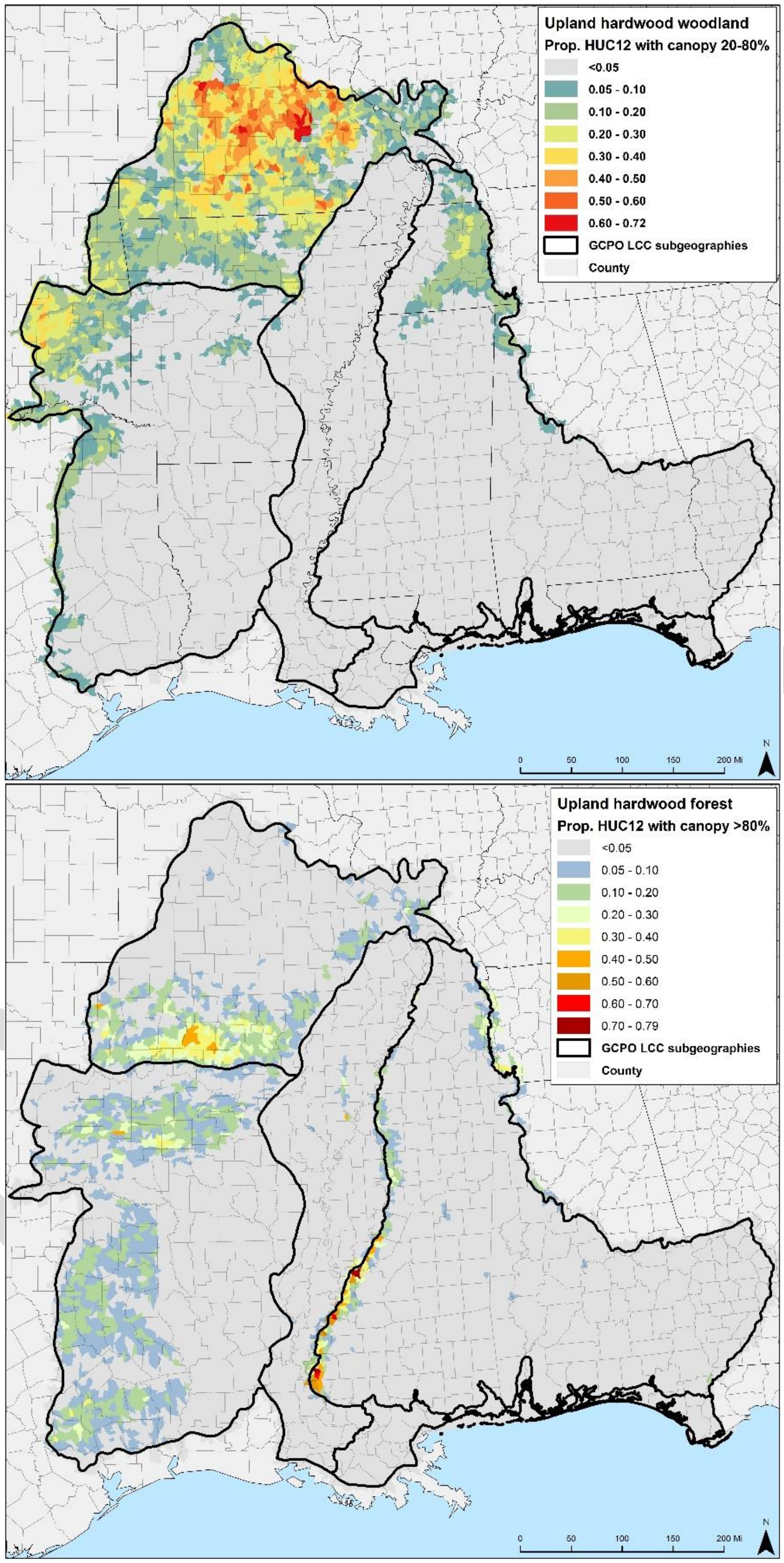

Figure UH.9. Upland hardwood woodland and forest pixels with 20-80% tree canopy cover (for woodlands) and >80% tree canopy cover (for forests) averaged by HUC12 watershed within the GCPO LCC geography, derived from the upland hardwood masks and 2011 NLCD Tree Canopy Cover layer.

Future Directions and Limitations

In addition to assuming the woodland and forest masks accurately classify GCPO upland hardwood systems, this assessment relies on the assumption that tree canopy cover estimates using regression algorithms for the desired canopy ranges were calculated with little bias and are reflective of actual conditions on the ground. Standard error on the NLCD tree canopy analytical product represents model uncertainty associated with each tree canopy cover pixel, and was calculated using the estimated variance on canopy cover from the random forest regression analysis. It is evident that standard error estimates for woodland and forest pixels within the target canopy cover ranges have some degree of uncertainty. Nonetheless, a 10-14% standard error suggests uncertainty in canopy cover estimates is tolerable for the purposes of this assessment. A potential alternative to use of NLCD 2011 tree canopy cover data is to assess Landfire percent tree canopy (Landfire 2013), which provides 10 percentile range estimates of forest canopy cover for pixels instead of unique pixel percentage estimates provided by the NLCD canopy layer. Landfire forest canopy cover is part of the Landfire fuels data group and is defined as the stand-level percent of tree canopy; it is also limited to Landfire existing vegetation types of forest and woodland.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- GCPO LCC Tree Canopy Cover (raster 250 m and proportional HUC12 vector)

Technical References

Breiman, L. 2001. Random forests. Machine Learning 45:15-32.

Cutler, R. D., T. C. Edwards, K. H. Beard, A. Cutler, K. T. Hess, J. Gibson, and J. J. Lawler. 2007. Random forest for classification in ecology. Ecology 88:2783-2792.

Landfire. 2013. Landfire Forest Canopy Cover layer. U.S. Department of Interior, Geological Survey. <http://www.landfire.gov/NationalProductDescriptions6.php> Accessed 15 June 2014.

U.S. Forest Service. 2005. Mark Twain National Forest – Forest Plan, Appendix A: Terrestrial Natural Communities. https://www.fs.usda.gov/main/mtnf/landmanagement/planning

USDA Forest Service Remote Sensing Applications Center. 2014. NLCD 2011 USFS Percent Tree Canopy (Analytical Version). <http://www.mrlc.gov/nlcd11_data.php> Accessed 15 June 2014.

Chapter 4: Condition, structure, average tree diameter

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Average DBH ≥14”

Average tree diameter (DBH) is also an important forest condition for some species requiring large trees and subsequent tree cavities for denning/nesting/roosting sites. The GCPO LCC ISA targets diameter of upland hardwood forest and woodland trees to be ≥14” dbh. The standardized Forest Inventory and Analysis (FIA) national program, which collects data using standardized field protocols across counties in every state annually, may be the only landscape-scale data source feasible to investigate average tree diameter in the absence of other large-scale data sources in the GCPO geography. We used FIA-imputed data on average tree diameter (DBH, inches) per acre (USDA Forest Service Remote Sensing Applications Center [USFS], personal communication) extracted through the upland hardwoods mask as a proxy for assessment of DBH within the Ozark Highlands and other GCPO geographies. The USFS imputed average DBH product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the FIA program. Note estimates of average DBH were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. The USFS-imputed average DBH layer was created in the target resolution for this assessment (250 m). We used an extract by mask function in ArcGIS to delineate average DBH in upland hardwoods, using the USFS imputed DBH layer as input data and the upland hardwoods woodland and forest layers described above as mask overlays. We then reclassified to extract woodlands and forest ≥14” DBH. There was very limited presence of average DBH ≥14” in upland hardwood systems in the GCPO geography. We therefore binned the data into quantiles and used the upper quantile of DBH values for woodlands (≥6.10” DBH) and forests (≥6.26” DBH) as a proxy to examine areas in the GCPO upland hardwoods that exhibited the “largest” trees on average. We summarized the data spatially as a binary reclassification of the top quantile (0,1), by summing acres within each GCPO subgeography, and by calculating the proportional area of a HUC12 watershed falling into the top DBH quantile for woodlands and forest.

Based on imputed FIA data at a 250 m pixel resolution we estimate only about 680 acres of upland hardwood woodland and 2,039 acres of upland hardwood forest within the entire GCPO geography fell within the target tree diameter endpoint of ≥14” dbh (**Table UH.12**). Mean upland hardwood woodland tree diameter in the Ozark Highlands was 5.17” and mean upland hardwood forest diameter was 5.49”, suggesting diameter of trees in the vast majority of upland hardwood systems may reflect stand age classes that are younger than targeted in the tree diameter endpoint. Average diameter was even less across the whole LCC at approximately 4.90” for woodland and forest systems. When examined by top DBH quantile, we estimate over 2.3 million acres (24%) of upland hardwood woodland acres in the Ozark Highlands exhibited an average DBH ≥6.10”, with nearly 3 million acres, or 21% of woodlands within the top quantile

GCPO-wide. We also found 24%, nearly 1 million acres, of upland hardwood forest in the Ozark Highlands exhibited an average DBH ≥6.26", with about 1.9 million acres (19%) found GCPO-wide.

Though no particular areas showed average DBH near or above 14", there were several distinct areas where woodlands and forests exhibited greater average diameter compared to other geographies. These showed in both the general graphic of average DBH (**Figure UH.10**) and in the proportional assessments of prevalence in HUC12 watersheds (**Figure UH.11**). For upland hardwood woodlands the greatest presence of large diameter trees appears to be restricted primarily to the Ozark Highlands, with areas of the Boston Mountains in Arkansas, parts of far southwestern Missouri, as well as portions of the Mark Twain National Forest and Lake of the Ozarks area showing larger trees compared to other areas. There were two very distinct areas of large diameter trees showing for upland hardwood forests, with the greatest prevalence found along the Mississippi Loess Hills in southwestern Mississippi and in the vicinity of Ozark National Forest in the Boston Mountains of Arkansas. However proportion of HUC12 watershed in these top quantile conditions did not exceed 40% in either system.

Table UH.12. Average tree diameter (DBH, inches), acres within the target ≥14" DBH range, and acres within the top quantile DBH range for upland hardwood woodland and forest systems by GCPO LCC subgeography, as derived from imputed USFS Forest Inventory and Analysis data.

LCC subgeography	Average DBH upland hardwood woodlands (inches)	Acres woodland w/ ≥14" dbh (target)	Acres woodland w/ ≥6.10" dbh (top quantile)	Average DBH upland hardwood forests (inches)	Acres forest w/ ≥14" dbh (target)	Acres forest w/ ≥6.26" dbh (top quantile)
Ozark Highlands	5.17	324	2,313,890	5.49	1,961	946,490
Mississippi Alluvial Valley	5.09	0	14,224	5.67	15	42,471
East Gulf Coastal Plain	4.74	0	190,920	5.33	62	340,032
West Gulf Coastal Plain	4.66	355	444,619	4.56	0	551,446
Gulf Coast	N/A	N/A	N/A	3.35	0	1,220
GCPO LCC	4.90	680	2,963,653	4.88	2039	1,881,659

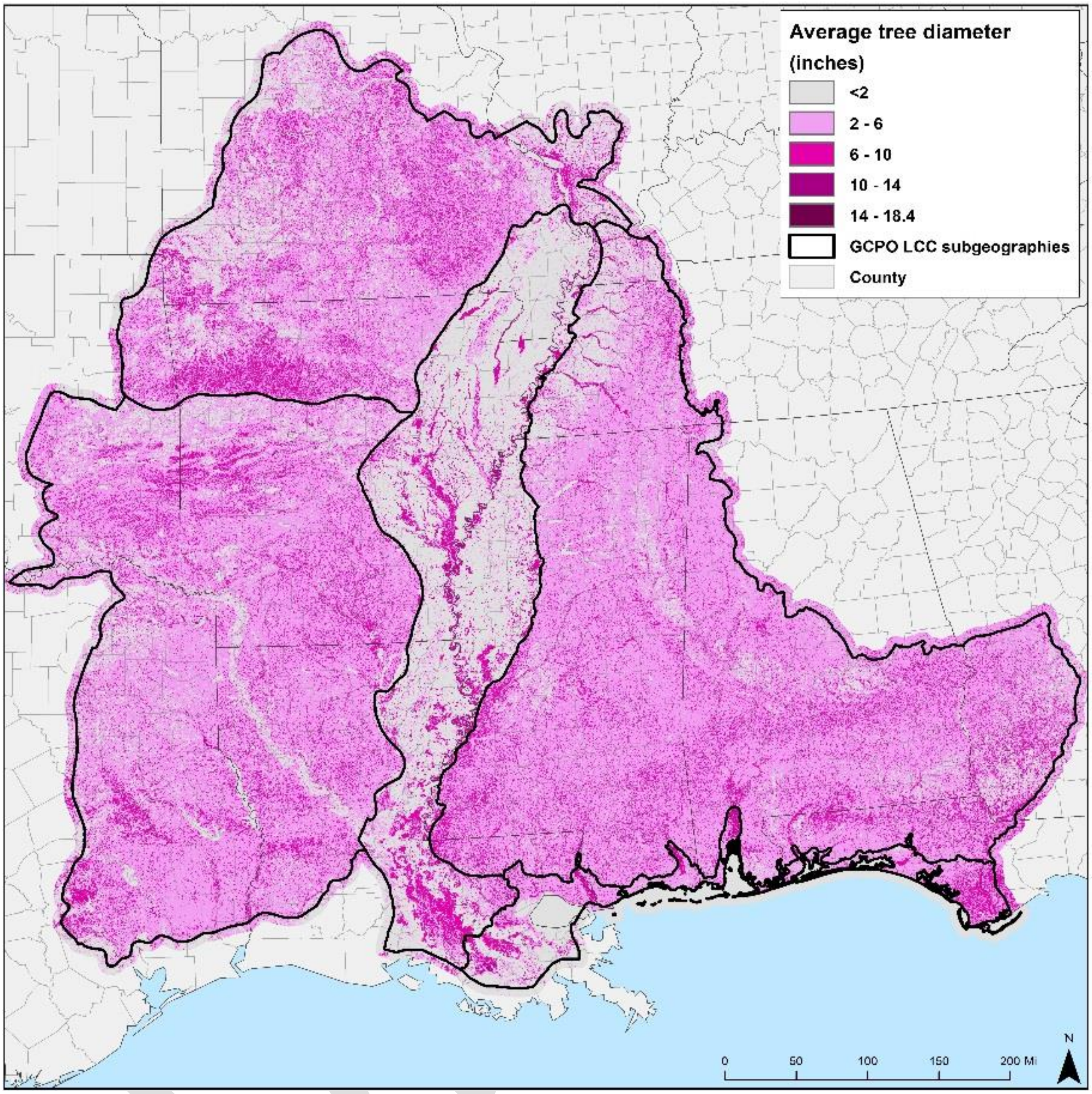

Figure UH.10. Average tree diameter (DBH, inches) within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

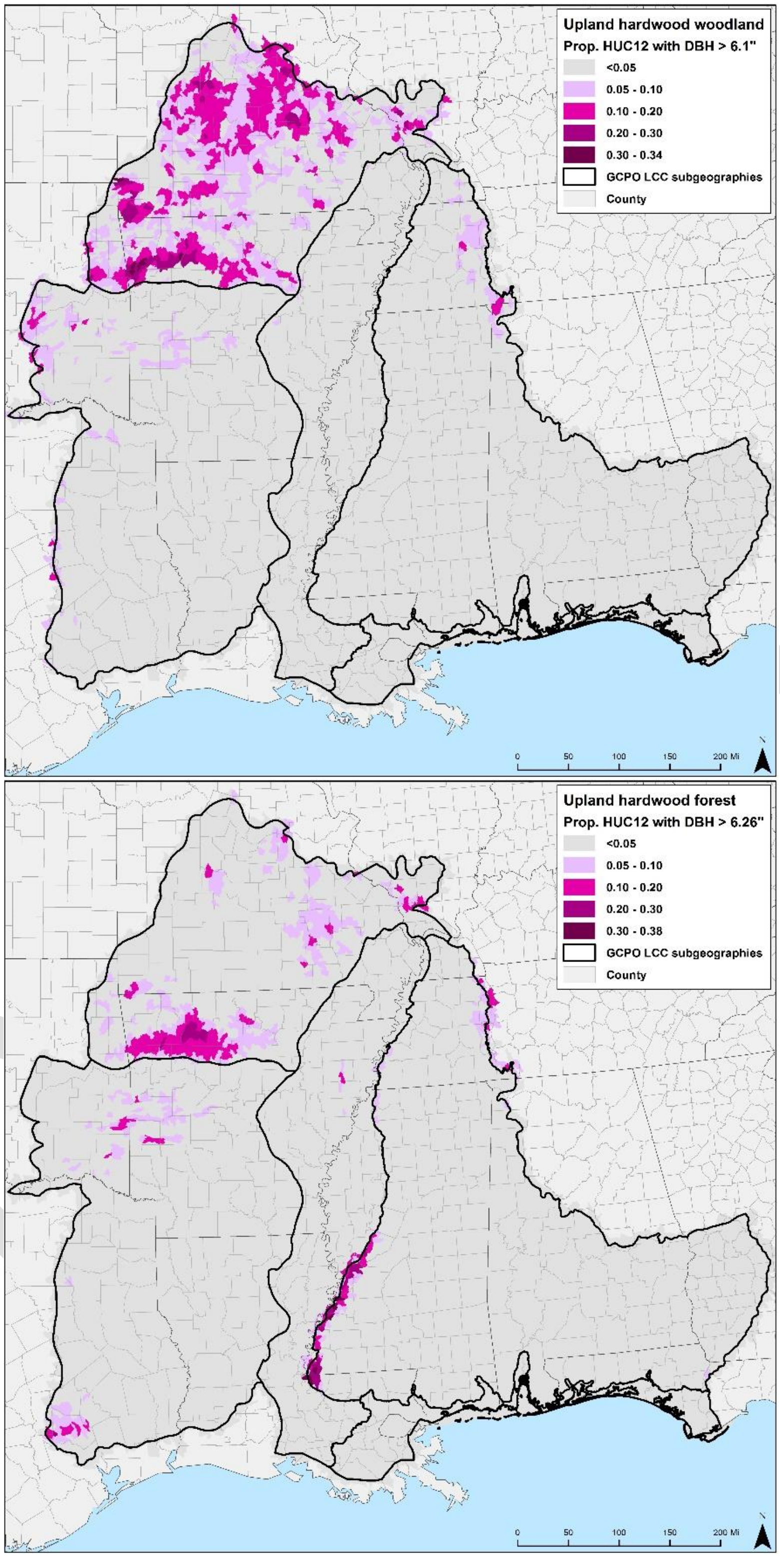

Figure UH.11. Upland hardwood woodland and forest pixels with ≥6.10" **DBH** ***(for woodlands) and ≥6.26" (for forests) averaged by HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.***

Future Directions and Limitations

The ISA targets larger tree diameters both as indicators of mature hardwood forest stands, but also because of the cavity function that older larger trees can provide for cavity denning/roosting priority species. Large hardwood trees are clearly limited on the landscape, as seen in the limited availability of average diameters >14” in this assessment. Our solution to this assessment was to use an upper quantile approach to determine where the top 20% of average tree diameters are in upland hardwood systems. However, this approach is arbitrary and simply points to larger than average trees, irrespective of cavity and denning functions. There are no doubt many trees >14” DBH on the landscape, but that information is diluted when examining the endpoint at this scale, and imputing FIA data to estimate DBH/acre within a 15.44 acre area (250 m pixels). We also rely heavily on the assumption that imputations of FIA data over MODIS satellite imagery are reliable in predicting other areas of larger than average tree diameter on the landscape. This assumption needs to be validated with field-level data.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- GCPO LCC Average Tree Diameter (raster 250 m and proportional HUC12 vector)

Chapter 5: Condition, structure, tree density

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Tree density:

- ~40 trees/ac for woodlands
- ~80 trees/ac for forest

Tree density has been shown to be an important component to upland hardwood woodland and forest systems in the Ozark Highlands. In a comprehensive review of historic forest conditions Foti (2004) suggested an average tree density of 52 trees per acre (range 38 -76) within Arkansas Ozarks upland forest. The ISA targets tree densities of around 40 trees/acre for upland hardwood woodland systems and around 80 trees/acre for upland hardwood forest systems. We again used plot-level FIA data imputed at 250 m resolution across the GCPO LCC to assess tree density. The USFS imputed tree density data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the Forest Inventory and Analysis National Program (FIA). Note estimates of tree density were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. The USFS-imputed tree density layer was created in the target resolution for this assessment (250 m). However, it was challenging to identify and map the very limited acreage amounts meeting exactly this target in upland hardwood woodlands and forest. We therefore assessed the mean tree density within each forest type, and acres meeting the target endpoint, ±10 trees/acre from the target endpoint. We first extracted the imputed FIA live tree density data, provided courtesy of the U.S. Forest Service Remote Sensing Applications Center, through the upland hardwood woodland and forest masks. We then reclassified each to extract woodlands with exactly 40 trees/ac as well as within a range of 30-50 trees/acre, and forests with exactly 80 trees/ac, as well as within a range of 70-90 trees/acre. We did explore the potential of using standard deviations from the mean to density conditions, but the wide range of density resulted in standard deviation metrics that were too broad for use in this analysis. We summarized the data spatially as a binary reclassification of the target range (0,1), by summing acres within each GCPO subgeography, and by calculating the proportional area of a HUC12 watershed falling into the target tree density range for woodlands and forest.

