EAST AND WEST GULF COASTAL PLAIN: OPEN PINE/SAVANNA

Introduction

Open Pine Woodland and Savanna of the East and West Gulf Coastal Plain is one of the nine priority habitat types identified in the Integrated Science Agenda Draft v4 (ISA) established by the Adaptation Management Science Team (AMST) of the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC)[1]. The desired ecological state for the open pine priority habitat system is described by the following landscape endpoints:

General Description of desired ecological state: Woodlands and savannas that are floristically rich and comprised mostly of site-appropriate pine with low basal area, open canopies, and dense herbaceous understories in large interconnected blocks

Condition: Structure (Mature)

- Basal Area: 40 – 70 ft^2 / acre
- Diameter at Breast Height: ≥ 20 ft^2 / acre of trees ≥ 14” DBH
- Canopy Cover: < 50%
- Midstory Shrubs: < 30% cover
- Midstory Hardwoods: < 20% cover
- Herbaceous Understory: > 65%

Temporal considerations: An appropriate distribution of successional stages

Amount: 20 million acres

Configuration: Large, interconnected blocks of open pine woodland and savanna

- Forest patch size: > 600 acres
- Connectivity: < 3 km to next nearest patch

Appendix 2 of the ISA lists 43 species (19 birds, 12 reptiles, 10 amphibians, and 2 mammals) in their Representative Species Pool for open pine woodland and savanna. Ten of these are limited by habitat characteristics reflective of the endpoints[2]: gopher tortoise (*Gopherus polyphemus*, threatened), red-cockaded woodpecker (*Picoides borealis*, endangered), Mississippi Sandhill crane (*Grus canadensis pulla*, endangered), Bachman’s sparrow (*Aimophila aestivalis*), Louisiana pine snake (*Pituophis ruthveni*), brown-headed

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[1] In this document, GCPO LCC refers to the partnership organization, and GCPO refers to the related geographic region.

[2] Species conservation status from US Fish and Wildlife Service <http://www.fws.gov/endangered/> accessed on March 19, 2015.

nuthatch (*Sitta pusilla*), Northern bobwhite (*Colinus virginianus*), pine warbler (*Setophaga pinus*), prairie warbler (*Setophaga discolor*), eastern diamondback rattlesnake (*Crotalus adamanteus*), and southeastern pocket gopher (*Geomys pinetis*).

System definition and conservation importance

Unlike most of the priority systems described in the ISA, Open Pine Woodland and Savanna identifies a particular genus (*Pinus*) as a primary vegetative component[3]. Most of the literature on open pine woodland and savanna ecosystems is focused on the longleaf/ wiregrass system. However, pine woodlands with herbaceous understory can occur north of the historic range of longleaf, most notably in the case of the fire-dependent shortleaf/ bluestem open pine community. At the time of European settlement, longleaf pine (*Pinus palustris*) dominated over 30 million hectares (74 million acres) of the South Atlantic and Gulf coastal plains from Virginia to east Texas (Van Lear et al. 2005, Frost 1993). Longleaf pine depends on frequent fire for stand maintenance and propagation, and the herbaceous understory associated with the species, dominated by wiregrass (*Aristida stricta, A. beyrichiana*) and bluestem grasses (*Andropogon spp., Schizachyrium spp.*), provides a continuous fuel layer to propagate fire through the system (Peet and Allard 1993). Most of the natural open pine system was lost to the naval stores and logging industries during the eighteenth to the mid-twentieth centuries (Frost 1993). Today much of the land historically associated with open pine woodland and savanna is used for agriculture, development, and plantations dominated by loblolly pine (*Pinus taeda*). Estimates of the portion of the original system extant today range from 3% (Frost 1993) to 5%, the larger estimate being comprised of 3 million acres with the largest concentration (both in the GCPO and in the original extent of the system) in Okaloosa and Santa Rosa counties in northwest Florida and adjacent Escambia County in Alabama (Outcalt and Sheffield 1996). In the absence of fire, natural open pine stands are highly susceptible to invasion by hardwood species, a successional process eventually resulting in a closed canopy mixed forest condition. Noss (2013) includes open pine woodland and savanna in his comprehensive review of southeastern grasslands, and the importance of the role played by the herbaceous understory to open pine systems is widely noted in the literature. Grassland systems of the Midwestern United States are unstable when in contact with woody vegetation, prone to invasion by forests on the eastern and northern extents of their range and by woodlands on the southern and southwestern extents (Axelrod 2006) and regional variations in fire frequency play a role in the spatial pattern of grassland, woodland, and forest in areas of the world where grasslands and forests are interspersed (Kline 1997, Anderson 2006, Axelrod 1985, Whittaker 1975). In the GCPO and the southeastern United States, open pine woodland and savanna, like fire-adapted grassland systems, might be considered as neither in climax nor equilibrium, but rather a shifting mosaic of disturbance-dependent patches in a larger landscape climatically suited for closed-canopy forest.

[3] The only other system that does so is the Upland Hardwoods of the Ozark Highlands, which mentions oak and hickory.

Open pine woodland and savanna is associated with high levels of species richness and diversity, despite the system's lack of structural complexity. Research on bird community response to mid-story thinning of southeastern pine forests indicates that the widely-held notion that species diversity increases with structural complexity and vertical stratification does not apply in this system (Singleton et al. 2012). Pine occurs on a variety of soil and landform types (poorly-drained flatwoods, mesic slopes, xeric sandhills, and rocky ridges) and supports a diversity of plant and animal species (Brockway et al. 2005). Peet and Allard (1993) observed high levels of species diversity: 140 species of vascular plants per 1000 m^2 in Mesic Longleaf Woodlands (highest in the temperate Western Hemisphere), 90 species per 100 m^2 in the Fall-line Longleaf Seepage Savanna (highest in North America), and 40 per m^2—highest in the western hemisphere—in the Atlantic Longleaf Savannas (NC), the Southern Longleaf Savannas (MS) and the Fall-line Longleaf Seepage Savannas (NC). These high levels of species richness, coupled with the rapidity of the system's disappearance, accounts for the status of the open pine/savanna system as one of critical conservation importance. Over 30 species associated with the longleaf ecosystem are federally listed as endangered or threatened (Van Lear et al. 2005).

Rapid Ecological Assessment Process: Development of a Draft Condition Index

Pine and mixed-pine forests are common in the geographical area of the GCPO. Our analysis indicates that, out of a total area of 180 million acres, about 49 million acres are covered by forests with a pine component. The "open" forested condition can be found on a variety of soil conditions and land forms from the Ozark Highlands to within feet of the Gulf Coast shoreline. The open pine savanna is a disturbance-dependent system nested within the larger pine/mixed-pine-hardwood forest matrix. Conceivably, any randomly sampled land unit from this matrix (described below as a "Pine Mask" or a set of selected ecological system classes) could be converted to and maintained as open pine savanna through management practices that mimic the historical disturbance pattern, such as thinning, hardwood removal, and prescribed fire.

We approach open pine as a (structural) variation of the larger pine-dominant or mixed pine-hardwood forest. Our method first identifies this larger forest system as a raster data layer of selected ecological system classes. This base layer, or "Pine Mask," representing the distribution of pine in the GCPO was created by selecting appropriate ecological system and land use classes from the National GAP Land Cover Data layer (US Geological Survey 2011). Outside the Pine Mask, a raster representing potential habitat was generated using the the LANDFIRE Biophysical Settings (BpS) data layer, which represents vegetation that may have been dominant on the landscape at the time of European Settlement. Within the Pine Mask layer, individual pixels were classified according to the two configuration metrics, resulting in four classes:

1. Those within a patch ≤ 600 acres
2. Those within a patch ≤ 600 acres that are within 3 km of another patch (of any size)
3. Those within a patch > 600 acres

4. Those within a patch > 600 acres that are within 3 km of another patch that is also > 600 acres.

The process then assessed four of the five forest condition endpoints (we found no data to adequately and comprehensively address the condition of the herbaceous ground story) within each of the four configuration bins using a set of data layer estimates of each condition. Basal Area estimates were obtained from the USFS live tree species basal area data product (Wilson et al. 2013). Canopy Cover estimates were obtained from the 2011 National Land Cover Database (NLCD) U.S. Forest Service Tree Canopy (analytical) product (USDA Forest Service Remote Sensing Applications Center 2014). All other data layers associated with condition endpoints (average tree diameter per acre, midstory basal area, midstory tree density, and average stand age) were obtained from unpublished data layers shared with GCPO staff by scientists at the USFS Remote Sensing Applications Center. These layers cover the 48 conterminous United States at a resolution of 250 meters and are derived from FIA surveys of forest health indicator variables.

Although the ISA specifies the East and West Gulf Coastal plains as the area of interest, compelling reasons exist for extending the assessment beyond the boundaries of these subgeographies in the GCPO. The National GAP Land Cover Data Product (US Geological Survey, Gap Analysis Program (GAP), 2011) shows ecological systems associated with East Gulf Coastal Plain pine forests extending into the Gulf Coast Subgeography on land between Choctawatchee Bay and the city of Apalachicola in Northwest Florida and northwest of Lake Pontchartrain in Louisiana. These ecological systems also extend west towards the City of Baton Rouge, Louisiana, on land mapped by the GCPO as being in the Mississippi Alluvial Valley. The “Broadly Defined Habitats” (BDF) table, linked to in the ISA, lists Crowley’s Ridge Sand Forest (in the Mississippi Alluvial Valley), and shortleaf pine-oak and shortleaf pine-bluestem woodlands (in the Ozark Highlands) as open pine woodland and savanna systems.

Calculating a Draft Condition Index for Open Pine/Woodland/Savanna

Introduction

The geographical distribution, condition, and configuration of open pine/woodland/savanna in the GCPO was assessed on a pixel-by-pixel basis at a spatial resolution of 250 meters, meaning that each pixel occupies 15.44 acres of land. The method employs a decision tree process (Figure 1) to assign a condition index score (green boxes) to each pixel by first assessing configuration (in terms of patch size and connectivity metrics, red boxes), breaking the landscape out into four bins of configuration conditions, then evaluating forest conditions within those bins by assigning to the pixel a single point for each condition endpoint indicated. Outside the pine mask, the potential for restoration is assessed by giving a single point to pixels that are not in a developed class of land according to NLCD 2011 and that potentially could be restored to the desired state based on LANDFIRE’s biophysical setting (BpS) data layer.

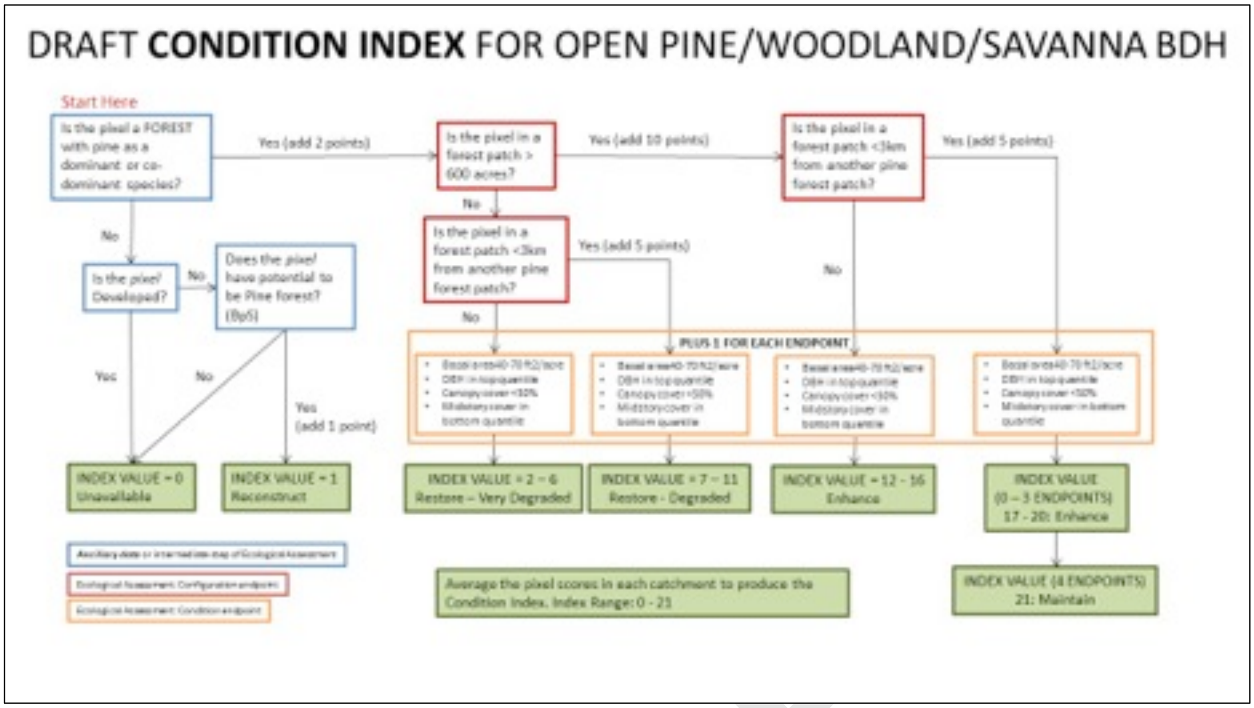

Figure 1: The decision tree assigns a condition index score to each pixel based on patch size and configuration (red boxes) and the presence of desired forest conditions, or endpoints (orange boxes).

The decision tree depicted in Figure 1 can be applied in a geoprocessing environment as a simple additive expression, in which pixels representing potential habitat are given a value of one, those in small patches given a value of two, those in large patches given a value of ten, and both sets given an additional value of five if they meet the connectivity requirement. From there, each pixel receives a single additional point for each endpoint condition indicated at that location (Figure 2).

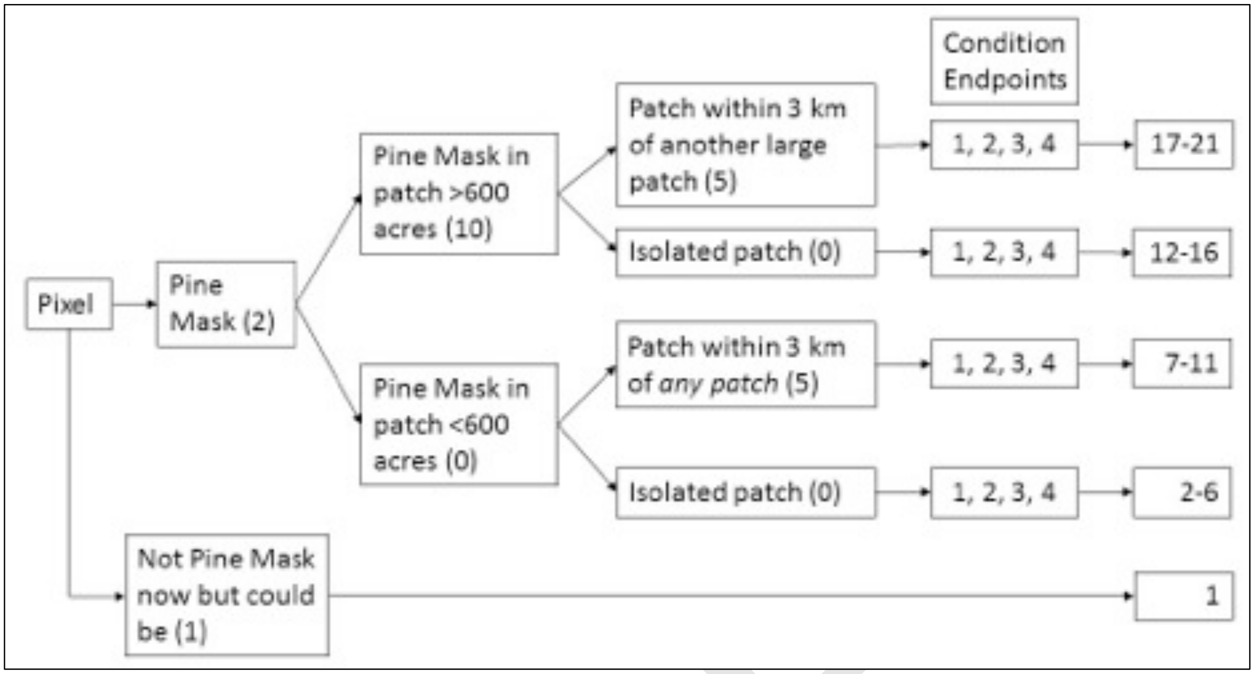

Figure 2: Scoring procedure in a geoprocessing environment. "Pine Mask" refers to a selection of ecological systems representing pine-dominant or pine-co-dominant forests, described below. Scores for each layer are in parentheses.

Geographic distribution of pine in the GCPO: The "Pine Mask"

The condition endpoints listed in the ISA for open pine woodland and savanna establish hypothesized metrics for the "openness" of the structure of the system in contrast to a closed-canopy pine or mixed pine-hardwood forest. The open pine priority system is, in this sense, defined by its condition, and assessing it involves the identification of a set of conditions within a larger landscape in which the genus *Pinus* plays a dominant role. The assessment process therefore began with the creation of a "mask" representing the presence of that larger landscape.

The Broadly Defined Habitats (BDH) document linked to in the ISA lists 14 ecological systems associated with the Open Pine Woodlands and Savanna habitat. From the National GAP Land Cover Data Product (US Geological Survey, Gap Analysis Program (GAP), 2011), we selected ecological system and land use classes (level 3, the most detailed level of classification) that either a) have language identical to the BDH in the description field, b) explicitly indicate the presence of open pine woodland savanna, or c) indicate the presence of or potential for a pine-dominant landscape, that is, mixed pine hardwood classes that could be considered as having been encroached upon by hardwoods in the absence of fire and which could be restored to open pine by thinning, burning, or other management practices.

We compared the layer of selected GAP ecological system classes to a layer of pine-dominant landscapes derived from the USFS live tree species basal area data product, which integrates vegetation phenology from MODIS imagery, along with climatic and topographic information, with extensive FIA field plot data of tree species basal area to map species distribution and basal area at 250 meter spatial resolution for the 48 conterminous states, USA (Wilson et al. 2013). We produced a pine-dominant layer by selecting pixels for which the summed basal area values of four southern pine species, loblolly (*P. taeda*), slash (*P. elliottii*), longleaf (*Pinus palustris*), and shortleaf (*P. echinata*), constitutes 75% of the summed basal area for all live trees. The USFS/FIA pine dominant basal area layers indicated that pine-dominant conditions exist on about 3.4 million acres in areas classified by GAP as managed tree plantations (class 8202, Evergreen Plantation or Managed Pine, and class 8203, Managed Tree Plantation), primarily in the West Gulf Coastal Plain. These ecological system classes were added to the GAP selection. Ultimately, 31 GAP classes were selected (Table 1). Acres are calculated by summing the 30 meter (900 m^2) pixels and multiplying by 0.2224. Pine mask acres by subgeography are shown in Table 2. For more information about the process of generating the Pine Mask, see Appendix 1.

GAP code	**GAP description**	**Acres**
4504	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Loblolly Modifier	95,174
4553	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	98,905
4505	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory	218,147
4506	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory	1,366
4536	Atlantic Coastal Plain Upland Longleaf Pine Woodland	10,915
5602	Atlantic Coastal Plain Xeric River Dune	1,213
4337	Crowley's Ridge Sand Forest	157,508
4301	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Hardwood Modifier	2,638,447
4309	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Mixed Modifier	3,617,749
4507	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	8,972,757
4501	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite Hardwood Modifier	2,317,288
4508	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	993,837
4509	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Scrub/Shrub Modifier	33,689
9901	East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory Modifier	195,023

9910	East Gulf Coastal Plain Near-Coast Pine Flatwoods	12,207
9902	East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier	79,541
9903	East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier	1,088,261
9904	East Gulf Coastal Plain Near-Coast Pine Flatwoods - Scrub/ Shrub Understory Modifier	2,426
9911	East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	118,145
4541	East-Central Texas Plains Pine Forest and Woodland	11,428
8202	Evergreen Plantation or Managed Pine	3,372,720
8203	Managed Tree Plantation	10,081,550
4549	Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	61,524
4328	Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	4,627,274
4322	Southeastern Interior Longleaf Pine Woodland	382
4538	Southern Appalachian Low Mountain Pine Forest	62,131
9913	West Gulf Coastal Plain Pine-Hardwood Flatwoods	306,989
4332	West Gulf Coastal Plain Pine-Hardwood Forest	5,170,941
4336	West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	465,455
4321	West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	447,448
9908	West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	2,570,855
	TOTAL	**47,831,295**

Table 2: Acres and percent coverage of Pine Mask by GCPO Subgeographies. Note: summing raster pixels by zones of subgeography results in a loss of the equivalent to 24,344 acres, or 0.05%.

SubGeography	Total acres	Pine Mask acres	Pine Mask as % of total
West Gulf Coastal Plain	52,698,200	22,382,544	42
East Gulf Coastal Plain	62,412,700	22,536,573	36
Mississippi Alluvial Valley	25,438,900	417,363	2
Ozark Highlands	33,706,600	1,285,139	4
Gulf Coast	6,013,850	1,185,332	20
TOTAL	**180,270,250**	**47,806,951**	**27**

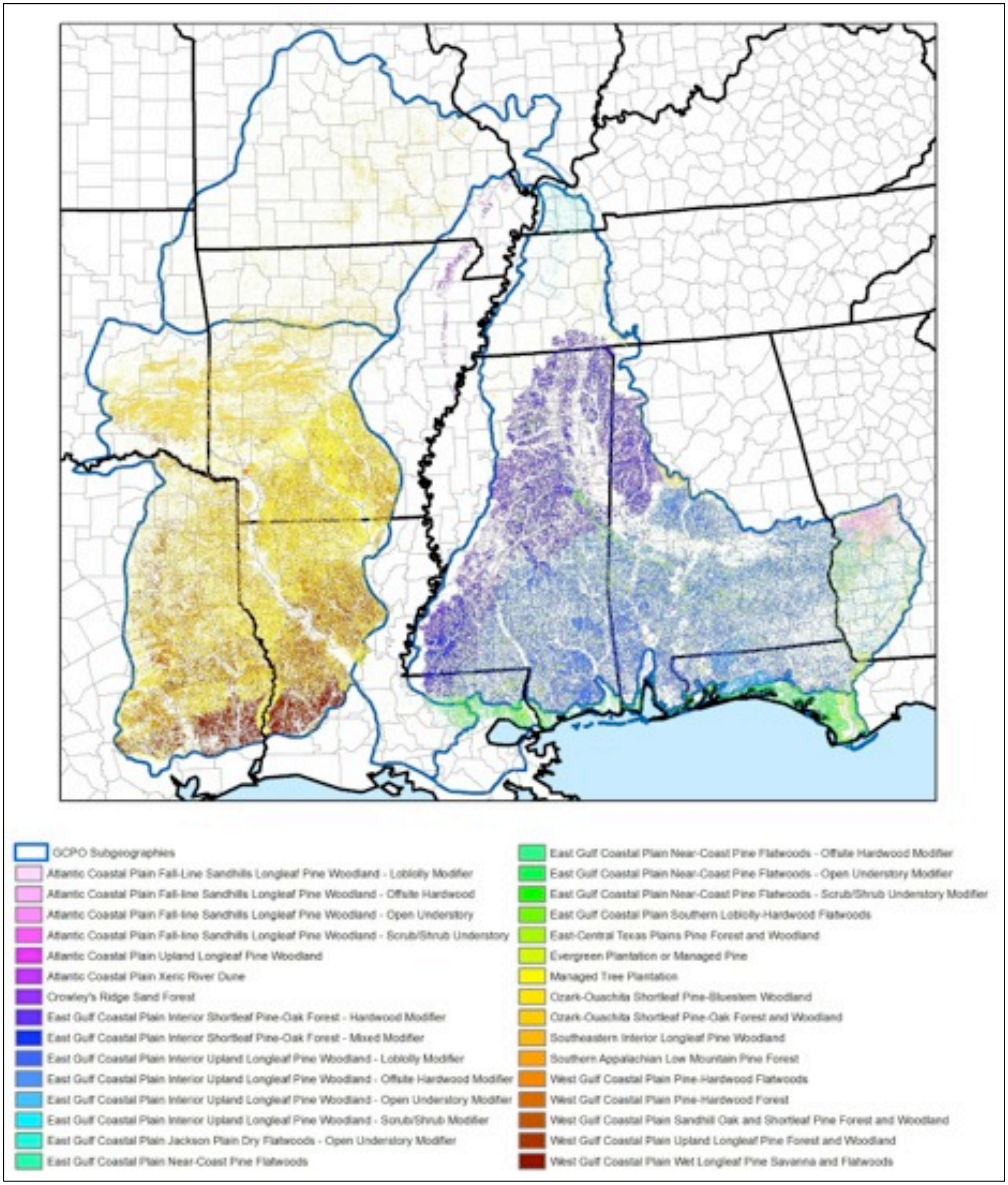

Figure 4: Spatial distribution of Pine Mask ecological systems within GCPO subgeographies.