As expected, we found very limited acreage of upland hardwood woodlands and forests meeting exact tree density targets, with only 5,915 acres of woodlands and 4,031 acres of forest meeting exact targets of 40 trees/acre and 80 trees/acre GCPO-wide, respectively (**Table UH.13**). Average tree density in both systems was 5-10 times greater than the target density. Tree density was as large as 3,848 trees per acre in the GCPO geography, with most acreage falling well above the tree density targets outlined in the ISA (**Figure UH.12**). There were, however, over 66,000 acres of upland hardwood woodlands that were found in the 30-50 trees/acre range in the Ozark Highlands (**Figure UH.13**), and over 110,000 acres GCPO-wide, with the majority of acreage found within the western portions of the Ozark Highlands, and along the LCC boundary in the West Gulf Coastal Plain. However, woodlands within a 30-50 trees/acre range never exceed more than 4% of a HUC12 watershed throughout the GCPO, and those areas were typified by pastoral landscapes with fragmented woodland interspersed throughout an agricultural or rural developed landscape. We also found over 50,000 acres of upland hardwood forest in the West Gulf Coastal Plain and nearly 13,000 acres in the Ozark Highlands that were found in the 70-90 trees/acre range. Areas of some prevalence of target forest tree densities were found primarily in Texas and southeastern Oklahoma, along the Sabine River, and east of Durant. However, percentages of HUC12 coverage never exceeded 2% anywhere in the GCPO. Given the millions of acres of woodland and forest cover demonstrated by other data sources (e.g., canopy cover), the tree density endpoint target may be generally outside of the range of conditions in the GCPO. Alternatively, it may also be a challenging metric to measure via the hybrid plot-remote sensing approach.

Table UH.13. Average tree density (trees/acre) and acres meeting endpoint targets and ±10 trees/acre from targets in upland hardwood woodlands and forest in the Ozark Highlands subgeography and entire GCPO LCC.

LCC subgeography	Average trees/ac upland hardwood woodlands	40 trees/ac (target)	30-50 trees/ac (± 10)	Average trees/ac upland hardwood forest	80 trees/ac (target)	70-90 trees/ac (± 10)
Ozark Highlands	430	3,413	66,641	500	618	12,757
Mississippi Alluvial Valley	347	301	880	417	62	1,390
East Gulf Coastal Plain	551	355	8,247	498	432	8,510
West Gulf Coastal Plain	409	2,116	34,518	481	2,904	50,209
Gulf Coast	N/A	N/A	N/A	308	15	278
GCPO LCC	434	5,915	110,286	441	4,031	73,143

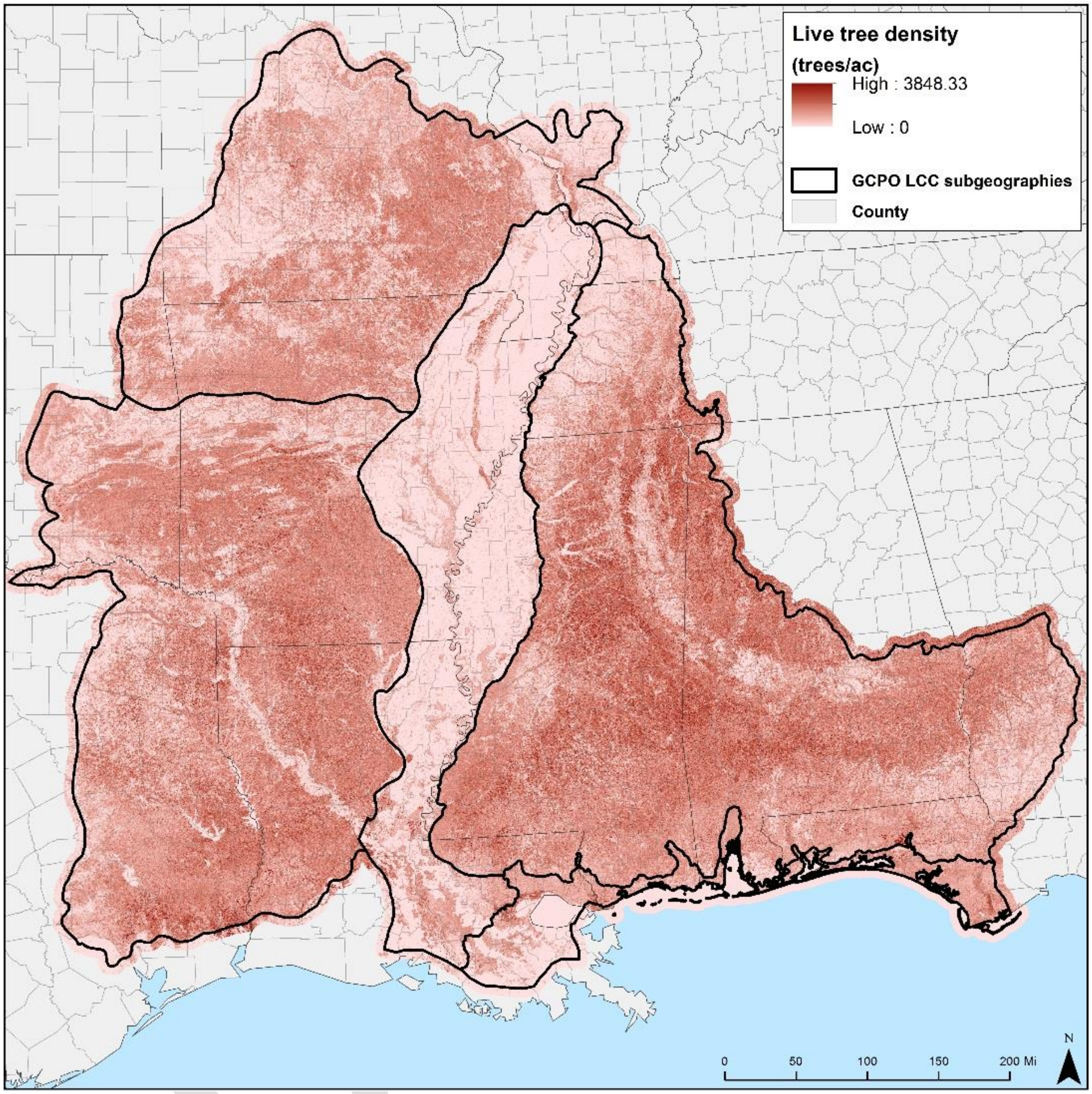

Figure UH.12. Total live tree density (trees/acre) within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

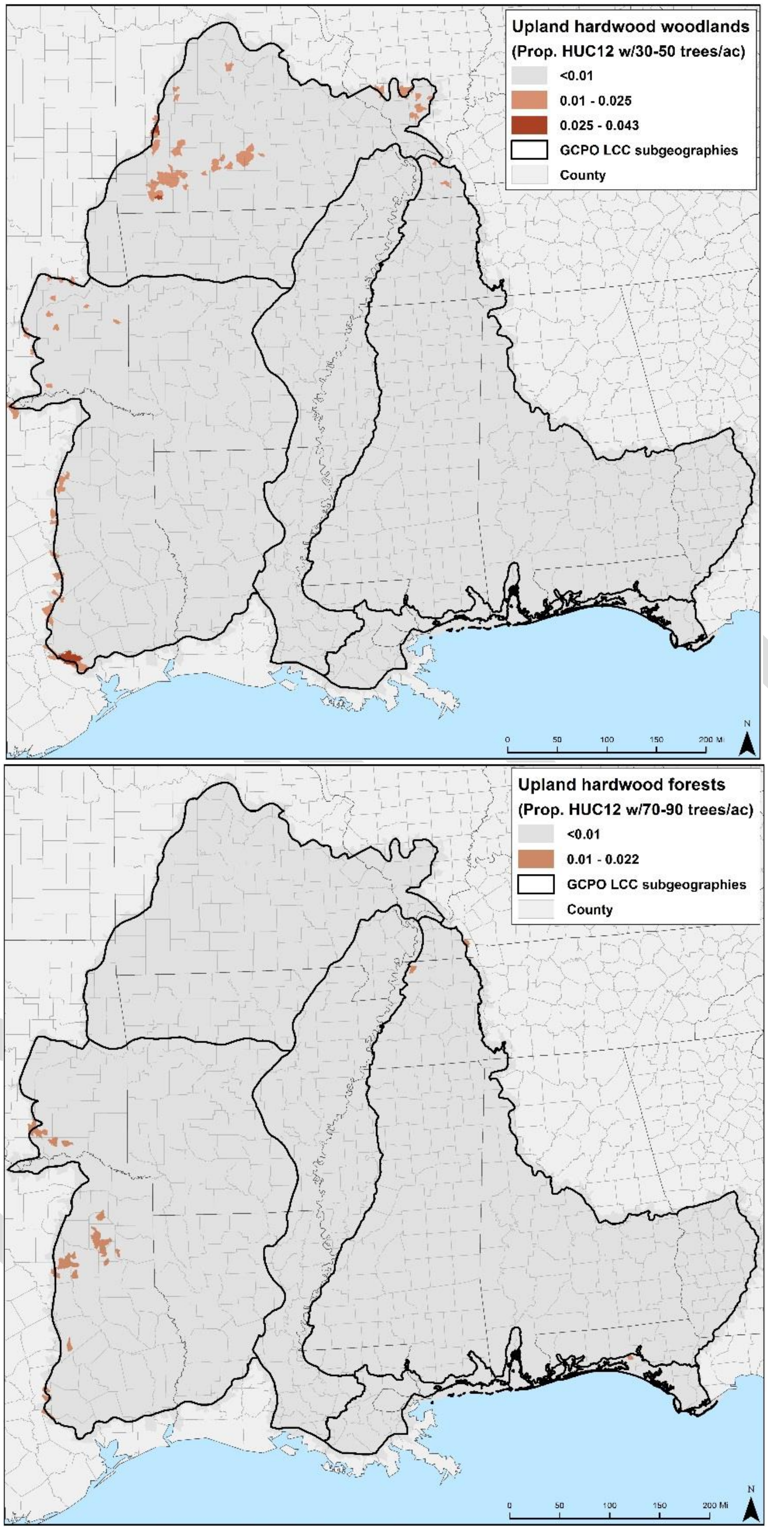

Figure UH.13. Imputed live tree density within 30-50 trees/acre target for upland hardwood woodlands and 70-90 trees/acre target for upland hardwood forests summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

Future Directions and Limitations

There appears to be a data mismatch between imputed FIA basal area (see below) and imputed tree density data. Target ranges of basal area appear to be much more prevalent in woodlands and forests across the GCPO landscape than target ranges of tree density. However, those values should be correlated to some extent. This data inconsistency may be an artifact of imputation, or an indication that a hybrid plot-remote sensing approach is not effective at mapping tree density. They may also reflect FIA inventory methodology, which records all trees >5" DBH on macroplots (USFS 2014). Given these caveats, the LCC will further pursue validation of the imputed tree density models prior to the next assessment revision.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- GCPO LCC Live Tree Density (raster 250 m and proportional HUC12 vector)

Technical References

Foti, T. L. 2004. Upland hardwood forests and related communities of the Arkansas Ozarks in the early 19th century. Pages 21-29 in M. A. Spetich, ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. USDA Forest Service, Southern Research Station, Asheville, NC.

U.S. Forest Service. 2014. Forest Inventory and Analysis National Core Field Guide, Volume 1: Field data collection procedures for phase 2 plots, Version 6.1.

Chapter 6: Condition, structure, snag density

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Snag density: 1 large (≥16” dbh) snag/5 acres

Standing dead trees, or snags, are an important habitat element in any forested system, and provide diurnal or seasonal shelter for many LCC priority species (Davis et al. 1983). Large diameter snags are particularly important for cavity roosting, nesting and denning species, including black bear, and Indiana bat, which have been shown to prefer >12” snags (Yates and Muzika (2006). To account for habitat needs across multiple priority species the ISA landscape endpoint for snag density in upland hardwood woodland and forest systems targets one large (≥16” dbh) snag for every five acres of forest (or approximately ~0.2 large snags/acre). We used USFS imputed density of large (>16” dbh) snags data (USDA Forest Service Remote Sensing Applications Center, personal communication) extracted through the upland hardwood woodland and forest masks for assessment of snag density within the Ozark Highlands and other GCPO geographies. The USFS imputed snag density data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the Forest Inventory and Analysis National Program (FIA). Density of large snags was imputed from plot-level FIA data coalescing standing dead trees >5” with dbh >16”. Note estimates of snag density were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. The USFS-imputed percent large snag density layer was created in the target resolution for this assessment (250 m). We used an extract by mask function in ArcGIS to delineate large snag density in upland hardwood woodland and forest, using the USFS imputed large snag density layer as input data and the woodland and forest data as masks. We then reclassified the product to pull out pixels with large snag density with at least 0.2 large snags/acre. Note the ISA endpoint targets exactly 0.2 snags ≥16”/ac, but due to data limitations we have assessed this endpoint to include all large snags with 0.2/ac density or greater, assuming a greater density of large cavities would not be a detriment to species as long as the forest system remained intact. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres upland hardwood (>0.2/ac snags >16”)/acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Average large snag density in upland hardwood woodlands and forests in all GCPO subgeographies exceeded 0.2 large snags/acre, with the exception of hardwood forests in the Gulf Coast (**Table UH.14**). Average large snag density was more than twice the desired endpoint for both systems in the Ozark Highlands. However, note that the endpoint targets exactly 0.2 large snags/acre, therefore it is assumed that snag densities greater than that target are also a desired condition. We estimate over 3.8 million acres (39%) of woodlands and over 1.6 million acres (44%) of forests meet or exceed the ISA snag density endpoint in the Ozark Highlands, with over 5.1 million and 3.5 million acres of woodland and forests meeting the endpoint GCPO-wide.

Areas of greatest large snag density overall in the Ozark Highlands can be found in the southwest and northwest corners of Missouri and Arkansas, just outside of Fayetteville, in parts of the Shawnee National Forest in southern Illinois, and scattered throughout the Mark Twain and Ozark National Forests in Missouri and Arkansas (**Figure UH.14**). Large snag density above the target 0.2/acre in upland hardwood woodlands were found in greatest concentration (30-50% of HUC12 watershed) in the Lake of the Ozarks vicinity in Missouri, as well as within Mark Twain National Forest in Missouri, and Ozark National Forest in Arkansas (**Figure UH.15**). There were also other areas of lower proportion in woodlands along the western GCPO border in the West Gulf Coastal Plains of Oklahoma and Texas, and in parts of western Tennessee and northwest Alabama in the East Gulf Coastal Plains. Large snag density above the target 0.2/acre in upland hardwood forests were found in greatest concentration (30-50% of HUC12 watershed) along the Mississippi Loess Hills north of Vicksburg, MS. Areas of the Mark Twain National Forest in Missouri, Ozark National Forest in Arkansas, and nearby Tyler Texas also saw concentrations 20-30% of the HUC12 watershed.

Table UH.14. Average snag density and acres demonstrating >1 large snag (>16" dbh) per 5 acres (0.2 large snag/acre) in upland hardwood woodland and forest by GCPO LCC subgeography.

LCC subgeography	Average snag density upland hardwood woodlands	Woodlands with >0.2 large snags/acre	Average snag density upland hardwood forest	Forests with >0.2 large snags/acre
Ozark Highlands	0.44	3,823,705	0.51	1,661,906
Mississippi Alluvial Valley	0.39	26,348	0.44	51,043
East Gulf Coastal Plain	0.25	359,801	0.30	413,438
West Gulf Coastal Plain	0.31	904,853	0.32	1,400,839
Gulf Coast	N/A	N/A	0.10	1,205
GCPO LCC	0.35	5,114,706	0.33	3,528,430

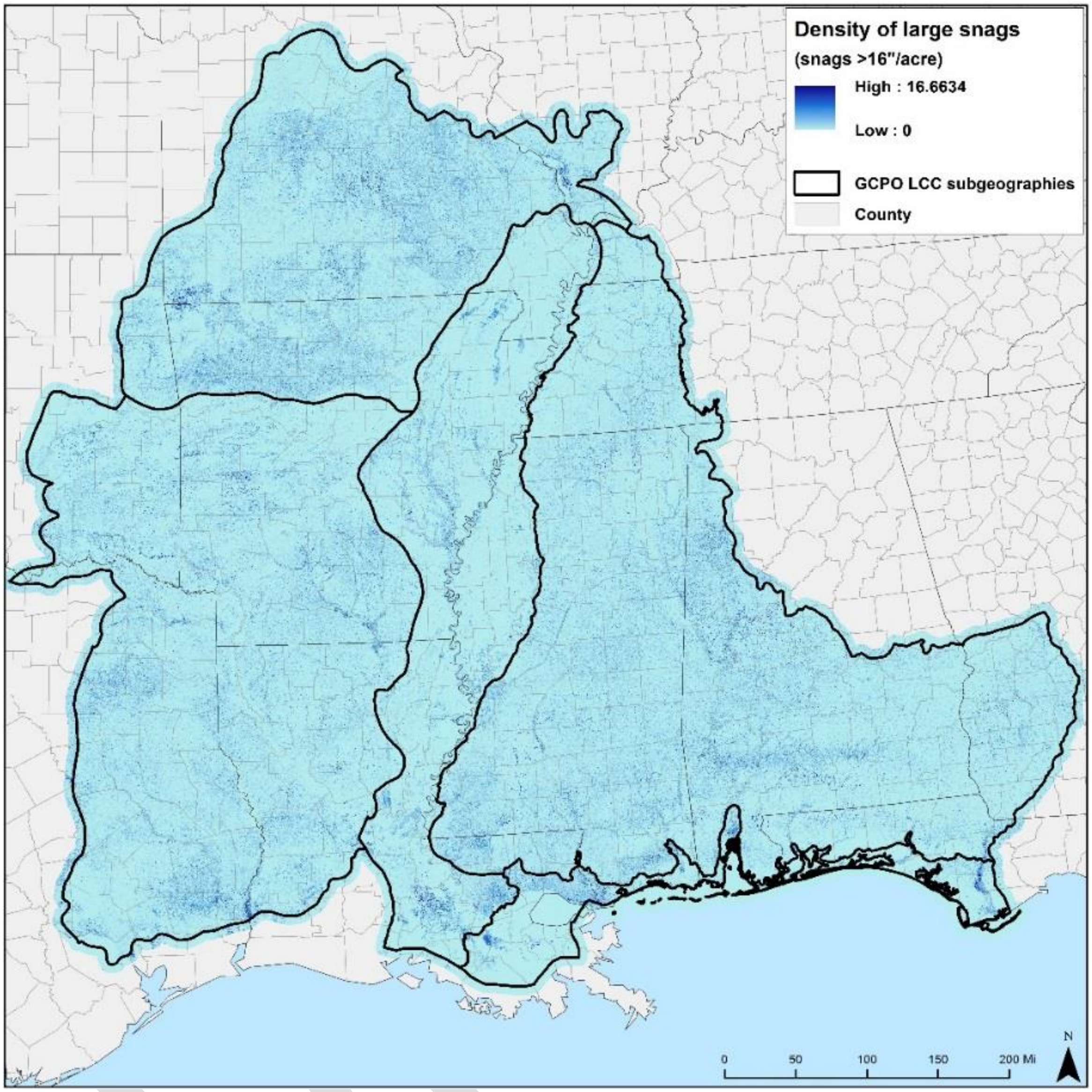

Figure UH.14. Density of large (>16" snags) (snags/acre) within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

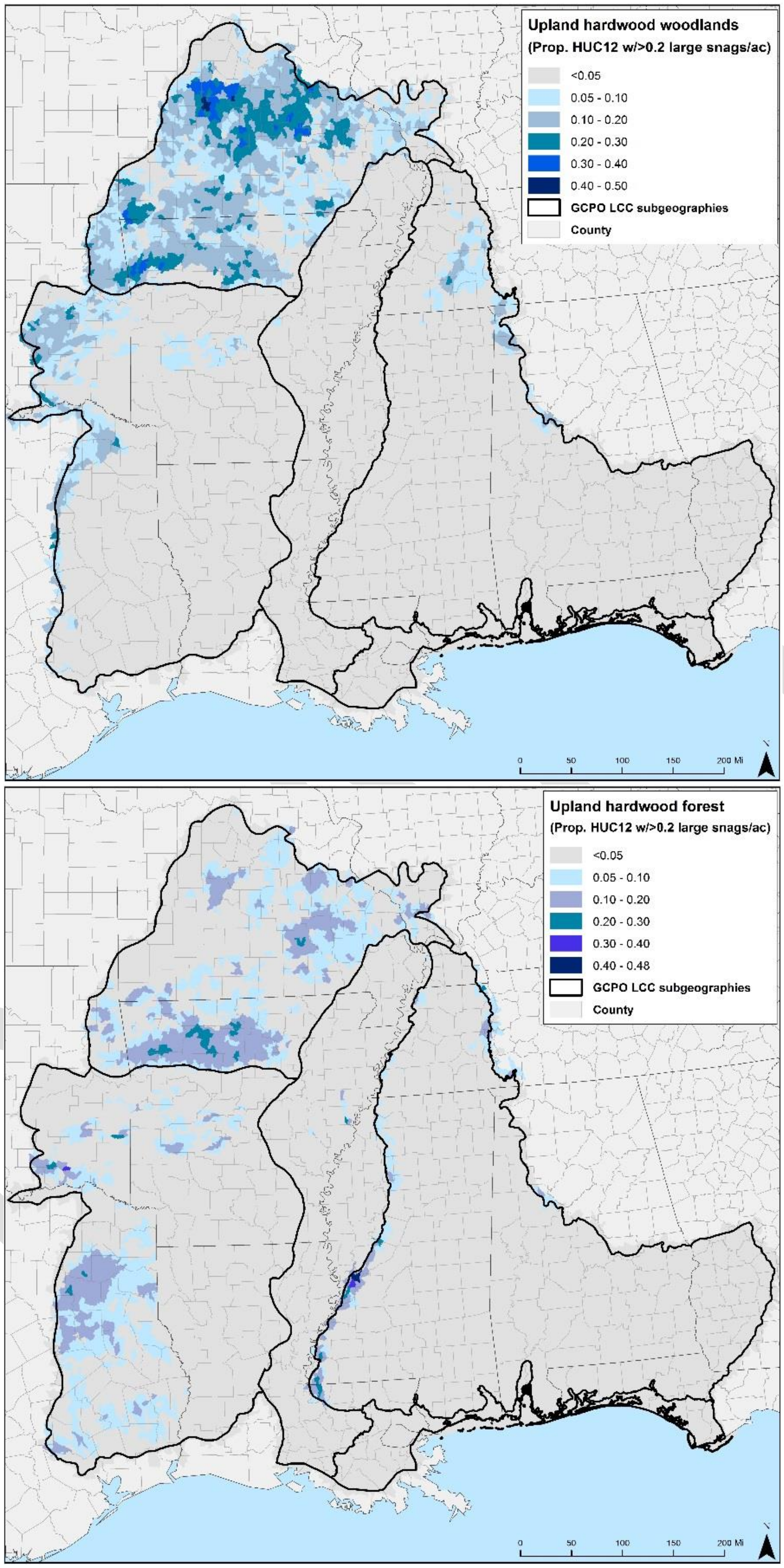

Figure UH.15. Upland hardwood woodlands and forests exhibiting the target range of snag density conditions of > 1 large (≥16" DBH) snag/5 acres summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

Future Directions and Limitations:

The current endpoint for snag density in the ISA targets 1 large (>16" DBH) snag/5 acres. Assuming this is a minimum threshold for the endpoint, we recommend the ASMT consider an upper threshold as well, if applicable. It has yet to be determined if too many large snags in a landscape would be detrimental to ecological integrity of a system. However, areas of high concentration of large snags could indicate a stressed or diseased upland hardwood forest. We also encourage evaluation of the >16" DBH threshold for standing dead wood, particularly as evidenced by cavity use requirements by LCC priority species.

FIA data are one of the only landscape-scale systematic forest characterizations presently available. However, estimates of large snag density presented here implicitly assume that FIA data plots collected once per 6,000 acres across the landscape provide accurate representations of snag densities across the upland hardwood system (Bechtold and Patterson 2005). Users should therefore recognize its potential limitations when drawing inference from imputed FIA-data. Future directions may also include use of advanced remote sensing technologies such as LiDAR to supplement plot-level forest inventory data and produce large-scale mapping of snag densities (e.g., Martinuzzi et al. 2009). However, assessment across the entire GCPO geography will not be possible until LiDAR becomes available for much of the remainder of the region.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- GCPO LCC Density of Large Snags (>16") per acre (raster 250 m and proportional HUC12 vector)

Technical References

Bechtold, W. A., and P. L. Patterson. 2005. The Enhanced Forest Inventory and Analysis Program – National sampling design and estimation procedures. U. S. Department of Agriculture, Forest Service Southern Research Station. General Technical Report SRS-80. Asheville, NC. < http://www.fia.fs.fed.us/library/sampling/ Accessed 30 June 2014.

Davis, J. W., G. A. Goodwin, and R. A. Ockenfels, editors. 1983. Snag Habitat Management: Proceedings of the Symposium, June 7-9, 1983, Northern Arizona University, Flagstaff. General Technical Report RM-99. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Flagstaff, AZ.

Martinuzzi, S. L. A. Vierling, W. A. Gould, M. J. Falkowski, J. S. Evans, A. T. Hudak, and K. T. Vierling. 2009. Mapping snags and understory shrubs for a LiDAR-based assessment of wildlife habitat suitability. Remote Sensing of Environment 113:2533-2546.

Yates, M. D., and R. M. Muzika. 2006. Effect of forest structure and fragmentation on site occupancy of bat species in Missouri Ozark forests. Journal of Wildlife Management 70:1238-1248.

Chapter 7: Condition, structure, snag density

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Dead/downed wood: One 6' log (≥8" dbh)/acre

Dead and downed wood, often termed "coarse woody debris" (hereafter, CWD) in any forest serves an important ecological function with regards to decomposition and nutrient cycling in forest ecosystems. CWD also provides critical habitat for many reptile and amphibian species, such as the red-backed salamander (*Plethodon cinereus*) (Herbeck and Larsen 1999), in addition to providing an important food source for insects and detritivores upon which many other species in the system depend. The ISA targets density of CWD around one 6' dead/down log of ≥8" DBH per acre, essentially indicating that on every acre there needs to be at least one sizable down log.

The FIA program does not collect plot-level data directly quantifying CWD, but does have a calculated class for carbon in down dead, which is provided as tons of carbon per acre of down dead woody matter >3" DBH and/or stumps and roots >3" DBH. This metric is derived from EPA Greenhouse Gas Inventory models, which include geographic area, forest type, and live tree carbon density, and can be imputed across the landscape using similar methods as other metrics above. However, the ISA presents CWD in terms of logs/acre and there presently is no direct algorithm that allows for the recalculation of the ISA endpoint in tons carbon/acre. We therefore made a broad assumption that areas with >0.05 tons carbon/acre (assuming a 6' long ≥8" DBH dead-down log weighs approximately 100 lbs and 1 lb of biomass equates to 0.0005 tons of carbon) would suffice for this endpoint, though we recognize this assumption is problematic and in need of testing and revision. The USFS-imputed dead-down wood layer was created in the target resolution for this assessment (250 m). Note estimates of dead-down wood were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. We used an extract by mask function in ArcGIS to delineate dead-down wood in upland hardwood woodland and forest, using the USFS imputed dead-down wood layer as input data and the woodland and forest data as masks. We then reclassified the product to pull out pixels with dead-down wood with at least 0.05 tons carbon/acre. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres upland hardwood (>0.05 tons carbon/ac dead-down wood/acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Average CWD in upland hardwood woodlands ranged from 1.48-1.82 tons carbon/acre, with the greatest CWD amounts found in the East Gulf Coastal plain and Ozark Highlands subgeographies (**Table UH.15**). Average CWD in upland hardwood forests ranged from 1.13-2.10 tons carbon/acre, with the greatest amounts found in the Ozark Highlands and Mississippi Alluvial valley. Given these caveats mentioned above we estimate nearly 9.8 million acres of upland hardwood woodland and nearly 3.8 million acres of upland hardwood forest contain >0.05 tons carbon/acre in dead/down wood (CWD) in the Ozark Highlands subgeography, with over 14.2 million acres of upland hardwood woodland and nearly 9.8 acres upland hardwood forest meeting this target in the entire GCPO geography (**Figure UH.16**). Dead-down wood in concentrations >0.05 tons carbon/acre were common in HUC12 watersheds, with some degree of concentration in the norther portions of the Ozark Highlands in west-central Missouri (**Figure UH.17**). For upland hardwood forests we observed concentrations within HUC12 watersheds along the Mississippi Loess Hills in Mississippi, and in lesser concentrations in the southern and eastern Ozark Highlands, throughout eastern Texas, and in parts of western Tennessee.

Table UH.15. Average tons carbon/acre dead-down wood and acres demonstrating >0.05 tons carbon/acre dead-down wood in upland hardwood woodland and forest by GCPO LCC subgeography.

LCC subgeography	Average dead-down wood (tons carbon/ac) upland hardwood woodlands	Acres woodlands w/ >0.05 tons carbon/acre	Average dead-down wood (tons carbon/ac) upland hardwood forest	Acres forests w/ >0.05 tons carbon/acre
Ozark Highlands	1.82	9,773,920	2.10	3,783,458
Mississippi Alluvial Valley	1.74	58,703	2.03	137,190
East Gulf Coastal Plain	1.88	1,423,218	1.99	1,415,202
West Gulf Coastal Plain	1.48	3,014,930	1.65	4,428,851
Gulf Coast	N/A	N/A	1.13	10,487
GCPO LCC	1.73	14,270,771	1.78	9,775,187

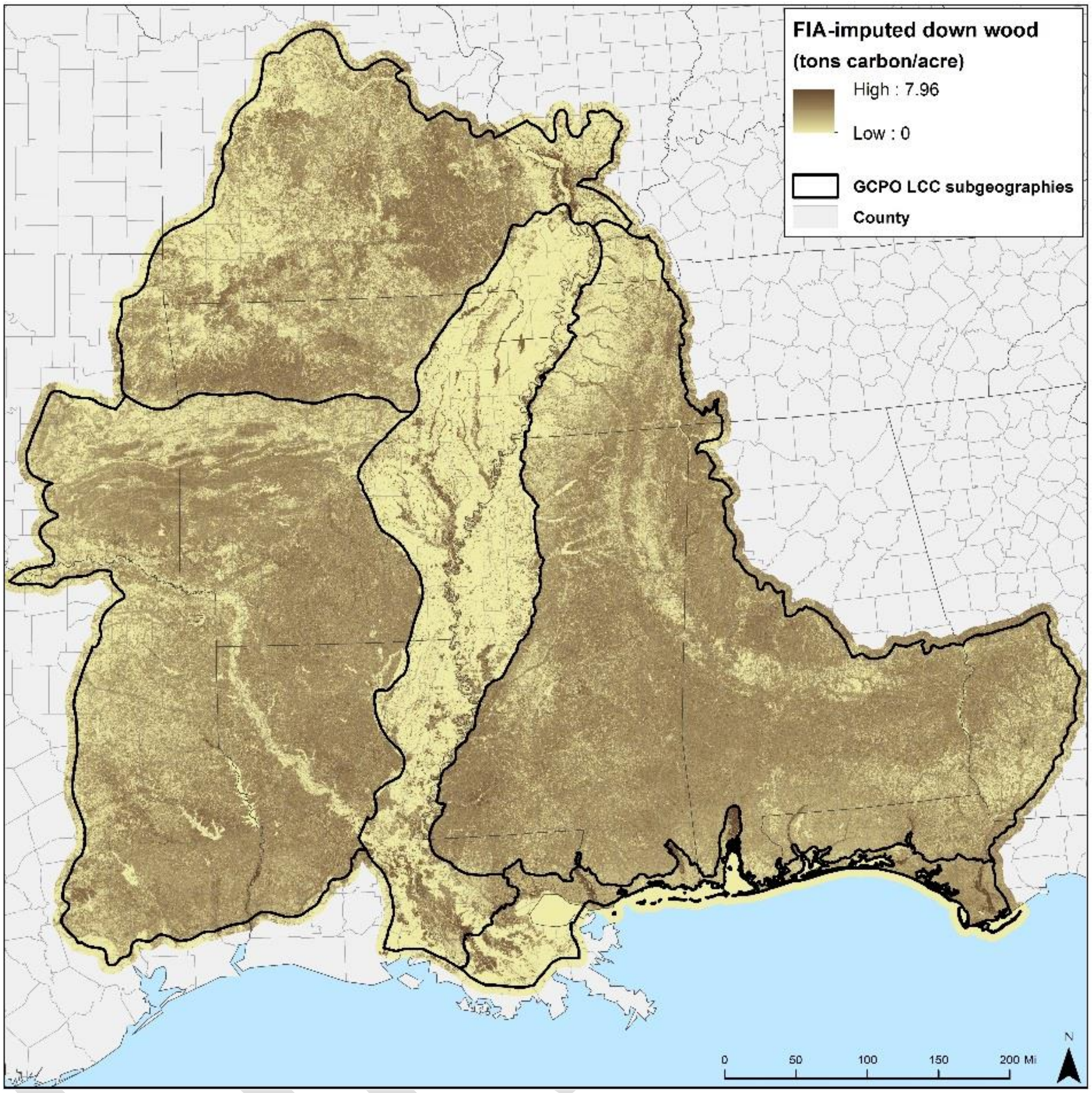

Figure UH.16. Dead-down wood in tons carbon/acre within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

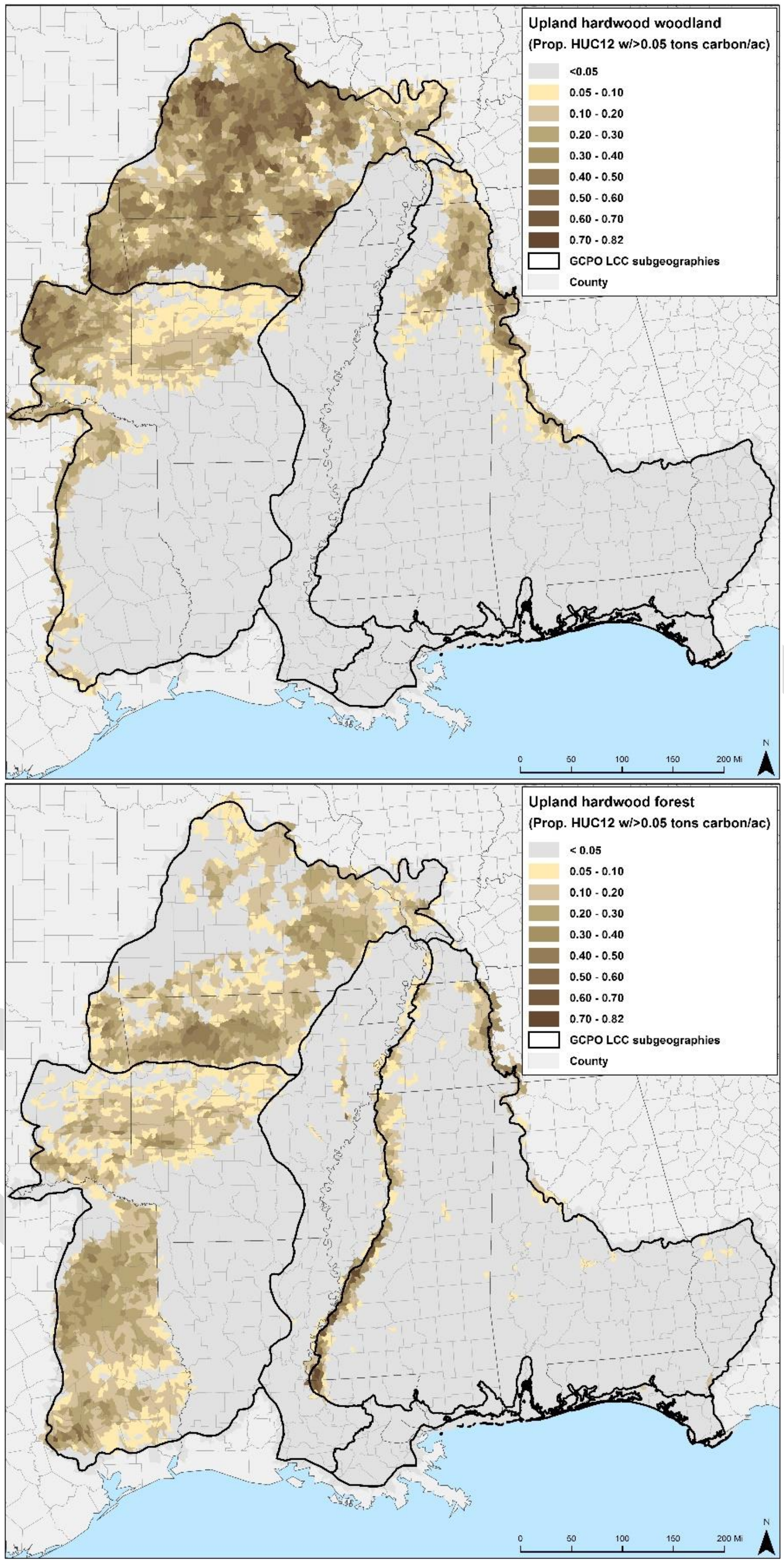

Figure UH.17. Upland hardwood woodlands and forests exhibiting >0.05 tons carbon/acre dead-down wood summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

Future Directions and Limitations

The current endpoint dead-down wood is based off of the assumption that a limited number of large down logs must be present in an upland hardwood system to support priority ISA species, particularly salamander and other detritus-dependent species. However, assuming this is a minimum threshold for the endpoint, we recommend the ASMT revisit this metric and the body of scientific literature that supports the minimum threshold based on species needs for this element of forest structure to make the habitat viable. An upper threshold may also be considered, similar to the assessment of large snag density if concentration of high amounts of down wood could indicate a stressed or diseased upland hardwood forest. Further, the assessment of CWD in the form of tons carbon/acre represents a broad assumption that >0.05 tons carbon/acre would be reflective of at least one 6' down log (≥8" dbh)/acre. Our recommendation for future ISA revisions is to quantify CWD in terms of carbon tonnage, such that the endpoint is more effectively measured in the future.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- Dead-down wood (tons carbon/acre) in the GCPO LCC geography (raster 250 m and proportional HUC12 vector)

Technical References

Herbeck, L., and D, Larsen. 1999. Plethodontid salamander response to silviculture practices in Missouri Ozark forests. Conservation Biology 13:623-632.

Chapter 8: Condition, structure, midstory density

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Midstory density ≤20%

Vertical structure in the form of vegetation layers has been identified as an important component of Ozark hardwood systems, with 2 to 3 layers desired for dry-mesic woodland and flatwood systems and 3 or greater layers for mesic and dry-mesic forest systems (M. Leahy, Missouri Department of Conservation, personal communication). Limited midstory density was identified in the ISA as an important component of upland hardwood systems in the GCPO geography, with midstory coverage ≤20% indicating a healthy additional vertical strata in the system. Midstory is an important habitat component for several ISA priority species, particularly those avian species who require midstory structure for nesting such as the wood thrush (*Hylocichla mustelina*).

We again used plot-level FIA data imputed at 250 m resolution across the GCPO LCC to assess tree density. The USFS imputed tree density data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the FIA program. Note estimates of midstory tree density were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. Midstory density is calculated by using FIA Phase II crown class code (CCLCD) of 5, which indicates the amount of sunlight received and the crown position in the canopy. A CCLCD = 5 indicated "overtopped" with trees and crowns entirely below the general canopy level and receiving no direct light either from above or the sides. For this assessment a CCLCD of 5 was combined with a diameter (DBH) value between 4.3 and 9.8" to assess midstory crown position in the canopy. However, the ISA endpoint of midstory density ≤20% is not an appropriate metric because it could either be defined as ≤20% of total live tree midstory density or could be defined as ≤20% midstory canopy cover. We therefore could not calculate percent midstory cover from FIA data in these systems, but in the absence of a quantifiable relationship between density and percent cover we used the bottom quantile (bottom 20%) of imputed midstory density values in upland hardwood woodlands (i.e., midstory density <99.35 trees/acre) and forests (i.e., midstory density <141.5 trees/acre) as a surrogate for ≤20% midstory cover. We used an extract by mask function in ArcGIS to delineate midstory density within the target ranges in upland hardwood woodland and forest, using the USFS imputed midstory density layer as input data and the woodland and forest data as masks. We then reclassified the product to pull out pixels with midstory density <99.35 trees/acre for woodlands and <141.5 trees/acre for forests. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres upland hardwood (midstory density target/acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Average midstory density ranged from 192-291 trees/acre in upland hardwood woodlands, and 91-293 trees/acre in upland hardwood forests (**Table UH.16**). We estimate 1.55 million acres (16%) of upland hardwood woodlands and over 44,419 million acres (12%) of upland hardwood forests exhibited the lower quantile range (i.e., lower 20%) of midstory density in the Ozark Highlands subgeography, with nearly 2.5 million acres woodland and 1.9 million acres forest in the lower quantile across the entire GCPO LCC geography. Midstory density across all GCPO systems appeared to be greatest along the southern GCPO border in eastern Texas, and in small areas in the Ozark Highands, as well as in pineywoods areas in the East Gulf Coastal Plain (**Figure UH.18**). However, concentrations of target bottom 20% of midstory densities in upland hardwood woodlands and forests never exceeded 34% of a HUC12 watershed (**Figure UH.19**). In upland hardwood woodlands, we observed the greatest concentrations of target midstory densities along the western GCPO boundary in the West Gulf Coastal Plains (eastern Oklahoma in particular), as well as in western portions of the Ozark Highlands. For upland hardwood forests we also observed greater concentrations of target midstory densities along the West Gulf Coastal Plains in eastern Oklahoma and Texas, as well as in the southern portion of the Mississippi Loess Hills in the East Gulf Coastal Plain subgeography.

Table UH.16. Average midstory density (trees/acre) and acres demonstrating midstory density <99.35 trees/acre in upland hardwood woodlands and <141.5 trees/acre in upland hardwood forests (representing bottom 20% of values as surrogate for midstory cover) by GCPO LCC subgeography.