A binary version (Pine Mask/Not Pine Mask) is displayed in Figure 5. Pixels representing the pine-dominant classes are sparse in the alluvial plains of big rivers, the Blackland Prairie Ecoregion of Mississippi and Alabama, and the Dougherty Plain Ecoregion of southeastern Alabama and southern Georgia. Agricultural vegetation is the dominant land ecological system/land use class in these areas. In the northern portion of the GCPO geography, Pine Mask pixels are sparsely scattered among the dominant hardwood forest and agricultural land classes.

Figure 5: Pine Mask represented by green pixels at 30 meter resolution. Individual pixels do not appear at this scale. Darker values of green represent greater concentrations of Pine Mask pixels.

A map summarizing the Pine Mask as percent coverage of HUC12 basins is shown in Figure 6. In the West Gulf Coastal Plain, the relative portion of the land unit occupied by the Pine Mask increases on a southward gradient. In the East Gulf Coastal Plain, the proportions are more uniformly distributed. The same gaps in Pine Mask coverage described above for Figure 4 are evident here.

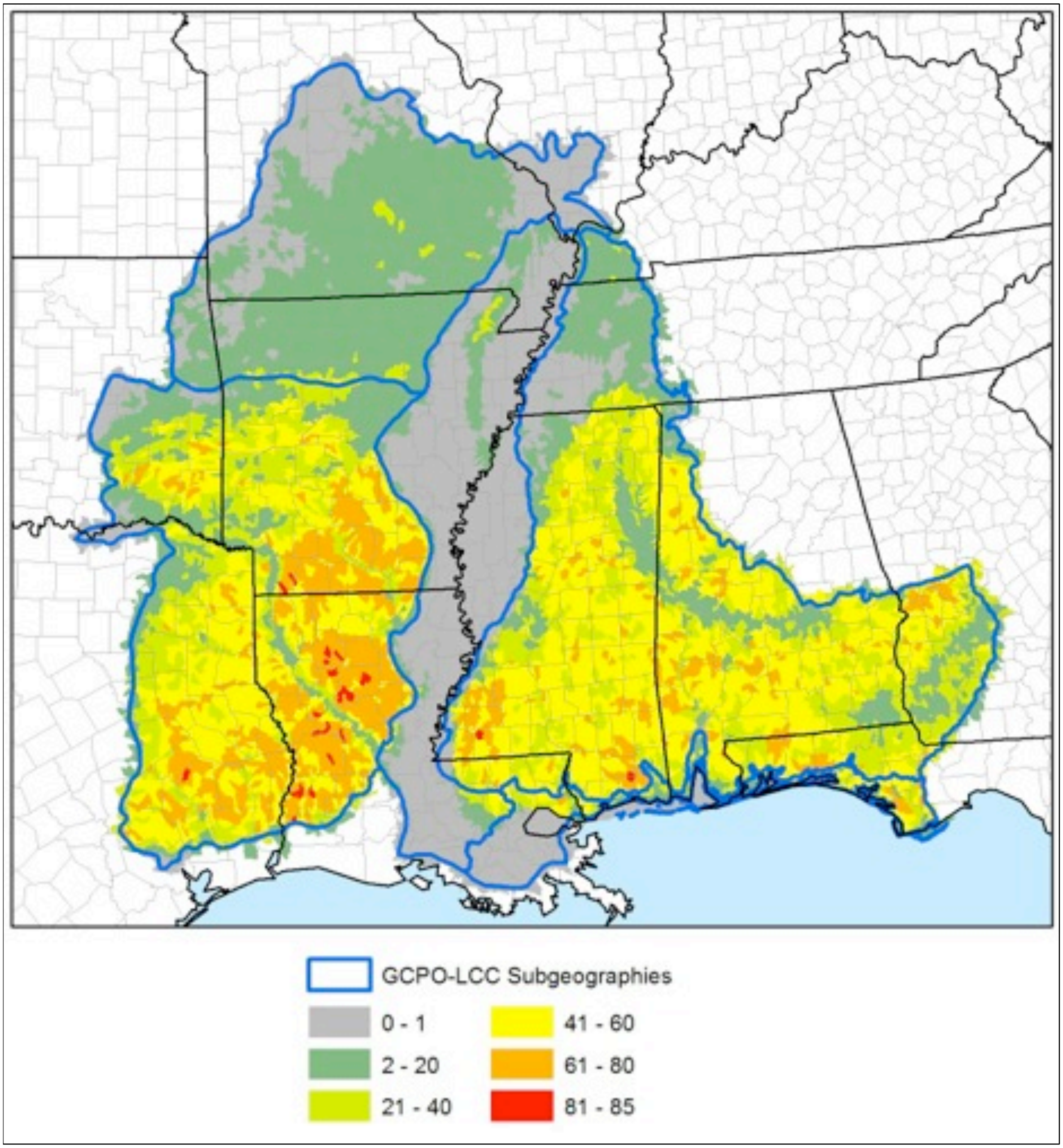

Figure 6: Percentage of area occupied by pine mask summarized by HUC12 watershed.

The Pine Mask covers 22.4 million acres (42%) of the West Gulf Coastal Plain and 22.6 million acres (36%) of the East Gulf Coastal Plain (Table 2). Acreage amounts for each ecological system within each GCPO subgeography are shown in Appendix 1. In the Mississippi Alluvial Valley the Pine Mask includes the Crowley's Ridge Sand Forest in Northeast Arkansas and patches of Near-Coast Pine Flatwoods where the MAV, GC, and EGCP come together in Southeast Louisiana. The Ozark Highlands subgeography features about 1.2 million widely-scattered acres of Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland (Figure 4).

Limitations and Future Directions

The genus *Pinus* is common in the Gulf Coastal Plain. It can be found on a wide variety of soils, substrates, and topographic positions. The goal of the Pine Mask is to identify areas where the presence of pine in the ecosystem is neither incidental nor opportunistic but dominant. Our mask may over-represent the amount of land on which the potential for open pine conservation or restoration exists, but it is not intended to be deterministic. It is a starting point from which the targeted endpoints, such as basal area of 40-70 ft^2/acre or canopy cover of <50%, can be assessed. As the first branch of the decision tree, an abundance of inclusiveness is preferable to excessive discernment.

The Pine Mask is based on the assumption that the National GAP Landcover Data layer is an accurate representation of existing ecological systems. The Pine Mask is also based on the assumption that the appropriate ecological systems were selected from the clipped GAP Landcover Data layer. Systems with the words “Woodland” or “Savanna” in the name are almost certainly appropriate. “Pine-Hardwood Forest” and “Managed Tree Plantation” are likely to contain a mix of appropriate and inappropriate landscapes.

Resampling the Pine Mask

Processing multiple input spatial data layers requires a common spatial resolution. Our process uses three input layers at a spatial resolution of 30 meters: GAP ecological systems, LANDFIRE biophysical settings, and NLCD Canopy Cover. We use four layers provided by USFS at a spatial resolution of 250 meters: Live Tree Basal Area, Midstory Tree Density, Midstory Basal Area, and Average Tree Diameter per Acre. The available resampling options present advantages and disadvantages:

- Resample the 250 meter layers down to 30 meters: keeps the spatial accuracy of the 30 meter layers intact, but generates misleading results for conditions described by the coarser resolution input layers. The 250 meter USFS layers use continuous, imputed values derived from plot-level data. Resampling these to a finer resolution does not repeat the imputation algorithm but merely reassigns the value in the larger pixel to a number of smaller cells, increasing the likelihood that the estimated value of any particular pixel location is erroneous. Furthermore, in a landscape of 180 million acres, file size and processing times increase the difficulty of each step of the process. Processes often fail to complete, and the output can be difficult to store.
- Resample the 30 meter layer to 250 meters: greatly increases process and data storing capabilities, but sacrifices spatial accuracy of some of the input layers. With categorical data, such as the GAP and LANDFIRE products, two options are available:
    - Resample using a majority procedure: assigns to the 250 meter output cell the value that occurs most often in the smaller input cells. The output layer describes where the input occurs most often. If a condition occurs infrequently, it may not appear at all in the output. Often total areal amounts described in the output layer differ from those of the input layer
    - Resample using a nearest neighbor procedure: assigns the value of the 30 meter input cell closest to the centroid of the 250 meter output cell to the

output. Allows for values that occur infrequently to appear in output cells even in cases where they do not cover a majority of the pixel space. Total aerial amounts of output conditions are closer to those of the inputs, but the spatial distribution of the representative pixels is somewhat arbitrary.

We chose to resample all input layers to 250 meters in order to facilitate data processing and storage and to preserve the integrity of the imputed USFS layers. Since the goal of this project is to identify large patches of a set of conditions, the Pine Mask was resampled using the majority rule. The advantages and limitations of the resampling options are discussed in greater detail in Appendix 2.

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Pixels outside the Pine Mask that have potential to be Open Pine

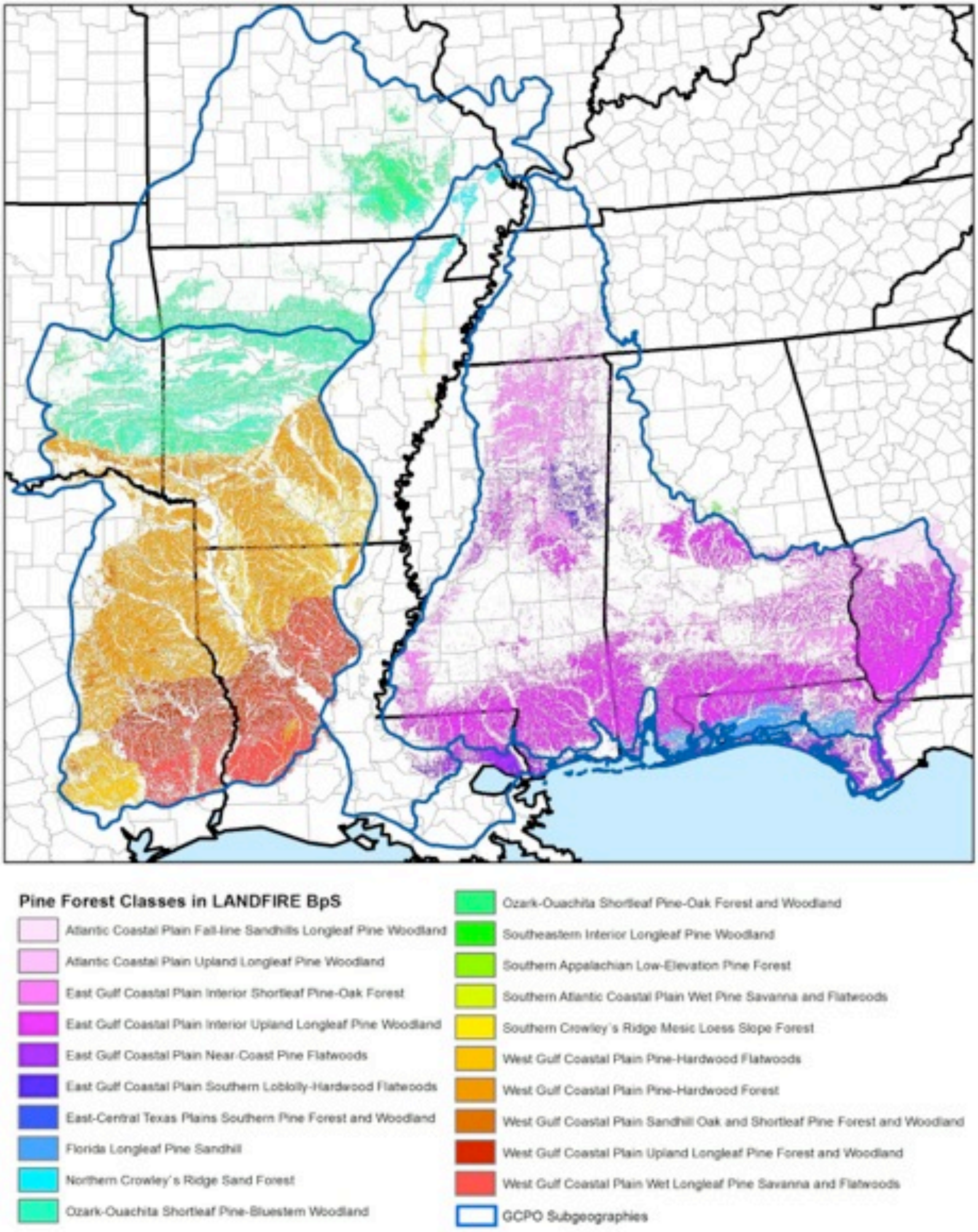
Introduction

In order to acknowledge currently non-forested landscapes suitable for open pine, we generated a layer of potential habitat based on the LANDFIRE Biophysical Settings (BpS) data layer, which represents vegetation that may have been dominant on the landscape at the time of European Settlement. Pixels classified as any developed class or as open water in the National Land Cover Database 2011 (NLCD) data layer were not considered. Both the BpS and NLCD data layers were resampled to 250 meter spatial resolution for this process. Forty-two BpS classes were selected to indicate potential for open pine (Table 4).

Table 4: Selected LANDFIRE BpS classes representing the potential for open pine.

BpS Name	**Acres**
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland	636,048
Atlantic Coastal Plain Upland Longleaf Pine Woodland	422,749
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest	4,203,714
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland	14,037,526
East Gulf Coastal Plain Near-Coast Pine Flatwoods	1,664,748
East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	919,551
East-Central Texas Plains Southern Pine Forest and Woodland	3,911
Florida Longleaf Pine Sandhill	1,299,781
Northern Crowley`s Ridge Sand Forest	388,028
Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	3,658,526
Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	4,682,902

Southeastern Interior Longleaf Pine Woodland	33,718
Southern Appalachian Low-Elevation Pine Forest	23,897
Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods	113
Southern Crowley`s Ridge Mesic Loess Slope Forest	94,201
West Gulf Coastal Plain Pine-Hardwood Flatwoods	2,473,924
West Gulf Coastal Plain Pine-Hardwood Forest	11,210,665
West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	636,073
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	2,568,446
West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	3,867,300
TOTAL	52,825,822


Pine Forest Classes in LANDFIRE BpS
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland
Atlantic Coastal Plain Upland Longleaf Pine Woodland
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland
East Gulf Coastal Plain Near-Coast Pine Flatwoods
East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods
East-Central Texas Plains Southern Pine Forest and Woodland
Florida Longleaf Pine Sandhill
Northern Crowley's Ridge Sand Forest
Ozark-Ouachita Shortleaf Pine-Bluestem Woodland
Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland
Southeastern Interior Longleaf Pine Woodland
Southern Appalachian Low-Elevation Pine Forest
Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods
Southern Crowley's Ridge Mesic Loess Slope Forest
West Gulf Coastal Plain Pine-Hardwood Flatwoods
West Gulf Coastal Plain Pine-Hardwood Forest
West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland
West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods
GCPO Subgeographies

Processing methods:

The LANDFIRE BpS layer was resampled to 250 meters using the nearest neighbor procedure and then reclassified so that the 42 selected classes were assigned a value of one and all other cells received a value of zero. The nearest neighbor procedure was used because, unlike the Pine Mask, the end goal here is not to locate and identify patches but rather to characterize the landscape generally. Also, the nearest neighbor procedure increases the likelihood that land cover classes that occur infrequently in the input will be preserved in the output.

The NLCD layer was resampled to 250 meter spatial resolution using the nearest neighbor procedure. As with the LANDFIRE BpS layer, nearest neighbor was used to preserve descriptions of land cover classes that occur infrequently. The resampled layer was reclassified so that open water and the four developed classes were assigned values of no data and all other classes were assigned values of one. This reclassified layer was used as an extraction mask on the LANDFIRE BpS layer. The extracted output was reclassified so that the extracted cells (representing land that is *not* water and *not* developed according to NLCD and *is also* one of the 42 selected potential pine forested systems according to LANDFIRE BpS) retained their value of one while all other cells were assigned a value of zero. This output was used as one of the input layers for calculation of the condition index.

Amount and Configuration

Amount: 20 million acres

Configuration: Patch size > 600 acres; < 3 km to next nearest patch

Introduction

Isolation of habitat patches and habitat fragmentation are often cited as having a major impact on small populations of species of conservation concern in complex landscapes. Most studies of habitat fragmentation and patch isolation take place in landscapes where the forests are considered isolated patches of suitable habitat surrounded by unsuitable expanses of open land, with corridors considered as linear forested areas through which species move from patch to patch. For open-habitat species, clear-cuts may represent isolated patches of suitable habitat surrounded by unsuitable forest (Dunning et al. 1995). Few studies quantify patch size and isolation/distance effects on species associated with open pine. Dunning et al. (1995) observe that Bachman's sparrow populations in managed pine disperse by utilizing clear-cuts, and that occupation of suitable habitat decreases with distance from potential source patches. They suggest that Bachman's sparrow dispersion is limited to 5-6 km for a two-year period. The Lower Mississippi Valley Joint Venture (2011) uses a patch size of > 230 ha/585 acres as a key limiting habitat characteristic for open pine in the Western Gulf Coastal Plain, based on requirements of northern bobwhite and red-cockaded woodpecker, and a connectivity measure of < 3km to the nearest patch, based on requirements of northern bobwhite, brown-headed nuthatch, and Bachman's sparrow. McIntyre (2012) does not offer configuration metrics for the system, but provides habitat patch size and spacing information for the associated species in a tabulated literature review in an appendix: 3.5 ha/8.6 acres and < 3 km between patches for Bachman's sparrow, 5 ha/12 acres and < 300 m between patches for brown-headed nuthatch, 60 ha and no minimum distance given for gopher tortoise, > 3000 ha/7413 acres and no minimum distance given for northern bobwhite, and 32-51 ha/79-126 acres and no minimum distance given for red-cockaded woodpecker.

The open pine savanna is a disturbance-dependent system nested within the larger pine/mixed-pine-hardwood forest matrix that dominates much of the uplands of the Gulf Coastal Plain. We assessed the amount and configuration metrics of this larger forested landscape matrix. Our pixel-by-pixel condition index calculation evaluates pixels within patches of pine-dominant or pine-codominant forest, an ecological system within which forest conditions are variable across the landscape. Our analysis of that entire system in terms of patches with neighbors allows for the possibility that for any particular location any number of endpoint conditions, or none at all, may exist. The process addresses configuration in two steps: pixels are first classified according the whether they are in a patch >600 acres, then, within those two classes, are classified again according to whether they are within 3 km of a neighboring patch. Within those four configuration classes, pixels are evaluated based on the presence or absences of endpoint conditions.

<u>Processing Methods</u>

To identify patches >600 acres, the Pine Mask raster was converted to a polygon shapefile and acreage amounts were calculated for each individual polygon. Two new shapefiles were created, one for polygons less than or equal to 600 acres, and one for polygons greater than 600 acres. To identify large patches with neighbors within 3 km, we (Figure 7):

1. Created a dissolved 1.5 km buffer on the > 600 acre patch polygons
2. Converted the buffer shapefile to raster and then back to polygon. This step converts the file from a single feature to multiple features.
3. Converted the patch polygons to a point shapefile.
4. Added a field named 'Count' to the point shapefile. Populated the field with values of one. This step allows for the patch polygons, represented as points, to be counted within the buffers.
5. Joined the point shapefile to the buffer shapefile based on spatial location and a "sum" procedure. This creates a field named "SUM" in the attribute table of the buffer that tallies the number of patches within each buffer polygon.
6. Selected buffers with a value greater than one in the sum field.
7. Created a new layer from the selection. This step creates a mask for selecting patches that have neighbors within 3 km.
8. Used the output from step seven to clip the 250 meter Pine Mask raster.

For the patches less than 600 acres in size, the process was modified by use of shapefiles and buffers representing *all* patches. In this way, the set of smaller patches were evaluated on whether they are within 3 km of a patch *of any size*, whereas the set of larger patches is evaluated on whether they are within 3 km of another large patch.

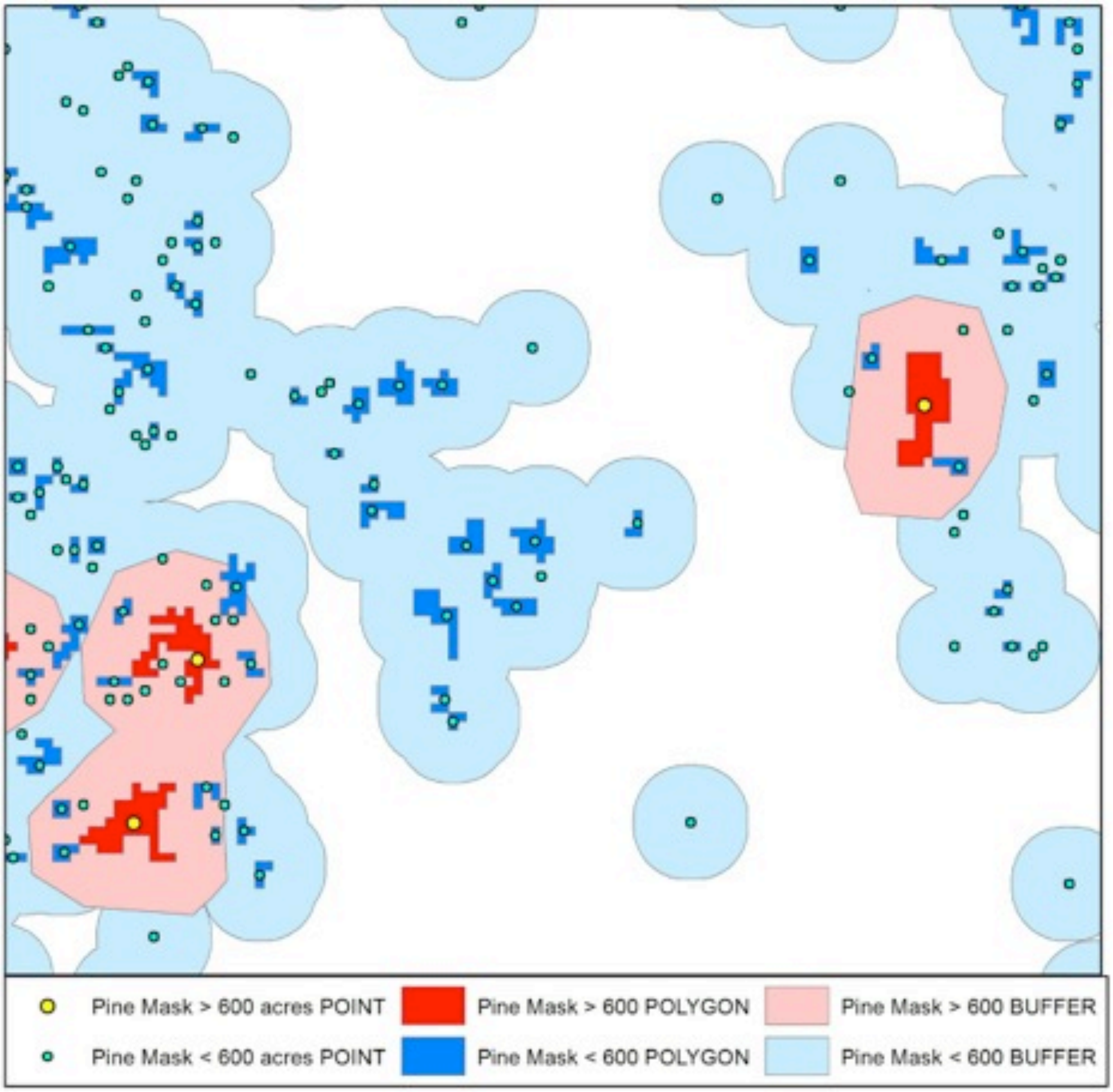


Figure 7: Pine Mask polygons, buffers, and points used to calculate configuration metrics.