LCC subgeography	Average midstory density (trees/ac) upland hardwood woodlands	Acres woodlands w/ <99.35 trees/acre	Average midstory density (trees/ac) upland hardwood forest	Acres forests w/ <141.5 trees/acre
Ozark Highlands	243	1,546,431	293	444,419
Mississippi Alluvial Valley	206	17,653	251	39,506
East Gulf Coastal Plain	291	142,796	273	272,928
West Gulf Coastal Plain	192	792,544	250	1,122,383
Gulf Coast	N/A	N/A	91	8,062
GCPO LCC	233	2,499,422	232	1,887,297

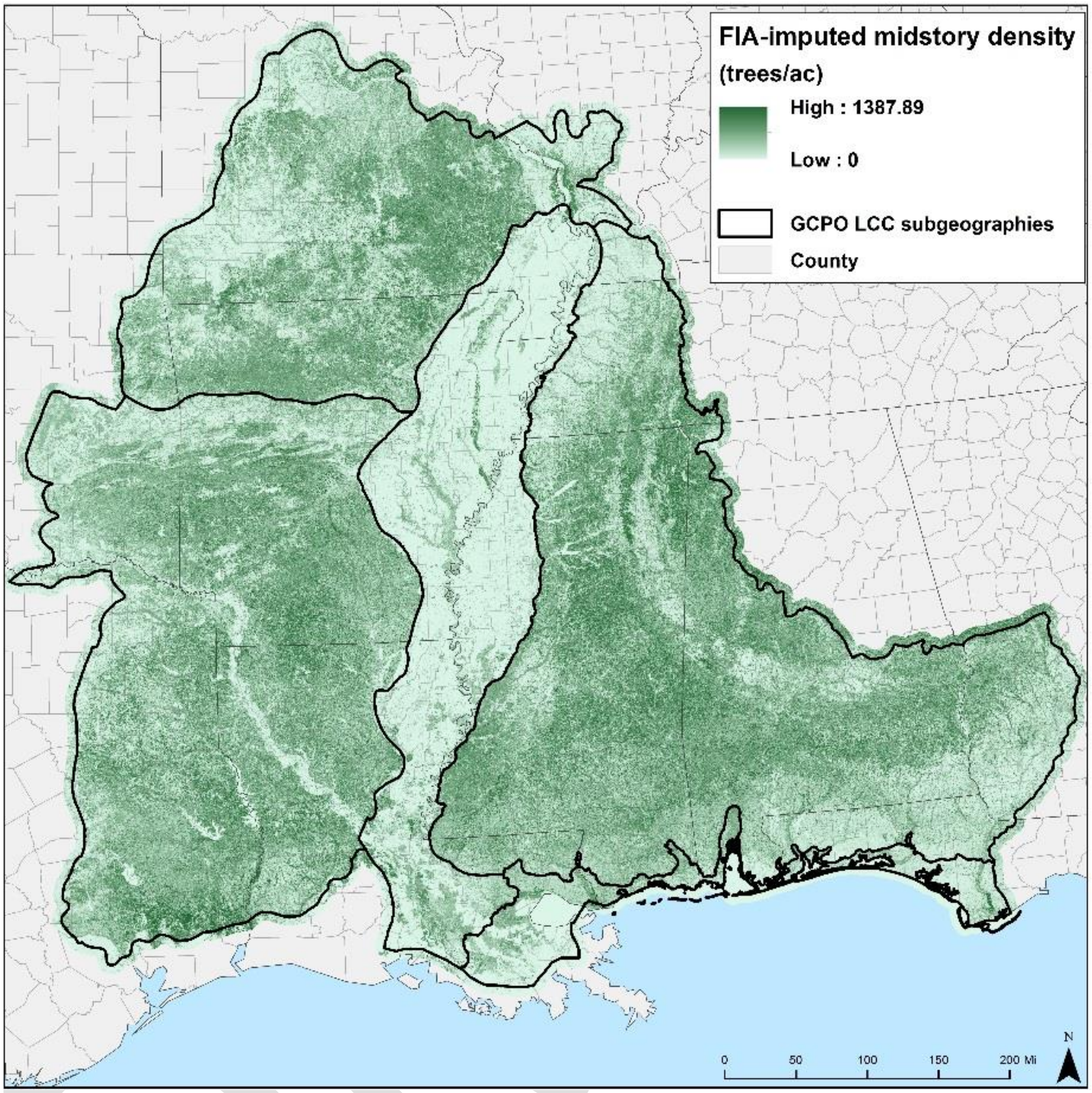

Figure UH.18. Midstory density (trees/acre) within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

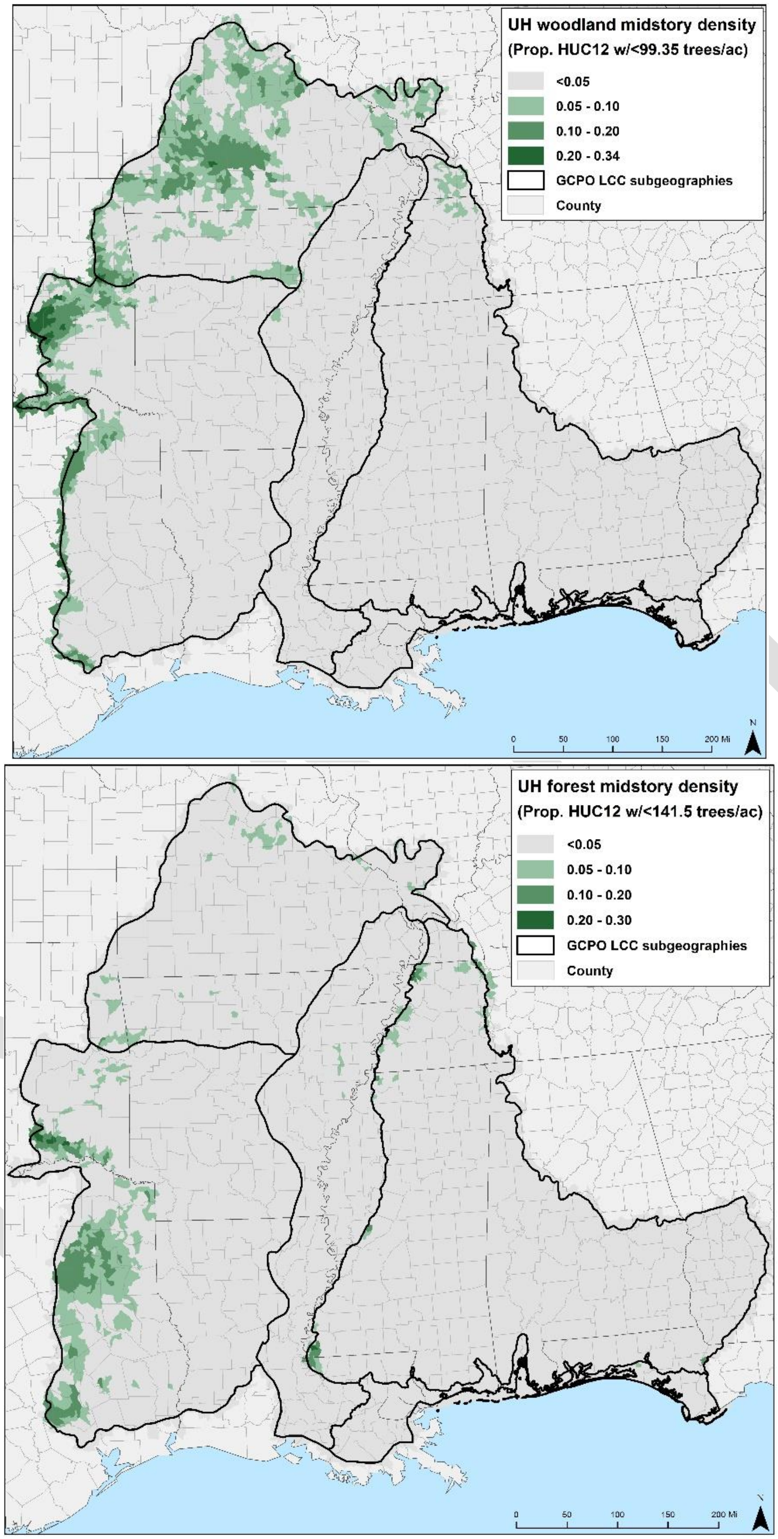

Figure UH.19. Upland hardwood woodlands exhibiting <99.35 midstory trees/acre and forests exhibiting <141.5 midstory trees/acre, reflecting the bottom 20% of midstory values, summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

Future Directions and Limitations

Upcoming revisions to the ISA must take a critical look at the endpoint for midstory density and clarify the desired measurable attribute such that this endpoint can be better reflected in future iterations of the GCPO conservation blueprint. Further, the endpoint must reflect the desired range of conditions that will elucidate the ecological integrity of the upland hardwoods system while supporting priority wildlife species.

Conservation Planning Atlas Links to Available Geospatial Data Outputs:

- Density of Midstory Trees (trees/acre) in the GCPO LCC (raster 250 m and proportional HUC12 vector)

Chapter 9: Condition, structure, basal area

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Condition

Desired Landscape Endpoint: Oak and hickory basal area:

- >90% for woodlands
- >70% for forests

Added Landscape Endpoint: Total live tree basal area:

- 30 - 80 ft^2/ac for woodlands
- 80 - 100 ft^2/ac for forests

Basal area is a measure of the cross-sectional area of trees calculated by multiplying the foresters' constant (0.005454) by the squared diameter of each tree to determine a measure of tree area (ft^2 or m^2) per unit area (acre or ha). Basal area can be thought of as the "footprint occupied by trees" in a given area, and is one of the primary forest inventory metrics used in southeastern forest management (LMVJV Forest Resource Conservation Working Group 2007). Similar to an assessment of forest canopy cover, basal area provides a measure of horizontal structure, and is closely associated with measures of vertical structure (e.g., canopy cover, Cade 1997). Basal area in the range of 30-60 ft^2/acre have been suggested for dry open woodlands and flatwoods,60-80 ft^2/ac for dry-mesic woodlands, and 70-80 ft^2/ac for mesic and dry mesic forest have been suggested previously for the Missouri Ozarks (M. Leahy, Missouri Department of Conservation, personal communication) and in the 80-100 ft^2/ac range in Mark Twain National Forest hardwoods (USFS 2005). Sheehan (2014) also reports an optimized range of basal area between 44 and 87 ft^2/ac for cerulean warbler habitat.

When assessing condition of upland hardwood woodland and forest systems, the ISA targets a large proportion of the basal area in those systems to be composed of oak and hickory species. This endpoint targets >90% of basal area as oak and hickory for upland hardwood woodland systems and >70% for upland hardwood forest systems, and results from the desire for these systems to contain ample hardwood mast-producing trees, particularly for species like the black bear and wild turkey (*Meleagris gallopavo*). However, in consultations with the GCPO ASMT during the conservation blueprint development, the team determined that an additional endpoint that examined total live tree basal area for woodland and forest systems would provide a more comprehensive assessment of basal area when used in combination of proportional oak-hickory composition. We therefore added a component to the basal area endpoint that targets 30 - 80 ft^2/ac total live tree basal area for upland hardwood woodlands and 80-100 ft^2/ac for upland hardwood forests. Assessing total basal area allows for better assessment of forest structure in addition to forest composition, and reduces the risk that forest systems with undesirable high basal area but that reflect the proper composition of oaks and hickories being included in the assessment.

We used plot-level imputed data from the FIA program at 250 m resolution to assess the proportion of total live tree basal area composed of oak and hickory species and total live tree basal area in the GCPO (USDA Forest Service Remote Sensing Applications Center, personal communication). The USFS per-species (Wilson et al. 2013) and total live tree basal area data product provides raster maps for the conterminous U.S. generated using a weighted k-nearest neighbor and canonical correspondence analysis from a combination of vegetation phenology data produced from 250 m resolution MODIS satellite imagery, ancillary environmental data, NLCD tree canopy cover data, and 2000-2009 plot-level field data from the FIA program (Wilson et al. 2012). Note live tree basal area estimates were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. Proportion of basal area comprised of oak and hickory species was developed using the per-species basal area to select out oak and hickory tree species, summing oak and hickory basal area, then calculating the proportion of the total live tree basal area comprised of oak and hickory species on a per-250 m pixel basis. We used an extract by mask function in ArcGIS to delineate pixels where total basal area and proportion of basal area oak and hickory were within the target ranges in upland hardwood woodland and forest systems, using the USFS imputed basal area layers as input data and the woodland and forest data as masks. We then reclassified each product to pull out pixels with total basal area 30 - 80 ft^2/ac and proportion of basal area oak-hickory >90% for upland hardwood woodlands. We did the same for upland hardwood forests, pulling out pixels with total basal area 80-100 ft^2/ac and proportion of basal area oak-hickory >70%. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres upland hardwood (basal area target/acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Average basal area within upland hardwood woodlands fell in the mid-range of the endpoint target in the Ozark Highlands subgeography (66 ft^2/ac), and GCPO-wide (63 ft^2/ac) suggesting woodlands delineated in this assessment consistently demonstrated an important component of forest structure (**Table UH.17**). Over 5.6 million acres (57%) of upland hardwood woodlands in the Ozark Highlands demonstrated 30-80 ft^2/ac basal area. We also found 64% of woodlands in the West Gulf Coastal Plain subgeography were within the targeted basal area range, and 59% GCPO-wide. We found only a small percentage of woodlands (6% in the Ozark Highlands, 5% GCPO-wide) exhibited >90% of their total basal area as oak and hickory species. This suggests that though woodlands are largely meeting forest structure targets, they are not in desired condition in terms of tree species composition.

Average basal area within upland hardwood forests fell below the lower threshold for endpoint target in the Ozark Highlands subgeography (77 ft^2/ac), and GCPO-wide (65 ft^2/ac) suggesting forests delineated in this assessment may have greater woodland structure characteristics than desired for a closed-canopy forest system (**Table UH.17**). We found that 1.4 million acres of upland hardwood forests (40%) in the Ozark Highlands, and 2.8 million acres (29%) GCPO-wide were within the target range of 80-100 ft^2/ac basal area. However, note that the range of targeted values for the forest endpoint is much more restrictive than the range of targeted values for woodland systems, so it is not surprising to see lower percentages falling within the target. We found 53% of upland hardwood forests in the Ozark Highlands (23% GCPO-wide) exhibited >70% of their total basal area as oak and hickory species. This suggests a contradiction to that of woodlands, whereby forests are not meeting forest structure targets, but are in desired condition in terms of tree species composition.

Table UH.17. Average total live tree basal area (ft^2/ac), acres demonstrating total basal area and proportion of basal area composed of oak and hickory species within endpoint targets in upland hardwood woodlands forests by GCPO LCC subgeography.

LCC subgeography	**Average basal area (ft^2/ac) upland hardwood woodlands**	**Acres woodlands w/30-80 ft^2/ac basal area**	**Acres woodlands w/>90% basal area oak-hickory**		**Average basal area (ft^2/ac) upland hardwood forests**	**Acres forests w/80-100 ft^2/ac basal area**	**Acres forests w/>70% basal area oak-hickory**
Ozark Highlands	**66**	**5,613,859**	**630,319**		**77**	**1,438,106**	**2,017,166**
West Gulf Coastal Plain	56	1,953,938	42,440		62	880,235	229,097
East Gulf Coastal Plain	69	793,455	263		73	437,870	4,000
Mississippi Alluvial Valley	62	32,093	664		73	46,919	13,313
Gulf Coast	N/A	N/A	N/A		40	757	0
GCPO LCC	63	8,393,344	673,686		65	2,803,887	2,263,576

Total basal area was generally consistent throughout forested systems in the Ozark Highlands (**Figure UH.20**). When summarized by HUC12 watershed we found areas in the northern and western Ozarks, in the vicinity of Lake of the Ozarks in central Missouri and west of Eufaula Lake in eastern Oklahoma to exhibit concentrations of upland hardwood woodlands between 30-80 ft^2/ac basal area (**Figure UH.21**). In some cases up to 62% of the HUC12 watershed met the woodland basal area target. There was also some concentration of woodlands within the target range in the eastern boundary of the Ozarks Highlands, along the Arkansas-Missouri border, south of the Mark Twain National Forest, and particularly within the Fourche Creek Conservation Area in Missouri. Concentrations of upland hardwood forest meeting the total basal area target of 80-100 ft^2/ac were typically <30% of the HUC12 watershed throughout the Ozark Highlands (**Figure UH.21**). The majority of forest acreage meeting the target range was found within the vicinity of the Ozark St. Francis National Forest in northern Arkansas, and the Mark Twain National Forest in southern Missouri. Areas of greatest concentration, nearly half of the HUC12 watershed in some instances were found primarily in private landownership along the Loess Hills in southwestern Mississippi, similar to what has been shown for other endpoints in this assessment.

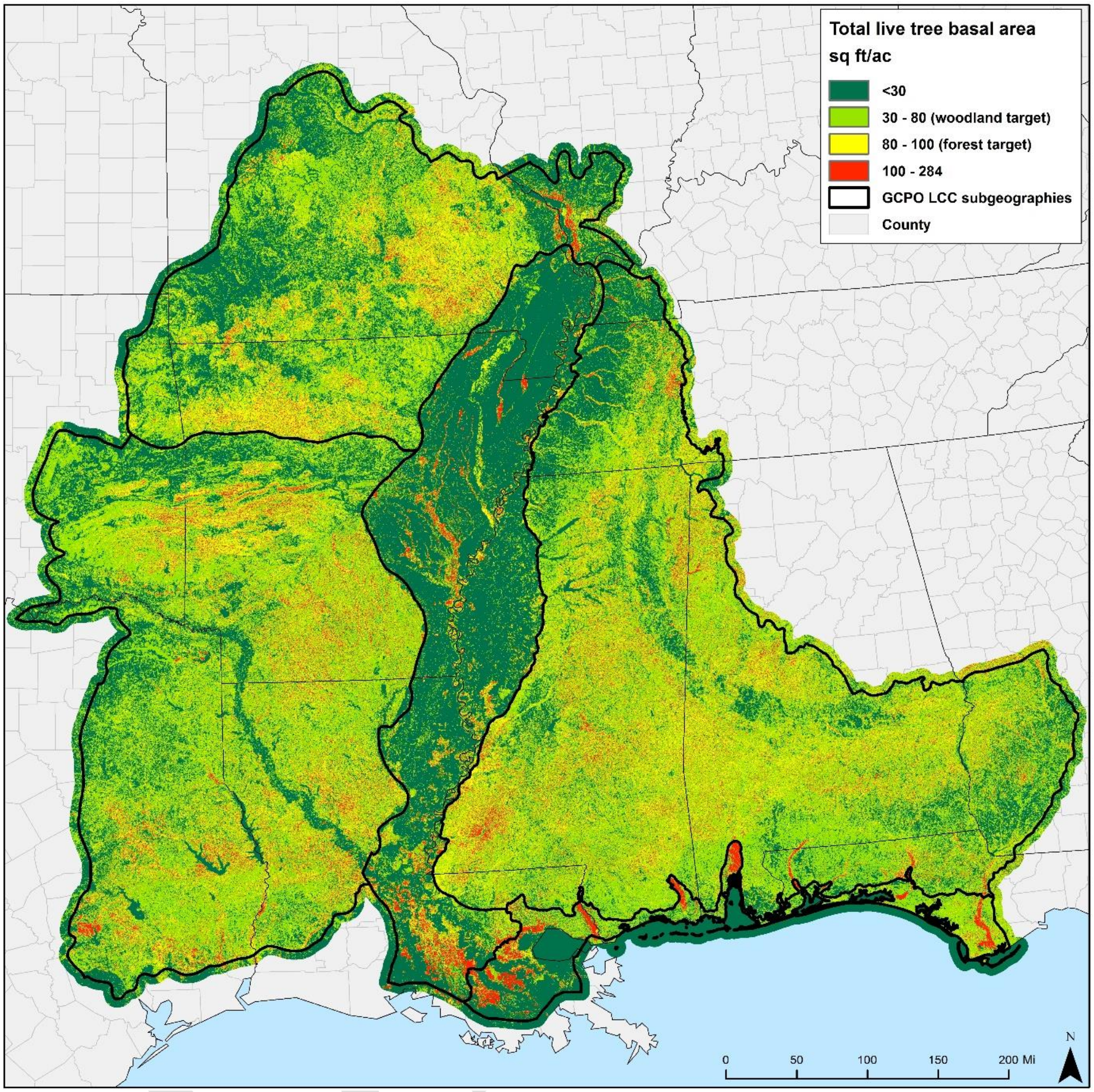

Figure UH.20. Total live tree basal area (ft^2/ac) within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

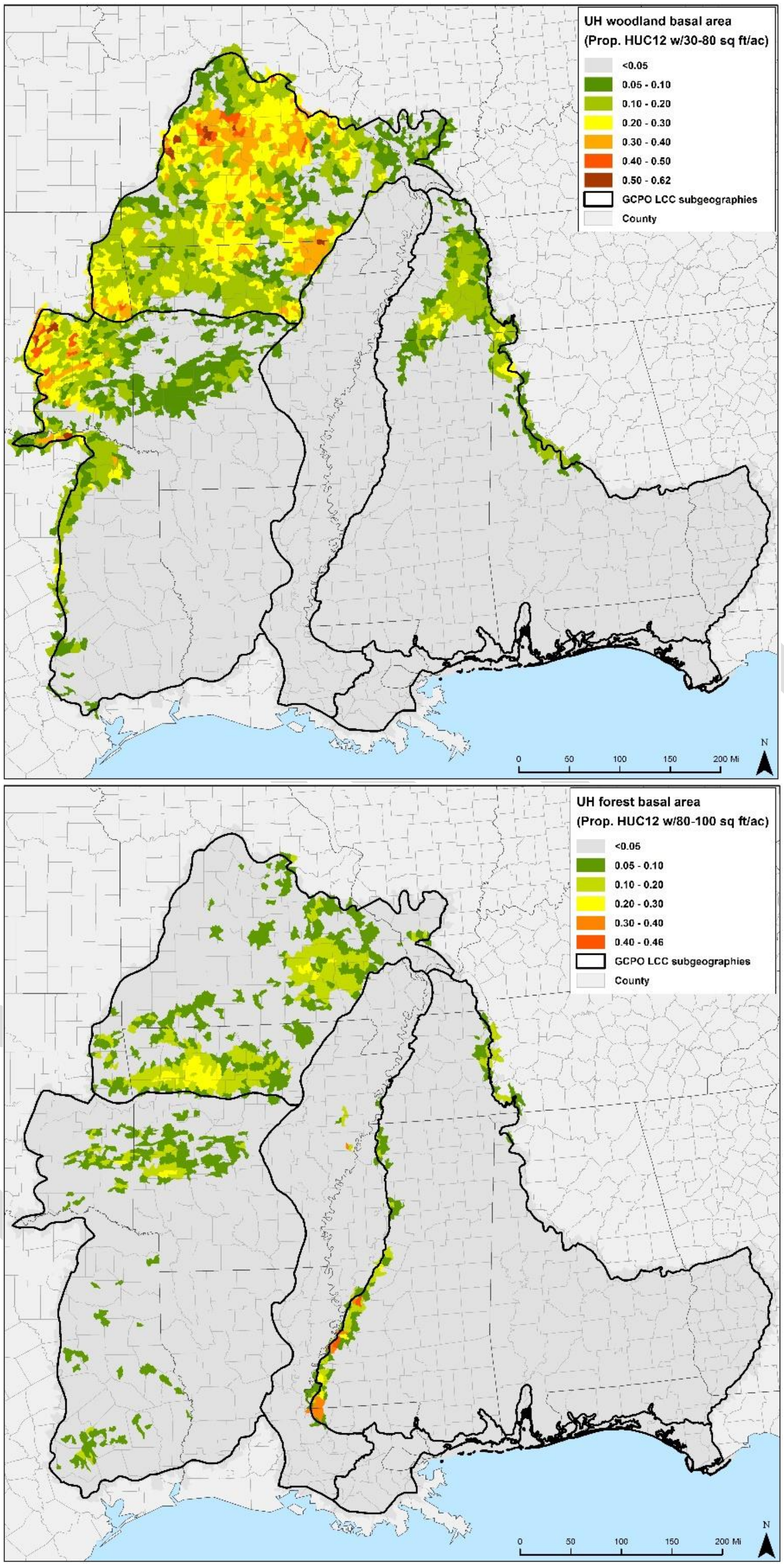

Figure UH.21. Upland hardwood woodlands exhibiting 30-80 ft^2/ac basal area and forests exhibiting 80-100 ft^2/ac basal area targets summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

When we examine the proportion of total basal area comprised of oak and hickory we found the Ozark Highlands and northwestern portions of the West Gulf Coastal Plain to dominate the GCPO LCC geography, with the vast majority of acreage reflecting >50% oak and hickory composition (**Figure UH.22**). When we examined by HUC12 watershed we found a limited area of the Ozark Highlands with a maximum of 37% of the watershed meeting the target endpoint of >90% of the total basal area being oak and hickory. These areas were found along the GCPO boundary in eastern Oklahoma, east of Muskogee, and in the vicinity of Lake of the Ozarks in central Missouri (**Figure UH.23**). There were more areas, but similar concentrations of upland hardwood forests meeting the target >70% proportion of basal area in oak and hickory. Similar to woodlands, acreage meeting target ranges never exceeded 36% of a watershed, with greatest concentrations in eastern Oklahoma, centered on the Cookson Hills fee title lands and Wildlife Management Area and Spavinaw Game Management Area. Other areas of concentration were found in the vicinity of the Ozark-St. Francis National Forest in northern Arkansas, and Mark Twain National Forest in southern Missouri.

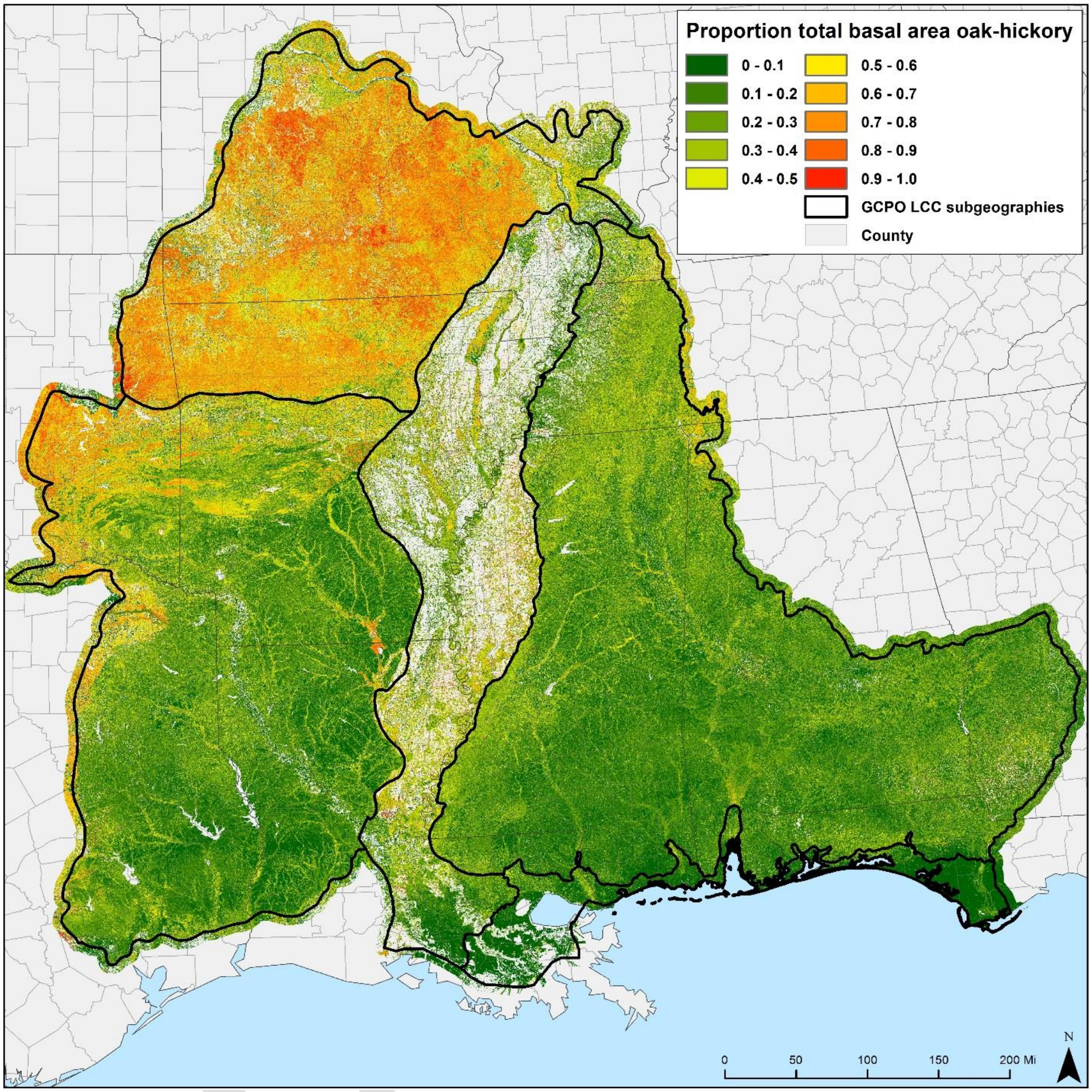

Figure UH.22. Proportion of total live tree basal area comprised of oak and hickory species within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

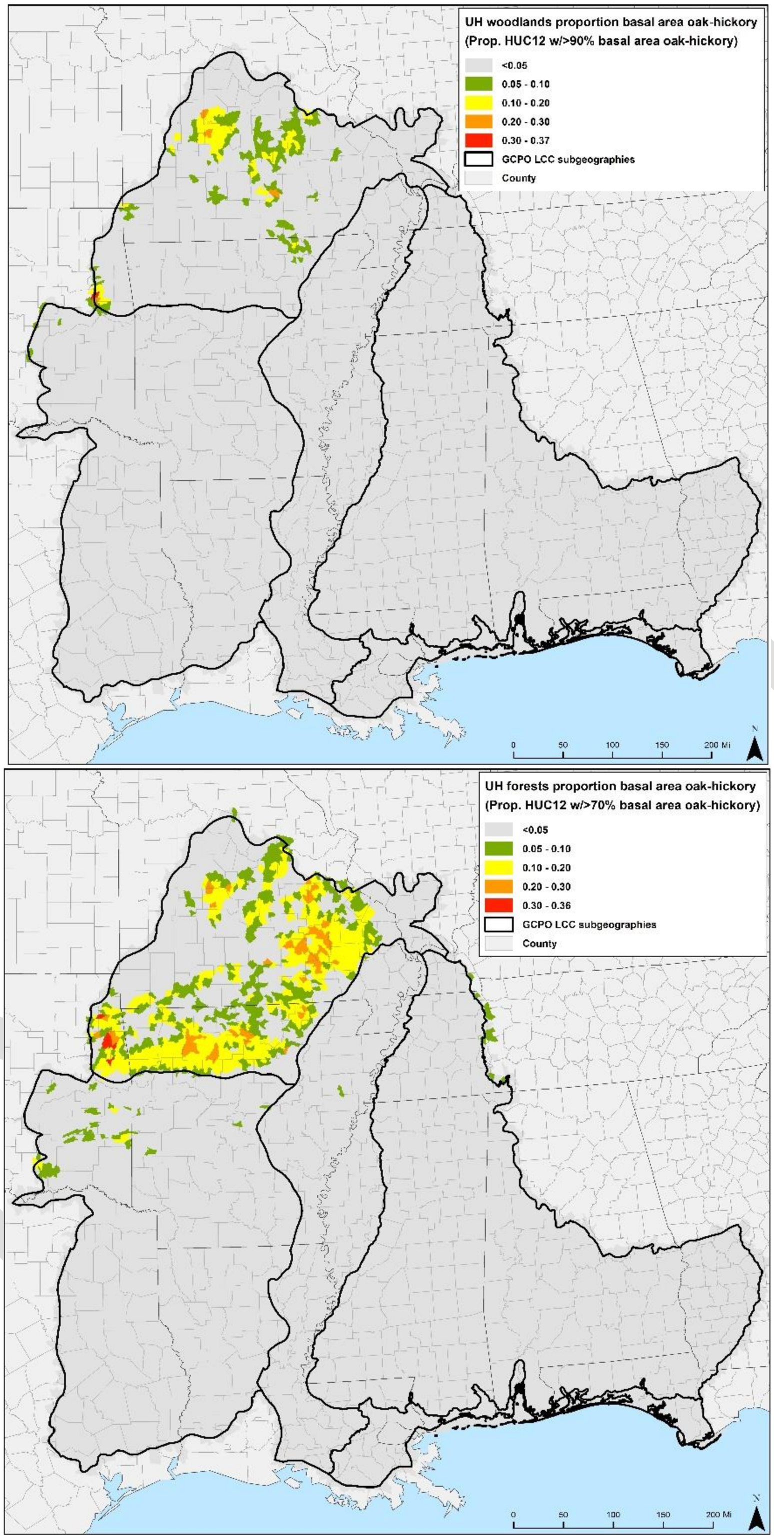

Figure UH.23. Upland hardwood woodlands exhibiting >90% of total basal area as oak-hickory and forests exhibiting >70% of basal area as oak-hickory, summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

Future Directions and Limitations

The endpoint suggesting proportion of total basal area dominated by oaks and hickories is an important consideration for upland hardwood systems, ensuring areas managed for upland hardwoods actually reflect a hardwood dominance. Through the endpoint the ASMT is suggesting that upland hardwood woodlands be almost entirely composed of oak and hickory species in the overstory. This constraint is relaxed some for upland hardwood forests, allowing for up to 30% of the total basal area to be comprised of species other than oak and hickory. Though this endpoint adequately addresses issues of forest composition, during the conservation blueprint process we quickly realized that assessing targets of proportional basal area alone says little about forest structure. A pixel that falls well outside the range of a desirable basal area for woodlands or forests could theoretically reflect the desired proportion of oak and hickory. Though these total basal area ranges have yet to be incorporated into an ISA revision, they were sanctioned by members of the ASMT and the consensus was that it was necessary to include these ranges as an expansion of the basal area endpoint in the ecological assessment and subsequent calculation of a condition index. We encourage the ASMT to formally consider the total basal area endpoint for addition to the next version of the ISA in addition to the proportion of oak-hickory endpoint for a more holistic assessment of forest structure. Live tree basal area estimates presented here relied on a combination of remote sensing, ancillary environmental data and plot-level FIA data to impute a continuous data layer. FIA data plots are collected at one plot per 6,000 acres across the landscape, are typically restricted to forest strata (Bechtold and Patterson 2005), and depend on the representativeness of plot-level data to the surrounding landscape (Riemann et al. 2010). However, the FIA program is one of the only landscape-scale forest characterizations collected in a systematic and standardized manner presently available. Because of these assumptions we recommend acreage estimates of target basal area across the MAV and GCPO landscape be approached cautiously, applied at a coarse scale, and acknowledge all potential limitations in interpretation. Given these caveats, the assessment of basal area suggest an interesting pattern whereby woodlands are largely meeting forest structure targets, based on total basal area, but they are not in desired condition in terms of tree species composition, based on proportion of basal area in oak and hickory species. In contrast, a much greater range of upland hardwood forests delineated in this assessment may exhibit more woodland structure characteristics than desired for a closed-canopy forest system. Basal areas in what is delineated as forest fall more within the range of a woodland than forest, and this finding is consistent with estimates from the assessment of overstory canopy cover. However, a greater percentage of forests fall within targets of proportion of basal area of oak hickory. Forest structure as represented by total basal area may be too low, but forest composition is closer to the desired condition than that of woodlands. Clarification and validation is needed to determine if these issues are related to woodland and forest classification or actual issues associated with forest management. It is possible that woodlands are being classified as forest, thus the observed total basal area lower than desired. Conversely, forests could be classified correctly, but just carrying or managed for basal area values below those used in this analysis.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Total Live Tree Basal Area and Proportion of Basal Area Oak-Hickory in the GCPO LCC (raster 250 m and proportional HUC12 vector)

Technical References

Bechtold, W. A., and P. L. Patterson. 2005. The Enhanced Forest Inventory and Analysis Program – National sampling design and estimation procedures. U. S. Department of Agriculture, Forest Service Southern Research Station. General Technical Report SRS-80. Asheville, NC. < http://www.fia.fs.fed.us/library/sampling/ Accessed 30 June 2014.

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Riemann, R., B. T. Wilson, A. Lister, and S. Parks. 2010. An effective assessment protocol for continuous geospatial datasets of forest characteristics using USFS Forest Inventory and Analysis (FIA) data. Remote Sensing of Environment 114: 2337-2352.

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Wilson, B. Tyler; Lister, Andrew J.; Riemann, Rachel I. 2012. A nearest-neighbor imputation approach to mapping tree species over large areas using forest inventory plots and moderate resolution raster data. Forest Ecology and Management. 271: 182-198. http://www.nrs.fs.fed.us/pubs/40312.

U.S. Forest Service. 2005. Mark Twain National Forest – Forest Plan, Appendix A: Terrestrial Natural Communities. https://www.fs.usda.gov/main/mtnf/landmanagement/planning

Chapter 10: Temporal considerations, distribution of successional stages, fire return interval

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

Landscape Attribute: Temporal considerations

Desired Landscape Endpoint:

- An appropriate distribution of successional stages; ≤10% of the landscape
- Fire return interval:
    - 3 years for woodland
    - 10 years for forest

Forest succession

Temporal dynamics of each GCPO priority system are recognized as important contributors to the overall system integrity. The ISA alludes to the desired condition that forest structure should be dominated by mature upland hardwood stands across the greater landscape. However, to ensure future forest sustainability a small portion (≤10% of the landscape) should be in a state of regeneration, or early forest succession. The ISA provides this endpoint as a general target, but lacks specificity regarding the desired composition of forest stand ages because there is limited literature available that assesses upland hardwood stand age from an ecosystem integrity perspective. Priority wildlife species will also respond differentially to forest stand age depending on life history needs of the species. Composition of early-successional forest in the landscape also depend on management regimes on protected lands and land use history in surrounding private lands. However, forest practitioners in the southeast typically practice even-aged management, particularly in long-rotation upland hardwood systems. Therefore, forest regeneration will more frequently be found in a patch mosaic of regenerating clearcuts, with some potential for uneven-aged management regimes in some of the larger protected lands in the Ozark Highlands and West Gulf Coastal Plain.

We used plot-level 250 m resolution imputed data from the FIA program to assess forest stand age as a proxy for successional stage distribution in the GCPO (USDA Forest Service Remote Sensing Applications Center, personal communication). The USFS stand age data provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the FIA program, and calculates stand age on a per-acre-of-land basis, though forested lands were the primary sampling frame. We first extracted the forest stand age data layer through the upland hardwood woodland and forest masks to assess stand age within our target system. Because the ISA does not provide criteria for determination of succession, we derived quantiles from the extracted stand age layer, and used the bottom quantile (bottom 20%) of imputed values in upland hardwood woodlands (i.e., stand age ≤22.2 years) and forests (i.e., stand age ≤19.5 years) to represent young and successional forests in the landscape. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres using the Tabulate Area tool in ArcGIS. We also could not determine the target size of the landscape within which to evaluate distribution of successional stages. Therefore, to be consistent with summary metrics the other endpoints in the assessment we assumed the landscape of interest to be at the scale of a HUC12 watershed. For display we calculated the proportional area (acres upland hardwood (stand age bottom quantile/acres HUC 12) within each HUC 12 watershed using the tabulate area tool in ArcGIS.

Using imputed FIA data we estimate age in upland hardwood woodland stands to be older on average in the Ozark Highlands than in other GCPO subgeographies, with woodlands in the Ozarks averaging 46 years/acre, compared to 36 years/acre when estimated GCPO-wide (**Table UH.18**). We found over 1.2 million acres of woodland pixels exhibited stand ages ≤22.2 years, representing 13% of woodlands in the Ozark Highlands. Over 2.6 million acres of woodlands, or 19% GCPO-wide, were found in a young forest condition, suggesting other subgeographies have a greater proportion of their woodlands in a younger successional stage than in the Ozarks. We found that upland hardwood forests also tend to be more mature on average in the Ozark Highlands compared to other subgeographies, with an average stand age of 53 years, compared to the GCPO-wide average stand age of 35 years (**Table UH.18**). However, we found much less acreage of young successional forests (≤19.5 years/acre) in the Ozark Highlands subgeography (147,954 acres, or 4% of forests) compared to other subgeographies. In fact, 20% of upland hardwood forests across the GCPO were found to be in a young forest successional stage, which is twice that desired in the ISA endpoint. When examined together we found upland hardwood woodland and forest stands tend to be youngest in the West Gulf Coastal Plain, East Gulf Coastal Plain, and Gulf Coast, with greater proportions of the woodland and forest systems being found in a young forest stage than those found in the Ozark Highlands.

Table UH.18. Average stand age (years)/acre, acres demonstrating stand age and within endpoint targets, as represented by the bottom 20% of stand age values, in upland hardwood woodlands and forests by GCPO LCC subgeography.

LCC subgeography	Average stand age (yr/ac) upland hardwood woodlands	Acres woodlands w/≤22.2 yr stand age	Average stand age (yr/ac) upland hardwood forests	Acres forests w/≤19.5 yr stand age
Ozark Highlands	**46**	**1,270,151**	**53**	**147,954**
West Gulf Coastal Plain	31	976,174	28	1,518,523
East Gulf Coastal Plain	31	401,222	33	253,962
Mississippi Alluvial Valley	37	18,440	39	20,896
Gulf Coast	N/A	N/A	22	5,251
GCPO LCC	36	2,665,987	35	1,946,586

An assessment of all imputed forest stand age values reveals that hardwood-dominated systems in the Ozark Highlands and Ouachita Mountains of the West Gulf Coastal Plain have some of the oldest stand ages in the GCPO geography, in addition to the forested wetland systems prevalent within the Mississippi Alluvial Valley and along the GCPO Gulf Coast (**Figure UH.24**). When assessed by proportion of HUC12 watershed it appears that much of the Ozark Highlands and northern portions of the West and East Gulf Coastal Plains fall within the threshold of ≤10% the landscape being in a young forest successional stage (**Figure UH.25**).

However, this assumes that a HUC12 watershed is an appropriate scale for the assessment of stand age. It is clear that there is a much greater prevalence of young forest regeneration in upland hardwood woodlands and forests in the western portions of the GCPO geography, particularly parts of eastern Oklahoma and Texas, where proportions of young forest succession regularly exceeded 10% in the HUC12 watershed **(Figure UH.25**). However, proportion of a HUC12 watershed never exceeded 25% for young forests in either woodland or forest system.