The process generated three raster layers for use in the condition index. Creation of a raster layer consisting of patches ≤ 600 acres and without neighbors is unnecessary: those pixels are worth no more than the Pine Mask itself in the generation of the condition index. The raster layer consisting of pixels in patches > 600 acres was assigned a value of ten. Those consisting of patches

Results

The process identified 247,542 patches of Pine Mask polygons. The majority of patches (97.5%) are less than 600 acres in size and have a neighbor within 3 km. 143,565 patches, or 58%, were represented by a single pixel, or 15.44 acres. 241,962 were less than and 5490 were greater than 600 acres in size (Table 5).

Table 5: Counts of forest patches within configuration thresholds

Patches	Total number of patches	Number of patches within 3 km of another patch	Total Acres	Acres in patches within 3 km of another patch
> 600 Acres	5490	5313	34,952,223	34,788,574
< 600 Acres	241,962	241,371	10,508,186	10,497,394

Future Directions and Limitations

The polygon shapefile created by converting the Pine Mask from raster to polygon aggregates adjacent pixels in orthogonal directions only and treats diagonally adjacent pixels as separate polygons. Diagonally adjacent pixels can be aggregated by using the buffer tool, but doing so produces patches that are larger than those described in the original raster. The amount by which these aggregated polygons are larger varies with the size of the buffer and the size and spatial complexity of the individual polygons. GCPO analysts are in consultation with our geomatics working group to address this problem.

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Condition

Introduction

The following sections describe how spatial data layers related to each of the condition endpoints were selected and processed before combining all layers in the map algebra procedure. Each section begins with the endpoint metric as stated by the draft ISA and a brief survey of scientific literature relating to the particular endpoint, followed by a description of the data and processing methods used, followed by a description of results, limitations, and future directions. Efforts by GCPO LCC partners to organize and assess the full range of species-habitat interactions in terms of forest condition endpoints, management recommendations, and decision support tools are summarized in the Conclusion to the chapter.

Basal Area

Desired Landscape Endpoint: Basal Area (pine): 40 – 70 ft^2/acre

Introduction

The characteristically open structure of southeastern pine forests was historically maintained by frequent fires, and the dense, closed structure of much of those same forests today is the result of the removal of the original trees followed by decades of fire suppression (Hedrick et al. 2007, Van Lear et al. 2005, Frost 1992). Typical basal area values in a frequently burned pine savanna range from 12 – 20 m^2/ha (52 – 87 ft^2/acre) (Varner et al 2005). All open pine restoration prescriptions involve reducing the number of trees and maintaining stands at some threshold density or basal area below that which occurs in the absence of disturbance. In the Ouachita National Forest, Hedrick et al. (2007) prescribe thinning to a residual basal area of 60 ft^2 per acre (below the current 90 -100 ft^2 basal area of pine and 30 ft^2 basal area of hardwoods per acre) followed by burning at 3- to 4-year intervals in order to restore historic stands of the pine-bluestem ecological system. Based on species-habitat interactions of four species that represent conservation priorities for longleaf pine restoration, McIntyre (2012) proposes a basal area 40 – 70 ft^2/acre (the same range indicated by the ISA) as a desired forest condition. The Lower Mississippi Valley Joint Venture (2011) uses <90 ft^2/acre as a desired forest condition for red-cockaded woodpecker and northern bobwhite in their Open Pine Landbird Plan.

We used the USFS live tree species basal area data product (Wilson et al. 2013) combined with the Pine Mask (described in the Introduction Chapter) for assessment of open pine woodland and savanna basal area within the East and West Gulf Coastal Plain and other GCPO geographies.

Data Sources and Processing Methods

The USFS live tree species basal area data product integrates vegetation phenology from MODIS imagery with extensive FIA field plot data of tree species basal area to map species distribution and basal area at 250 meter spatial resolution for the 48 conterminous U.S. states (Wilson et al. 2013). The modeling approach uses k-nearest neighbor and canonical correspondence weighting techniques, along with a stratification derived from the 2001 National Land-Cover Database tree canopy cover layer. Our assessment used a raster layer containing values for the sum of basal area values for all species clipped to a 2km buffer of the HUC12 basins contained within and intersecting the GCPO boundary.

The Pine Mask data layer identifies pine-dominant or mixed pine ecological system and land use classes of land at 250 meter spatial resolution and is described in detail in the Introduction to this chapter.

We used the Pine Mask as an extraction mask on the live tree species basal area layer. We then reclassified the result so as to eliminate all cells with values below 40 or above 70. The final result was a raster layer representing the existence of 2 conditions: 1) the Pine Mask, and 2) total live species basal area is 40 – 70 ft^2/acre.

Summary of Findings

The assessment indicates that 16.3 million acres of pine-dominant systems with basal area 40 – 70 ft^2/acre exist in the East and West Gulf Coastal plains (Table 6). Land with the desired basal area accounts for 38% of the Pine Mask in both the East and West Gulf Coastal Plains and in the GCPO overall. The Pine Mask does not occupy large portions of the other subgeographies, but where it exists the portion characterized by the target basal area ranges from 28% in the Ozark Highlands to 46% in the Gulf Coast (Table 7).

Table 6: Acreage amounts for Pine Mask basal area values below, within, and above the endpoint range of 40 – 70 ft^2/acre in the GCPO.

Subgeography	Total	Pine Mask	0 - 40 ft^2/acre	40 - 70 ft^2/acre	70 - 285 ft^2/acre
West Gulf Coastal Plain	52,698,200	22,047,471	3,346,234	8,273,972	10,427,265
East Gulf Coastal Plain	62,412,700	21,382,408	1,799,177	8,024,600	11,558,631
Mississippi Alluvial Valley	25,438,900	336,716	71,225	113,314	152,177
Ozark Highlands	33,706,600	578,568	57,452	160,468	360,648
Gulf Coast	6,013,850	1,096,518	213,875	502,865	379,778
TOTAL	180,270,250	45,441,680	5,487,963	17,075,220	22,878,498

Table 7: Acres of Pine Mask basal area values below, within, and above the endpoint range as percentages of the total area and the Pine Mask.

	As % of total area			As % of Pine Mask		
Subgeography	< 40 ft^2/acre	40 - 70 ft^2/acre	>70 ft^2/acre	< 40 ft^2/acre	40 - 70 ft^2/acre	>70 ft^2/acre
West Gulf Coastal Plain	6	16	20	15	38	47
East Gulf Coastal Plain	3	13	19	8	38	54
Mississippi Alluvial Valley	0	0	1	21	34	45
Ozark Highlands	0	0	1	10	28	62
Gulf Coast	4	8	6	20	46	35
TOTAL	3	9	13	12	38	50

The desired endpoint occurs throughout the East and West Gulf Coastal Plains, with highest concentrations in southeastern Texas, southern Mississippi and Alabama, northwestern Florida, and central Georgia (Figures 8 and 9). Areas where basal areas exceed the desired maximum of 70 ft^2/acre (opportunities for restoration by thinning) are shown in Figure 10.

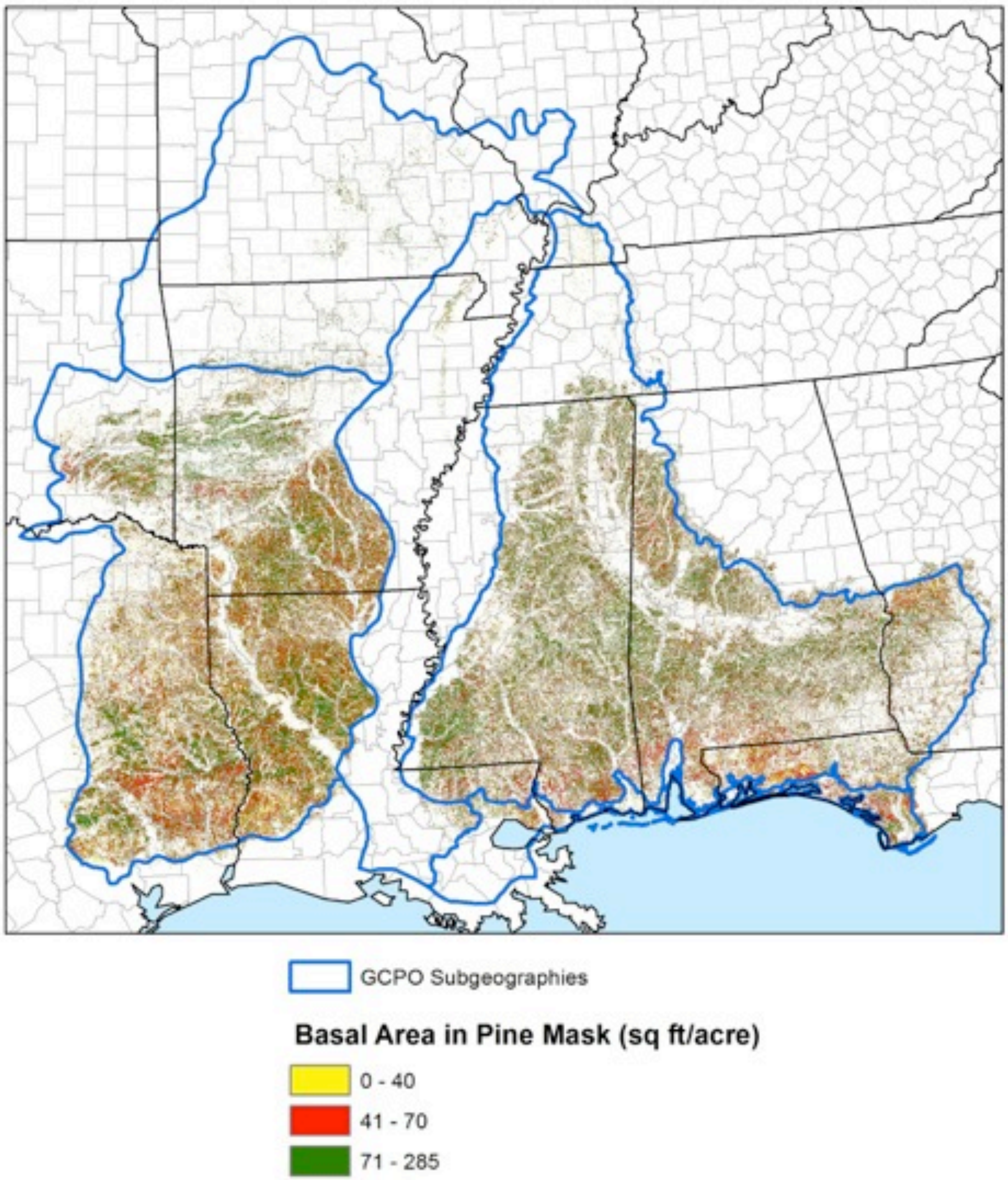

Figure 8: Raster layer representing Pine Mask pixels with basal area below, within, and above the desired range of 40 - 70 ft^2/acre.

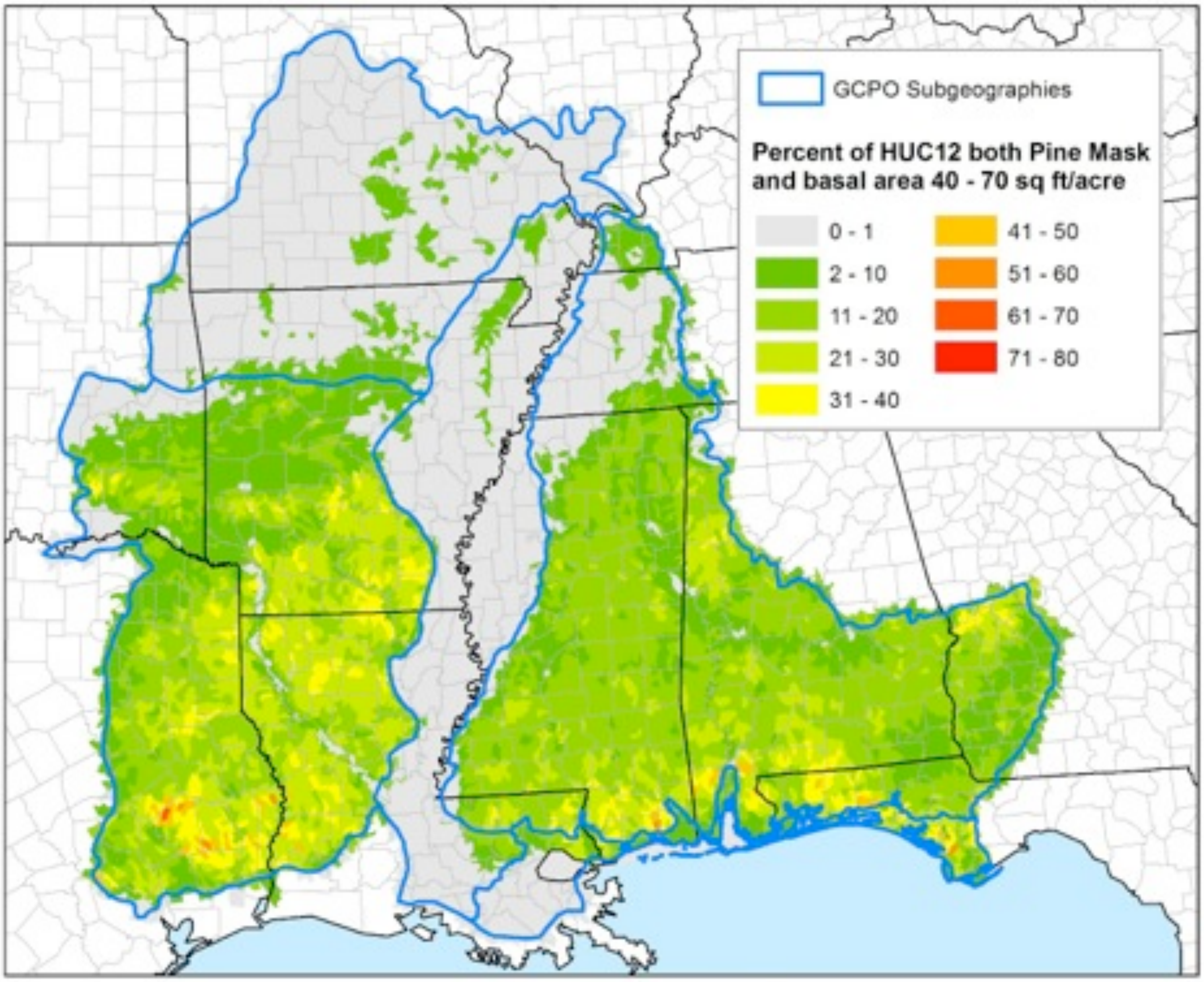

Figure 9: Percent of HUC12 basin area both Pine Mask AND basal area 40 - 70 ft^2/acre.

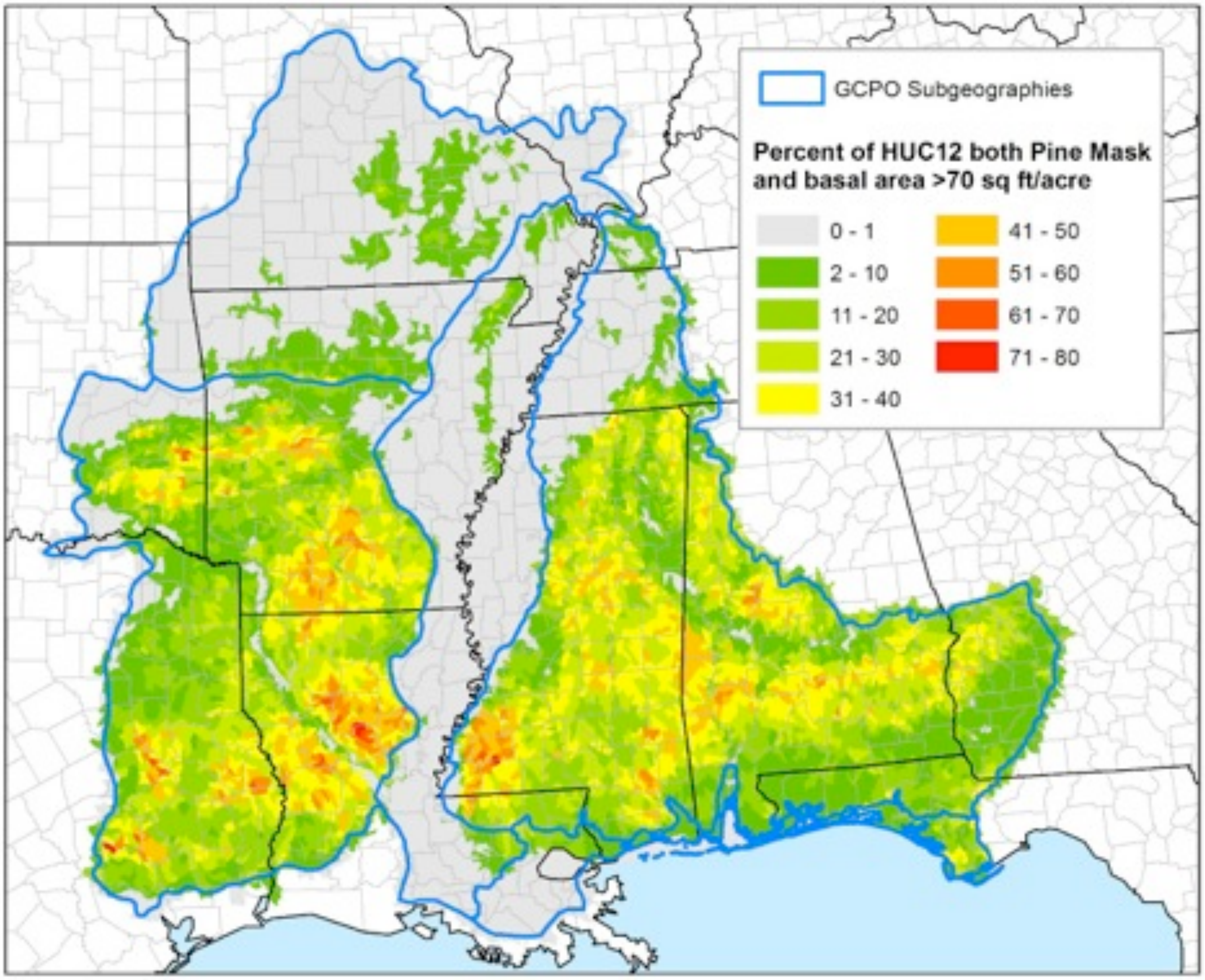

Figure 10: Percent of HUC12 basin area occupied by both Pine Mask and basal area values higher than the desired range of 40 – 70 ft^2/acre.

Future Directions and Limitations

Assessing the Endpoint

The Lower Mississippi Valley Joint Venture (2011) uses a pine basal area measure of <90 ft^2/acre (with no lower bound) as a key limiting habitat characteristic for two of their four umbrella species for their open pine decision support tool. They provide a metric for hardwood basal area (<20 ft^2/acre) as well. McIntyre (2012) uses the same 40 – 70 range identified in the ISA, based on a literature review of the habitat preferences of eight species. At the Joseph W. Jones Ecological Center in Georgia, these species are often observed in open pine stands with basal areas below 40 ft^2/acre (Mike Conner, personal communication). The absence of a lower bound for the canopy cover endpoint in the ISA calls into question whether one is necessary for basal area, and, if so, whether the one provided fails to recognize stands in which conditions are amenable to the target species. In other words, the notion that areas of about 15 acres (the size of a 250 meter pixel) with no trees at all are acceptable in a larger open pine woodland savanna matrix is supported by the canopy cover endpoint but rejected by the basal area endpoint. If treeless patches are not to be tolerated, the basal area estimation layer has correctly rejected treeless areas and the canopy cover layer has incorrectly selected them. If treeless areas are allowed, the basal area layer has rejected a portion of pixels indicative of a condition considered desirable by the canopy cover layer.

Assessing the Data

The USFS live tree species basal area data product is based on information collected between 2000 and 2009. The data layer was published by the US Forest Service in 2013 and is publically available. The data layer does not address the research question exactly because it pertains to all species, whereas the ISA endpoint pertains to the genus pine alone. This gap between the endpoint and the data is discussed in the “Alternate Approaches” subsection below.

Alternate Approaches

All species basal area vs. pine alone

The ISA condition endpoint for basal area specifies pine. While developing the Pine Mask, we processed basal area data layers for the 4 most common southeastern pine species (see Introduction to this chapter). We did not use this data product in the regional assessment of the endpoint because it contains no information about the contribution of other species to the total basal area. Our use of the “all species” layer rather than the sum-of-pine layer assumes that 40-70 ft^2 per acre is the desired condition for the forest generally and not just the contribution of pine to the total. We are confident that the Pine Mask effectively prevents inclusion of areas where non-pine contributions to the total basal area are significant. A future refinement of the endpoint would be the identification of a threshold basal area for non-pine species and the production of a data layer characterizing forests in terms of both the pine and non-pine contribution to the total basal area.

Limitations

This assessment assumes that the USFS live tree basal area data product is an accurate representation of basal area amounts within the GCPO. The USFS live tree species basal area data layer contains hexagon-level measures of confidence, but these measures were not used in this analysis. The limitation inherent in the distinction between “all species” in the data and “pine only” in the endpoint is made less severe by the use of the Pine Mask. The correspondence between data and endpoint is comparatively strong and therefore the output raster layer produced here is given a score of **two** in the map algebra equation (described in the “Amount and Configuration” section below).

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Lower Mississippi Valley Joint Venture. 2011. Open Pine Landbird Plan West Gulf Coastal Plain/Ouachitas: A report to the Lower Mississippi Valley Joint Venture Management Board. <http://lmvjv.org/library/WGCPO_Landbird_Open_Pine_Plan_Oct_2011.pdf> Accessed September 24, 2014.

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Diameter at Breast Height

Desired Landscape Endpoint: ≥20 ft^2/acre of trees ≥14" DBH

Introduction

The importance of the presence of large mature pines to the open pine woodland and savanna priority system is well-documented, although specific values for minimum size and age to support pine-grassland adapted species are rarely found in the literature. The presence of large-diameter (>14") pine trees is considered a key limiting habitat characteristic for open pine umbrella species red-cockaded woodpecker and brown-headed nuthatch (Lower Mississippi Valley Joint Venture, 2011). Red-cockaded woodpecker (RCW) builds nesting cavities exclusively in large, old, live pine trees, and a major cause of the decline in RCW population is the disappearance of pines of sufficient size and age for cavity excavation (Walters 1991, U.S. Fish and Wildlife Service, 2003). This endpoint establishes a minimum standard: at least a portion of the basal area (20 square feet of each acre) must be occupied by trees of at least 14" DBH. Since a 14" diameter tree takes up about one square foot of space on the ground, the endpoint could be restated as requiring at least 20 trees of diameter ≥14" per acre.