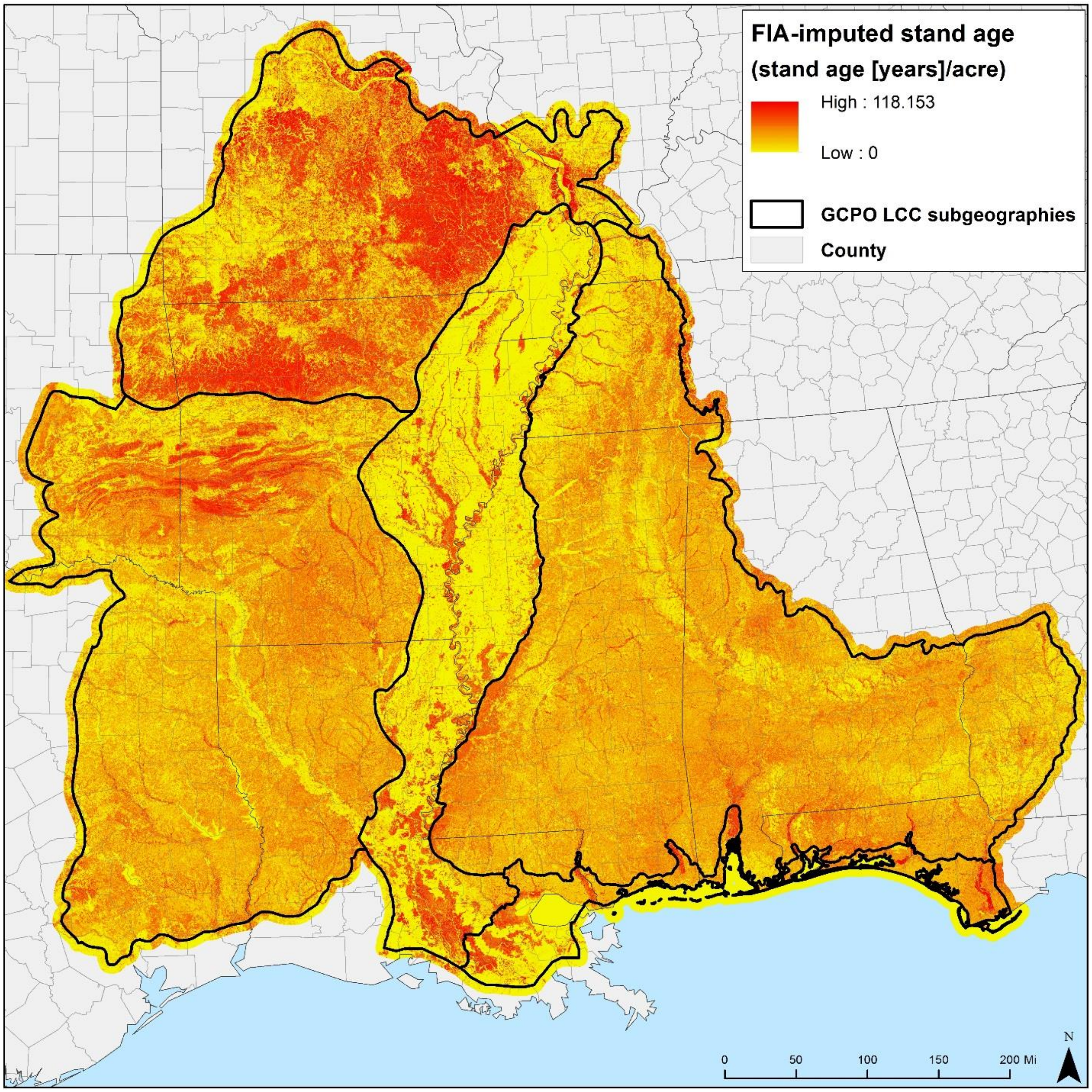


Figure UH.25. Mean forest stand age (years)/acre within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

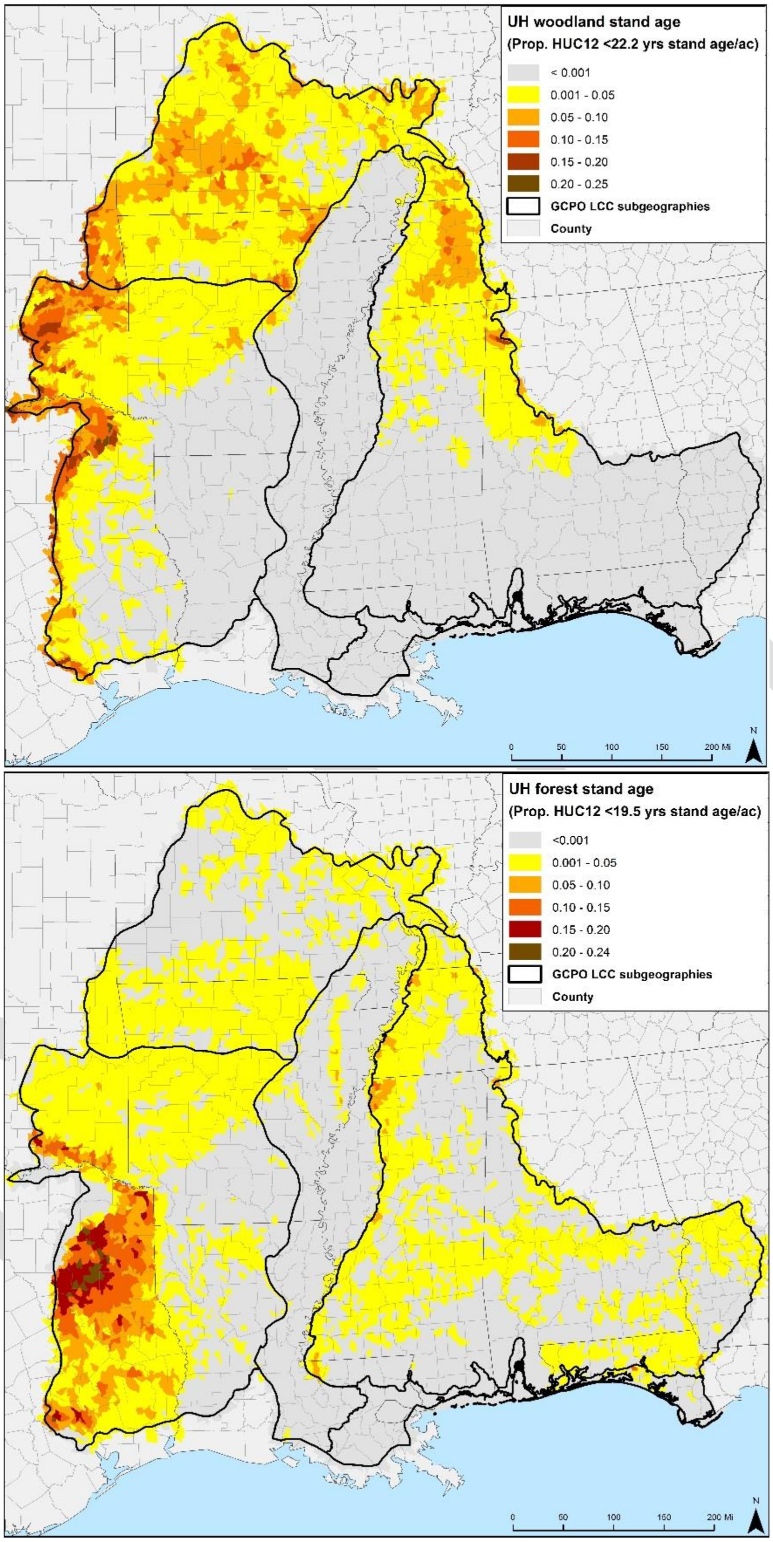


Figure UH.26. Upland hardwood woodlands exhibiting stand ages/acre of <22.2 years and forests exhibiting stand ages/acre <19.5 years, reflecting the bottom quantile, or bottom 20% of stand age values, and summarized by proportion of HUC12 watershed within the GCPO LCC geography, derived from imputed Forest Inventory and Analysis data provided by the USFS Remote Sensing Applications Center.

Fire return interval

Fires were a characteristic trait of upland hardwood systems in the Ozark Highlands, often maintaining hardwood woodland conditions throughout the region. Though not as well-promoted as in pine systems, fire has been suggested as essential to oak forest systems, with minimal damage due to bark thickness in many oak species (Van Lear 2004). Fire return intervals have been suggested to vary in the Ozarks from 12-18 years on average during Native American occupation times, to 4 years on average during European settlement through 1940 (Shang et al. 2007). Active efforts to suppress wildfires after the 1940's in Ozark upland hardwood systems is thought to have significantly changed the composition and structure of the forest, from what would have been a mixed shortleaf pine and white-oak dominated forest to red-oak dominated forests with dangerous levels of fuel loading on the forest floor (Chapman et al. 2006, Shang et al. 2007). Current management of upland hardwood forests in the Ozarks targets a 3-5 year fire return interval (FRI) for dry open woodland and flatwood systems, a 3-15 year FRI for dry-mesic woodlands, and >20-30 year FRI for dry-mesic and mesic forest systems (M. Leahy, Missouri Department of Conservation, personal communication).

The ISA emphasizes the importance of disturbance in maintaining system dynamics, suggesting fire return intervals of 3 years for woodlands and 10 years for forests in upland hardwood systems in the Ozark Highlands. To address this endpoint we examined historic mean fire return interval and observed fire disturbance data (through 2012) using data on vegetation disturbance provided by the Landfire program (Landfire 2013a,b). The Landfire Mean Fire Return Interval (MFRI) data uses vegetation and disturbance dynamics models to depict the presumed historic average period of time between fires at 30 m spatial resolution. The data is heavily dependent on the Landfire biophysical settings data, and displayed in 22 different categories of FRI length, including 5 year increments (0-50 years), 10 year increments (50-100 years), and in 25-500 year increments at >100 years. We summarized pixel-level counts of target historic FRI's with 0-5 years serving as a proxy for the 3 year ISA target for woodlands, and 6-10 years serving as a proxy for the 10 year ISA target for upland hardwood forests. We also summarized by proportion of acreage within a HUC12 watersheds met target proxies. We also explored the Landfire Fire Regime Group data layer, but found those groupings (e.g., Group I, <= 35 year fire return interval, low and mixed severity) to lack the specificity needed to meet our objectives (Landfire 2016).

We found that most areas within the Ozarks exhibited 0-10 year mean historic FRI, though there were apparent data inconsistencies in other regions, particularly in southern portions of the Mississippi Alluvial Valley (**Figure UH.27**). We estimate approximately 6.4 million acres of woodland exhibit a mean historic fire regime between 0-5 years in the Ozark Highlands, as a proxy for the ISA target of 3 years (**Table UH.19**). In contrast only 8,973 acres of upland hardwood forest in the Ozark Highlands exhibit a mean historic FRI from 6-10 years, suggesting the target ISA endpoint may need to be revisited for clarification. When summarized by HUC12 watershed, the majority of woodlands in the Ozark Highlands exhibited at least some, and up to 68% of a watershed meeting the 0-5 year mean historic FRI proxy target (**Figure UH.28**). We found very few HUC12 watersheds that exhibited even limited proportions of targeted 6-10 year historic FRI's for upland hardwood forest systems (not displayed), with much greater coverage at 0-5 years (**Figure UH.28**). This may suggest either upland hardwood forest FRI targets may need refinement to reduced FRI, or that historic FRI calculations may not accurately reflect the pre-European settlement conditions, where time periods between fires in this system were thought to be much longer than those following settlement.

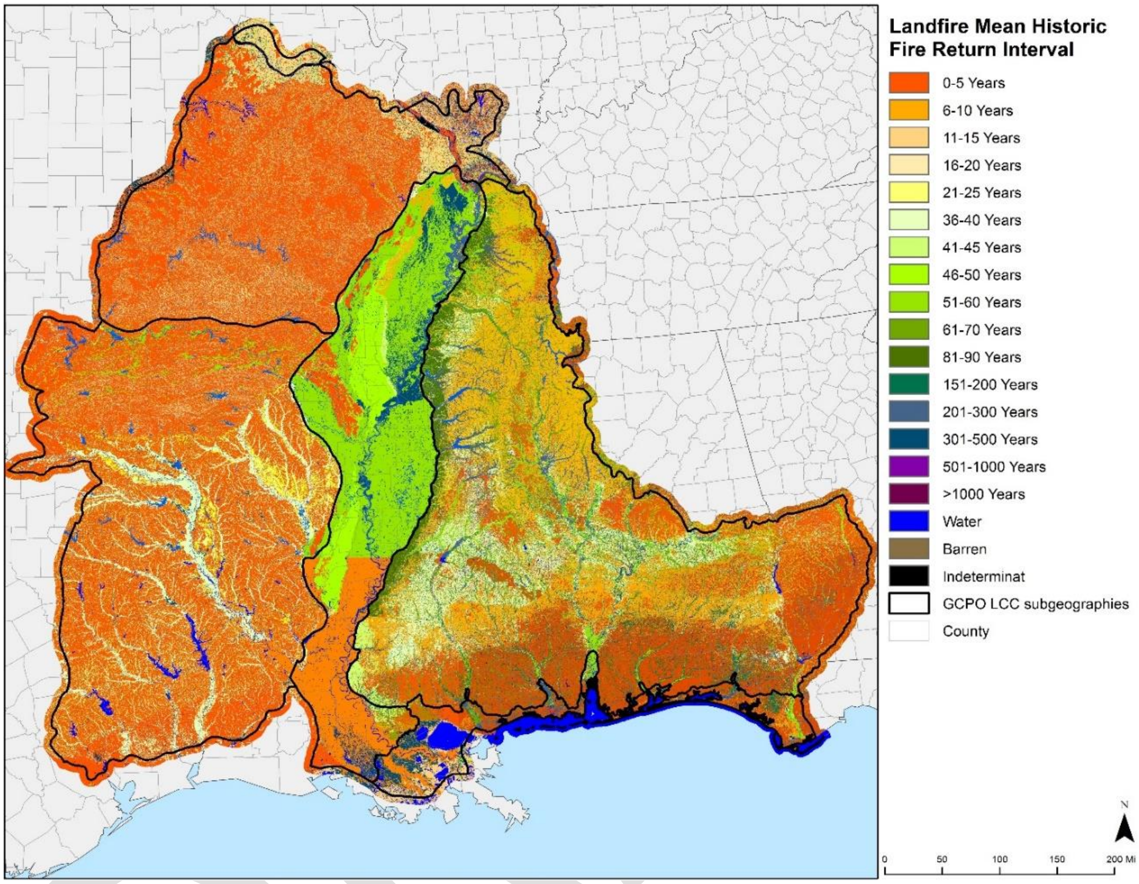
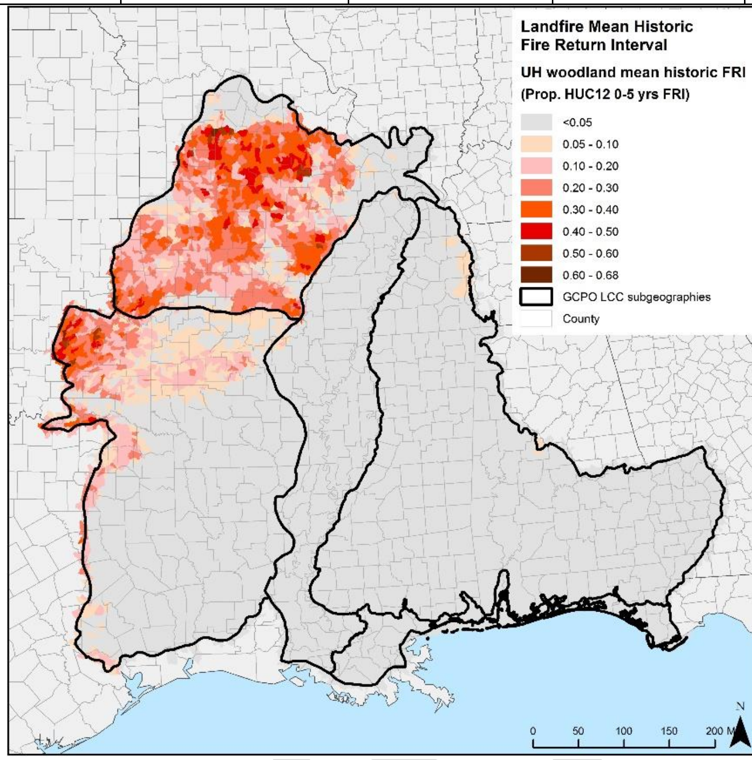


Figure UH.27. Landfire ***mean historic fire return interval within the GCPO geography.***

Table UH.19. Acres of upland hardwood woodland and forest reflecting a mean historic fire return interval 0 – 5 years and 6 – 10 years, derived by Landfire ***and summarized by GCPO LCC subgeography.***

LCC subgeography	UH woodland acres FRI 0-5 yrs	UH woodland acres FRI 6-10 yrs	UH forest acres FRI 0-5 yrs	UH forest acres FRI 6-10 yrs
Ozark Highlands	**6,411,175**	**11,676**	**2,344,410**	**8,973**
West Gulf Coastal Plain	2,290,480	402	2,975,007	77
East Gulf Coastal Plain	65,823	1,081,409	154,904	191,537
Mississippi Alluvial Valley	28,479	3,753	10,317	14,085
Gulf Coast	N/A	N/A	9,189	417

GCPO LCC	8,795,956	1,097,240	5,493,827	215,090



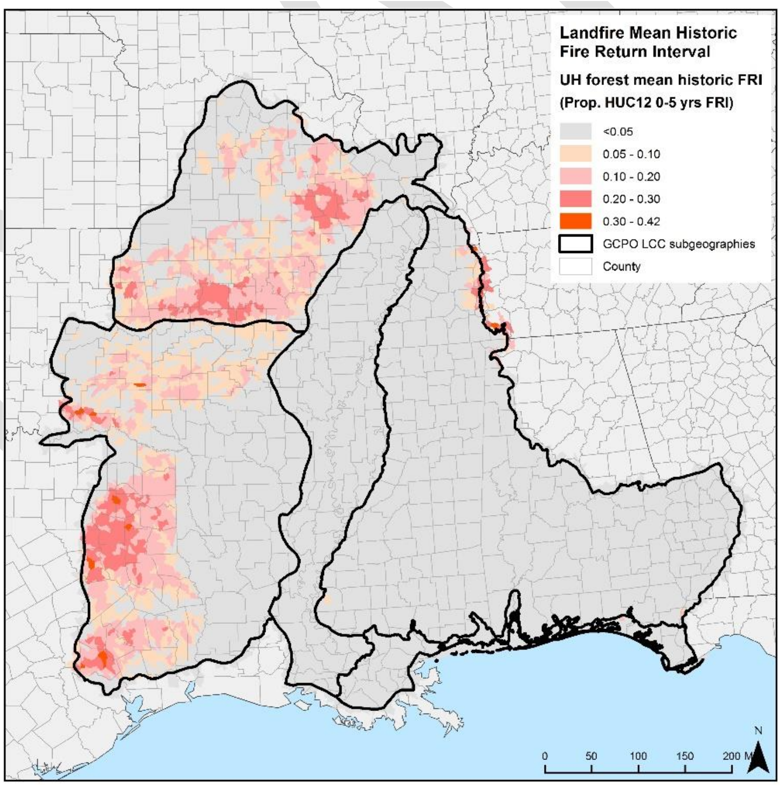


Figure UH.28. Upland hardwood woodlands and forests with 0-5 year Landfire ***mean historic fire return summarized by proportion of HUC12 watershed within the GCPO LCC***

geography. Note the target 6-10 year historic FRI proxy for forests is not depicted due to lack of available data.

Though information on historic fire regime is useful, particularly in concert with potential vegetation cover, it is equally, if not more so important to understand present fire return intervals on the GCPO landscape if possible. The Landfire Vegetation Disturbance layer set is a comprehensive database that uses Landsat change detection models (Jin et al. 2013) and derived indices, and several fire mapping tools (e.g., Monitoring Trends in Burn Severity, Burned Area Reflectance Classification), and information on local disturbance events to track multiple types of vegetation disturbance over time (Landfire 2014b). The dataset characterizes the data on a per-pixel basis by year of disturbance, disturbance type, and severity. Layers are available as year-specific disturbance grids (2005-2012), or a composite disturbance grid summarizing all years. We originally sought to use the time since disturbance field in the vegetation disturbance layer, which is summarized in intervals of one year, 2-5 years, 6-10 years, etc. However, we realized these values indicated the time that has elapsed since the pixel was actually disturbed to the point where it was included in the model. For purposes of this assessment we clipped each annual disturbance layer to a 10 km buffer around the GCPO boundary, resampled to a 250 m resolution using a nearest-neighbor algorithm, and reclassified to capture all fire-related disturbance classes into a binary (fire, no fire) layer for each year. We realized quickly when visualizing the data that, though it appears that fire prevalence has increased each year since 1999; we cannot differentiate between greater amounts of fire on the landscape vs. greater amounts of fire reporting to the Landfire program each year for purposes of this rapid assessment. Further, we also realized quickly that the vast majority of fire-generated disturbance is displaying on protected lands, which is likely due to Landfire's incorporation of national public lands fire databases into their vegetation disturbance product. Nevertheless, it is clear that there appear to be areas within the GCPO landscape that are reporting frequent fire within the same areas across multiple years, including many areas within the West and East Gulf Coastal Plains, and some areas in the Ozark Highlands (**Figure UH.29**).

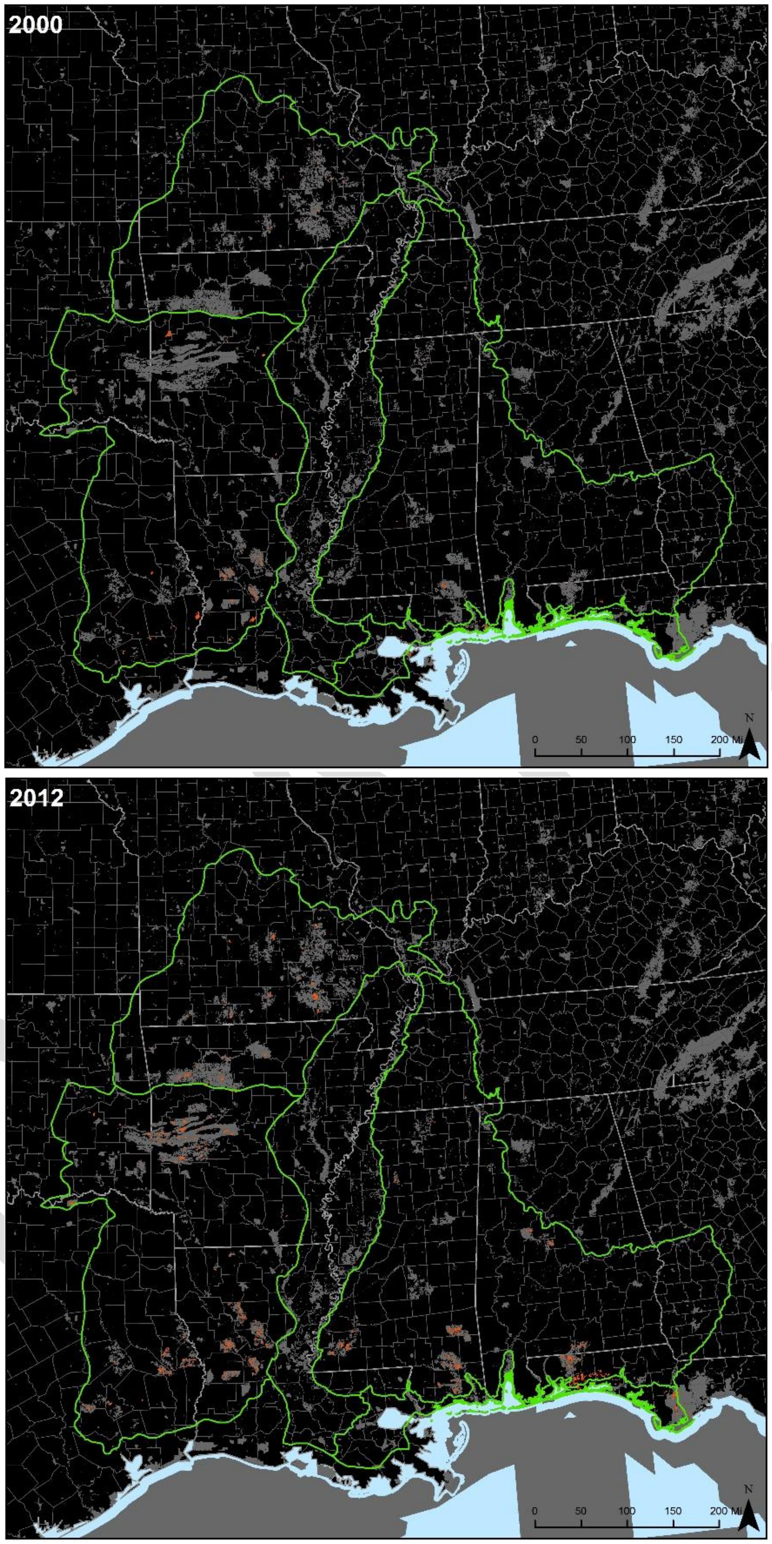


Figure UH.29. Landfire ***Vegetation Disturbance specific to wild and prescribed fire (red) in the GCPO geography (green) in 2000 compared to 2012 overlaid on protected areas available in PAD-US 1.4 (dark gray), reflecting either an increase in fire disturbance or an increase in reporting of disturbance metrics to*** Landfire***.***

Future Directions and Limitations

Given the limited specificity of the ISA endpoint relating to an appropriate distribution of successional stages in upland hardwood woodland and forest systems, combined with limited scope of data on fire return interval within the GCPO geography, the decision was made to exclude temporal considerations from incorporation into the upland hardwood condition index scoring, and subsequently into the LCC conservation blueprint. However, the framework exists for future data improvements that allow for estimation of empirical fire return intervals using remote sensing and other techniques, particularly to capture fire disturbance data on private lands in the GCPO geography.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Imputed Forest Stand Age and Estimated Proportion of HUC12 Watersheds in Young Forest Stage in the GCPO LCC (raster 250 m and proportional HUC12 vector)
- Landfire data distribution site (including Mean FRI and Vegetation Disturbance data) (raster)

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Chapter 11: Conclusion: Condition Index

Subgeography: OZARK HIGHLANDS

Ecological System: Upland Hardwoods

A Condition Index Tracking Desired Ecological States for GCPO Upland Hardwood Woodland and Forest

The preceding chapters describe an assessment of each individual quantifiable landscape endpoint for the upland hardwood woodland and forest system. However, the goal of this ecological assessment is to determine spatially where in the GCPO all measurable upland hardwood landscape endpoints are met. Thus the assessment indicates where the system exists in or nearly-in the desired ecological state outlined in the GCPO LCC Integrated Science Agenda, as well as provides the framework for identifying where management actions may improve ecological condition in this system. The desired ecological state for GCPO upland hardwoods is described as "*large blocks of oak forest and woodland in appropriately distributed successional stages in predominately forested landscapes. Woodlands are characterized by moderate canopy cover and tree densities that allow ample light to reach the ground, supporting a variety of grasses and forbs. Forests are characterized by nearly closed overstory canopy with well-developed subcanopy, shrub, and understory strata comprised of shade-tolerant species*". The final step in the assessment is therefore to combine individual endpoint criteria for woodland and forest systems to calculate a series of condition index values based on a set of decision criteria related to how many landscape configuration and condition endpoints are met.