Data Sources and Processing Methods

We were unable to locate geospatial data that addresses this requirement directly. However, as with endpoints describing midstory cover (see below), we were able to use proxy variables imputed from plot-level data to estimate the general diameter condition: a landscape characterized by the presence of large, mature trees. Of the USFS/FIA data layers provided to the GCPO LCC by the Remote Sensing Applications Center (described in the chapter introduction), the most useful for characterizing a forest of large, mature trees is a measure of average tree diameter per acre. We used the Pine Mask to extract values from the national map. Units are inches and values within the Pine Mask range from 0 to 18.42 with a mean of 4.91. When classified by the quantile method (5 bins of equal size), the bottom value in the top bin is 6.07, which is 0.75 standard deviations above the mean (Table 7). This distance from central tendency, along with the size of the sample (one fifth of the observations), suggests that the top quantile is a suitable proxy.

Table 7: Data value breaks for bins of average diameter per acre, quantile method. "Distance" refers to the distance between the 4th break and the mean, measured in standard deviations.

Bin breaks	Average diameter (inches)
1	3.68
2	4.48
3	5.20
4	6.07
5 (max value)	18.42
Mean	4.91
Standard deviation	1.55
Distance	0.75

Summary of Findings

In the East and West Gulf Coastal Plains, this analysis identifies about 9 million acres, or 5% of the total area, where average tree diameter per acre is relatively high. Within Pine Mask pixels, the top quantile values (displayed as 19 rather than the expected 20 percent due to edge effects and the conversion from pixel counts to acres) are slightly more concentrated in subgeographies outside the East and West Gulf Coastal Plain (Table 8). The spatial configuration of the target condition is represented in raster format (Figure 11) and summarized by HUC12 basin (Figure 12).

Table 8: Acreage amounts for top quantile of average DBH per acre by subgeography

SubGeography	Total acres	Pine Mask acres	Pine Mask and average DBH/acre >6"	Pine Mask and average DBH/acre >6" as % of total	% Pine Mask with average DBH/acre >6"
West Gulf Coastal Plain	52,698,200	22,047,471	3,997,571	8	18
East Gulf Coastal Plain	62,412,700	21,382,408	4,250,668	7	20
Mississippi Alluvial Valley	25,438,900	336,716	105,374	0	31
Ozark Highlands	33,706,600	578,568	160,602	0	28

Gulf Coast	6,013,850	1,096,518	278,826	5	25
TOTALS	180,270,250	45,441,680	8,793,041	5	19

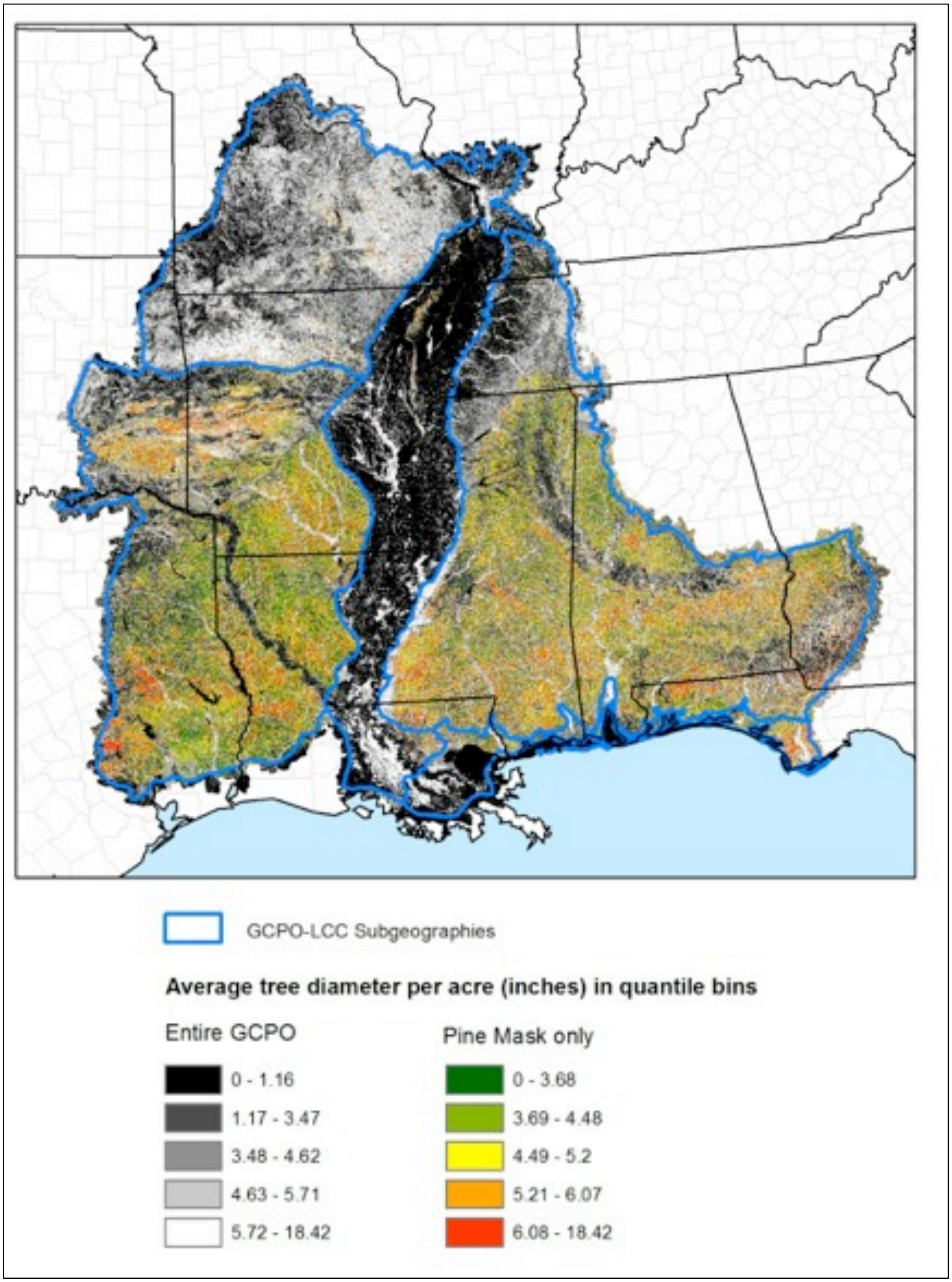

Figure 11: Raster map of average tree diameter in quantile bins both in the GCPO and in the Pine Mask

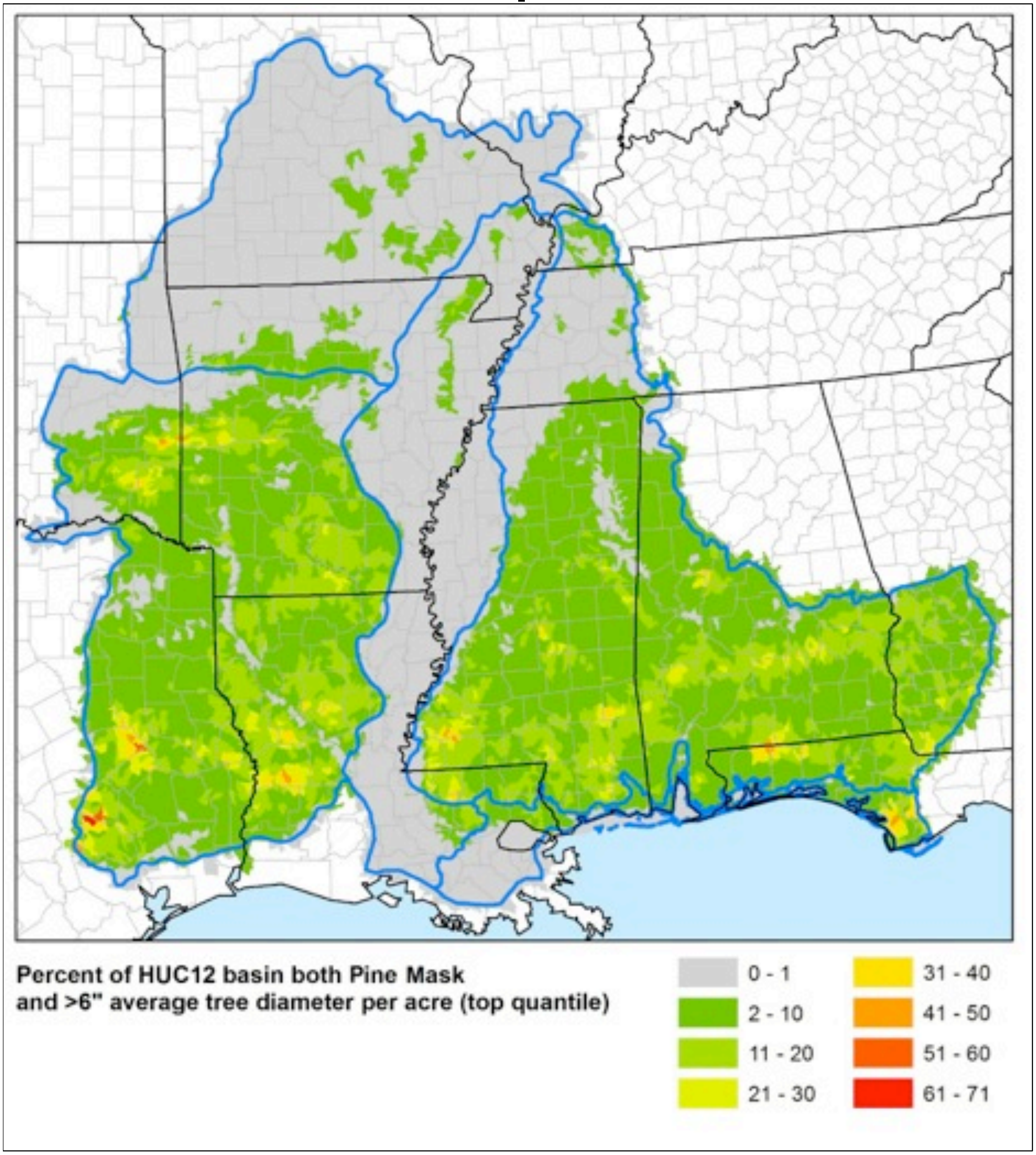

Figure 12: Percentage of HUC12 basin occupied by Pine Mask pixels with top quantile class (>6") average tree diameter per acre pixels

Future directions and limitations

Assessment of the endpoint

The minimum standard of 20 square feet per acre of trees ≥14” DBH is ecologically sound in terms of habitat-species interactions in a healthy system, but unsuitable for analysis beyond the site/stand scale due to lack of available data.

Assessing the data

While the endpoint is too complex for regional scale analysis, the regional scale data layer used here (average DBH/acre) is too simple for species-habitat interaction modeling. Issues related to the endpoint – data disconnect are discussed in the “Alternate approaches” subsection below:

Alternate Approaches

Large values in a dataset of average tree diameter per acre alone do not positively indicate the presence of large trees, and small values do not necessarily preclude it. Twenty or more large trees can be found on an acre with low average diameter, provided a sufficient number of small trees are also present. This assessment would be improved by the development of a data layer that summarizes FIA plot level data with a statistic other than the average. FIA technicians record DBH for all trees with diameter of >5” in a subplot, and while an interpolated data surface from a direct count of the number of trees ≥14” per plot may be beyond the scope of a rapid ecological assessment, other, simpler statistics bring us closer to the metric. Information about the measure and direction of skew might be helpful: the minimum number of large trees is more likely to occur in stands where the distribution of diameter values is negatively skewed.

Forest Inventory and Analysis (FIA) data currently constitutes the most sound and robust source of information about landscape-level understory conditions available. GCPO LCC staff will continue to work with USFS, LANDFIRE, and others to develop spatial data layers from FIA data to address questions related to rapid ecological assessments. A more detailed description of the utility of FIA data can be found in the Comprehensive Limitations and Future Directions section at the end of this chapter.

In addition to efforts to refine the data to match the endpoint, a future direction could address the possibility of revising the endpoint by quantifying species-habitat interactions in terms of average tree (or average pine) diameter per acre rather than as a minimum count or coverage of large trees. Moving forward with the assumption that average tree diameter for healthy Open Pine stands should be high, what would be an appropriate threshold? We could also explore the possibility of combining measures of stem density and stand age [low density + high average DBH + high stand age] in an endpoint that more closely aligns the ecological need for the presence of large trees with the available data

Setting aside efforts to develop an ecologically-based threshold value for average diameter per acre, and returning momentarily to the notion of a threshold derived from calculated statistics, one could argue that a measurement of departure from central tendency based on distance from the mean by standard deviations is preferable to one based on quantile measures. Such a threshold results in portions of the Pine Mask representative of the desired condition that are somewhat smaller than the 20% indicated by the quantile method. One standard deviation from the mean returns a threshold of 6.46 (16% of the Pine Mask pixels have values higher than this threshold). Two standard deviations from the mean returns a threshold of 8 (3% of the pixels).

Limitations

This analysis is based on the assumption that the average tree diameter per acre data layer is an accurate representation of conditions within the GCPO geography. Since the layer is unpublished and does not pertain exactly to the condition endpoint as described in the ISA, the raster layer produced by this step is scored with a value of **one** in the map algebra equation (described in the "Amount and Configuration" section below).

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Canopy Cover

Desired Landscape Endpoint: Overstory canopy cover: <50%

Introduction

Frequently burned southeastern pine savanna structure is typified by a spatially variable but mostly open canopy (Varner et al. 2005). Nearly all published research on open pine restoration and conservation associates species response and ecosystem health with periodic thinning and the reduction of basal area and canopy cover. In the shortleaf/bluestem system of the Ouachita Mountains, restoration treatments (thinning, herbicide application, burning) resulted in greater values for herbaceous cover, bird abundance (especially for pine-grassland endemics), abundance of small mammals, nectar resources, and butterfly abundance when compared to (untreated) control stands (Thill et al. 2004). Reduced canopy cover from mid-rotational thinning of managed loblolly stands in the Conservation Reserve Program in Mississippi resulted in increased abundance of early-successional and pine-grassland adapted avian species and ground layer grasses and forbs (Singleton et al. 2012). The Lower Mississippi Valley Joint Venture (2011) establishes 60%

canopy cover as the upper limit for 3 of the 4 birds used in their Open Pine Landbird Plan. Based on a literature review of 8 endemic species, McIntyre (2012) uses a range of 40 – 60% canopy cover as a habitat metric for longleaf restoration.

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 Pine Mask (described in the Introduction Chapter) for assessment of open pine woodland and savanna overstory canopy cover within the East and West Gulf Coastal Plain and other GCPO geographies.

Data Sources and Processing Methods

The NLCD 2011 USFS tree canopy analytical layer contains values representing the proportion of each 30x30m pixel covered by tree canopy (0 to 100%) produced using random forest regression algorithms (Breiman 2001, Cutler et al. 2007).

The Pine Mask layer, described in more detail in the introduction chapter, is derived from a selection of National Gap Analysis (GAP) ecological systems that indicate the presence of open pine/savanna or pine-dominant forest that could be converted to such through management. Pixels are 250x250 meters in size and have values of 1 (Pine Mask) and No Data (other ecological systems).

In order to include the canopy cover data layer in the additive mapping procedure, we resolved the discrepancy in spatial resolution between it and the coarser layers derived from USFS/FIA data. We first clipped the 30 meter NLCD tree canopy layer to a 2km buffer of the GCPO HUC12 basin polygons. We aggregated the clipped layer using a cell factor of 8 and 'MEAN' as the aggregation technique. This produced a 240 meter tree canopy layer for which each cell value is the average of the 64 values in the 8x8 cell neighborhood. This 240 meter raster was then resampled to 250 meter using 'NEAREST' as the resampling technique. The 250 meter raster was then extracted by the 250 meter version of the Pine Mask, resulting in a raster of Pine Mask cells populated with average canopy cover values. This raster was reclassified so as to retain only those cells with values <50 for use in the map algebra procedure.

Summary of Findings

In the East and West Gulf Coastal Plains, about 6.4 million acres are identified as having both Pine Mask conditions and canopy cover of < 50%. The desired condition occurs on about 14% of the Pine Mask area (6% of the total area) for the 2 subgeographies. The other subgeographies have higher rates within their Pine Mask areas, but much lower total amounts (Tables 9 and 10).

Table 9: Acres of Pine Mask with Canopy Cover above and below the threshold endpoint of 50% by Subgeography

Subgeography	Total acres	Acres Pine Mask	Canopy Cover in Pine Mask	
			< 50%	>50%
West Gulf Coastal Plain	52,698,200	22,047,471	3,531,531	18,515,940
East Gulf Coastal Plain	62,412,700	21,382,408	2,856,096	18,526,312
Mississippi Alluvial Valley	25,438,900	336,716	85,762	250,954
Interior Highlands	33,706,600	578,568	303,170	275,398
Gulf Coast	6,013,850	1,096,518	174,454	922,064
TOTAL	180,270,250	45,441,680	6,951,013	38,490,667

Table 10: Acres of Pine Mask with Canopy Cover above and below the threshold endpoint of 50% as a percentage of total area and of Pine Mask, by Subgeography

Subgeography	As % of total area		As % of Pine Mask	
	< 50%	>50%	< 50%	>50%
West Gulf Coastal Plain	7	35	16	84
East Gulf Coastal Plain	5	30	13	87
Mississippi Alluvial Valley	0	1	25	75
Ozark Highlands	1	1	52	48
Gulf Coast	3	15	16	84
TOTAL	4	21	15	85

For the entire GCPO, the Pine Mask is generally characterized by higher percentage canopy cover values. Of the total 47.8 million acres, 28.8 million (60%) have canopy cover values greater than 90% (Figure 13).

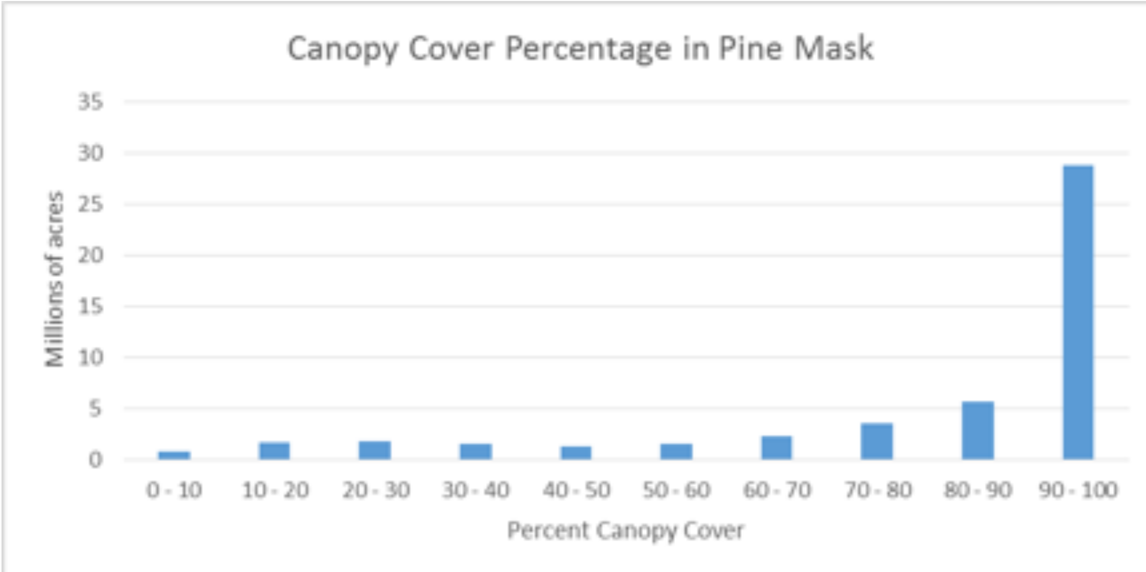

Figure 13: Canopy cover percentage values in the Pine Mask in 10 equal interval bins.

Patches of Pine Mask with canopy cover < 50% are widely scattered throughout the East and West Gulf Coastal Plains. Through the other subgeographies, such patches are more sparsely distributed. Most HUC12 catchments in the East and West Gulf coastal plains contain at least some patches, with coverage generally less than 20% of the area of the catchment. The highest concentrations of the condition are around Fort Benning in western Georgia and Choctawatchee Bay (Eglin Air Force Base) in northwestern Florida (Figures 14 and 15).

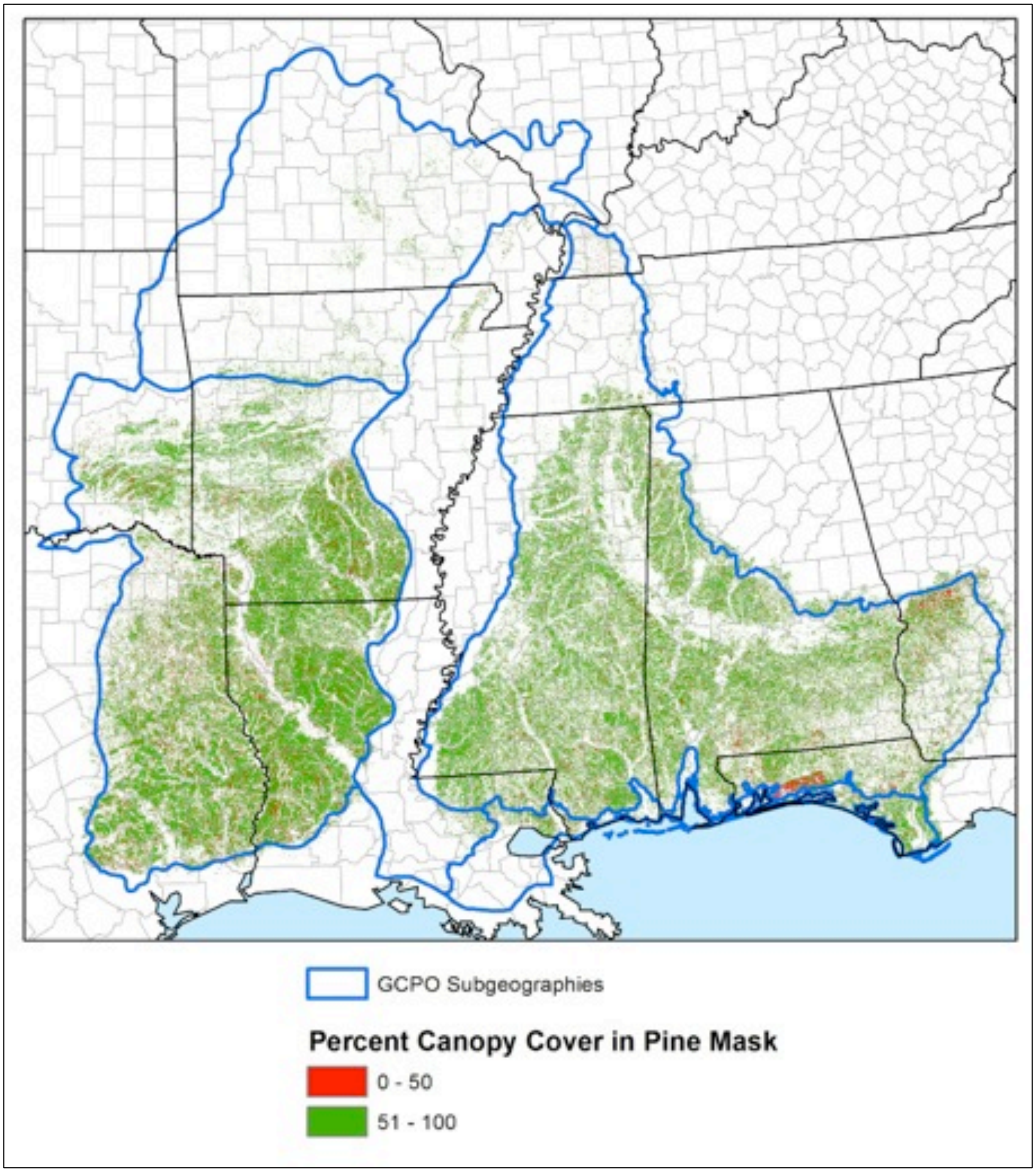

Figure 14: Raster layer of canopy cover values above and below the 50% threshold in the Pine Mask

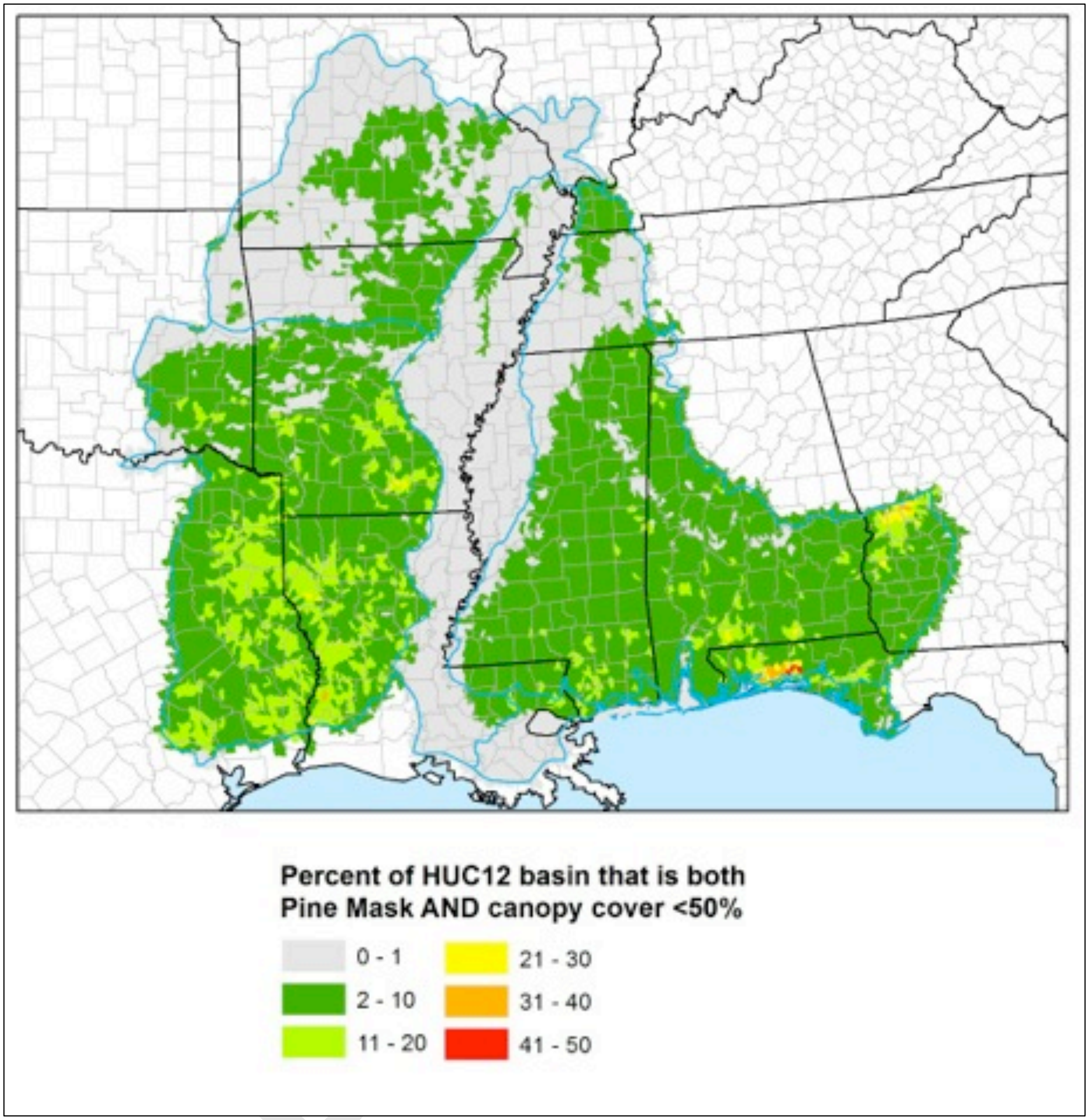

Figure 15: Amount of land that is both Pine Mask and <50% canopy cover displayed as percentages of HUC12 catchments.

Future Directions and Limitations

Assessing the endpoint

The word "canopy" can refer to foliar layers other than the overstory. As a partnership working with multiple organizations utilizing varied definitions of such terms, the LCC should consider modifying the endpoint name to "overstory canopy" or "tree canopy" as some of our partner reviewers have suggested.

The ideal range of percent canopy cover for open pine woodland and savanna varies in the literature. The Open Pine Management Decision Support Tool developed by the Lower Mississippi Valley Joint Venture WGCPO Landbird Working Group puts the range at 25 – 60%. McIntyre (2012) states that 40 – 60% is ideal based on a literature review for the 4 priority species Northern bobwhite quail, Bachman's sparrow, red-cockaded woodpecker, and gopher tortoise. The canopy cover endpoint as expressed in the ISA (<50%) has no minimum value (or an understood minimum of zero), which seems to contradict the endpoints for basal area (40 – 70 ft^2/acre) and DBH (≥20 ft^2/acre of trees ≥ 14" DBH), which indicate that a minimal presence of trees is desirable. On the other hand, the Pine Mask itself likely prevents the assessment from sampling large treeless areas, and the presence of small, scattered, treeless patches is a general characteristic of open pine woodland and savanna. The upper bound of 50% may be too restrictive, given the literature cited here. Unpublished data from the Joseph W. Jones Ecological Center in Georgia indicates that many pine-grassland adapted species are observed in stands with greater canopy cover (Mike Conner, personal communication).

<u>Assessing the data</u>

The data layer contains a separate band estimating model uncertainty, which was not incorporated in this assessment. Future efforts could establish uncertainty thresholds, potentially increasing assessment accuracy at the risk of excluding suitable parcels. A potential alternative to the use of NLCD 2011 land cover and 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 estimated as part of the LANDFIRE fuels data group, is defined as the stand-level percent of tree canopy and is limited to LANDFIRE existing vegetation types of forest and woodland.

<u>Alternate Approaches</u>

There are many different resampling processes available to the geospatial analyst. The ArcGIS environment offers two basic approaches, each containing a different set of algorithms, or techniques, used to recreate the input values at the output resolution. The Aggregate Tool uses a cell factor approach, meaning that the spatial resolution (length of cell side) of the resulting raster is either a factor or a multiple of the input. The techniques used by the Aggregate Tool are sum, minimum, maximum, mean and median. The alternate approach, the Resample Tool, is not restricted by cell factors: the output spatial resolution can be any whole number. The Resample Tool uses different algorithms (or techniques): nearest, bilinear, cubic, and majority. We determined that the best technique for summarizing canopy covers in larger neighborhoods is to take the average of the inputs. However, we can't use average to create the output in a single step because 250 is not a multiple of 30. We aggregated the input with a cell factor 8, creating a 240 meter raster, then resampled to 250 meters using the "nearest" technique, which assigns the input value nearest the centroid of the output cell. This two-step approach provides the best estimate of average canopy cover values at the coarser scale, but alternative approaches are possible.

Limitations

This assessment of percent canopy cover within pine-dominant landscapes assumes that the NLCD 2011 USFS Tree Canopy cover (analytical) data layer accurately represents actual canopy cover conditions within the GCPO geography. Since this is a published data layer that addresses the condition endpoint measurement directly, the output raster layer produced by this step is given a score of **two** in the map algebra equation (described in the "Amount and Configuration" section below).

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Midstory Shrubs, Midstory Hardwoods

Condition:

Midstory shrubs: < 30% cover

Midstory hardwoods < 20% cover

Introduction

Based on a literature review of eight priority species, McIntyre (2012) deems 20% coverage as the upper threshold for midstory conditions in an ecologically functioning open pine system. Because hardwoods are generally valuable to wildlife, including some longleaf specialists, the value of a lower limit, or whether a complete absence of hardwoods is desirable, is unclear. The correlation between the development of a hardwood understory and abandonment of nesting cavities by red-cockaded woodpeckers (RCW) is well-documented (Walters 1991). Aggressive prescribed burning programs, including late summer burns, have been proposed for controlling hardwoods and young pines in RCW colony areas (Connor and Rudolph 1989). Reduction of the hardwood midstory may also improve foraging success for northern bobwhite by increasing arthropod biomass (Burke et al 2008). Brown-headed nuthatch prefers pine savanna with low midstory density for nest site selection, perhaps because midstory canopy inhibits movement between the low nesting sites and high foraging sites (Dornak et al., 2004). The absence (or sparse distribution, if present) of understory trees and shrubs is clearly important to the ecological functioning of the open pine system. As is the case with other landscape-level forest characteristics, the USFS Forest Inventory and Analysis program (FIA) is the only comprehensive source for data collected in a systematic and standardized manner presently available.

Data Sources and Processing Methods

GCPO LCC staff worked with USFS Remote Sensing Applications Center scientists to develop raster data layers relevant to our habitat assessment tasks (see chapter introduction). Of these, "Density of midstory trees" and "Basal area of mid-story trees" are most relevant to the endpoints *midstory shrubs < 30% cover* and *midstory hardwoods < 20% cover*. We know of no established method for converting percent cover values to measures of either basal area or tree density. The [Gingrich stocking diagram] uses inputs of basal area per square feet and trees per acre to obtain a quadratic mean estimation of percent stocking. "Stocking" is a silvicultural term that refers to an indication of growing space occupancy relative to a pre-established standard. Therefore, if a mathematical relationship between stocking and percent cover were established, a species-appropriate Gingrich stocking diagram might be useful for establishing threshold values for our data. At this point, however, we are employing the logic that all three measures (basal area, density, and percent cover) refer to the same general condition: the amount of biomass contributing to the mid-story canopy in the woodland/savanna. Lacking any mathematical description of the relationship between these variables, we can use statistical descriptions of central tendency and variance in the data to establish the parameters, especially since we have established that a value of zero is probably acceptable and the upper threshold is relatively low.

The USFS data layers do not distinguish between shrubs, hardwoods and pines but rather refer to "all trees", which is problematic because nearly all literature on open pine restoration identifies midstory hardwoods specifically as being undesirable, whereas the presence of some amount of midstory pine is necessary for stand regeneration. This lack of specificity is another limitation to the method presented here: we emphasize that the current method characterizes the midstory canopy generally rather than addressing the endpoint explicitly.

Once clipped to the GCPO and extracted by the Pine Mask, midstory density values (stems per acre) range from 0 to 1389 with a median of 268 and a standard deviation of 164. Midstory basal area values (ft^2/acre) range from 0 to 52 with a median of 10 and standard deviation of 6. Frequency distributions of both are positively skewed: the larger values are very uncommon (Figure 16).

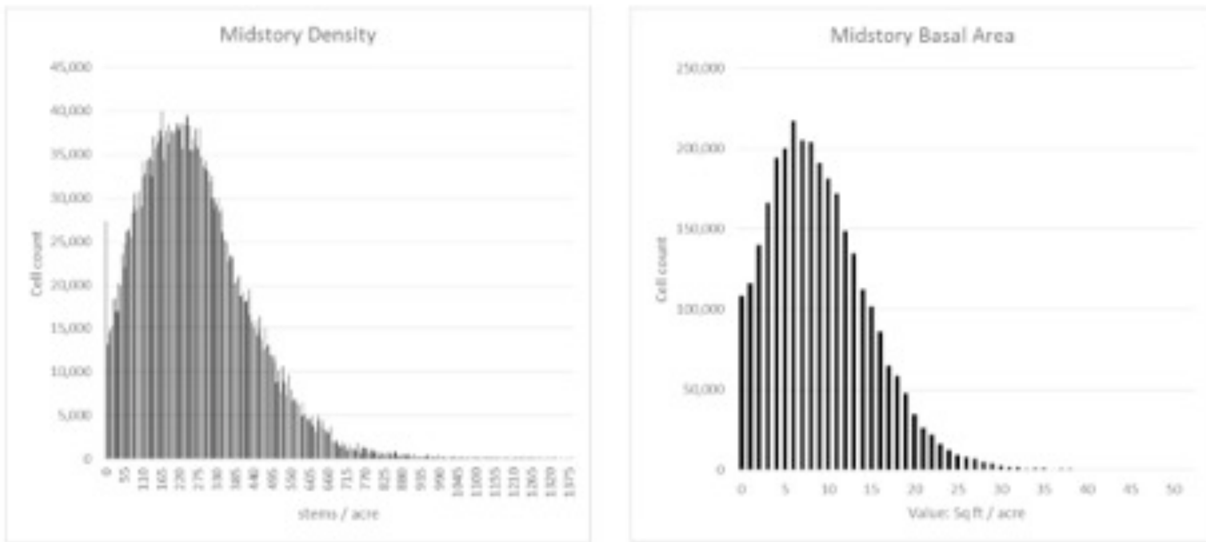

Figure 16: Histograms for FIA-derived Midstory Density and Midstory Basal area data.

Dividing the recorded values using the quantile method (5 bins of equal size) happens to be an effective partitioning method for both variables because 1) the lowest data break value for both is approximately one standard deviation below the mean, a good departure from central tendency, and 2) the bin contains one-fifth of the data, providing sample that is large enough to work with (Table 11).

Table 11: Statistics for USFS Midstory data layers

	Density of midstory trees	Basal area of midstory trees
Range	0 - 1388	0 - 52
Top value in bottom quantile	120	4.31
Standard Deviation	164	5.96
Mean	268	9.58

Summary of Findings

The highest concentration of raster layer cells with values in the lowest quantile for midstory tree density and midstory basal area in the East Gulf Coastal Plain is in Okaloosa and Santa Rosa counties in northwest Florida, the same area identified by Outcalt and Sheffield (1996) as having the highest concentration of original longleaf forest. The highest concentration in the West Gulf Coastal Plain is in Beauregard Parish, Louisiana, south of the Kisatchie National Forest. In the Gulf Coast subgeography, a high concentration of the target is found in Gulf County Florida, on land managed by the Florida Department of Environmental Protection under the auspices of the Surface Water Improvement and

Management (SWIM) Program. Raster layers of midstory basal area and midstory density classified by quantiles are shown in Figure 17.

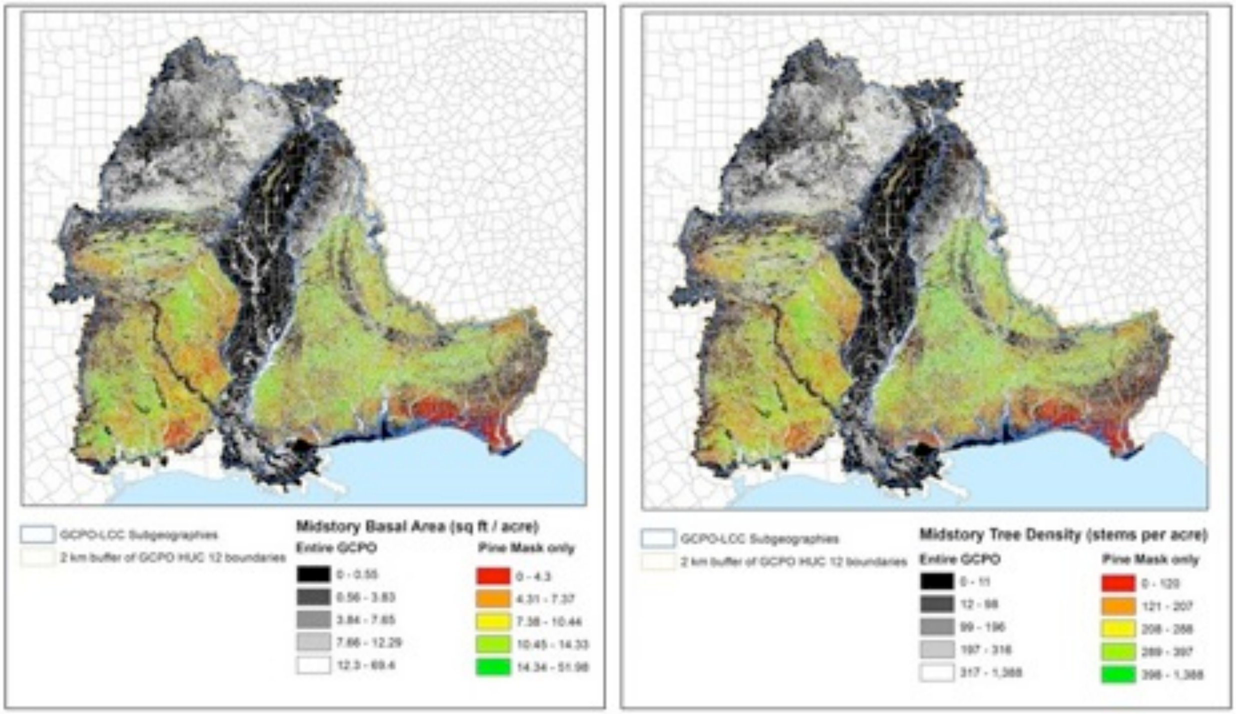

Figure 17: Midstory basal area and tree density raster layers, both within the Pine Mask and the entire GCPO, in quantile bins.

The two midstory raster layers are virtually indistinguishable because the 2 variables are spatially and ecologically correlated. For the targeted endpoint condition, that is, the lowest quantile of each data layer, 75% of the cells for either layer are also occupied by cells of the other layer. We chose to combine the 2 layers by selecting the union of the 2 layers (pixels characterized by the presence of either or both conditions), as a general estimation of areas within the pine mask where midstory cover is low. The result is summarized by HUC12 basin and subgeography in Figure 18.

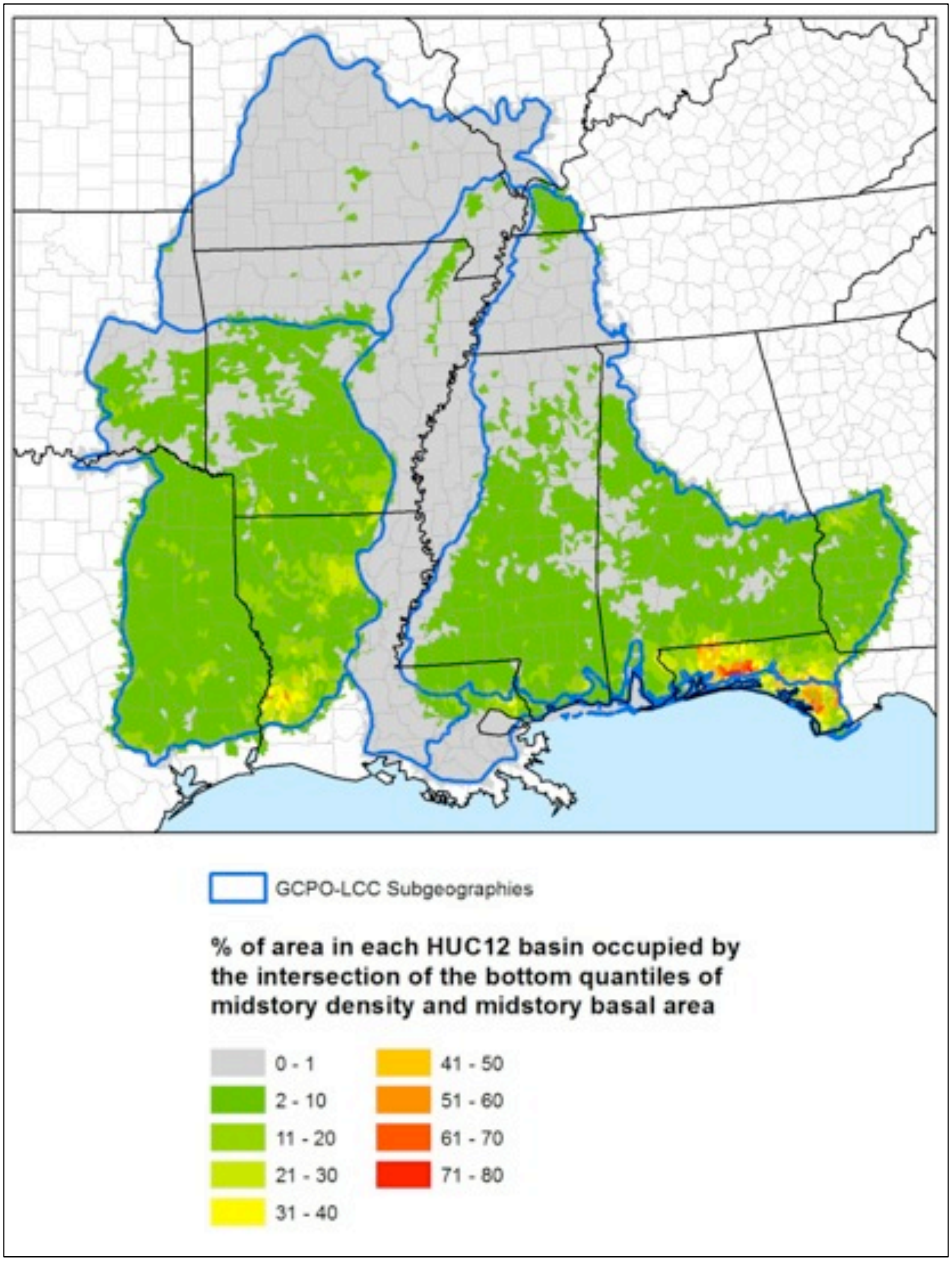

Figure 18: Union of the lowest quantile of midstory tree density and midstory basal area data layers, summarized by HUC12 basin

Table 12: Acres of sparse midstory conditions (characterized by the union of the lowest quantile of midstory tree density and midstory basal area data layers) by subgeography

Subgeography	Total	Pine Mask	Union of bottom quantile midstory variables	Union as % of total area	Union as % of Pine Mask
West Gulf Coastal Plain	52,698,200	22,047,471	5,063,224	10	23
East Gulf Coastal Plain	62,412,700	21,382,408	4,659,885	7	22
Mississippi Alluvial Valley	25,438,900	336,716	117,591	0	35
Ozark Highlands	33,706,600	578,568	92,316	0	16
Gulf Coast	6,013,850	1,096,518	788,444	13	72
TOTAL	180,270,250	45,441,680	10,721,459	6	24

The union of the bottom quantiles for estimates of midstory density and midstory basal area cover about 9.7 million acres of pine-dominant forest in the East and West Gulf Coastal Plains. As a percentage of the pine mask, sparse midstory conditions occur at the highest rate (72%) in the Gulf Coast subgeography, with the highest concentrations in Bay and Gulf Counties, Florida.

Future Directions and Limitations

Assessing the Endpoint

The notion that the midstory layer should be sparse or nonexistent in healthy open pine systems is well-supported in the literature, and the single source that quantifies the threshold (McIntyre 2012) uses the same value (20% cover) for midstory generally that the ISA uses for hardwoods. Whether hardwoods should be targeted specifically as detrimental and whether shrubs should be defined separately and given a separate threshold is less well-supported in the literature.

Assessing the Data

These raster layers have limitations in that they were produced and provided to the GCPO LCC as preliminary data layers to support this ecological assessment and are not yet released for peer-reviewed analysis. Based on preliminary results from an unpublished study examining species-habitat interrelationships in open pine forest in southern Mississippi, midstory condition values from the USFS data layers do not correspond well with observed forest conditions at research plots (Figure 18). Some of the discrepancy can be attributed to the differences in scale, where forest conditions on research plots were measured within an acre of a reference point, and the USFS-FIA derived data uses a 250 meter cell, equivalent to about 15 acres.