We used a series of raster calculations in a dichotomous decision-based framework to compile a per-pixel draft condition index value at a 250 m resolution for GCPO upland hardwoods based on the number of configuration and condition endpoints met within each pixel in the GCPO (**Figure UH.30**). We began by identifying potential upland hardwood woodlands and forests, then combining this information with other forest configuration and condition endpoints (**Table UH.20**) to create sets of condition index values. This condition index information then provides a critical input layer into protection and management opportunity maps that drive the GCPO LCC Landscape Conservation Blueprint process in combination with information on existing conservation investments, partner priorities, potential threats, and species-habitat associations to create a blueprint for large-scale conservation efforts into the future.

Table UH.20. Landscape endpoints defining desired ecological state (DES) for upland hardwood woodlands and forest in the GCPO LCC geography, including the value specified by the GCPO Integrated Science Agenda (ISA), and metric and value used in the rapid ecological statement. *Note values for connectivity, succession, and fire return interval were not evaluated due to limited endpoint specificity or data availability.

Endpoint	Value specified	Metric assessed	Value used
Amount of woodland and forest	1.9 million ac (woodland) 0.7 million ac (forest)	Total acres (all conditions & in desired state)	1.9 million ac (woodland) 0.7 million ac (forest)
Forest patch size, interdigitated forest types	≥5,000 ac	Patch size all forest	≥3,000 ac
Landscape composition (woodland and forest in 10-km radius)	>70%	Composition of all forest in 10 km radius landscape	>70%
Connectivity*	Adequate	Not included in assessment	
Overstory canopy cover	20-80% (woodlands) ≥80% (forests)	Percent cover	20-80% (woodlands) ≥80% (forests)
Average tree diameter	≥14 in	Average dbh (inches)	≥6.10” (woodlands) ≥6.26” (forests) [top quantile]
Tree density	≈40 trees/ac (woodlands) 80 trees/ac (forests)	Trees/acre	30-50 tpa (woodlands) 70-90 tpa (forests) [+/-10 tpa from target]
Large snag density	1 large (≥16” dbh) snag/5 acres	Large snags/acre	≥ 0.2 large snags/ac
Dead/downed wood	One 6’ log (≥8” dbh)/acre	Tons carbon down wood/acre	≥0.05 tons/ac
Midstory density	≤20%	Trees/acre	<99.35 tpa (woodlands) <141.5 tpa (forests) [bottom quantile]
Total live tree basal area	Not specified in ISA	Square feet/acre	30-80 sqft/ac (woodlands) 80-100 sqft/ac (forests)
Oak and hickory basal area	>90% (woodlands) >70% (forests)	Proportion basal area oak and hickory	>90% (woodlands) >70% (forests)
Distribution of successional stages	≤10% of the landscape	Not included in DES assessment	
Fire return interval	3 years (woodland) 10 years (forest)	Not included in DES assessment	

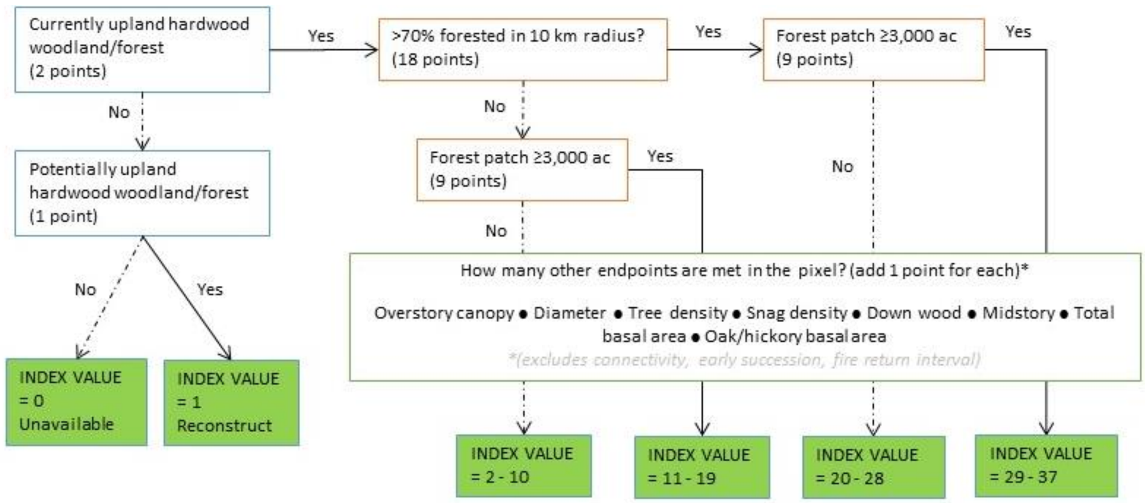

Figure UH.30. Dichotomous decision-based approach using landscape endpoints to assessing the configuration and condition of upland hardwood woodlands and forest within the GCPO LCC. Note individual woodland and forest condition endpoint thresholds may vary (see Table UH.20).

Data Sources and Processing Methods

1. *Identification of potential upland hardwoods*

Pixels not identified as upland hardwoods but that were identified as having the potential to be upland hardwood woodlands or forest were given a condition index value of 1 in the decision tree, provided the pixels were not classified as developed or open water. Potential upland hardwood pixels were derived from a combination of potential classes in the Central Hardwoods Joint Venture Ecological Potential data layer, and the Landfire Biophysical Settings (BPS) layer. The Ecological Potential layer was developed by Central Hardwoods Joint Venture staff and partners and represents an expert-driven process to identifying where vegetative communities were once found and where management activities to restore natural vegetative communities have the greatest potential for success. The process used land-type associations and abiotic and biotic attributes to map eleven natural vegetative communities, which include classes of open oak woodlands (20-50% overstory canopy cover), closed oak woodlands (50-80% overstory canopy cover), and mesic closed canopy upland forests (>80% overstory canopy cover) in the Central Hardwoods Joint Venture geography (**Table UH.21**). The Landfire BPS layer provides a national dataset that maps the presumed pre-European settlement vegetative communities that dominated the landscape, and uses the present-day "biophysical environment" in combination with approximations of past disturbance regimes to map out pixels classified to NatureServe Ecological Systems.

For purposes of deriving the potential layer in the condition index we resampled 30 m resolution ecological potential and 30 m resolution BPS data to 250 m using a nearest neighbor algorithm. For woodland, we used the resampled open and closed canopy woodland ecological potential data in the GCPO Ozark Highlands subgeography and mosaicked the data with the resampled BPS woodland classes for the remaining GCPO subgeographies (**Table UH.21**). For forest we used the resampled mesic forest ecological potential data in the Ozark Highlands subgeography and mosaicked the data with the resampled BPS hardwood forest classes for the remaining subgeographies. Thus the potential upland hardwoods layers used in the ecological assessment reflect the ecological potential data in the Ozark Highlands, and BPS elsewhere in the GCPO.

Table UH.21. Potential upland hardwood woodland and forest classes in GCPO subgeographies derived from the Central Hardwoods Joint Venture Ecological Potential data in the Ozark Highlands, and from Landfire Biophysical Settings in the East and West Gulf Coastal Plains, Gulf Coast, and Mississippi Alluvial Valley.

	Potential Woodland Classes	**Potential Forest Classes**
Ozark Highlands	CHJV Ecological Potential: • Open oak woodlands • Closed oak woodlands	CHJV Ecological Potential: • Mesic Forest
East & West Gulf Coastal Plain, Gulf Coast, Mississippi Alluvial Valley	Landfire Biophysical Settings: • East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland [*13060*] • East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland [*13070*] • Crosstimbers Oak Forest and Woodland [*13080*] • North-Central Interior Dry-Mesic Oak Forest and Woodland [*13100*] • North-Central Interior Dry Oak Forest and Woodland [*13110*] • Ouachita Montane Oak Forest [*13120*] • Allegheny-Cumberland Dry Oak Forest and Woodland [*13170*] • South-Central Interior/Upper Coastal Plain Flatwoods [*13260*] • Central and South Texas Coastal Fringe Forest and Woodland [*13380*] • Central Interior Highlands Dry Acidic Glade and Barrens [*13630*] • Ozark-Ouachita Dry Oak Woodland [*13640*] • Southern Ridge and Valley/Cumberland Dry Calcareous Forest [*13760*] • Lower Mississippi River Dune Woodland and Forest [*13810*] • Edwards Plateau Limestone Savanna and Woodland [*13830*] • North-Central Interior Oak Savanna [*13940*] • Alabama Ketona Glade and Woodland [*14080*] • South-Central Interior/Upper Coastal Plain Wet Flatwoods [*14570*] • East-Central Texas Plains Post Oak Savanna and Woodland [*15190*]	Landfire Biophysical Settings: • Ozark-Ouachita Dry-Mesic Oak Forest [*13040*] • Southern Interior Low Plateau Dry-Mesic Oak Forest [*13050*] • North-Central Interior Maple-Basswood Forest [*13140*] • Southern Appalachian Oak Forest [*13150*] • Southern Piedmont Mesic Forest [*13160*] • Central and Southern Appalachian Montane Oak Forest [*13200*] • South-Central Interior Mesophytic Forest [*13210*] • Southern Crowley`s Ridge Mesic Loess Slope Forest [*13220*] • West Gulf Coastal Plain Mesic Hardwood Forest [*13230*] • East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest [*13250*] • South-Central Interior/Upper Coastal Plain Flatwoods [*13260*] • East Gulf Coastal Plain Northern Loess Bluff Forest [*13270*] • East Gulf Coastal Plain Southern Loess Bluff Forest [*13290*] • Ozark-Ouachita Mesic Hardwood Forest [*13340*] • West Gulf Coastal Plain Chenier and Upper Texas Coastal Fringe Forest and Woodland [*13390*] • Atlantic Coastal Plain Mesic Hardwood Forest [*13430*] • Southern Coastal Plain Mesic Slope Forest [*13570*] • South-Central Interior/Upper Coastal Plain Wet Flatwoods [*14570*] • Mississippi River Alluvial Plain Dry-Mesic Loess Slope Forest [*15090*]

We also sought to remove pixels from the potential layer that were presently developed (open space, and low, medium, and high intensity development), as well as pixels currently considered open water as these pixels have low probability of converting back to upland hardwood systems in the future. Developed and open water pixels were reclassified out of the 2011 National Land Cover Database (NLCD) and used as a mask to indicate that areas currently under development or open water were not expected to be converted to forest over time. We used a series of map algebra calculations to extract out developed (NLCD classes, 21, 22, 23, 24) and open water (NLCD class 11) from potential hardwood pixels. The product identified where upland hardwood woodlands and forest could potentially be on the landscape based on edaphic, geographic and local site conditions. We also removed areas of existing woodlands and forests (i.e., the hardwood masks) to exclude current hardwoods from being quantified in the potential layer. The layers of "potential" upland hardwood woodlands and forest were calculated at 250 m resolution, then reclassified to a binary 1 or 0 (**Figure UH.31).** Pixels of potential woodlands and forests were given a score of 1 when included in the condition index calculations below.

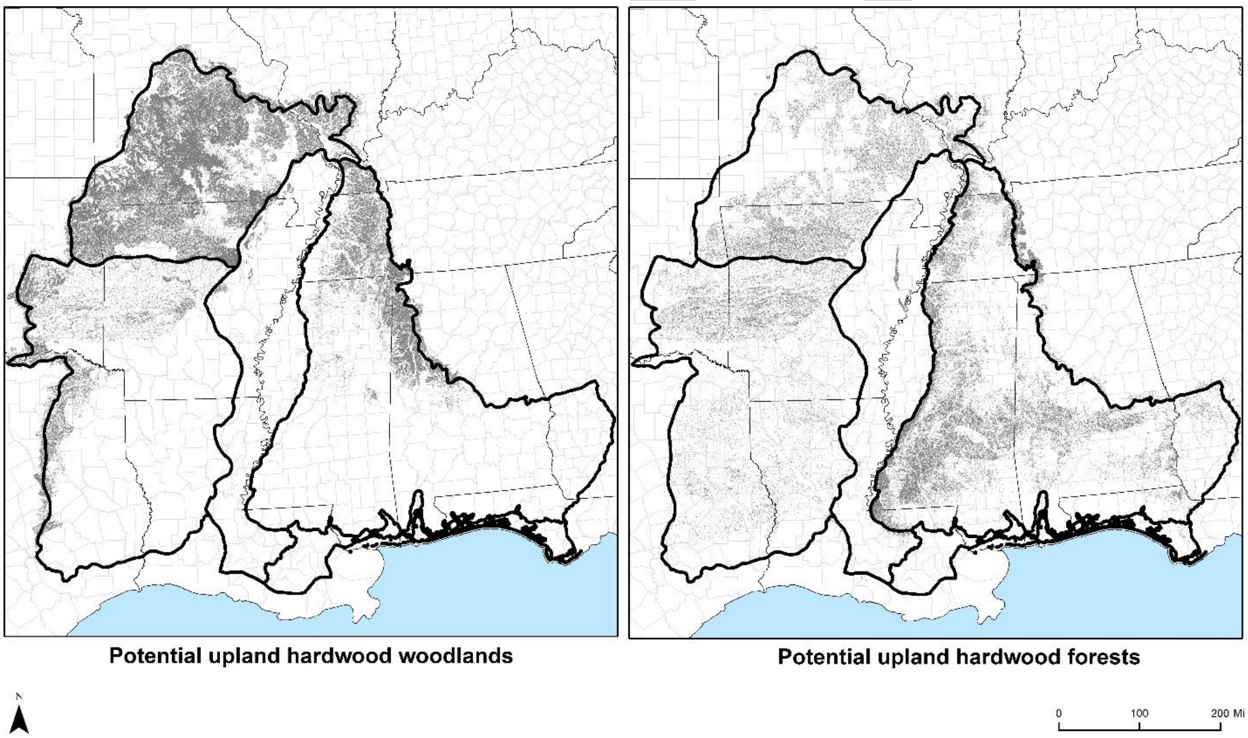

Figure UH.31. Potential upland hardwood woodland (left) and hardwoods (right) at 250 m resolution developed from the Central Hardwoods Joint Venture Ecological Potential data layer in the Ozark Highlands and Landfire Biophysical Settings data layer in the remaining GCPO geography.

2. *Condition index*

Though some endpoints were limited by availability of data or lack of measurable ISA targets, we were able to assess upland hardwood systems that fell within desired thresholds for forest landscape composition, forest patch size, overstory canopy, average tree diameter, tree density, snag density, dead/down wood density, midstory density, total basal area, and proportional oak/hickory basal area. Excluded were measures of connectivity, fire return interval, and early succession due to either uncertainty in endpoint thresholds across forest patches, or limitations associated with available large-scale data. These excluded variables will be incorporated into subsequent assessments as quantitative targets and/or data become available.

In addition to pixels of potential hardwoods described above, pixels identified as current upland hardwood woodland and forest were given a score of 2, whereas pixels found in predominantly forested landscapes with >70% forest cover were given a score of 18, and pixels found in forest patches ≥3,000 ac were given a score of 9. Pixels meeting remaining condition endpoints were given one additional point for each endpoint, totaling up to eight points. This scoring system allowed for calculation of a condition index value (CIV) based on the decision tree outlined in **Figure UH.30**. Under this scoring system, existing woodland and forest pixels that were found in a predominately non-forested landscape and in forest patches <3,000 ac (i.e., smaller fragmented patches) scored a CIV from 2 - 10, depending on how many condition endpoints were met. Woodland and forest pixels found in predominately non-forested landscapes but in large patches ≥3,000 ac (i.e., large patch in a fragmented landscape) scored a condition index value from 11 - 19, depending on the number of condition endpoints. Pixels that were found in predominately forested landscapes but in forest patches <3,000 ac patches scored a CIV from 20 - 28. This scoring system assumes a small forest patch in a predominately forested landscape may be in better overall condition than a large forest patch in a fragmented non-forested landscape, but this assumption needs to be validated with empirical research. Woodland and forest pixels that were found in predominately forested landscapes and in large (≥3,000 ac) forest patches scored a CIV from 29 - 37. An index value of 37 represents hardwood pixels that are estimated to be in the desired ecological state, as determined by the suite of measurable condition endpoints. Note that this approach weighs forest configuration endpoints over hardwood condition endpoints, such that condition index values are based first on forest composition and patch size, followed by condition endpoints.

Determining Relative Contribution of Landscape Endpoints using a Barcode Approach

Up to this point information contributing to the calculation of the hardwoods condition index value has been additive, such that relative contribution of individual landscape endpoints determining each CIV score were unknown. It is critical that in addition to simply knowing where pixels scored high CIV values across the GCPO, we also understand which landscape endpoints were responsible for those scores. This “bar code” approach provides a unique identifier for each combination of endpoint scores for upland hardwood pixels within the landscape. To create the barcodes we used a Combine tool in ArcGIS to concatenate landscape endpoint scores into a single field. This, however, required careful tracking of the order of condition endpoints going into the concatenation. This approach provides a much greater amount of information to conservation planners regarding the relative contribution of endpoint data to the summed condition index value in a transparent framework. Because of the large number of possible combinations of endpoints quantified, we found 330 unique barcode values in upland hardwood woodlands and 305 in upland hardwood forests, with a subset depicted in **Figure UH.32**.

Potential upland hardwood? (1 point)	Current upland hardwood? (2 points)	Pixel in >70% forested landscape? (18 points)	Pixel in >3,000 ac forest patch? (9 points)	Canopy cover 20-80% [woodland], ≥80% [forest]? (1 point)	Avg DBH ≥6.10” [woodland], ≥6.26” [forest]? (1 point)	Tree density tpa 30-50 [woodland], 70-90 [forest]? (1 point)	≥0.2 large snags/ac? (1 point)	≥0.05 tons carbon down wood/ac? (1 point)	Midstory density tpa <99 [woodland], <142 [forest]? (1 point)	Basal area sq ft/ac 30-80 [woodland], 80-100 [forest]? (1 point)	% BA oak & hickory >90% [woodland], >70% forest? (1 point)	Condition Index Score	Barcode Value
1	0	0	0	0	0	0	0	0	0	0	0	1	100000000000
0	2	0	0	0	0	0	0	0	0	0	0	2	020000000000
0	2	0	0	1	0	0	0	0	0	0	0	3	020010000000
0	2	0	0	1	1	0	0	0	0	0	0	4	020011000000
0	2	0	0	1	1	1	0	0	0	0	0	5	020011100000
0	2	0	0	1	1	1	1	0	0	0	0	6	020011110000
0	2	0	0	1	1	1	1	1	0	0	0	7	020011111000
0	2	0	0	1	1	1	1	1	1	0	0	8	020011111100
0	2	0	0	1	1	1	1	1	1	1	0	9	020011111110
0	2	0	0	0	0	1	1	1	1	1	1	10	020011111111
0	2	0	9	0	0	0	0	0	0	0	0	11	020900000000
0	2	0	9	1	0	0	0	0	0	0	0	12	020910000000
0	2	0	9	1	1	0	0	0	0	0	0	13	020911000000
0	2	0	9	1	1	1	0	0	0	0	0	14	020911100000
0	2	0	9	1	1	1	1	0	0	0	0	15	020911110000
0	2	0	9	1	1	1	1	1	0	0	0	16	020911111000
0	2	0	9	1	1	1	1	1	1	0	0	17	020911111100
0	2	0	9	1	1	1	1	1	1	1	0	18	020911111110
0	2	0	9	1	1	1	1	1	1	1	1	19	020911111111
0	2	18	0	0	0	0	0	0	0	0	0	20	0218000000000
0	2	18	0	1	0	0	0	0	0	0	0	21	0218010000000
0	2	18	0	1	1	0	0	0	0	0	0	22	0218011000000
0	2	18	0	1	1	1	0	0	0	0	0	23	0218011100000
0	2	18	0	1	1	1	1	0	0	0	0	24	0218011110000
0	2	18	0	1	1	1	1	1	0	0	0	25	0218011111000
0	2	18	0	1	1	1	1	1	1	0	0	26	0218011111100
0	2	18	0	1	1	1	1	1	1	1	0	27	0218011111110
0	2	18	0	1	1	1	1	1	1	1	1	28	0218011111111
0	2	18	9	0	0	0	0	0	0	0	0	29	0218900000000
0	2	18	9	1	0	0	0	0	0	0	0	30	0218910000000
0	2	18	9	1	1	0	0	0	0	0	0	31	0218911000000
0	2	18	9	1	1	1	0	0	0	0	0	32	0218911100000
0	2	18	9	1	1	1	1	0	0	0	0	33	0218911110000
0	2	18	9	1	1	1	1	1	0	0	0	34	0218911111000
0	2	18	9	1	1	1	1	1	1	0	0	35	0218911111100
0	2	18	9	1	1	1	1	1	1	1	0	36	0218911111110
0	2	18	9	1	1	1	1	1	1	1	1	37	0218911111111

Figure UH.32. Example matrix of barcode value scores produced via condition index value (CIV) calculations for upland hardwood systems to determine individual endpoint contribution to condition index scores. Note only a subset of barcode values are shown here.