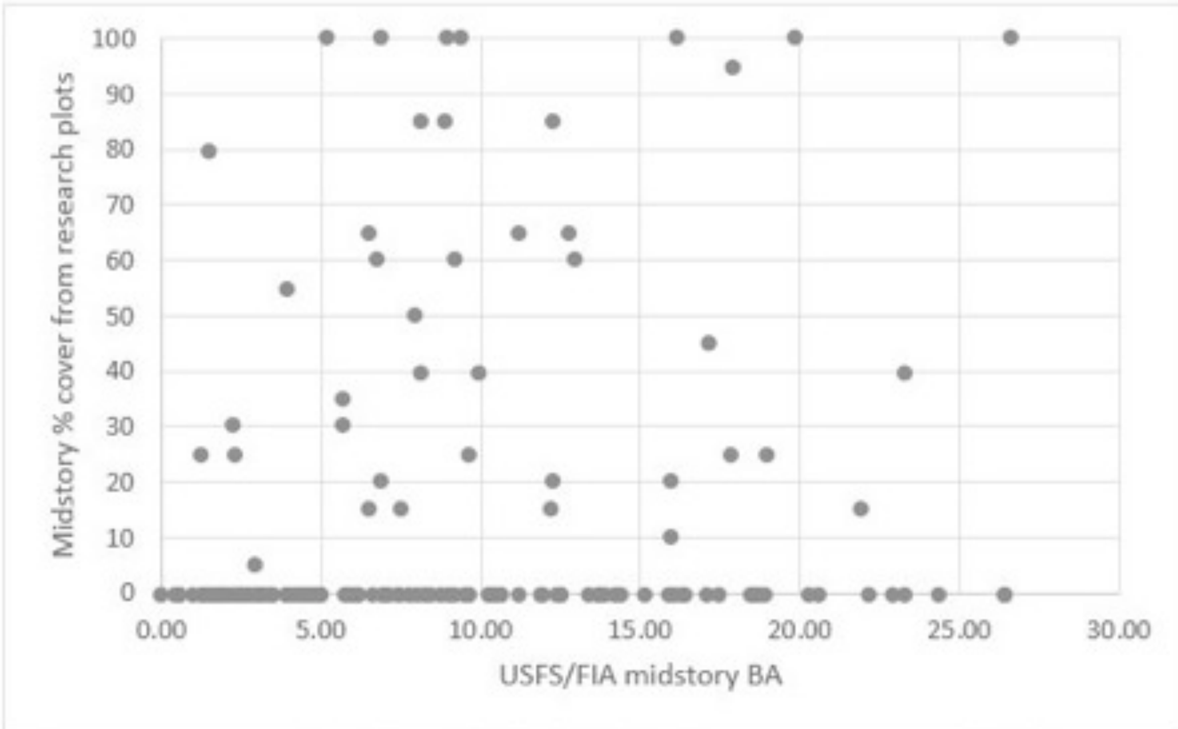

Figure 18: Midstory % cover values from field research plots in Mississippi plotted against corresponding FIA-derived midstory basal area values from the USFS/FIA-derived data layer show no correlation

The USFS data layers used in this analysis are also limited in that no distinction is made between trees and shrubs. We are uncertain that a standard distinction exists across all the conservation sciences. Utah State University Extension considers a tree to be a woody plant having one erect perennial stem (trunk) with at least 3" DBH, a definitely formed crown of foliage, and a mature height of at least 13 feet. Shrubs are woody plants that don't meet these criteria: multiple stems, possibly erect but also possibly close to the ground, no stems over 3", and a mature height under 13 meters (Utah State University). Exceptions are common: some trees have more than one trunk, some shrubs grow taller than 13', etc. FIA data do not address the shrub-tree distinction directly.

<u>Alternate Approaches</u>

An assessment of midstory conditions that does not distinguish between pine and hardwood or between shrubs and trees would be consistent with both the literature and the available data. A future direction might involve a more detailed analysis of FIA data to gain a better understanding of the spatial variation of these vegetation class dichotomies. The tree/shrub distinction could employ a species-based approach (calling all wax myrtles and gallberries shrubs, regardless of structural characteristics of individuals, for example). A species-based approach to the pine/hardwood distinction would be very straightforward. Such an analysis should be preceded by an evaluation of what is gained by bringing this level of detail to a regional-scale assessment.

Limitations

This assessment assumes that the estimations of midstory basal area and midstory stem density accurately represent forest conditions in the GCPO. Since the data layers are unpublished and do not exactly pertain to the ISA condition endpoint, the raster layer created by this step is given a score of **one** in the map algebra equation (described in the "Amount and Configuration" section below).

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Herbaceous Understory

Desired Landscape Endpoint: Herbaceous understory >65%

Introduction

The understory community is an important component of any forest ecosystem, providing habitat, affecting nutrient cycling, increasing species diversity, and preventing erosion (Suchar and Crookston 2010). McIntyre (2012) calls the species-rich understory dominated by grasses a "hallmark characteristic" of high quality longleaf pine ecosystems, where understory features have the additional role of providing fuel and carrying fire through the system. Burke et al. (2008) found that managing the understory for a diversity of herbaceous species and sufficient bare ground for foraging improved brooding habitat for bobwhite chicks. Other studies (Thill et al. 2004, Burger et al. 1998) indicate that the grassy understory, typically maintained by fire, along with the open midstory and open canopy, is associated with larger populations of many species of concern, including the endangered species red-cockaded woodpecker. McIntyre (2012) describes the desired understory condition as 65% contiguous herbaceous cover with 20% or greater graminoid composition.

Data Sources and Processing Methods, Summary of Findings

Regional and landscape-level assessments of conditions below the top of the forest canopy are challenging. Researchers typically approach the challenge through the use of highly advanced remote sensing technology such as LiDAR (e.g., Hill and Broughton 2009, Martinuzzi et al. 2009, Wing et al. 2012), by collecting and interpolating field measurements at the plot level, or by using a metric surrogate to represent understory. These methods are not feasible for a rapid ecological assessment at the scale of the GCPO geography.

Forest Inventory and Analysis (FIA) data currently constitutes the most sound and robust source of information about landscape-level understory conditions available. Hypothetically, ground cover conditions could be interpolated from P2 and P3 indicator data (described in the Comprehensive Future Directions and Limitations Section, below), augmented by known relationships between herbaceous percent cover and slope, altitude, and other variables (Suchar and Crookston 2010).

Future Directions and Limitations

At this time there is no decisive means to provide reasonable measures of forest understory cover at the landscape scale within the GCPO. One alternative to seeking continuous measures is to consider the condition as a categorical class. The GAP analysis program data product attaches forest condition modifiers to some of the ecological system classes: loblolly modifier, shrub/scrub modifier, and open understory modifiers. LANDFIRE offers reference databases that crosswalk FIA plot data with GAP and NatureServe ecological systems classes. A preliminary investigation into these databases indicates that herbaceous percent cover data is only collected in non-forested classes. As we continue to engage with partners in LANDFIRE, GAP, USFS and USGS we will continue to explore possible approaches to the challenge of quantifying patterns of percent herbaceous cover in forest and woodland classes of land at a regional scale.

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Burger Jr, L. W., C. Hardy, and J. Bein. 1998. Effects of prescribed fire and midstory removal on breeding bird communities in mixed pine-hardwood ecosystems of southern Mississippi. In *Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings* no. 20: 107-113.

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Temporal Considerations
The ISA calls for "an appropriate distribution of successional stages." Few studies address what an "appropriate distribution" for open pine might be, and none propose any particular distribution in terms of a measurable endpoint. Temporal considerations vary according to which species for which management efforts are designed, which in turn vary by geography. Research on this particular aspect of open pine conservation has a long way to go before a general model is developed.

McIntyre (2012) notes that all 4 species used in his East Gulf Coastal Plain longleaf restoration model (red-cockaded woodpecker, gopher tortoise, Bachman's sparrow, Northern bobwhite quail) show an affinity for mature forests. In developing a Decision Support Tool for the Western Gulf Coastal Plain, the Lower Mississippi Joint Venture (2011) notes that brown-headed nuthatch (which they substituted for gopher tortoise, otherwise using the same keynote species to develop their model) also requires mature pine stands.

Even-aged silviculture has dominated management of southeastern forests for the past several decades, but single-tree selection, uneven-aged management is an increasingly common alternative. Even-aged pine silviculture under short rotations can eliminate habitat for species dependent on snags, cavity trees, hard mast, and downed woody materials, whereas uneven-aged management fails to provide suitable habitat for species that require early successional conditions. The difference in wildlife response to the two different practices is poorly understood, especially for pine forests (Thill and Koerth 2005).

McIntyre (2012) developed a transition matrix of 11 possible stages (or "states") for his longleaf pine restoration model. They are:

- Agricultural (AG)
- Open (OPEN)
- Early Successional Habitat (PINE ESH)
- Pine Saplings (PINE SAP)
- Pine Poles (PINE POL)
- Pines Greater than 12" DBH (PINE GT12)
- Two-aged Pine (PINE 2A)
- Uneven Aged Pine (PINE UA)
- Mixed Pine Hardwood (MIXED)
- Uneven Aged Hardwood (HDWD UA)
- Developed (DEVEL)

Transitions between states, either by natural processes or restoration efforts, are well-understood for some states but not for all. McIntyre notes that all 4 keystone species in his model utilize the mature stage of development, but 2 (Bachman's sparrow and Northern bobwhite quail) also utilize the early successional stage.

McIntyre (2012) acknowledges that afforestation of lands not currently in forest cover and reforestation of recently cutover land will be necessary to meet the Longleaf Stewardship Fund's range-wide conservation goals and that for these areas the wildlife response will take decades. Brockway et al (2006) emphasize that the temporal framework in which longleaf forest restoration occurs must be considered in terms of decades or even centuries. The literature indicates that, while all successional stages are important in the long term, near future wildlife response can only occur through the maintenance and restoration of older stands. The "appropriate distribution," then, would include some amount of recently harvested or non-forest land and a much larger portion of mature forest.

USFS Remote Sensing Applications Center scientists developed and shared with GCPO-LCC staff a raster data layer of average stand age per acre. Lacking an endpoint metric for any particular range of stand ages, but understanding that the presence of mature trees is required for most species of greatest concern for open pine, we clipped the layer to the GCPO geography, extracted the pine mask cells, and binned the data using the quantile method (five bins of equal size). Figure 19 shows the spatial distribution of stand age classes in the pine mask in the GCPO. Figure 20 shows the percentage of each HUC12 basin in the GCPO occupied by pine mask pixels belonging to the top bin, which contains average stand age values ranging from 38 to the maximum 115 years.

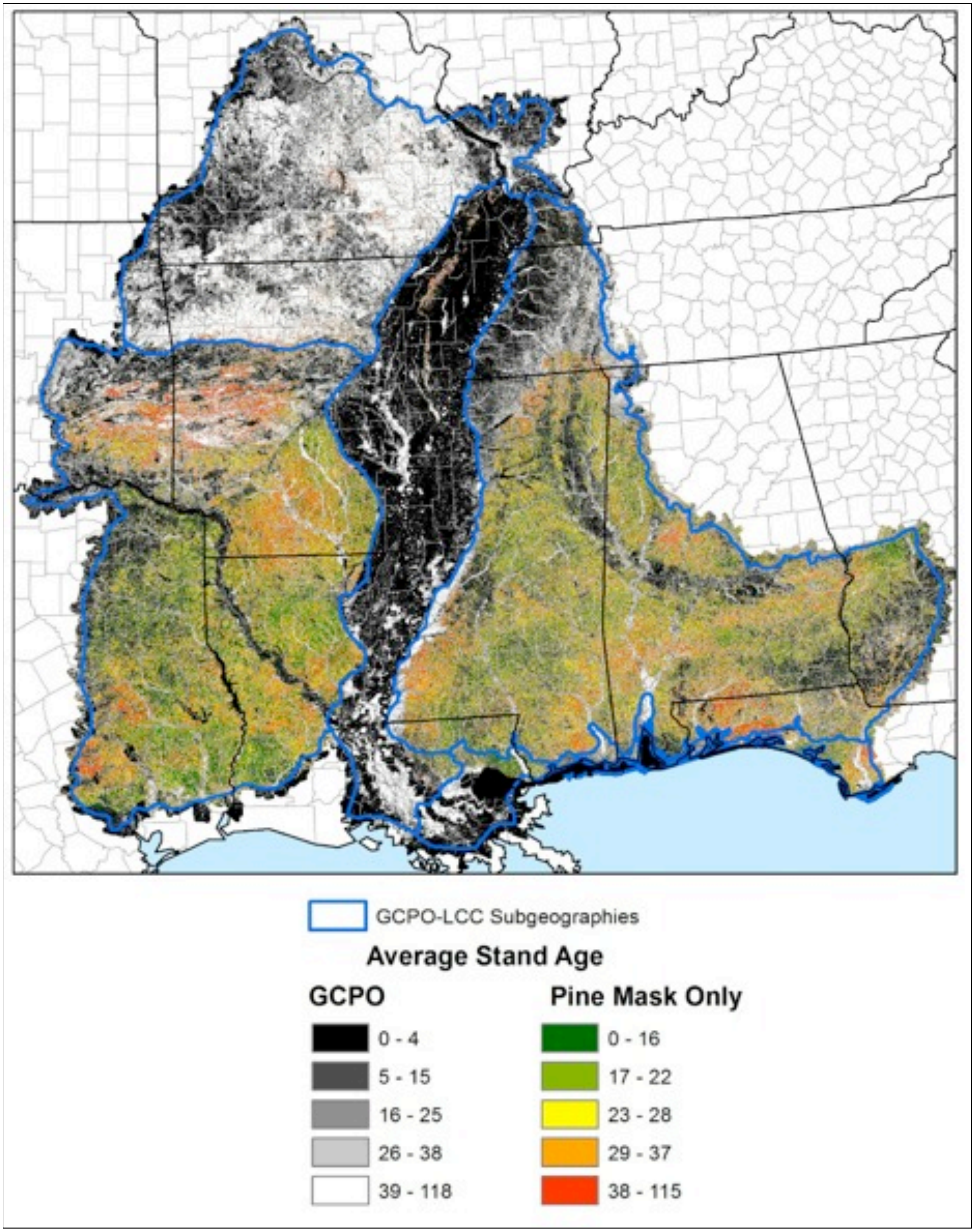

Figure 19: Average stand age per acre in the GCPO overall and in the Pine Mask specifically, in quantile bins.

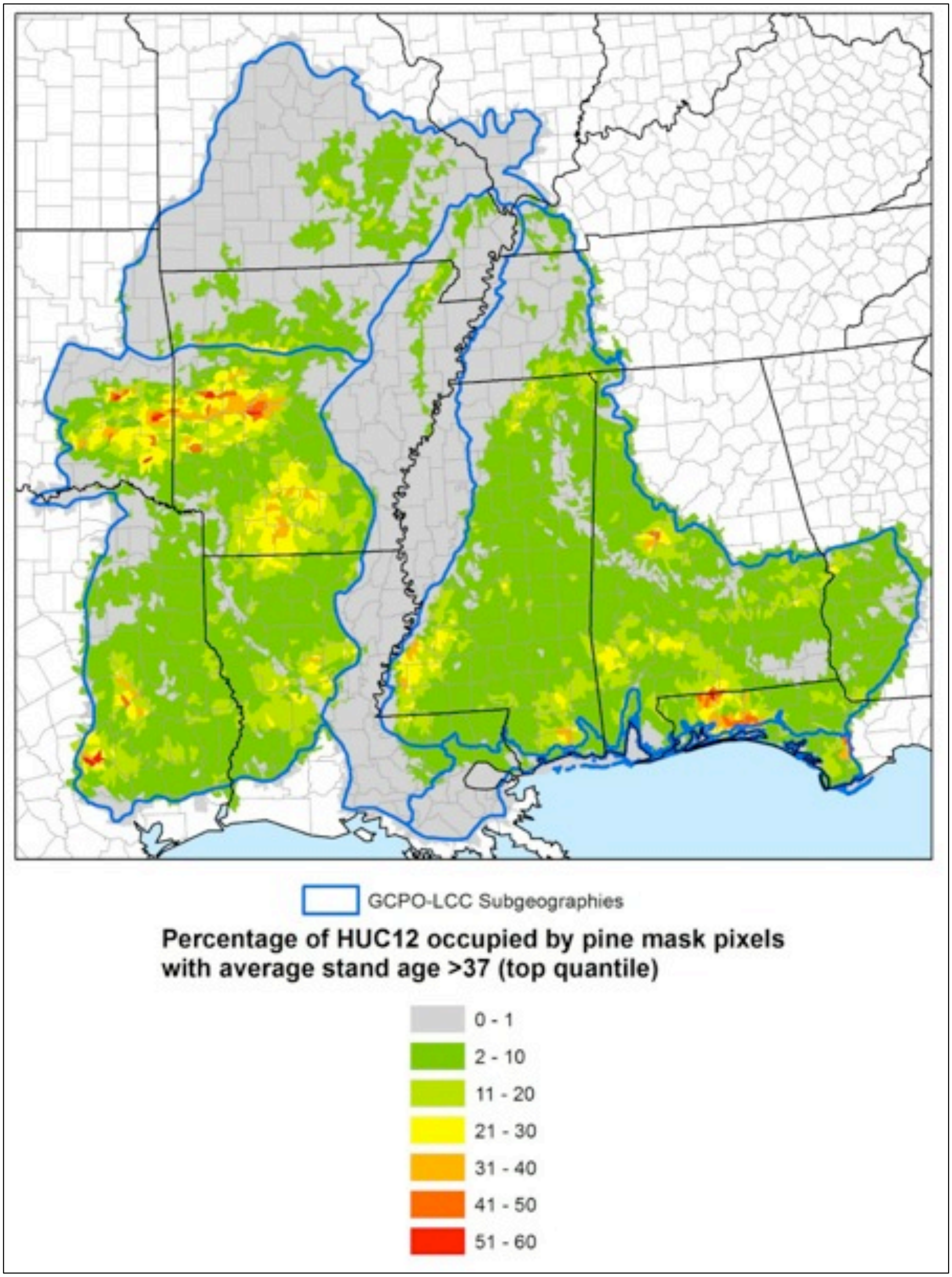

Figure 20: Percentage area of each HUC12 basin occupied by pine mask pixels with stand age >37 (top quantile of stand age)

The spatial pattern of the concentration of top quantile stand age shown in Figures 19 and 20 corresponds strongly with the pattern of the concentration of high average tree diameter per acre shown in the DBH section, but not with patterns displayed by other inputs. We chose not to include the stand age layer in the additive mapping procedure, pending further discussion with the Adaptation Management Science Team regarding how an appropriate distribution of successional stages can be described numerically.

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Results

This process identified 1.45 million pixels, about 22.4 million acres, in patches >600 acres within 3km from another patch with at least one endpoint present. Of these, 6,467 pixels, representing 99,850 acres, indicate the presence of all four endpoints (Table 13).

Table 13: Acres represented by each condition index score

Condition Index	Interpretation	Acres
0	Unavailable/Non-habitat	111,297,727
1	Potentially open pine: Reconstruct	23,528,244
2	Small patch, no neighbor, no endpoints: Restore	2,316
3	Small patch, no neighbor, 1 endpoint: Restore	4,478
4	Small patch, no neighbor, 2 endpoints: Restore	3,320
5	Small patch, no neighbor, 3 endpoints: Restore	633
6	Small patch, no neighbor, 4 endpoints: Restore	46
7	Small patch with a neighbor, no endpoints: Restore	3,152,678
8	Small patch with a neighbor, 1 endpoint: Restore	4,614,352
9	Small patch with a neighbor, 2 endpoint: Restore	2,200,432
10	Small patch with a neighbor, 3 endpoint: Restore	487,117
11	Small patch with a neighbor, 4 endpoints: Restore	42,815
12	Big patch, no neighbor, no endpoints: Enhance	44,606
13	Big patch, no neighbor, 1 endpoint: Enhance	68,970
14	Big patch, no neighbor, 2 endpoints: Enhance	37,334
15	Big patch, no neighbor, 3 endpoints: Enhance	11,518

16	Big patch, no neighbor, 4 endpoints: Enhance	1,220
17	Big patch with a neighbor, no endpoints: Enhance	12,372,937
18	Big patch with a neighbor, 1 endpoint: Enhance	15,414,895
19	Big patch with a neighbor, 2 endpoints: Enhance	5,593,480
20	Big patch with a neighbor, 3 endpoints: Enhance	1,307,413
21	Big patch with a neighbor, 4 endpoints: Maintain	99,850

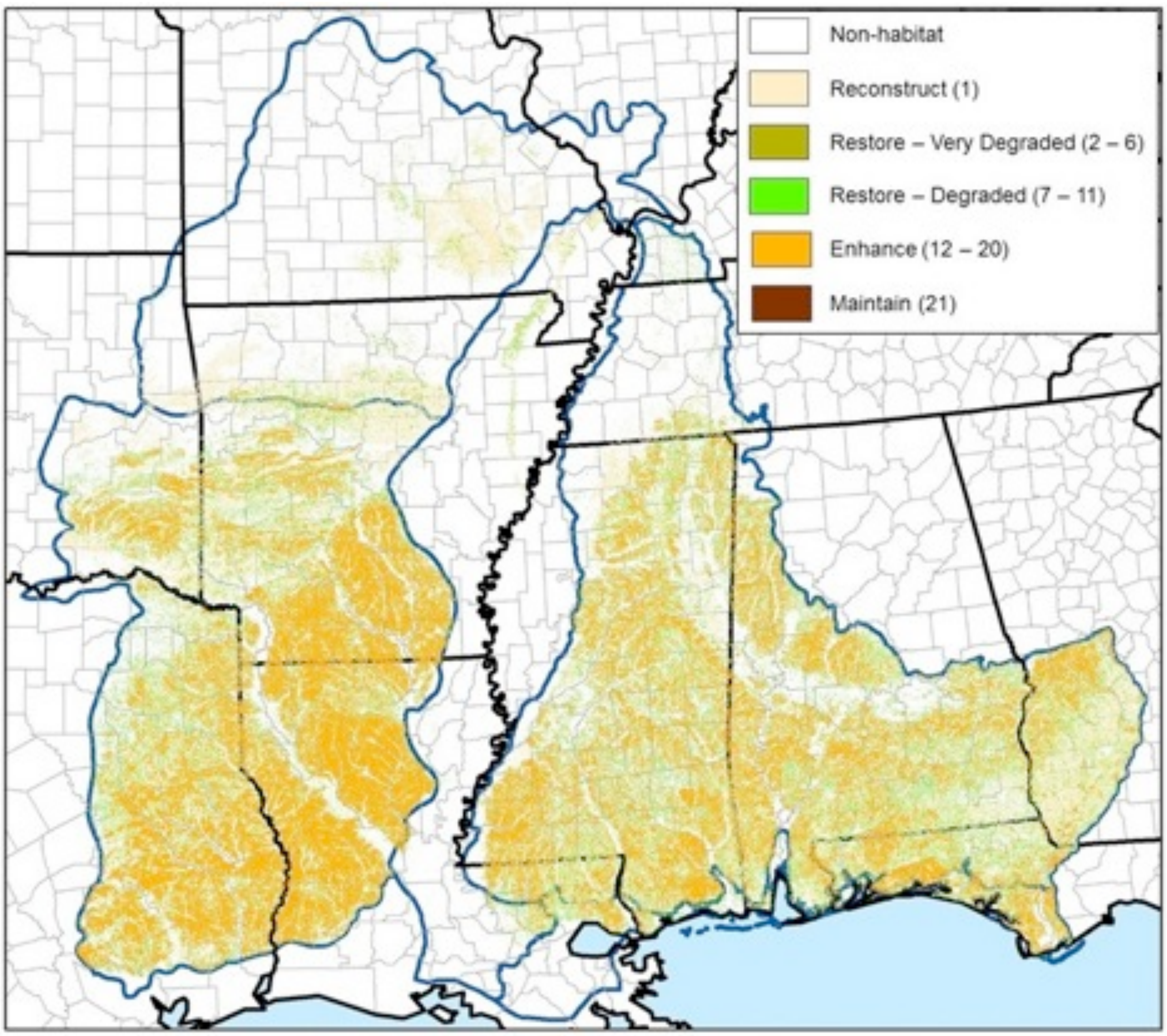

Figure 21: Mapped Open Pine Condition Index. Top-score pixels (condition index = 21) are not visible at this scale.

A map of the raster condition index layer shows that pine and mixed-pine forests in small (<600 acres, green) and large (>600 acres, orange) patches dominate the West and East Gulf Coastal Plains (Figure 21). While pixels describing the presence of all six (two configuration and four forest condition) endpoints are rare, opportunities for conservation are widespread in the landscape. The "Enhance" condition class, those in larger patches either with or without a neighbor and in any condition, covers 34.8 million acres. Of that, about a third, or 12.4 million acres have no endpoints present while the remaining 22.4 million acres have at least one.

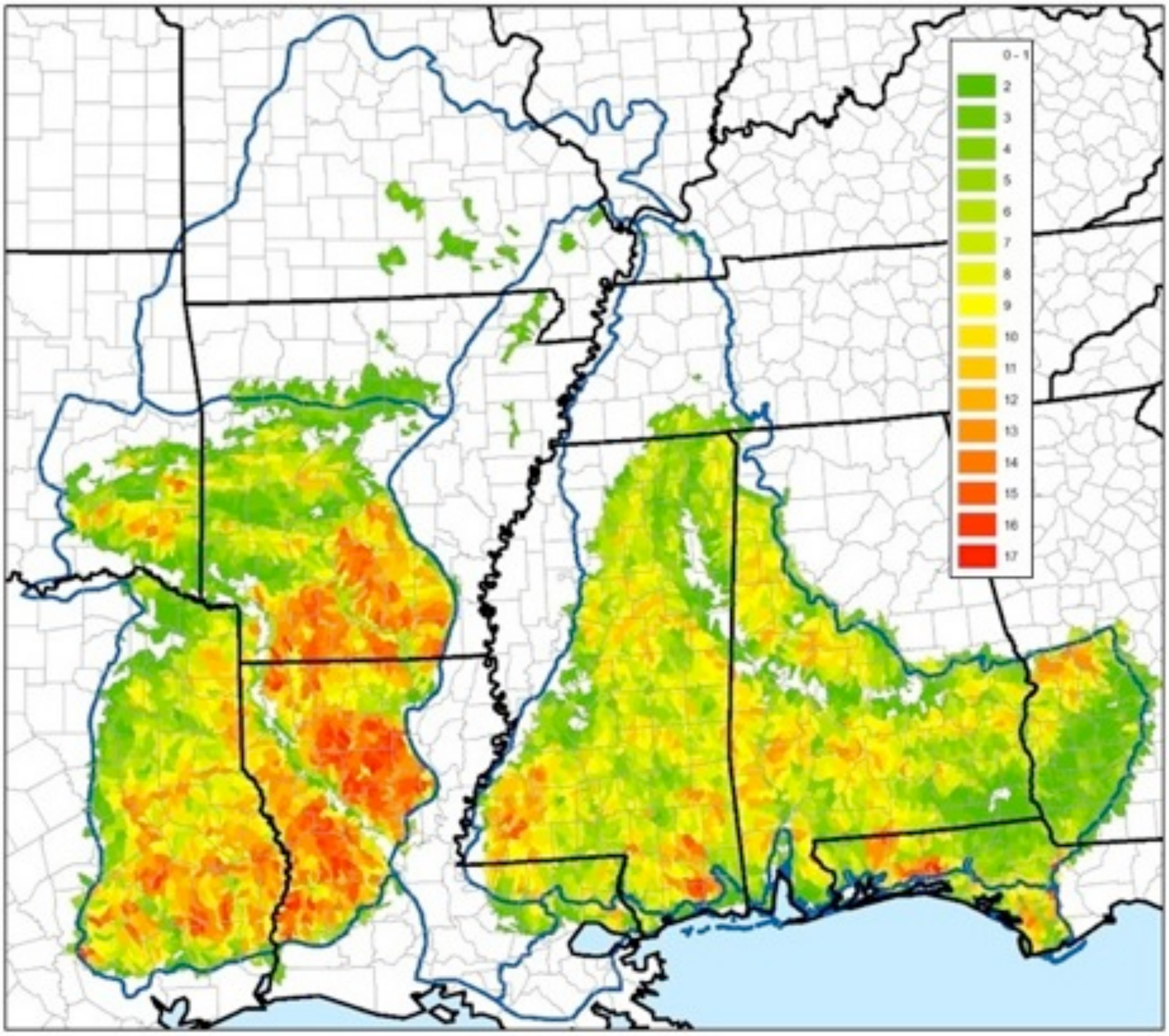

Figure 22: Average condition index score in HUC 12 catchments.

Condition Index scores were averaged by HUC 12 catchment in a process that takes into account all possible scores (all pixels) ranging from 0 – 21. The Cypress Creek in Beauregard Parish, Louisiana, indicates the highest average index (16.45). Most of the catchments with the highest average condition index scores are found in the West Gulf Coastal Plain, particularly in Louisiana and Southern Arkansas (Figure 22). In the East Gulf Coastal Plain, concentrations of high average condition indexes are found in and around the Homochito and De Soto National Forests in Mississippi and the Black River State Forest and Eglin Air Force Base in Florida.

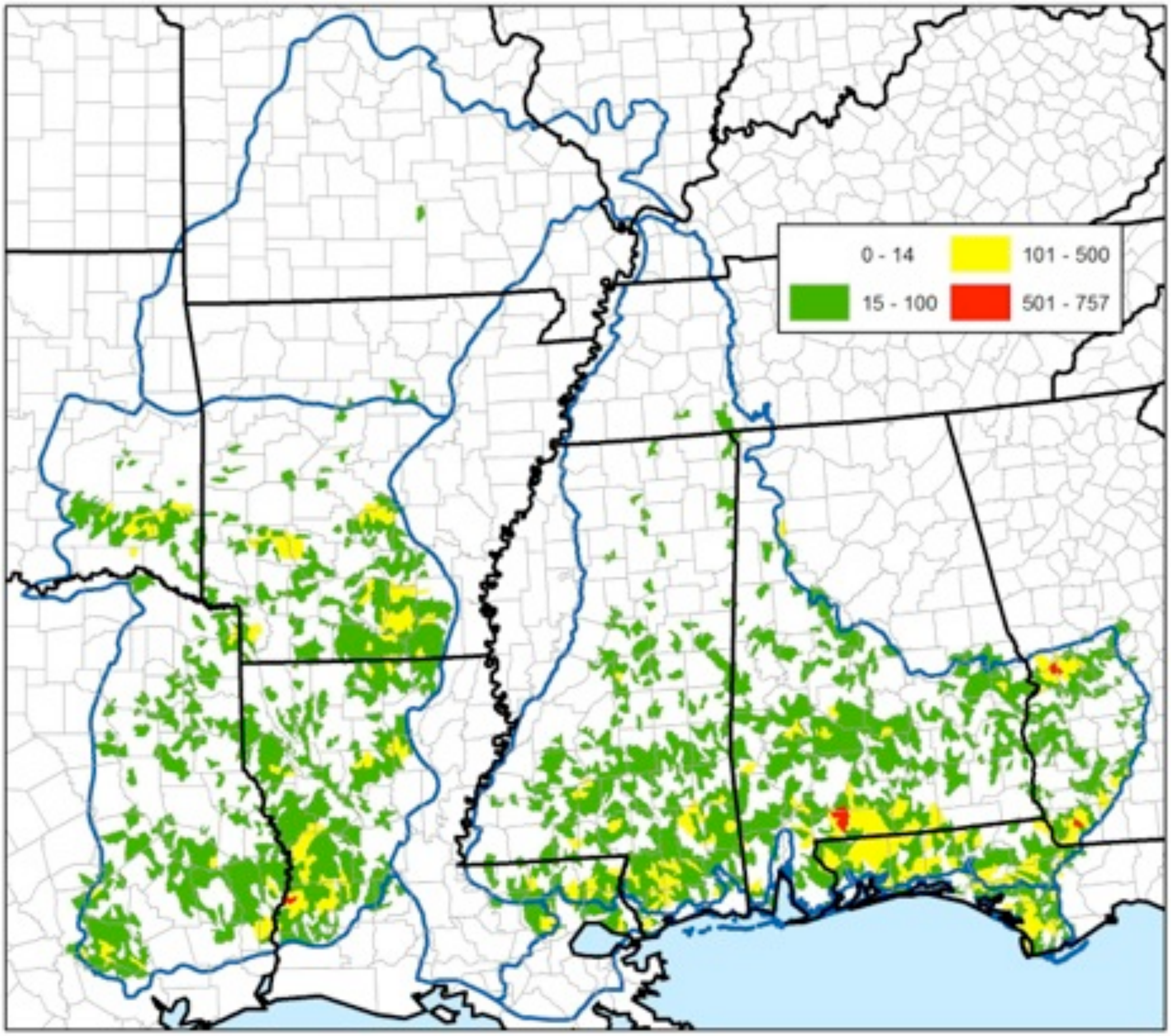

Figure 23: Acres of the Desired Ecological State (e. g. Condition Index = 21) in HUC 12 watersheds.

Figure 23 considers only those pixels for which the top score of 21, representing the desired ecological state, are found. Pixel counts were converted to acres and summed within HUC 12 catchments. A 250 meter pixel occupies 15.44 acres of land: catchments with no pixels meeting the criteria (less than 15 acres) are given no color in the map. Seven catchments (out of a total 7905) indicate > 500 acres of desired ecological state. The Dean Creek Watershed in Escambia and Conecuh Counties, Alabama, and the Lower Pine Knot Creek Watershed in Chattohoochee and Marion counties, Georgia, indicate the greatest amount with 757 acres (49 pixels) each.

Comprehensive Limitations and Future Directions

The objective of this open pine and woodland rapid ecological assessment is to provide useful information about the placing of open pine management efforts (thinning, burning, reforestation, enhancement, etc,) at the scale of the GCPO. Healthy open pine systems are associated with a great variety of soil moisture and physiographic conditions (Brockway et al 2005, Peet and Allard 1993). Therefore, management goals and objectives can vary somewhat within GCPO subgeographies and even more so at specific sites. The quality of available spatial data and endpoint metrics of desired conditions can also vary at local scales. Specific site-scale conditions, particularly regarding understory (a condition for which regional scale spatial data is lacking), as well as landscape context and site history, are critical to successful implementation of conservation design. An acceptable level of accuracy for any regional-scale ecological assessment may prove inadequate for some portion of specific locations within the region.

Another objective of this rapid ecological assessment is to continue the conversation with government agencies and LCC partners regarding the data needed to assess this priority system at a regional scale, particularly for below-canopy conditions. We anticipate improvements in LIDAR-derived and FIA-derived estimates of midstory and groundlayer related metrics in the near future. We also recommend modifying the units used by the ISA to assess condition metrics in certain cases. Midstory hardwood and shrub amounts, for example, are assessed by the ISA in terms of percent cover, whereas the data available uses units of basal area and stem density.

Forest Inventory and Analysis (FIA) data currently constitutes the most sound and robust source of information about landscape-level understory conditions available. As we continue to refine the rapid ecological assessment process, we will continue to explore ways to combine FIA data with ancillary data (topography, substrate, landcover, etc) to assess midstory and groundlayer conditions. The USDA Forest Service's Inventory and Analysis (FIA) is a continuous survey of the status and trends of the nation's forests. FIA sampling employs a nation-wide grid system designed so that at least one permanent sampling plot is installed within each 6000-acre hexagonal unit (Gray et al. 2012). Ground samples of the plots occur on a 3-phase basis. Phase 1 (P1) interprets remote sensing data products to stratify the plots into land classes based on characteristics such as forest/ nonforest or the presence of water. Stratification reduces variance in the Phase 2 (P2) ground-level plots when stratified estimation methods are used (O'Connell et al. 2014). P2 plots are designed to be an acre in size, but not all trees in the plot are measured. Rather, measurements are made within a standardized cluster of subplots. Precise geographic locations of a subset (20%) of P2 plots within each county are perturbed, or "fuzzed" by a distance of 0.5 to 1 mile, and swapped to protect the privacy of private landowners and in accordance with public laws prohibiting the disclosure of proprietary information (O'Connel et al. 2014). The effects of perturbed/swapped plots heve been shown to be negligible for design-based estimates of forest conditions, and effects on model-based estimates, which can be deemed unacceptable, depend on the modeling technique, the spatial resolution of the units on which variables are observed, spatial correlation in the variables, and the quality of fit of the model to the data. Methods for circumventing these negative effects exist (McRoberts et al. 2005). P2 sampling addresses the traditional FIA attributes of interest, mostly related to tree sizes of all species. A subset (1 out of every 16, or 1 for every 96,00 acres) of P2 plots are selected for Phase 3 (P3) sampling, which includes all the P2 attributes plus additional measurements related to forest health, including tree-crown assessment, soil sampling, lichen communities, understory vegetation structure, ozone bioindicators, and down woody material (Bechtold and Patterson 2005).

P2 sampling includes "Core" measures absolutely required for all plots, plus a set of "core optional" vegetation protocols collected at the discretion of each FIA unit. These optional protocols include canopy cover and growth habit of graminoids, forbs, and shrubs at various layers (<2', 2' – 6', 6' – 16', >16') (Forest Inventory and Analysis 2014). Therefore, information related to woody midstory and herbaceous understory conditions in the GCPO may exist (if not now, at some point in the future) at the P2 level.

At the P3 level, a set of VEG indicator measures are taken for a set of 3 (1 m^2) quadrats in each subplot. These measures include canopy cover for each species of shrub, forb and graminoid present at each of the 4 forest levels and frequency counts of vascular plant species at the plot, subplot and quadrat levels (Schulz et al. 2009).

FIA data is available for download by state at the FIA Datamart. As of this writing, however, within the GCPO geography, fields in the VEG indicator tables are populated only for the states of Missouri and Tennessee. Once data for all states becomes available online, county level summaries for percent cover for shrubs, graminoids and forbs at the forest canopy heights mentioned above can be produced.

Conclusion

"Open Pine" as a priority ecological system is an evolving scientific concept. Open Pine forests occur naturally on a wide range of sites in the southeastern United States. Communities representative of the larger system can be found on xeric, subxeric, mesic, and seasonally wet soils, on the maritime fringes or the coastal plains and uplands of the continental interior (Peet and Allard 1993). Conservation of Open Pine Woodland occurs in a regional context featuring a wide range of starting conditions, land-use histories and ongoing management practices (McIntyre 2012).

Several entities are engaged in projects aimed at developing a better understanding of species-habitat interactions and management of open pine woodland and savanna systems in the southeastern United States:

- The Lower Mississippi Valley Joint Venture has developed an open pine Decision Support Tool for the West Gulf Coastal Plain/Ouachita region based on four umbrella species (Lower Mississippi Valley Joint Venture, 2011).
- The East Gulf Coastal Plain Joint Venture (EGCP JV) is also developing an open pine Decision Support Tool.
- The Joseph W. Jones Ecological Center, in partnership with the National Fish and Wildlife Foundation (NFWF) and with input from the EGCP JV, USFS, USFWS, and others, is developing a set of wildlife habitat metrics for the Longleaf Stewardship Program that is also based on 4 umbrella species (McIntyre 2012).

Scientific literature on stand-level interactions between forest structure and the individual species is voluminous, and the GCPO LCC is funding five projects aimed at further refining definitive, region-wide, standardized, forest condition metrics to define wildlife needs and system integrity.

- The Desired Ecological States Provided by Managed Forests project, led by Ray Iglay of Mississippi State University, is developing a meta-analysis of scientific literature on species response to silvicultural practices along with harvest scheduling software to generate projections of desired ecological states resulting from different management scenarios.
- Using Wildlife Habitat Models to Evaluate Management Endpoints for Open Pine Woodland and Savanna, led by Mike Conner of the Joseph W. Jones Ecological Research Center, uses presence-absence data for pine-grassland adapted species to generate biometric habitat models and evaluate the endpoints in the ISA.
- Developing and Applying Desired Forest Condition Metrics to Enhance Wildlife Habitat and Biodiversity within Southern 'Open Pine' Ecosystems, led by Rickie White of NatureServe, addresses existing abiotic and biotic metrics for the full range of open pine and savanna ecosystems across the southeastern United States.
- Scott Rush, of Mississippi State University, is leading a project on Influence of Landscape and Stand-Scale Factors on Priority Wildlife Species in Open Pine Stand Types, the only one to address landscape context factors such as urbanization (in addition to forest structure) in relation to occupancy rates of pine-grassland adapted species in southern Mississippi.
- Open pine is one of three systems addressed in a project directed towards understanding and modeling landowner engagement opportunities for sustaining ecosystem services, led by Robert Grala of Mississippi State University.

As these projects move forward, the metrics presented in the ISA and used in this rapid ecological assessment will necessarily be re-evaluated. As we complete our rapid ecological assessment for other priority systems, GCPO LCC staff anticipates continued cooperation with partners and the Adaptation Management Science Team to both refine the endpoint metrics and develop or procure comprehensive spatial data products relevant to those metrics.

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Appendix 1: Development of the Pine Mask

The Pine Mask was created in the following steps:

1. Review the "Broadly Defined Habitats" (BDF) list developed for the GCPO-LCC and linked to in the ISA.

2. Select ecological system and land use classes (level 3, the most detailed level of classification) from the National GAP Land Cover Data Product (US Geological Survey, Gap Analysis Program (GAP), 2011) that either a) have language identical to the BDF in the description field, b) explicitly indicate the presence of open pine woodland savanna, or c) indicate the presence of or potential for a pine-dominant landscape (generally mixed pine hardwood classes that could be considered as having been encroached upon by hardwoods in the absence of fire and which could be restored to open pine by thinning, burning, etc.).
3. Independently create a layer of "pine-dominant" pixels by using species information from the United States Forest Service (USFS) live tree species basal area data product (Wilson et al. 2013) filtered through the National Landcover Database 2011 (Jin et al. 2013). Derived in part from observations of the presence of species at Forest Inventory Analysis (FIA) plots, the USFS-derived product was used as a rapid verification step, against the layer of selected ecological systems from GAP. This step revealed the presence in the landscape of areas where pine was observed to be the dominant species by USFS/FIA scientists at locations where the role of pine in the landscape was unmentioned or unclear in the GAP ecological system description.
4. Select additional ecological system and land use (ESLU) classes from the National GAP Landcover Data product according to observations from step 3 and reclassify. Three separate classification procedures were executed, resulting in three raster data layers:
    a. A reclassified layer in which the selected ecological systems retain their GAP ecological system and land use identities and all other pixels are classified as 0 (Figure 2).
    b. A reclassified layer in which all selected ecological systems have a value of 1 and all other pixels have a value of 0. This layer is used to calculate zonal statistics, such the portion of each subwatershed (HUC12 level) covered by Pine Mask pixels.
    c. A reclassified layer in which all selected ecological systems have a value of 1 and all other pixels have a value of 'No Data.' This layer is used as an extraction mask on other data layers, a processing step used in the endpoint assessment chapters below.

These steps are depicted graphically in the following conceptual diagram (Figure 1)

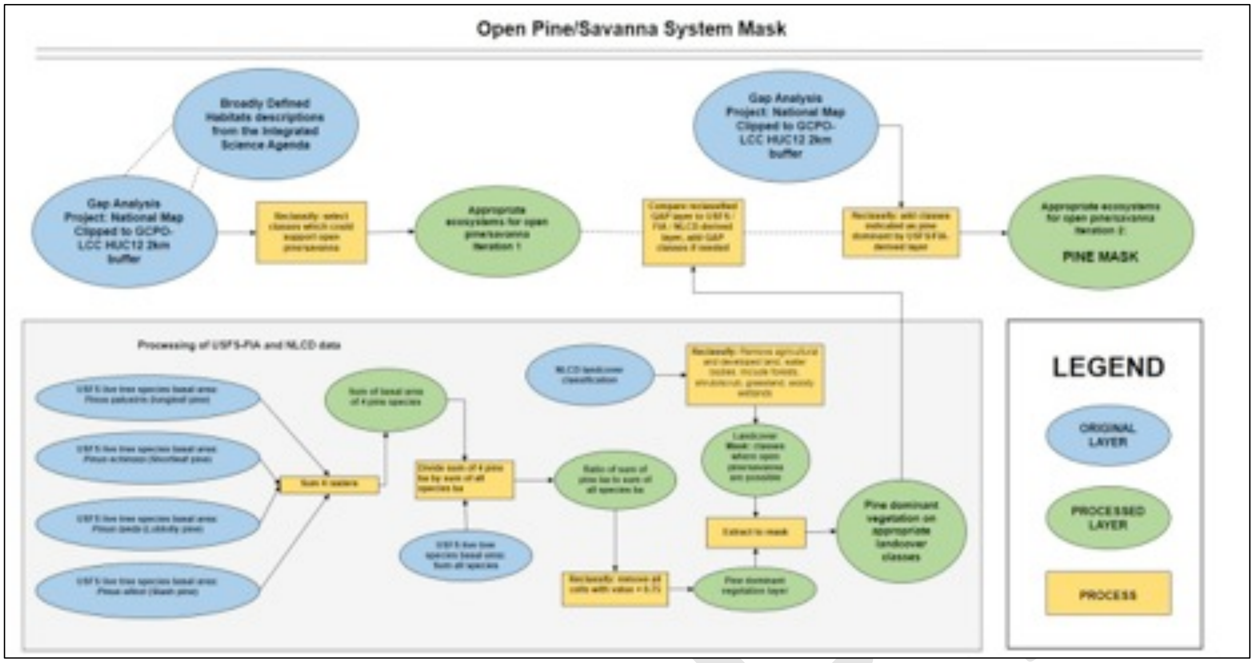

Figure 1: Conceptual diagram of the process of creating the Pine Mask

Data Sources and processing methods

Broadly Defined Habitats

The Broadly Defined Habitats (BDH) document linked to in the ISA lists 14 ecological systems associated with the Open Pine Woodlands and Savanna habitat. We created a map of the geographic distribution of pine in the GCPO (a "Pine Mask" for geoprocessing steps in the assessment method) by matching systems listed in the BDH to those in the System Descriptions document associated with the US National Map of terrestrial ecological systems created by NatureServe and to those that comprise the National GAP Land Cover Data Layer.

The GAP analysis project

Data description: The National GAP Land Cover Data Layer provides information on the distribution of native vegetation types, modified and introduced vegetation, developed areas, and agricultural areas of the 48 conterminous United States at 30 meter spatial resolution. The data incorporates a meso-scale (an intermediate level between the local ecosystem and the broader ecoregion) ecological classification system developed by NatureServe, which defines ecosystems in terms of plant community types occurring within similar landscapes (Comer et al. 2003). The data product is based on 1999-2000 imagery from the Landsat TM project and incorporates Normalized Difference Vegetation Index (NDVI), brightness, greenness and wetness indices, a digital elevation model (DEM) and regionally varying ancillary data. The modeling process used decision tree (CART) classifiers, implementing "a binary partitioning algorithm to successively split a multidimensional 'cloud' of explanatory data into increasingly homogenous subsets." The chief limitation of the product is the age of the imagery, whereby inaccuracies are likely where vegetative cover has changed significantly during the last 15 years. Another limitation is that, in areas west of the Mississippi River in the GCPO geography, the GAP analysis project based their ecological classifications on data from LANDFIRE, an interagency vegetation, fire, and fuel characteristics mapping program sponsored by the Wildland Fire Leadership Council.