Summary of Findings

Using a dichotomous, decision-based approach (see **Figure UH.30**), we found no upland hardwood woodland pixels met all ISA endpoints (CIV=37) (**Table UH.22**). Only 13 pixels in the Ozark Highlands (200 ac) exhibited a CIV=36, with the barcode value indicating all but the endpoint for tree density was met for these pixels. We found 21,590 acres in the Ozark Highlands, and 1,220 acres in the West Gulf Coastal Plain exhibited a CIV=35 (i.e., indicating all but 2 endpoints were met). In total over 2.6 million acres (27% of all woodlands) in the Ozark Highlands and 3.2 million acres (23% of all woodlands) across the GCPO fell within the upper CIV bin (CIV≥29), where pixels met endpoints for forest composition and patch size, as well as one or more woodland condition endpoints (**Table UH.23**). Woodland pixels with CIV≥29 were found in distinct patches throughout the Ozarks and Ouachita’s in Missouri, Arkansas, and Oklahoma, with additional acreage in western Tennessee, west Central Alabama and scattered in other areas (**Figure UH.33**). We found 1,463,510 acres of the upland hardwood woodland system (10% of all GCPO hardwood woodlands) are considered currently protected under the PAD-US 1.4 database (GAP status 1-3). We found 65% (950,581) of those protected acres exhibiting a CIV in the top bin (≥29), reflecting woodland conditions approaching the desired ecological state. These high value protected woodlands were found in Ozark-St. Francis and Ouachita National Forest, and along the Buffalo National River in Arkansas, Mark Twain National Forest in Missouri, and in several other state management areas, national wildlife refuges, easements, and other conservation lands within Arkansas, Missouri, and Oklahoma. We estimate 71% of woodlands nearing desired condition are not currently considered protected.

We also found no upland hardwood forest pixels met all ISA endpoints (CIV=37). We found only 2,826 acres in the Ozark Highlands and 1,621 acres in the West Gulf Coastal Plain exhibited a CIV=36, with the barcode value again indicating all but the endpoint for tree density was met for these pixels (**Table UH.23**). We found 77,421 acres in the Ozark Highlands, 9,452 acres in the West Gulf Coastal Plain, and 2,517 acres in the East Gulf Coastal Plain exhibited a CIV=35 (i.e., indicating all but 2 endpoints were met). In total over 2 million acres (53% of all upland hardwood forest) in the Ozark Highlands and 3 million acres (31% of all upland hardwood forest) across the GCPO fell within the upper CIV bin (CIV≥29), where pixels met endpoints for forest composition and patch size, as well as one or more woodland condition endpoints (**Table UH.22**). Upland hardwood forest pixels with CIV≥29 were found in distinct patches in the eastern Ozarks (St. Francois Mountains) in Missouri, as well as in the Boston Mountains and Ouachita's in Arkansas, and eastern Oklahoma (**Figure UH.33**). These forest patches were frequently (but not exclusively) associated with large tracts of public forest lands, including Mark Twain, Ozark-St. Francis, and Ouachita National Forests. However, there were also distinct high density patches of good condition upland hardwood forest along bluffs of the Mississippi Valley Loess Hills in southwestern Mississippi (Adams, Claiborne, Jefferson, Warren, and Wilkinson counties), as well as an additional large patch intersecting Benton, Carroll, Decatur and Henderson counties between Natchez Trace State Park and Tennessee National Wildlife Refuge in western Tennessee. We found 1,437,147 acres of the upland hardwood forest system (15% of all GCPO hardwood forests) are considered currently protected under the PAD-US 1.4 database (GAP status 1 -3). We found 80% (1,150,798) of those protected acres exhibiting a CIV in the top bin (≥29), reflecting forest conditions approaching the desired ecological state. These protected forests were mainly found in Mark Twain, Ozark-St. Francis and Ouachita National Forest, and along the Buffalo National River. The high quality upland hardwood forest patches along the Loess Hills in Mississippi and adjacent to the Tennessee National Wildlife Refuge in Tennessee appear to be privately owned. We estimate 62% of upland hardwood forests nearing desired condition are not currently considered protected.

Table UH.22. Acreage summary by LCC subgeography and upland hardwood system type for condition index values found to be in Condition Index Value (CIV) bins.

Subgeography	Upland hardwood system type	Acres CIV = 2 - 10 (<3k ac patches, <70% forested landscape)	Acres CIV = 11 - 19 (small patches, >70% forested landscape)	Acres CIV = 20 - 28 (large patches, <70% forested landscape)	Acres CIV = 29 - 36 (large patches, >70% forested landscape)
Ozark Highlands	Woodland	2,751,516	4,042,965	395,384	2,606,960
	Forest	423,878	1,184,777	163,228	2,014,370
East Gulf Coastal Plain	Woodland	591,184	753,671	12,649	68,170
	Forest	440,882	567,184	49,977	360,218
West Gulf Coastal Plain	Woodland	1,250,661	1,128,993	117,313	551,770
	Forest	1,876,486	1,815,065	95,228	672,497
Mississippi Alluvial Valley	Woodland	14,100	38,518	402	5,992
	Forest	16,139	111,831	834	8,695
Gulf Coast	Woodland	0	0	0	0
	Forest	7,089	2,842	571	911
GCPO LCC	Woodland	4,607,461	5,964,146	525,747	3,232,892
	Forest	2,764,474	3,681,697	309,839	3,056,691

Table UH.23. Acres upland hardwood woodland (left) and forest (right) reflected in the upper bin of Condition Index Values (CIV = 30-36) across the GCPO geography. Acreages are also summed by Barcode value representing relative contribution of each landscape endpoint to the CIV score across the GCPO geography. See Figure UH.32.

Upland Hardwood Woodland			
Condition Index Value	**Acres Condition Index Value**	**Barcode Value**	**Acres Barcode Value**
30	266,719	0218900000100	232
		0218900001000	266,487
31	962,428	0218900001001	9,745
		0218900001010	323,383
		0218900001100	12,139
		0218900011000	185,978
		0218900100100	31
		0218901001000	148,757
		0218910000100	386
		0218910001000	282,009
32	1,240,792	0218900001011	6,255
		0218900001101	139
		0218900001110	12,633
		0218900011001	3,923
		0218900011010	149,931
		0218900011100	1,591
		0218900101100	417
		0218901001001	3,521
		0218901001010	57,143
		0218901001100	4,587

Upland Hardwood Forest			
Condition Index Value	**Acres Condition Index Value**	**Barcode Value**	**Acres Barcode Value**
30	153,530	0218900000100	124
		0218900001000	153,406
31	650,026	0218900001001	122,935
		0218900001010	76,402
		0218900001100	31,104
		0218900011000	82,209
		0218901001000	24,093
		0218910000100	31
		0218910001000	313,252
32	1,018,537	0218900001011	110,178
		0218900001101	7,181
		0218900001110	494
		0218900011001	120,634
		0218900011010	55,460
		0218900011100	11,274
		0218900101100	710
		0218901001001	28,618
		0218901001010	15,521
		0218901001100	7,181
		0218901011000	14,718

		0218901011000	165,128
		0218910000101	31
		0218910001001	15,120
		0218910001010	416,897
		0218910001100	24,417
		0218910011000	259,445
		0218911001000	119,614
33	591,755	0218900001111	216
		0218900011011	7,830
		0218900011110	5,884
		0218900101101	46
		0218900111100	62
		0218901001011	3,815
		0218901001101	15
		0218901001110	5,266
		0218901011001	3,042
		0218901011010	36,201
		0218901011100	1,838
		0218910001011	20,046
		0218910001101	479
		0218910001110	18,857
		0218910011001	18,857
		0218910011010	262,318
		0218910011100	5,668
		0218910101100	710
		0218911001001	18,656
		0218911001010	60,062
		0218911001100	2,903
		0218911011000	118,981
34	148,170	0218901001111	124
		0218901011011	4,556
		0218901011110	5,699
		0218901111100	15
		0218910001111	494
		0218910011011	32,510
		0218910011101	170
		0218910011110	10,934
		0218910101101	31
		0218910111100	139
		0218911001011	11,012
		0218911001110	6,765
		0218911011001	9,869
		0218911011010	65,267
		0218911011100	571
		0218911101100	15
35	22,826	0218901011111	46
		0218910011111	93
		0218910111101	15
		0218911001111	201
		0218911011011	17,853
		0218911011110	4,618
36	201	0218911011111	201

		0218910001001	113,730
		0218910001010	238,873
		0218910001100	34,440
		0218910011000	175,043
		0218911001000	84,479
33	825,795	0218900011011	119,599
		0218900011101	3,691
		0218900011110	77
		0218900101101	154
		0218900111100	293
		0218901001011	46,857
		0218901001101	3,614
		0218901001110	819
		0218901011001	38,703
		0218901011010	14,378
		0218901011100	2,903
		0218910001011	89,792
		0218910001101	4,556
		0218910001110	6,348
		0218910011001	72,742
		0218910011010	150,657
		0218910011100	7,923
		0218910101100	324
		0218911001001	47,352
		0218911001010	133,977
		0218911001100	19,830
		0218911011000	61,205
34	314,812	0218900011111	31
		0218900111101	15
		0218901001111	571
		0218901011011	45,236
		0218901011101	3,954
		0218901011110	571
		0218901101101	15
		0218910001111	31
		0218910011011	76,448
		0218910011101	2,672
		0218910011110	247
		0218910101101	15
		0218910111100	15
		0218911001011	50,178
		0218911001101	6,641
		0218911001110	6,749
		0218911011001	36,046
		0218911011010	75,877
		0218911011100	9,498
35	89,545	0218901011111	633
		0218910011111	46
		0218911001111	8,278
		0218911011011	71,985
		0218911011101	3,907
		0218911011110	4,695
36	4,448	0218911011111	4,448

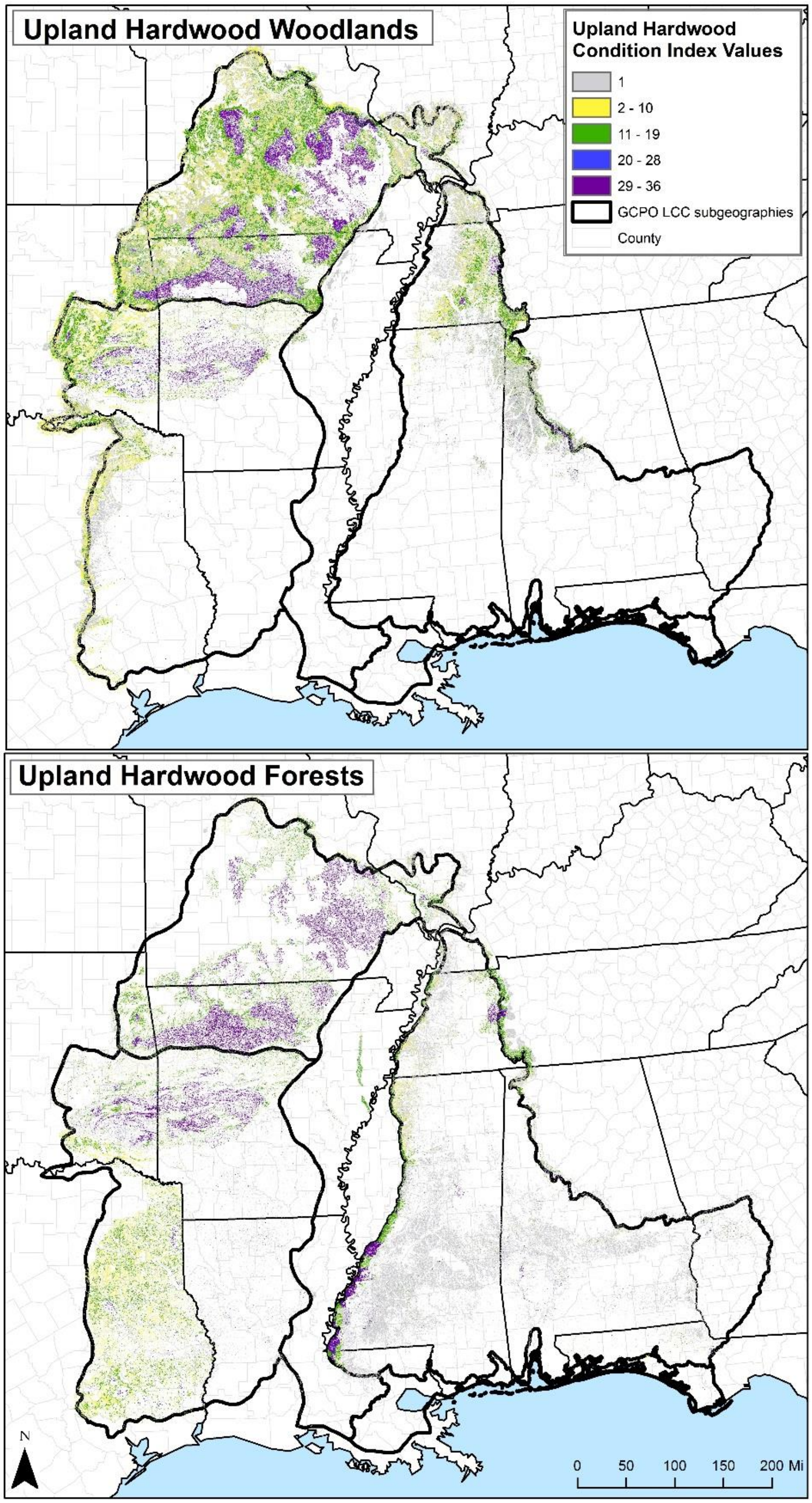

Figure UH.33. Condition index values based on decision-criteria for upland hardwood woodlands (above) and forest (below) ranging from a value of 1 indicating potential hardwoods to values of 29-36 indicating existing hardwoods meet most of the measurable endpoints and are approaching the desired ecological state.

Conclusion: Final Insights, Opportunities and Future Directions for GCPO Upland Hardwood Woodland and Forest

The ecological assessment of upland hardwood woodland and forest systems was an effort to quantify, in a spatial context, the features in a landscape that would reflect a sustainable hardwood system with ecological integrity. The assessment provided a good initial and comprehensive look at the state of upland hardwoods in the GCPO geography. It is clear that large public landholdings in the Ozark Highlands and West Gulf Coastal Plain subgeographies are bastions of quality upland hardwood forest condition. However, it is also evident that upland hardwood systems fall short of desired acreage amounts meeting all landscape endpoints. However, this assessment relies heavily on interpretations of imputed and often remotely-sensed data, therefore must be approached with caveats to scale of application. Through this process we were able to identify several information gaps that, if addressed, could improve the accuracy and precision of this work.

Landscape endpoint opportunities

Landscape endpoints represent hypothesized target thresholds, or the range of conditions for a particular landscape or habitat feature in which we would expect particular priority species to occur. However, in many cases relationships among species and habitat are only coarsely understood, such that knowledge of a preferred range of habitat conditions in upland hardwood woodland and forest is primarily speculative. Though compared to other terrestrial and aquatic systems in the ISA the hardwood system has a well-defined set of numerical targets for most of the landscape endpoints, we recommend that future versions of the ISA attempt to define quantitative targets for landscape endpoints presently defined qualitatively (e.g., connectivity, successional stages) to the extent possible. Well-defined thresholds for endpoints will facilitate incorporation of those endpoints into future Conservation Blueprint iterations, and will strengthen the value of the Blueprint product. The ASMT should also be encouraged to re-evaluate the priority species endpoints for this system to determine if those species are appropriate indicators of a healthy forest system. The LCC is actively engaged with the ASMT to refine ISA targets based on improved understanding of priority species and species-habitat relationships over time such that future ISA endpoint targets more accurately reflect the habitat needs over the range of priority species within a system.

Data limitations

In addition to limitations regarding definition of ISA landscape endpoints, there are also situations where the geospatial data available to address an endpoint are limited in scope, resolution, or temporal scale. In some cases comprehensive datasets available for use were outdated, and had to be supplemented with more current local data and used in tandem. In other cases we relied on data imputations while acknowledging the need for further validation of data products. In other cases no data was available to address the endpoint directly and we either relied on data proxies, or eliminated the particular endpoint from the assessment. In all these cases the assessment has been valuable in identifying tangible information gaps which have the capacity to be addressed through funding of future mapping endeavors.

Figure UH.34 below represents a qualitative assessment of each landscape endpoint and the regional data available to evaluate that endpoint. For each landscape endpoint identified in the ISA for upland hardwood woodland and forest systems we present a sliding scale from red (low quality) to green (high quality) based on our experiences in compilation of the ecological assessment. Each endpoint was assessed based on its measurability, or utility in developing a spatially-explicit assessment of that metric, and not on its relevance to the integrity of the system.

We also assessed the availability of data that could be used to assess each endpoint and have assigned a place on the sliding scale based on data inputs that could be used. In taking this purely qualitative approach there are some clear issues that arose. In some cases we have adequate data available with which to assess the endpoint, but the endpoint is vaguely defined such that it is difficult to quantify. In other cases we have adequately defined endpoints, but comprehensive data was not available to assess it. Finally, in the best case scenario we were provided with a measurable endpoint and comprehensive data is available from which to assess that endpoint. Ideally, this provides a baseline from which we can strive to work with the ASMT to improve either the description of the landscape endpoint, or seek to improve the data used to assess the endpoint.

Category	Landscape Endpoint	Metric Assessment	Regional Data Assessment
Amount	1.9 million acres woodland; 0.7 million acres forest		
Configuration	Forest patch size ≥3,000 ac of interdigitated forest habitat types		
	Landscape composition (woodland and forest in 10 km radius) >70%		
	Adequate connectivity		
Condition: Structure	Canopy cover 20-80% for woodlands; >80% for forests		
	Avg. DBH ≥14" (*used ≥6.10" and ≥6.26" dbh for woodland and hardwood, top quantile*)		
	Tree density ~40 tpa (*used 30-50 tpa*) for woodlands; ~80 tpa (*used 70-90 tpa*) for forests		
	Snag density 1 large (≥16" dbh) snag/5 ac		
	Dead/downed wood – one 6' log (≥8" dbh)/ac (*used >0.05 tons/ac down wood*)		
	Midstory density ≤20% (*used <99.35 and <141.5 tpa for woodlands and forests, bottom quantile*)		
Condition: Composition	Oak and hickory basal area >90% for woodlands, >70% for forests (*also used total basal area 30-80 ft²/ac and 80-100 ft²/ac for woodlands and forests as separate endpoint*)		
Temporal	Appropriate distribution of successional stages; ≤10% of landscape		
	Fire return interval 3 years for woodland; 10 years for forest		

Figure UH.34. Qualitative assessment of measurability and data availability/utility for each landscape endpoint identified in the GCPO LCC Integrated Science Agenda for upland hardwood woodland and forest systems. Each endpoint was evaluated based on its measurability (i.e., utility in developing a spatially-explicit assessment of that metric) and availability of data for assessment, and not on its relevance to the integrity of the system.

Future directions

The assessment has highlighted the need for better understanding and mapping of forests and woodlands in upland hardwood systems, as well as identifies ample opportunities to fill data gaps and refine GCPO ISA-defined landscape endpoints that better reflect desired upland hardwood system condition. Future directions related to improving ISA endpoints and ecological assessment include but are not limited to:

- Updates to the assessment incorporating state-level data on upland hardwood woodland extent, and clarifying inconsistencies among forest and woodland classes across space.
- Assessment of accuracy and limitations to use of imputed plot-level Forest Inventory and Analysis Program data of the U.S. Forest Service with alternative data sources for evaluating forest structure (e.g., LiDAR, local inventory data, etc...)
- Refined estimates of forest composition, patch-size and particularly defining connectivity needs for priority wildlife species identified in the ISA and other state and federal planning documents.
- Improved recommendations regarding distribution of successional stages within upland hardwood systems.
- Further improvements of disturbance data to better estimate fire return intervals across multiple systems.
- Refined ISA endpoints targeting measurable thresholds where unclear.

The outcomes of this ecological assessment effort were incorporated into the GCPO LCC Conservation Blueprint 1.0, released October 2016, and refinements to input data and endpoint definition are currently underway in preparation for Conservation Blueprint 2.0. The intent of the blueprint is to map a connected network of lands and waters deliberately designed to sustain natural and cultural landscapes in the GCPO geography now and into the future. Outcomes of the ecological assessment reflect the current state of each of the nine priority ecological systems identified by the ASMT. However, the blueprint also reflects shared partner conservation priorities, stressors and threats such as sea-level rise and urbanization, as well as species distribution models. These four elements combined (current system state, stressors, species, and partner priorities) represent the initial set of elements the GCPO LCC is using to develop a conservation blueprint for the future.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Condition Index Value binned groupings for GCPO upland hardwood woodland and forest (woodland raster, forest raster)

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