Process: We identified 12 ecological systems in a regionally clipped version of the National GAP Land Cover Data layer (US Geological Survey 2011) with descriptions identical to those in the BDH document. Four of these systems were subdivided by various modifiers (shrub/scrub understory, open understory, etc.), bringing the total number of matching systems to 19. The 2 BDH systems that do not appear in the GAP data layer are Florida Longleaf Pine Sandhill and West Gulf Coastal Plain Stream Terrace Sandyland Longleaf Pine Woodland. We identified 12 additional systems in the GAP layer attribute table that indicate the presence of or potential for a pine-dominant landscape. Five of these have the words "longleaf pine woodland" in the name, with the full names having no exact match in the BDH list. Others included pine-dominant systems occurring in sparsely scattered patches on the eastern edge of the GCPO, plus 2 classes of tree plantation geographically interspersed within the BDH systems (Table 1).

The USFS live tree species basal area layer

Data description: The USFS live tree species basal area data product integrates vegetation phenology from MODIS imagery, along with climatic and topographic information, with extensive FIA field plot data of tree species basal area to map species distribution and basal area at 250 meter spatial resolution for the 48 conterminous states, USA (Wilson et al. 2013). The modeling approach uses k-nearest neighbor and canonical correspondence weighting techniques, along with a stratification derived from the 2001 National Land-Cover Database tree canopy cover layer. In addition to individual species layers, we also used a raster layer containing values for the sum of all basal area values for all species clipped to a 2km buffer of the HUC12 basins contained within and intersecting the GCPO boundary. This layer was created and shared by Barry T. Wilson of the USDA Forest Service, Northern Research Station.

Process: We checked the amount and configuration of pine-dominant landscapes indicated by the selected GAP classes against a modified version of the USFS live tree species basal area data product. This validation step is important because 1) the layer is derived from a process and an agency completely independent of GAP, and 2) although imputed, data values are derived from direct observations of relative proportions of tree species in the landscape from USFS FIA plots.

We produced a "pine-dominant" raster mask by first summing the basal area values found in raster layers for 4 southern pine species: loblolly (*P. taeda*), slash (*P. elliottii*), longleaf (*Pinus palustris*), and shortleaf (*P. echinata*) (Figure 2). This layer was divided by the layer containing estimates of the sum of all species basal area values to obtain a set of values representing the portion of total basal area accounted for by pine species basal area at each location. This ratio layer was then reclassified to reject all pixels with values <0.75 (the same ratio used in the NLCD2011 evergreen forest classification description), creating the 'pine-dominant' layer. Finally, the layer was filtered through a mask of appropriate NLCD classes (described below) to remove all pixels representing incidental occurrences of pine-dominant stands in developed areas, croplands, and pastures.

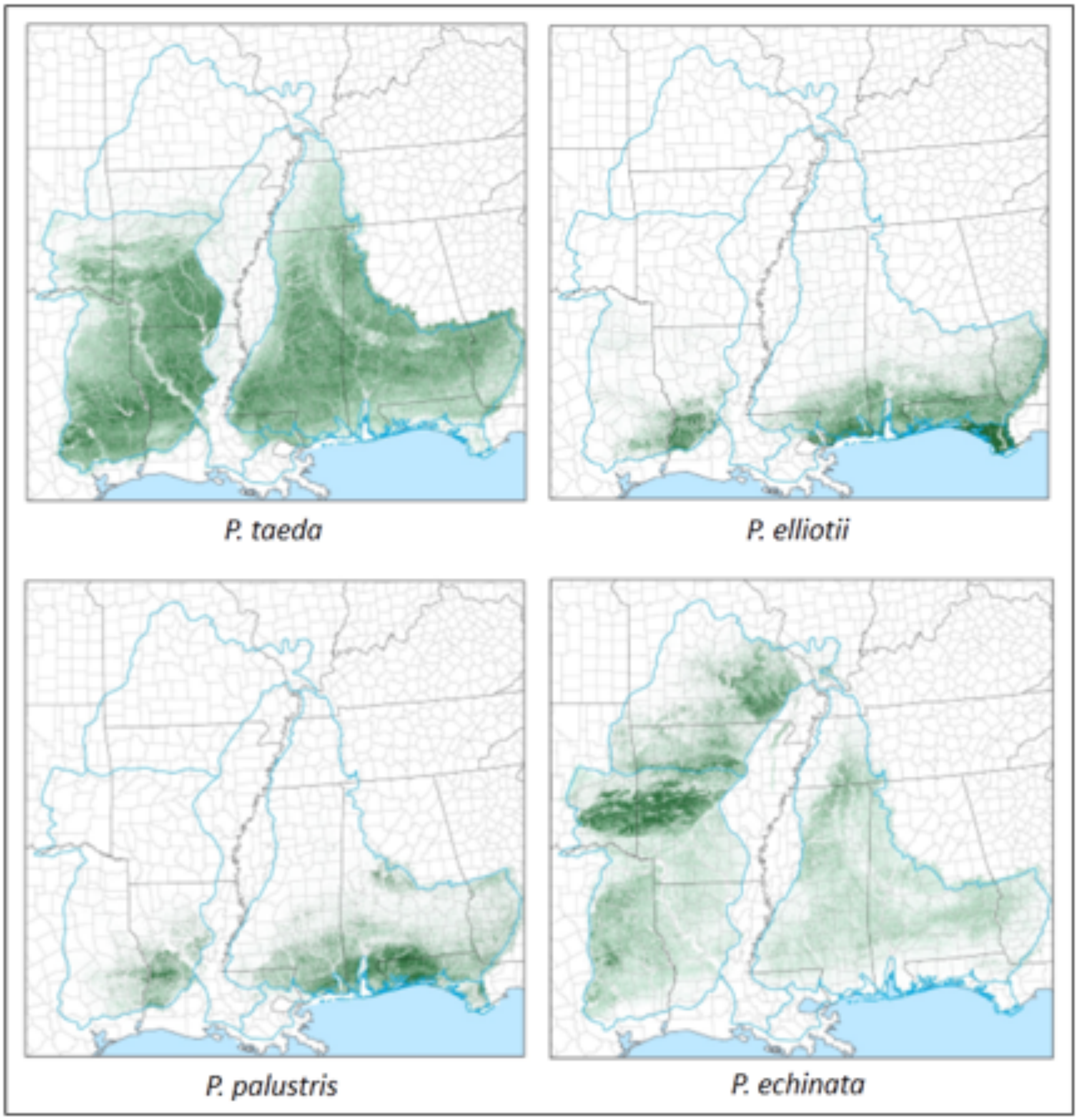

Figure 2: Live tree basal area values for 4 pine species. Darker color indicates higher values. Blue lines represent boundaries of GCPO subgeographies.

National Land Cover Database 2011 (NLCD 2011)

Data description: The NLCD Land Cover Database was created by the Multi-Resolution Land Characteristics (MRLC) Consortium. It is based primarily on a decision-tree classification of 2011 Landsat satellite data, producing a 16-class land cover classification scheme applied consistently across the United States at a spatial resolution of 30 meters.

Process: The NLCD Land Cover Database (Jin et al. 2013) was used to remove areas of cultivated land, developed land, and open water from the USFS/FIA live tree species basal area layer. In order to resolve the discrepancy in spatial resolution, we resampled the GAP-derived Pine Mask to 250 meters using the Majority rule.

Comparison of GAP-derived and USFS/FIA derived layers

The USFS/FIA derived layer was used to confirm that the appropriate ecological system and land use classes were selected from the GAP data layer. A comparison of the two layers showed broad agreement across the region, with the USFS/FIA layer indicating more broadly scattered and patchy configurations within the broader and more spatially intact landscapes indicated by the GAP layer. Both layers rejected the same areas as being "non-pine," with the exception of managed pine plantations (discussed below), which were indicated strongly by the USFS/FIA layer but not by the GAP layer. The USFS/FIA layer lacks the spatial continuity necessary for development into a pine mask because it only accounts for a single characteristic of the landscape: the ratio of pine to non-pine basal area per unit of land. A themed map of ecological systems is a better choice for such a mask because it takes into account multiple landscape parameters.

Classes added due to the USFS/FIA analysis

The modified version of the USFS live tree species basal area data layer indicates that pine-dominant conditions exist on about 3.4 million acres in areas classified by GAP as managed tree plantations (class 8202, Evergreen Plantation or Managed Pine, and class 8203, Managed Tree Plantation), primarily in the West Gulf Coastal Plain. Conservation in cooperation with industrial production of forest products is supported in the literature (Van Lear et al. 2005, Brockway et al. 2005, America's Longleaf 2009, Outcalt 2000) and a GCPO-LCC funded project aims to describe management options for desired ecological states in commercially managed forests. Class 8202, Evergreen Plantation or Managed Pine, occurs only east of the Mississippi River, while class 8203, Managed Tree Plantation, occurs only west of the Mississippi River, suggesting that the latter is the LANDFIRE equivalent of the class as designated by GAP. Managed tree plantation has no description, but likely refers to pine plantations (rather than those of other genera) because it is mostly found in interspersed with pine-dominant ecological system classes in areas of eastern Texas and western Louisiana.

Results

A map of the distribution of pine-dominant or mixed pine ecological system and land use classes was created in order to identify areas of land within the GCPO where forest condition endpoints indicative of open pine woodland and savanna could be evaluated. In geoprocessing terms, this map constitutes a "Pine Mask," or raster data layer through which data layer estimations of the forested conditions can be extracted. The Pine Mask was created by selecting 31 ecological systems and land use (Level 3) classes from the National GAP Land Cover Data Layer (Table 1) based on the Broadly Defined Habitats list from the ISA and spatial patterns in the ratio of pine to non-pine species in USFS/FIA live tree basal area data layers. Ecological system classes of pine within subgeographies is shown in Table 2.

Table 1: Representative Open Pine ecological systems selected from GAP

GAP Level 3	**Selected GAP Systems with identical name matches to BDH (modifiers added by GAP)**	**Acres in GCPO**
4301	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Hardwood Modifier	2,638,447
4309	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Mixed Modifier	3,617,749
4321	West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	447,448
4328	Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	4,627,274
4332	West Gulf Coastal Plain Pine-Hardwood Forest	5,170,941
4336	West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	465,455
4337	Crowley's Ridge Sand Forest	157,508
4501	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite Hardwood Modifier	2,317,288
4507	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	8,972,757
4508	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	993,837
4509	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Scrub/Shrub Modifier	33,689
4549	Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	61,524
9902	East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier	79,541
9903	East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier	1,088,261
9904	East Gulf Coastal Plain Near-Coast Pine Flatwoods - Scrub/ Shrub Understory Modifier	2,426
9908	West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	2,570,855
9910	East Gulf Coastal Plain Near-Coast Pine Flatwoods	12,207
9911	East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	118,145
9913	West Gulf Coastal Plain Pine-Hardwood Flatwoods	306,989
	Selected GAP Systems with similar name matches to BDH	
4322	Southeastern Interior Longleaf Pine Woodland	382
4504	Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland - Loblolly Modifier	95,174
4505	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory	218,147
4553	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	98,905

4506	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory	1,366
4536	Atlantic Coastal Plain Upland Longleaf Pine Woodland	10,915
	Other selected GAP systems	
4538	Southern Appalachian Low Mountain Pine Forest	62,131
4541	East-Central Texas Plains Pine Forest and Woodland	11,428
5602	Atlantic Coastal Plain Xeric River Dune	1,213
8202	Evergreen Plantation or Managed Pine	3,372,720
8203	Managed Tree Plantation	10,081,550
9901	East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory Modifier	195,023
	TOTAL Acres	**47,831,295**

Table 2: Ecological Systems in Pine Mask by Subgeography. Systems representing amounts <1000 acres were removed from the table but are included in the totals.

East Gulf Coastal Plain	**Acres**	**% of total subgeography**
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Hardwood Modifier	2,637,894	4.23
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Mixed Modifier	3,617,635	5.80
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite Hardwood Modifier	2,315,306	3.71
Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland - Loblolly Modifier	95,181	0.15
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory	218,152	0.35
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory	1366	0.00
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	8,930,251	14.31
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	992,906	1.59
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Scrub/Shrub Modifier	33,683	0.05
Atlantic Coastal Plain Upland Longleaf Pine Woodland	10,542	0.02
Southern Appalachian Low Mountain Pine Forest	62,157	0.10
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	88,534	0.14
Atlantic Coastal Plain Xeric River Dune	1213	0.00
Evergreen Plantation or Managed Pine	3,148,050	5.04
East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory Modifier	181,191	0.29
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier	16,696	0.03
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier	66,752	0.11
East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	117,666	0.19
TOTALS	**22,536,279**	**36.11**

West Gulf Coastal Plain		
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	446,354	0.85
Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	3,367,576	6.39
West Gulf Coastal Plain Pine-Hardwood Forest	5,160,342	9.79
West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	465,446	0.88
East-Central Texas Plains Pine Forest and Woodland	11,428	0.02
Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	61,524	0.12
Managed Tree Plantation	10,007,950	18.99
West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	2,565,743	4.87
West Gulf Coastal Plain Pine-Hardwood Flatwoods	296,155	0.56
TOTALS	**22,382,521**	**42.47**
Interior Highlands		
Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	1,257,390	3.73
Managed Tree Plantation	20,637	0.06
East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory Modifier	6375	0.02
TOTALS	1,284,978	3.81
Mississippi Alluvial Valley		
Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	2308	0.01
West Gulf Coastal Plain Pine-Hardwood Forest	10,558	0.04
Crowley's Ridge Sand Forest	157,508	0.62
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	10,103	0.04
Evergreen Plantation or Managed Pine	19,245	0.08
Managed Tree Plantation	52,886	0.21
East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory Modifier	7461	0.03
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier	28,290	0.11
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier	105,496	0.41
West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	5006	0.02
East Gulf Coastal Plain Near-Coast Pine Flatwoods	6274	0.02
West Gulf Coastal Plain Pine-Hardwood Flatwoods	10,781	0.04
TOTALS	**417,448**	**1.64**
Gulf Coast		
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite Hardwood Modifier	2014	0.03
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	42,553	0.71
Evergreen Plantation or Managed Pine	203,617	3.39

East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier	34,144	0.57
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier	893,254	14.85
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Scrub/Shrub Understory Modifier	2386	0.04
East Gulf Coastal Plain Near-Coast Pine Flatwoods	5933	0.10
TOTALS	**1,185,629**	**19.72**

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Appendix 2: Pine Mask Resampling Issues

Processing input data layers in a map algebra procedure requires that the discrepancies in spatial resolution among data layers be resolved. In addition to the pine-species and all-species basal area data layers used in the creation of the Pine Mask, the ecological assessment procedure used three additional 250 meter layers derived from USFS/FIA data:

midstory tree density, midstory basal area, and average diameter per acre. We combined these with two 30 meter layers: an NLCD 2011 estimate of canopy cover and the Pine Mask. Additionally, we consulted a 250 meter USFS/FIA data layer estimation of average stand age per acre for the "Temporal Considerations" subsection, but did not use it in the map algebra equation. Since a majority (six out of eight) of the data layers used are at the coarser resolution, we chose to resample the 30 meter layers up to 250 meters rather than resample the FIA/USFS layers down to 30 meters.

In the case of the GAP-derived Pine Mask layer, another reason for sampling up to 250 rather than down to 30 is derived from the fact that the GAP product constitutes categorical data whereas the USFS/FIA layers use continuous, imputed values derived from plot-level data. Resampling the USFS/FIA-derived layers to a finer resolution does not repeat the imputation algorithm but merely reassigns the value in the larger cell to a number of smaller cells, implying an unjustified level of homogeneity across a large area and increasing the likelihood that any particular cell is an erroneous estimate of conditions on the ground. The Pine Mask, on the other hand, is a binary categorical data layer (pine/non-pine), and resampling at a coarser resolution creates a new, larger neighborhood and simply asks whether a majority of the original 30 meter pixels in the neighborhood belong to the category. In this way, the pine/non-pine character of the land is still "true," just at a larger scale. For the Pine Mask resampling procedure, both input and output layers are binary (Pine Mask = 1; Not Pine Mask = 0). Cell values for the 250 meter output layer represent the majority of values present in the input neighborhood captured by each output cell. With only two values, each output cell represents the condition met by >50% of the cells in the input neighborhood. All references to the "Pine Mask" in the Condition section refer to this resampled, 250 meter version.

Resampling with a majority rule vs. nearest neighbor

The nearest neighbor resampling process assigns to the output cell the value of the input cell that is nearest to the center of the output cell. Resampling based on majority assigns the value that occurs most often within the output cell. Majority is arguably a more valid rule for summarizing a binary mask at a larger scale: areas where the "yes" pixels occur on fewer than half the pixels in the neighborhood are summarized as "no" and areas where they occur on more than half are summarized as "yes." The nearest neighbor procedure risks returning an inappropriate "yes" response in those areas where the occurrence of the desired condition is sparse yet happens to occur at the center of the larger output cell, a situation that may be viewed as a local instance of a "false positive," especially in landscapes where the desired configuration of the condition is clustered. Additionally, the nearest neighbor procedure in some cases produces local "false negative" outputs rejects areas where densely-configured pine input pixels happen to have a non-pine cell at the output centroid (Figure 7).

Resampled digital images generate values for total areal amounts of land cover classes that differ from those indicated by the originals, depending on the aggregation techniques and spatial resolutions used (Nelson et al. 2009). If the land cover class configuration is sparse and scattered, that is, occurring in small patches across a landscape but rarely in sufficient concentration to dominate a 250 meter pixel (as is the case with pine forest systems in the Ozark Highlands), the majority procedure produces a map that, while more accurate pixel-by-pixel, significantly underestimate the total areal amount of the class. In other words, if the 30 meter data layer describes a condition at a rate of about 45% of each 250 meter output pixel, the majority procedure produces a map in which it does not occur at all, whereas the nearest neighbor produces a map in which it occurs on about 45 % of the pixels somewhat randomly distributed across the landscape. In the case of the Pine Mask in the GCPO, the nearest neighbor procedure produces total acreage values nearly identical to those indicated by the 30 meter input layer, whereas the majority procedure produce values that are 5% less overall and range from 1% less in the West Gulf Coastal Plain and 55% less in the Ozark Highlands (Table 3). The discrepancy in the Ozark Highlands is due to the scattered configuration of the 30 meter Pine Mask pixels in the input layer: in about half the cases they are not clustered in sufficient concentration to meet the majority rule. The nearest neighbor procedure returns the value of the input cell at the centroid of the output cell, so the output equivalent to the 55% percent of the pixels rejected by the majority procedure are a in fact a random selection of the widely scattered input pixels wherever they happen to occur at the centroid of the 250 meter output grid rather than faithful reproduction of the spatial configuration of the input. Because the Draft Integrated Science Agenda is focused on large patches of open pine in the East and West Gulf Coastal Plains, the majority resampling procedure was used to better identify and locate large patches in those geographies, with the knowledge that both procedures have limitations.

Table 3: Pine mask acreage values calculated from pixel counts for the 30 meter original and the 250 meter outputs using the Majority and Nearest Neighbor resampling procedures, by GCPO subgeography. The Nearest Neighbor procedure returns total acreage values nearly identical to those of the original layer. The Majority procedure returns values that are 1-5 % less in the East and West Gulf Coastal Plains, and 55% less in the Ozark Highlands.

	30 meter original	250 meter resample: Majority			250 meter resample: Nearest Neighbor		
Subgeography	Acres	Acres	Acres difference	% difference	Acres	Acres difference	% difference
West Gulf Coastal Plain	22,382,544	22,047,471	335,073	1	22,391,366	8,822	0
East Gulf Coastal Plain	22,536,573	21,382,408	1,154,165	5	22,538,000	1,427	0
Mississippi Alluvial Valley	417,363	336,716	80,647	19	414,780	2,583	1
Ozark Highlands	1,285,139	578,568	706,571	55	1,284,963	176	0
Gulf Coast	1,185,332	1,096,518	88,814	7	1,182,442	2,891	0
TOTAL	47,806,951	45,441,680	2,365,271	5	47,811,550	4,599	0

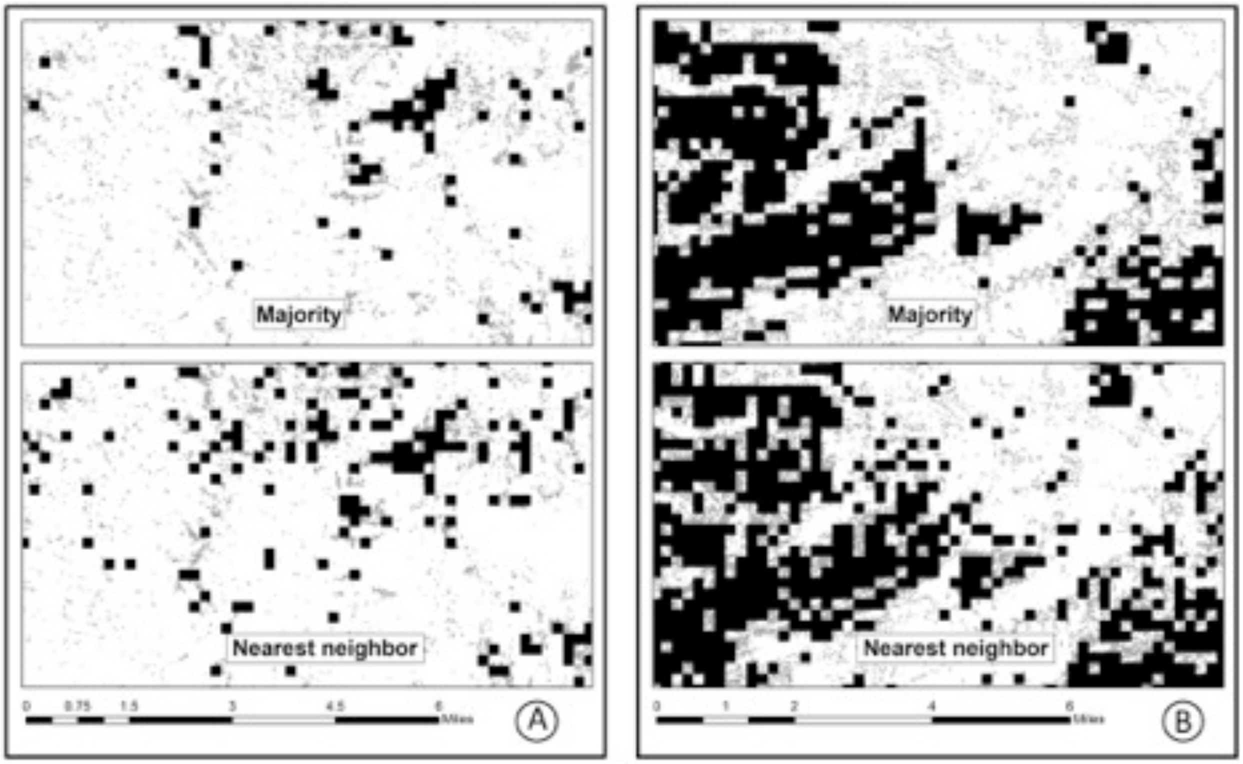

Figure 7: The result of resampling using majority and nearest neighbor in the Ozark Highlands (Mark Twain National Forest in Oregon and Carter Counties, Missouri, A), and in the West Gulf Coastal Plain (Ouachita National Forest, Yell County, Arkansas, B). Thirty meter input layer is grey, 250 meter output layer is black and superimposed. The nearest neighbor procedure randomly selects in areas where input pixels are sparse and disconnected, and rejects some densely configured portions of patch interiors where non-target input pixels happen to align with cell centroids in the output layer.

Ultimately this research aims to produce polygons of suitable habitat. Therefore, collecting more pixels from patch interiors and rejecting more disconnected, isolated pixels (as the majority procedure does) is preferable to producing total acreage values exactly matching those of the original 30 meter raster.